MiCOM P54x
P543, P544, P545 & P546

Current Differential Relay

P54x/EN M/J74

Software Version	41 & 51
Hardware Suffix	K

Technical Manual

Note: The technical manual for this device gives instructions for its installation, commissioning, and operation. However, the manual cannot cover all conceivable circumstances or include detailed information on all topics. In the event of questions or specific problems, do not take any action without proper authorization. Contact the appropriate Schneider Electric technical sales office and request the necessary information.

Any agreements, commitments, and legal relationships and any obligations on the part of Schneider Electric including settlements of warranties, result solely from the applicable purchase contract, which is not affected by the contents of the technical manual.

This device MUST NOT be modified. If any modification is made without the express permission of Schneider Electric, it will invalidate the warranty, and may render the product unsafe.

CONTENTS

SI

SAFETY INFORMATION

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CONTENTS

Page (SI) -

1 INTRODUCTION

This guide and the relevant equipment documentation provide full information on safe handling, commissioning and testing of this equipment. This Safety Information section also includes reference to typical equipment label markings.

Documentation for equipment ordered from Schneider Electric is dispatched separately from manufactured goods and may not be received at the same time. Therefore this guide is provided to ensure that printed information which may be present on the equipment is fully understood by the recipient.

The technical data in this Safety Information section is typical only, see the technical data section of the relevant product publication(s) for data specific to a particular equipment.

WARNING Before carrying out any work on the equipment the user should be familiar with the contents of this Safety Information section and the ratings on the equipment's rating label.

Reference should be made to the external connection diagram before the equipment is installed, commissioned or serviced.

Language-specific, self-adhesive User Interface labels are provided in a bag for some equipment.

2 HEALTH AND SAFETY

The information in the Safety Information section of the equipment documentation is intended to ensure that equipment is properly installed and handled in order to maintain it in a safe condition.

It is assumed that everyone who will be associated with the equipment will be familiar with the contents of that Safety Information section, or this Safety Guide.

When electrical equipment is in operation, dangerous voltages will be present in certain parts of the equipment. Failure to observe warning notices, incorrect use, or improper use may endanger personnel and equipment and also cause personal injury or physical damage.

Before working in the terminal strip area, the equipment must be isolated.

Proper and safe operation of the equipment depends on appropriate shipping and handling, proper storage, installation and commissioning, and on careful operation, maintenance and servicing. For this reason only qualified personnel may work on or operate the equipment.

Qualified personnel are individuals who:

- Are familiar with the installation, commissioning, and operation of the equipment and of the system to which it is being connected;
- Are able to safely perform switching operations in accordance with accepted safety engineering practices and are authorized to energize and de-energize equipment and to isolate, ground, and label it;
- Are trained in the care and use of safety apparatus in accordance with safety engineering practices;
- Are trained in emergency procedures (first aid).

The equipment documentation gives instructions for its installation, commissioning, and operation. However, the manuals cannot cover all conceivable circumstances or include detailed information on all topics. In the event of questions or specific problems, do not take any action without proper authorization. Contact the appropriate Schneider Electric technical sales office and request the necessary information.

3 SYMBOLS AND LABELS ON THE EQUIPMENT

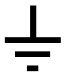
For safety reasons the following symbols which may be used on the equipment or referred to in the equipment documentation, should be understood before it is installed or commissioned.

3.1 Symbols

Caution: refer to equipment documentation

Caution: risk of electric shock

Protective Conductor (*Earth) terminal



Functional/Protective Conductor (*Earth) terminal

Note	*This symbol may also be used for a Protective Conductor (Earth) Terminal if that terminal is part of a terminal block or sub-assembly e.g. power supply.*

***CAUTION The term “Earth” used throughout this technical manual is the direct equivalent of the North American term “Ground”.**

3.2 Labels

See Safety Guide (SFTY/4L M) for typical equipment labeling information.

4 INSTALLING, COMMISSIONING AND SERVICING

Manual Handling

Plan carefully, identify any possible hazards and determine whether the load needs to be moved at all. Look at other ways of moving the load to avoid manual handling. Use the correct lifting techniques and Personal Protective Equipment to reduce the risk of injury.

Many injuries are caused by:

- Lifting heavy objects
- Lifting things incorrectly
- Pushing or pulling heavy objects
- Using the same muscles repetitively.

Follow the Health and Safety at Work, etc Act 1974, and the Management of Health and Safety at Work Regulations 1999.

Equipment Connections

Personnel undertaking installation, commissioning or servicing work for this equipment should be aware of the correct working procedures to ensure safety.

The equipment documentation should be consulted before installing, commissioning, or servicing the equipment.

Terminals exposed during installation, commissioning and maintenance may present a hazardous voltage unless the equipment is electrically isolated.

The clamping screws of all terminal block connectors, for field wiring, using M4 screws shall be tightened to a nominal torque of 1.3 Nm.

Equipment intended for rack or panel mounting is for use on a flat surface of a Type 1 enclosure, as defined by Underwriters Laboratories (UL).

Any disassembly of the equipment may expose parts at hazardous voltage, also electronic parts may be damaged if suitable electrostatic voltage discharge (ESD) precautions are not taken.

If there is unlocked access to the rear of the equipment, care should be taken by all personnel to avoid electric shock or energy hazards.

Voltage and current connections shall be made using insulated crimp terminations to ensure that terminal block insulation requirements are maintained for safety.

Watchdog (self-monitoring) contacts are provided in numerical relays to indicate the health of the device. Schneider Electric strongly recommends that these contacts are hardwired into the substation's automation system, for alarm purposes.

To ensure that wires are correctly terminated the correct crimp terminal and tool for the wire size should be used.

The equipment must be connected in accordance with the appropriate connection diagram.

Protection Class I Equipment

- Before energizing the equipment it must be earthed using the protective conductor terminal, if provided, or the appropriate termination of the supply plug in the case of plug connected equipment.
- The protective conductor (earth) connection must not be removed since the protection against electric shock provided by the equipment would be lost.
- When the protective (earth) conductor terminal (PCT) is also used to terminate cable screens, etc., it is essential that the integrity of the protective (earth) conductor is checked after the addition or removal of such functional earth connections. For M4 stud PCTs the integrity of the protective (earth) connections should be ensured by use of a locknut or similar.

The recommended minimum protective conductor (earth) wire size is 2.5 mm² (3.3 mm² for North America) unless otherwise stated in the technical data section of the equipment documentation, or otherwise required by local or country wiring regulations.

The protective conductor (earth) connection must be low-inductance and as short as possible.

All connections to the equipment must have a defined potential. Connections that are pre-wired, but not used, should preferably be grounded when binary inputs and output relays are isolated. When binary inputs and output relays are connected to common potential, the pre-wired but unused connections should be connected to the common potential of the grouped connections.

Pre-Energization Checklist

Before energizing the equipment, the following should be checked:

- Voltage rating/polarity (rating label/equipment documentation);
- CT circuit rating (rating label) and integrity of connections;
- Protective fuse rating;
- Integrity of the protective conductor (earth) connection (where applicable);
- Voltage and current rating of external wiring, applicable to the application.

Accidental Touching of Exposed Terminals

If working in an area of restricted space, such as a cubicle, where there is a risk of electric shock due to accidental touching of terminals which do not comply with IP20 rating, then a suitable protective barrier should be provided.

Equipment Use

If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

Removal of the Equipment Front Panel/Cover

Removal of the equipment front panel/cover may expose hazardous live parts, which must not be touched until the electrical power is removed.

UL and CSA/CUL Listed or Recognized Equipment

To maintain UL and CSA/CUL Listing/Recognized status for North America the equipment should be installed using UL or CSA Listed or Recognized parts for the following items: connection cables, protective fuses/fuseholders or circuit breakers, insulation crimp terminals and replacement internal battery, as specified in the equipment documentation.

For external protective fuses a UL or CSA Listed fuse shall be used. The Listed type shall be a Class J time delay fuse, with a maximum current rating of 15 A and a minimum d.c. rating of 250 Vd.c., for example type AJT15.

Where UL or CSA Listing of the equipment is not required, a High Rupture Capacity (HRC) fuse type with a maximum current rating of 16 Amps and a minimum d.c. rating of 250 Vd.c. may be used, for example Red Spot type NIT or TIA.

Equipment Operating Conditions

The equipment should be operated within the specified electrical and environmental limits.

Current Transformer (CT) Circuits

Do not open the secondary circuit of a live CT since the high voltage produced may be lethal to personnel and could damage insulation. Generally, for safety, the secondary of the line CT must be shorted before opening any connections to it.

For most equipment with ring-terminal connections, the threaded terminal block for current transformer termination has automatic CT shorting on removal of the module. Therefore external shorting of the CTs may not be required, the equipment documentation should be checked to see if this applies.

For equipment with pin-terminal connections, the threaded terminal block for current transformer termination does NOT have automatic CT shorting on removal of the module.

External Resistors, including Voltage Dependent Resistors (VDRs)

Where external resistors, including Voltage Dependent Resistors (VDRs), are fitted to the equipment, these may present a risk of electric shock or burns, if touched.

Battery Replacement

Where internal batteries are fitted they should be replaced with the recommended type and be installed with the correct polarity to avoid possible damage to the equipment, buildings and persons.

Insulation and Dielectric Strength Testing

Insulation testing may leave capacitors charged up to a hazardous voltage. At the end of each part of the test, the voltage should be gradually reduced to zero, to discharge capacitors, before the test leads are disconnected.

Insertion of Modules and PCB Cards

Modules and PCB cards must not be inserted into or withdrawn from the equipment whilst it is energized, since this may result in damage.

Insertion and Withdrawal of Extender Cards

Extender cards are available for some equipment. If an extender card is used, this should not be inserted or withdrawn from the equipment whilst it is energized. This is to avoid possible shock or damage hazards. Hazardous live voltages may be accessible on the extender card.

External Test Blocks and Test Plugs

Great care should be taken when using external test blocks and test plugs such as the MMLG, MMLB and MiCOM P990 types, hazardous voltages may be accessible when using these. *CT shorting links must be in place before the insertion or removal of MMLB test plugs, to avoid potentially lethal voltages.

**Note*	*When a MiCOM P992 Test Plug is inserted into the MiCOM P991 Test Block, the secondaries of the line CTs are automatically shorted, making them safe.*

Fiber Optic Communication

Where fiber optic communication devices are fitted, these should not be viewed directly. Optical power meters should be used to determine the operation or signal level of the device.

Cleaning

The equipment may be cleaned using a lint free cloth dampened with clean water, when no connections are energized. Contact fingers of test plugs are normally protected by petroleum jelly, which should not be removed.

5 DE-COMMISSIONING AND DISPOSAL

De-commissioning

The supply input (auxiliary) for the equipment may include capacitors across the supply or to earth. To avoid electric shock or energy hazards, after completely isolating the supplies to the equipment (both poles of any dc supply), the capacitors should be safely discharged via the external terminals prior to de-commissioning.

Disposal

It is recommended that incineration and disposal to water courses is avoided. The equipment should be disposed of in a safe manner. Any equipment containing batteries should have them removed before disposal, taking precautions to avoid short circuits. Particular regulations within the country of operation, may apply to the disposal of the equipment.

6 TECHNICAL SPECIFICATIONS FOR SAFETY

Unless otherwise stated in the equipment technical manual, the following data is applicable.

6.1 Protective Fuse Rating

The recommended maximum rating of the external protective fuse for equipments is 16A, High Rupture Capacity (HRC) Red Spot type NIT, or TIA, or equivalent. Unless otherwise stated in equipment technical manual, the following data is applicable. The protective fuse should be located as close to the unit as possible.

DANGER **CTs must NOT be fused since open circuiting them may produce lethal hazardous voltages.**

6.2 Protective Class

IEC 60255-27: 2005	Class I (unless otherwise specified in the equipment documentation).
EN 60255-27: 2005	This equipment requires a protective conductor (earth) connection to ensure user safety.

6.3 Installation Category

IEC 60255-27: 2005	Installation Category III (Overvoltage Category III)
EN 60255-27: 2005	Distribution level, fixed installation.
	Equipment in this category is qualification tested at 5 kV peak, 1.2/50 μs, 500 Ω, 0.5 J, between all supply circuits and earth and also between independent circuits.

6.4 Environment

The equipment is intended for indoor installation and use only. If it is required for use in an outdoor environment then it must be mounted in a specific cabinet of housing which will enable it to meet the requirements of IEC 60529 with the classification of degree of protection IP54 (dust and splashing water protected).

Pollution Degree	Pollution Degree 2 Compliance is demonstrated by reference to safety standards.
Altitude	Operation up to 2000m
IEC 60255-27:2005	
EN 60255-27: 2005	

DOCUMENTATION UPDATE FROM VERSIONS 0040 AND 0050K TO 0041 AND 0051K

Since versions 0400 and 0050K (P54x/EN M/I64), several changes on existing features have been amended or added. These are described below:

Document Ref.	Section	Page No.	Description
-	-	-	**EC declaration of conformity** Latest version to reflect relay software
P54x/EN IT/G74	1.	3	**MiCOM documentation structure** Paragraph 1 : amended
	3.	6	**Product Scope** P543 and P545 features description : updated P544 and P546 features description : updated
	3.1	6 9 - 10	**Functional overview** Row 2 of table : feature description amended Data in row 3 of table : added ANSI code 78 : added to table Functional diagram : updated
P54x/EN TD/J74	-	3	**High break contacts** Data added
	-	6	**Out of step** Data added
	-	8	**Fault locator** Data added : after disturbance records
	-	9	**InterMiCOM^{64} fiber optic teleprotection** Paragraph 2 : amended Table : re-written
	-	15 - 16	**Througout** 0.10…500.00/In Ω changed to 0.05…500.00/In Ω
	-	16	**Aided scheme 1** Send on trip data added
	-	19	**Out of step** Data added

Document Ref.	Section	Page No.	Description
P54x/EN TD/J74 Continued	-	19	**Supervision** VTS mode data added
P54x/EN ST/B74	1.1	4	**Relay settings configuration** ANSI code 78 : added to PowerSwing Block description
	1.3.1	10 12 - 13	**Line parameters** Line impedance minimum setting : changed from 0.1/I Ω to 0.05/In Ω Fault resistance minimum setting : changed from 0.1/I Ω to 0.05/In Ω
	1.3.3	16 - 19 17 18	**Distance elements (only for models with distance option)** Throughout section : minimum setting changed from 0.1/I Ω to 0.05/In Ω R3 Ph. Res Rev. : description amended R3 Gnd. Res Rev. : description amended
	1.3.5	23	**Scheme logic (basic and aided scheme logic). Only in models with distance option** AIDED SCHEME 1 : Send on trip data added
	1.3.6	27 - 28	**Power swing blocking** OST Mode, Z5, Z6, Z5', Z6', R5, R6, R5', R6', Blinder Angle, Delta t and Tost : data added
	1.3.16	39	**Circuit breaker fail and undercurrent function** I< Current Set : description amended
	1.3.17	40	**Supervision (VTS, CTS, Inrush detection and special weak infeed blocking)** VT SUPERVISION : VTS mode data added
	1.3.18	42	**System checks (check sync. function)** CS1 Phase angle minimum setting : changed from 5˚ to 0˚ CS2 Phase angle minimum setting : changed from 5˚ to 0˚

Document Ref.	Section	Page No.	Description
P54x/EN ST/B74 Continued	1.3.19	42	**Auto-reclose function** 1 Pole dead time minimum setting : changed from 0.2s to 0.05s Dead time 1 minimum setting : changed from 0.2s to 0.05s
	1.4.1	48	**System data** Software Ref. 1 and Software Ref. 2 : software version updated
	1.4.7.3	56	**Communications settings for DNP3.0 protocol** Last 2 lines of table : added
	1.4.7.4	56	**Communications settings for Ethernet port** NIC Link Timeout : description amended
P54x/EN OP/B74	1.1.6	21 - 22	**Mesh corner and 1½ breaker switched substations** Relay calculations after Figure 10 : amended
	1.2	22	**Disabling/enabling differential protection** New section added
	1.3	23	**Differential relay compatibility with previous versions** Paragraph 1 : re-written Last paragraph : added
	1.5.3	24	**Pole dead logic** Paragraph 1 : re-written
	1.20	44	**Out of step detection and tripping** New section added
	1.20.1	44	**Out of step detection** New section added
	1.20.1.1	44 - 45	**Characteristic** New section added
	1.20.1.2	45 - 46	**Operating principle** New section added
	1.23.2	58	**Distance scheme POR - permissive overreach transfer trip** Figure 37 : updated

Document Ref.	Section	Page No.	Description
P54x/EN OP/B74 Continued	2.1.3.1	86	**Trip initiate signals** Paragraph re-written
	2.1.8	92	**Auto-reclose logic diagrams** Figure 66 : updated Figure 67 : updated
	2.4	105	**Voltage transformer supervision - fuse fail** Paragraph 6 : added Paragraph 7 : re-written
	2.5.1	108	**Differential CTS (no need of local voltage measurements to declare CTS)** Paragraph before figure 79 : added
P54x/EN AP/J74	2.2.16	20 - 21	**Out of step protection** New section added
	2.2.17	21 - 22	**Critical stability angle** New section added
	2.2.17.1	22 - 23	**Setting option recommendation** New section added
	2.2.17.2	23 - 25	**Blinder limits determination** New section added
	2.2.17.3	25	**Delta t, R5 and R6 setting determination** New section added
	2.2.17.4	26	**Tost (trip delay) setting** New section added
	2.2.17.5	26	**Blinder angle setting** New section added
	2.2.17.6	26 - 27	**Out of step operation on series compensated lines** New section added
	2.2.23	28	**General setting guidelines for DEF (directional ground overcurrent)** Setting data changed from : between 5 and 20% In to between 10 and 20% In

Document Ref.	Section	Page No.	Description
P54x/EN PL/B74			**Description of logic nodes**
		21	DDB number 437 : data added
		25	DDB numbers 550 - 555 : data added
		26	DDB numbers 556 to 575 : data added
			DDB numbers 807 to 831 : changed to 807 to 828
		31	DDB numbers 829 - 831 : data added
	1.7	39 - 40	DDB numbers 1375 - 1385 : data added
			Factory default programmable scheme logic
			Data in table : updated
	1.8	41	Note after table : added
			Standard relay output contact mappings
	1.10	44	Heading changed
			Optional high break relay output contact mappings
	1.11	47 - 49	New section added
P54x/EN FD/I74			**IRIG-B modulated or demodulated board (optional)**
	1.1.5	5	Heading changed
			Co-processor board
	2.2	8	1st sentence : re-written
			High break relay board
	2.5.3	11 - 12	New section added
			High break contact applications
	2.5.3.1	12 - 13	New section added
			Ethernet board
			Last paragraph : added
	2.8	14	Figure 5 : added
P54x/EN CM/I74			**Out of step protection (if enabled)**
	6.2.7	43 - 44	New section added
			Predictive OST setting
	6.2.7.1	44	New section added
			OST setting
	6.2.7.2	45	New section added

Document Ref.	Section	Page No.	Description
P54x/EN CM/I74			**Predictive and OST setting**
Continued	6.2.7.3	45	New section added
			'Tost' timer test
	6.2.7.4	45	New section added
			Commissioning test record
	10.	58 - 72	Amended to reflect latest relay software
			Setting record
	11.	73 - 104	Amended to reflect latest relay software
P54x/EN IN/G74			**P54x external connection diagrams**
		12 - 19	Figures 5 - 12 : descriptions updated
	8.	20 - 27	Figures 13 - 20 : added
P54x/EN VH/I74			**Firmware and service manual version history**
	-	-	Amended to reflect latest relay software

IT

INTRODUCTION

Date:	**7th August 2006**
Hardware Suffix:	**K**
Software Version:	**41 and 51**
Connection Diagrams:	**10P54302xx (xx = 01 to 02) & 10P54303xx (xx = 01 to 02)**
	10P54402xx (xx = 01 to 02) & 10P54403xx (xx = 01 to 02)
	10P54502xx (xx = 01 to 02) & 10P54503xx (xx = 01 to 02)
	10P54602xx (xx = 01 to 02) & 10P54603xx (xx = 01 to 02)

IT

CONTENTS

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FIGURES

1. MiCOM DOCUMENTATION STRUCTURE

The manual provides a functional and technical description of the P54x differential and distance protection relay and a comprehensive set of instructions for the relay's use and application.

The section contents are summarized below:

P54x/EN IT Introduction

A guide to the P54x range of distance relays and the documentation structure. General safety aspects of handling Electronic Equipment is discussed with particular reference to relay safety symbols. Also a general functional overview of the relay and brief application summary is given.

P54x/EN TD Technical Data

Technical data including setting ranges, accuracy limits, recommended operating conditions, ratings and performance data. Compliance with norms and international standards is quoted where appropriate.

P54x/EN GS Getting Started

A guide to the different user interfaces of the protection relay describing how to start using it. This section provides detailed information regarding the communication interfaces of the relay, including a detailed description of how to access the settings database stored within the relay.

P54x/EN ST Settings

List of all relay settings, including ranges, step sizes and defaults, together with a brief explanation of each setting.

P54x/EN OP Operation

A comprehensive and detailed functional description of all protection and non-protection functions.

P54x/EN AP Application Notes

This section includes a description of common power system applications of the relay, calculation of suitable settings, some typical worked examples, and how to apply the settings to the relay.

P54x/EN PL Programmable Logic

Overview of the programmable scheme logic and a description of each logical node. This section includes the factory default (PSL) and an explanation of typical applications.

P54x/EN MR Measurements and Recording

Detailed description of the relays recording and measurements functions including the configuration of the event and disturbance recorder and measurement functions.

P54x/EN FD Firmware Design

Overview of the operation of the relay's hardware and software. This section includes information on the self-checking features and diagnostics of the relay.

P54x/EN CM Commissioning

Instructions on how to commission the relay, comprising checks on the calibration and functionality of the relay.

P54x/EN MT Maintenance

A general maintenance policy for the relay is outlined.

P54x/EN TS **Troubleshooting**

Advice on how to recognize failure modes and the recommended course of action. Includes guidance on whom within Schneider Electric to contact for advice.

P54x/EN SC **SCADA Communications**

This section provides an overview regarding the SCADA communication interfaces of the relay. Detailed protocol mappings, semantics, profiles and interoperability tables are not provided within this manual. Separate documents are available per protocol, available for download from our website.

P54x/EN SG **Symbols and Glossary**

List of common technical abbreviations found within the product documentation.

P54x/EN IN **Installation**

Recommendations on unpacking, handling, inspection and storage of the relay. A guide to the mechanical and electrical installation of the relay is provided, incorporating earthing recommendations. All external wiring connections to the relay are indicated.

P54x/EN VH **Firmware and Service Manual Version History**

History of all hardware and software releases for the product.

IT

2. INTRODUCTION TO MiCOM

MiCOM is a comprehensive solution capable of meeting all electricity supply requirements. It comprises a range of components, systems and services from Schneider Electric.

Central to the MiCOM concept is flexibility.

MiCOM provides the ability to define an application solution and, through extensive communication capabilities, integrate it with your power supply control system.

The components within MiCOM are:

- P range protection relays;
- C range control products;
- M range measurement products for accurate metering and monitoring;
- S range versatile PC support and substation control packages.

MiCOM products include extensive facilities for recording information on the state and behavior of the power system using disturbance and fault records. They can also provide measurements of the system at regular intervals to a control center enabling remote monitoring and control to take place.

For up-to-date information on any MiCOM product, visit our website:

www.schneider-electric.com

IT

3. PRODUCT SCOPE

The P54x is designed for all overhead line and cable applications, as it interfaces readily with the longitudinal (end-end) communications channel between line terminals.

P54x includes a high-speed current differential unit protection with optional high performance sub cycle distance protection including phase segregated aided directional earth fault DEF. Four P54x models are offered:

P543 and P545:

Features included only in the P543 and P545 models are: Differential for Plain and Transformer Feeders and 1/3 Pole Auto-reclose.

P543 in (60TE /12”) with 16 inputs and 14 standard outputs (or 7 standard and 4 high break outputs option)

P545 in (80TE /19”) with 24 inputs and 32 standard outputs (or 16 standard and 8 high break outputs option)

P544 and P546:

Features included only in the P544 and P546 models are Differential for Mesh Corner

P544 in (60TE /12”) with 16 inputs and 14 standard outputs (or 7 standard and 4 high break outputs option)

P546 in (80TE /19”) with 24 inputs and 32 standard outputs (or 16 standard and 8 high break outputs option)

3.1 Functional overview

The P54x distance relay contains a wide variety of protection functions. The protection features are summarized below:

			Models			
ANSI	**FEATURE**		**P543**	**P544**	**P545**	**P546**
	Optocoupled digital inputs		16	16	24	24
	Standard relay output contacts		14	14	32	32
	Standard and high break output contacts		(11)	(11)	(24)	(24)
	Dual rated 1A and 5A CT inputs		•	•	•	•
	Tripping Mode - single or three pole		•	•	•	•
	ABC and ACB phase rotation		•	•	•	•
	Multiple password access control levels		•	•	•	•
87	Phase segregated current differential		•	•	•	•
	2 and 3 terminal lines/cables		•	•	•	•
	Feeders with in-zone transformers		•		•	
	Suitable for use with SDH/SONET networks (using P594)		•	•	•	•
21P/21G	Distance zones, full-scheme protection		5	5	5	5
	Characteristic	Phase elements	Mho and quadrilateral			
		Ground elements				
	CVT transient overreach elimination		•	•	•	•
	Load blinder		•	•	•	•
	Easy setting mode		•	•	•	•

		Models			
ANSI	**FEATURE**	**P543**	**P544**	**P545**	**P546**
	Mutual compensation (for fault locator and distance zones)	•	•	•	•
85	Communication-aided schemes, PUTT, POTT, Blocking, Weak Infeed	•	•	•	•
	Accelerated tripping - loss of load and Z1 extension	•	•	•	•
50/27	Switch on to fault and trip on recluse - elements for fast fault clearance upon breaker closure	•	•	•	•
68	Power swing blocking	•	•	•	•
78	Out of step	•	•	•	•
67N	Directional earth fault (DEF) unit protection	•	•	•	•
50/51/67	Phase overcurrent stages, with optional directionality	4	4	4	4
50N/51N/ 67N	Earth/ground overcurrent stages, with optional directionality	4	4	4	4
51N/67N/SEF	Sensitive earth fault (SEF	4	4	4	4
67/46	Negative sequence overcurrent, with optional directionality	•	•	•	•
46BC	Broken conductor (open jumper), used to detect open circuit faults	•	•	•	•
49	Thermal overload protection	•	•	•	•
27	Undervoltage protection stages	2	2	2	2
59	Overvoltage protection stages	2	2	2	2
59N	Residual voltage stages (neutral displacement)	2	2	2	2
50BF	High speed breaker fail. Two-stage, suitable for re-tripping and backtripping	•	•	•	•
CTS	CT supervision (including differential CTS, patent pending)	•	•	•	•
VTS	Current and voltage transformer supervision	•	•	•	•
79	Auto-reclose - shots supported	4		4	
25	Check synchronism, 2 stages with additional system split detection	•		•	
	Alternative setting groups	4	4	4	4
FL	Fault locator	•	•	•	•
	SOE event records	512	512	512	512
	Disturbance recorder, samples per cycle. For waveform capture	48	48	48	48
	Circuit breaker condition monitoring	•	•	•	•
	Graphical programmable scheme logic (PSL)	•	•	•	•

		Models			
ANSI	**FEATURE**	**P543**	**P544**	**P545**	**P546**
	IRIG-B time synchronism	(•)	(•)	(•)	(•)
	Second rear communication port	(•)	(•)	(•)	(•)
	InterMiCOM^{64} teleprotection for direct relay-relay communication	(•)	(•)	(•)	(•)

The P54x supports the following relay management functions in addition to the functions illustrated above.

- Measurement of all instantaneous & integrated values
- Circuit breaker control, status & condition monitoring
- Trip circuit and coil supervision
- Programmable hotkeys (2)
- Control inputs
- Programmable allocation of digital inputs and outputs
- Fully customizable menu texts
- Power-up diagnostics and continuous self-monitoring of relay

Application overview

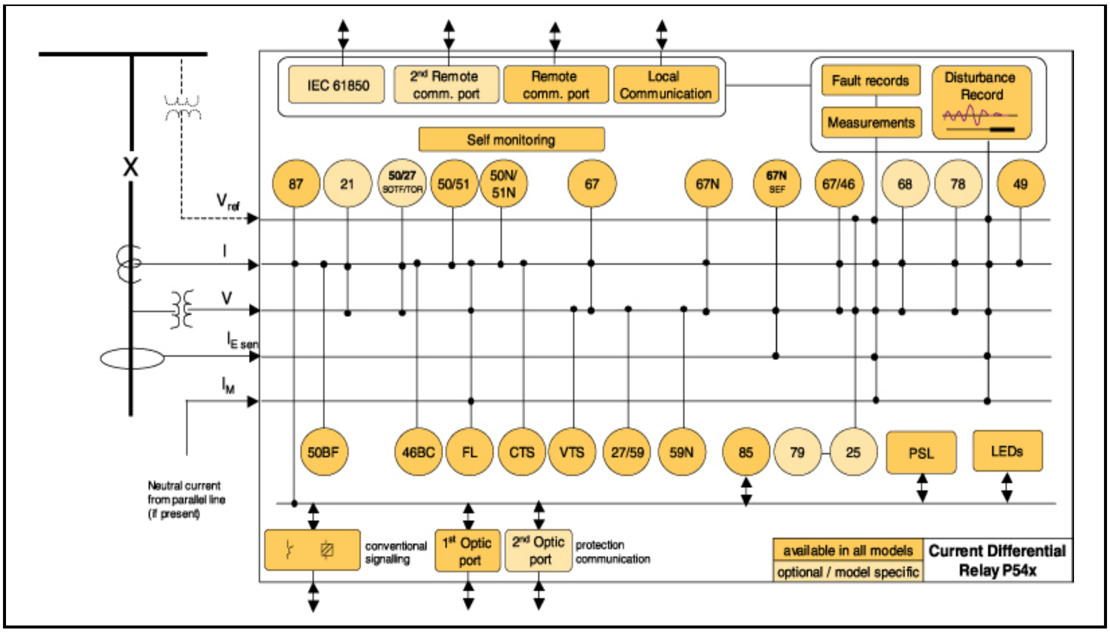


Figure 1: Functional diagram

3.2 Ordering options

Information Required with Order

P54x Distance Protection **P54x** [ ] [ ] [1] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ]

C Diff with Distance, 1/3 pole auto-reclose	3
C Diff with Distance, for 2 breaker configuration	4
P543 with extra I/O	5
P544 with extra I/O	6
Auxiliary Voltage Rating	
24 - 48 Vdc	1
48 - 125 Vdc	2
110 - 250 Vdc	3
Hardware Options	
Nothing	1
IRIG-B only (Modulated)	2
Fiber optic converter only	3
IRIG-B (Modulated) & fiber optic converter	4
Ethernet (100MHz)	6
Rear Comms Board	7
IRIG-B (Modulated) plus Rear Comms Board	8
Ethernet (100MHz) plus IRIG-B (Modulated)	A
Ethernet (100MHz) plus IRIG-B (Un-modulated)	B
IRIG-B (Un-modulated)	C
Product Specific	
850nm dual channel	A
1300nm SM single channel	B
1300nm SM dual channel	C
1300nm MM single channel	D
1300nm MM dual channel	E
1550nm SM single channel	F
1550nm SM dual channel	G
850nm MM + 1300mn SM	H
850nm MM + 1300mn MM	J
850nm MM + 1550mn SM	K
1300mn SM + 850nm MM	L
1300mn MM + 850nm MM	M
Reserved for future single channel	N
Reserved for future single channel	P
1550mn SM + 850nm MM	R
850nm dual channel + High Break	S
1300nm SM single channel + High Break	T
1300nm SM dual channel + High Break	U
1300nm MM single channel + High Break	V
1300nm MM dual channel + High Break	W
1550nm SM single channel + High Break	X
Reserved RWE	Y
1550nm SM dual channel + High Break	Z
850nm MM + 1300mn SM + High Break	0
850nm MM + 1300mn MM + High Break	1
850nm MM + 1550mn SM + High Break	2
1300mn SM + 850nm MM + High Break	3
1300mn MM + 850nm MM + High Break	4
1550mn SM + 850nm MM + High Break	5
Reserved for future single channel	6
Reserved for future single channel	7

IT

Protocol Options	
K-Bus	1
IEC60870-5-103 (VDEW)	3
DNP3.0	4
IEC 61850 + Courier via rear EIA(RS)485 port	6
IEC 61850 + IEC 60870-5-103 via rear EIA(RS)485 port	7
Mounting	
Flush/Panel Mounting	M
Rack (P545, P546 only)	N
Language Options	
Multilingual - English, French, German, Spanish	0
Multilingual - English, French, German, Russian	5
Software Number	
Without Distance	41
With Distance	51
Settings File	
Default	0
Customer	1
Hardware Suffix	
Note 1.	K

Note 1:

A = Original

B = Universal Optos, New Relays, New Co-Processor Board, New PSU

G = CPU2

J = Dual Rated Optos

K = Extended CPU2

TD

TECHNICAL DATA

Date:	**7th August 2006**
Hardware Suffix:	**K**
Software Version:	**41 and 51**
Connection Diagrams:	**10P54302xx (xx = 01 to 02) & 10P54303xx (xx = 01 to 02)**
	10P54402xx (xx = 01 to 02) & 10P54403xx (xx = 01 to 02)
	10P54502xx (xx = 01 to 02) & 10P54503xx (xx = 01 to 02)
	10P54602xx (xx = 01 to 02) & 10P54603xx (xx = 01 to 02)

Technical Data

Mechanical Specifications

Design
Modular MiCOM Px40 platform relay, available in 2 different case sizes:

P543 and P544: 60TE, front of panel flush mounting, or 19" rack mounted (ordering options).

P545 and P546: 80TE, front of panel flush mounting, or 19" rack mounted (ordering options).

Enclosure Protection
Per IEC 60529: 1989
IP 52 Protection (front panel) against dust and dripping water.
IP 30 Protection for sides of the case.
IP 10 Protection for the rear.

Weight
P543 approx. 9.2 kg
P544 approx. 11.5 kg
P545 approx. 11 kg
P546 approx. 13.1 kg

Terminals

AC Current and Voltage Measuring Inputs
Located on heavy duty (black) terminal block:
Threaded M4 terminals, for ring lug connection.
CT inputs have integral safety shorting, upon removal of the terminal block.

General Input/Output Terminals
For power supply, opto inputs, output contacts and COM1 rear communications.
Located on general purpose (grey) blocks:
Threaded M4 terminals, for ring lug connection.

Case Protective Earth Connection
Two rear stud connections, threaded M4.
Must be earthed (grounded) for safety, minimum earth wire size $2.5mm^2$.

Front Port Serial PC Interface
EIA(RS)232 DTE, 9 pin D-type female connector.
Courier protocol for interface to MiCOM S1 software.
Isolation to ELV level.
Maximum cable length 15m.

Front Download/Monitor Port
EIA(RS)232, 25 pin D-type female connector.
For firmware downloads.
Isolation to ELV level.

Rear Communications Port
EIA(RS)485 signal levels, two wire
Connections located on general purpose block, M4 screw.
For screened twisted pair cable, multi-drop, 1000m max.
For K-Bus, IEC-870-5-103, or DNP3 protocol (ordering options).
Isolation to SELV level.

Optional Second Rear Communications Port
EIA(RS)232, 9 pin D-type female connector, socket SK4.
Courier protocol: K-Bus, EIA(RS)232, or EIA(RS)485 connection.
Isolation to SELV level.

Optional Rear IRIG-B Interface modulated or un-modulated
BNC socket
Isolation to SELV level.
50 ohm coaxial cable.

Optional Rear Fiber Connection for SCADA/DCS
BFOC 2.5 -(ST®)-interface for glass fiber, as per IEC 874-10.
850nm short-haul fibers, one Tx and one Rx.
For Courier, IEC-870-5-103 or DNP3 protocol (ordering options).

Optional Rear Ethernet Connection for IEC 61850

10BaseT/100BaseTX Communications
Interface in accordance with IEEE802.3 and IEC 61850
Isolation: 1.5kV
Connector type: RJ45
Cable type: Screened Twisted Pair (STP)
Max. cable length: 100m

100 Base FX Interface
Interface in accordance with IEEE802.3 and IEC 61850
Wavelength: 1300nm
Fiber: multi-mode 50/125µm or 62.5/125µm
Connector type: BFOC 2.5 -(ST®)

TD

Ratings

AC Measuring Inputs
Nominal frequency: 50 and 60 Hz (settable)
Operating range: 45 to 65Hz
Phase rotation: ABC or CBA

AC Current
Nominal current (In): 1 and 5 A dual rated.
(1A and 5A inputs use different transformer tap connections, check correct terminals are wired).
Nominal burden per phase: < 0.15 VA at In
Thermal withstand:
continuous 4 In
for 10s: 30 In
for 1s; 100 In
Linear to 64 In (non-offset AC current).

AC Voltage
Nominal voltage (Vn): 100 to 120 V or 380 to 480V phase-phase.
Nominal burden per phase: < 0.02 VA at Vn.
Thermal withstand:
continuous 2 Vn
for 10s: 2.6 Vn

Power Supply

Auxiliary Voltage (Vx)
Three ordering options:
(i) Vx: 24 to 48 Vdc
(ii) Vx: 48 to 110 Vdc, and 30 to 100Vac (rms)
(iii) Vx: 110 to 250 Vdc, and 100 to 240Vac (rms)

Operating Range
(i) 19 to 65V (dc only for this variant)
(ii) 37 to 150V (dc), 24 to 110V (ac)
(iii) 87 to 300V (dc), 80 to 265V (ac)
With a tolerable ac ripple of up to 12% for a dc supply, per IEC 60255-11: 1979.

Nominal Burden
Quiescent burden: 11W. (Extra 1.25W when fitted with second rear communications board)
Additions for energized binary inputs/outputs:
Per opto input:
0.09W (24 to 54V),
0.12W (110/125V),
0.19W (220/120V).
Per energized output relay: 0.13W

Power-up Time
Time to power up < 11s.

Power Supply Interruption
Per IEC 60255-11: 1979
The relay will withstand a 20ms interruption in the DC auxiliary supply, without de-energizing.
Per IEC 61000-4-11: 1994
The relay will withstand a 20ms interruption in an AC auxiliary supply, without de-energizing.

Battery Backup
Front panel mounted
Type ½ AA, 3.6V Lithium Thionyl Chloride Battery

Field Voltage Output
Regulated 48Vdc
Current limited at 112mA maximum output

Digital (“Opto”) Inputs
Universal opto inputs with programmable voltage thresholds. May be energized from the 48V field voltage, or the external battery supply.
Rated nominal voltage: 24 to 250Vdc
Operating range: 19 to 265Vdc
Withstand: 300Vdc.
Nominal pick-up and reset thresholds:
Nominal Battery 24/27: 60 - 80% DO/PU
(logic 0) <16.2 (logic 1) >19.2
Nominal Battery 24/27: 50 - 70% DO/PU
(logic 0) <12.0 (logic 1) >16.8
Nominal Battery 30/34: 60 - 80% DO/PU
(logic 0) <20.4 (logic 1) >24.0
Nominal Battery 30/34: 50 - 70% DO/PU
(logic 0) <15.0 (logic 1) >21.0
Nominal Battery 48/54: 60 - 80% DO/PU
(logic 0) <32.4 (logic 1) >38.4
Nominal Battery 48/54: 50 - 70% DO/PU
(logic 0) <24.0 (logic 1) >33.6
Nominal Battery 110/125: 60 - 80% DO/PU
(logic 0) <75.0 (logic 1) >88.0
Nominal Battery 110/125: 50 - 70% DO/PU
(logic 0) <55.0 (logic 1) >77.0
Nominal Battery 220/250: 60 - 80% DO/PU
(logic 0) <150.0 (logic 1) >176.0
Nominal Battery 220/250: 50 - 70% DO/PU
(logic 0) <110 (logic 1) >154
Recognition time:
<2ms with long filter removed,
<12ms with half-cycle ac immunity filter on.

Output Contacts

Standard Contacts
General purpose relay outputs for signaling, tripping and alarming:
Rated voltage: 300 V
Continuous current: 10 A
Short-duration current: 30 A for 3s

Making capacity: 250A for 30ms
Breaking capacity:
DC: 50W resistive
DC: 62.5W inductive (L/R = 50ms)
AC: 2500VA resistive (cos ϕ = unity)
AC: 2500VA inductive (cos ϕ = 0.7)
Response to command: < 5ms
Durability:
Loaded contact: 10 000 operations minimum,
Unloaded contact: 100 000 operations minimum.

High Break Contacts

Relay outputs for tripping:
Rated voltage: 300 V
Continuous current: 10 A dc
Short-duration current: 30 A dc for 3 s
Making capacity: 250A dc for 30 ms
Breaking capacity:
DC: 7500W resistive
DC: 2500W inductive (L/R = 50ms)
Subject to maxima of 10A and 300V
Response to command: < 0.2ms
Durability:
Loaded contact: 10 000 operations minimum,
Unloaded contact: 100 000 operations minimum.

Watchdog Contacts

Non-programmable contacts for relay healthy/relay fail indication:
Breaking capacity:
DC: 30W resistive
DC: 15W inductive (L/R = 40ms)
AC: 375VA inductive (cos ϕ = 0.7)

IRIG-B 12X Interface (Modulated)

External clock synchronization per IRIG standard 200-98, format B12X.
Input impedance 6kΩ at 1000Hz
Modulation ratio: 3:1 to 6:1
Input signal, peak-peak: 200mV to 20V

IRIG-B 00X Interface (Un-modulated)

External clock synchronization per IRIG standard 200-98, format B00X.
Input signal TTL level
Input impedance at dc 10kΩ

Environmental Conditions

Ambient Temperature Range

Per IEC 60255-6: 1988
Operating temperature range:
-25°C to +55°C (or -13°F to +131°F).
Storage and transit:
-25°C to +70°C (or -13°F to +158°F).

Ambient Humidity Range

Per IEC 60068-2-3: 1969:
56 days at 93% relative humidity and +40°C
Per IEC 60068-2-30: 1980:
Damp heat cyclic, six (12 + 12) hour cycles, 93% RH, +25 to +55°C

Type Tests

Insulation

Per IEC 60255-5: 2000,
Insulation resistance > 100MΩ at 500Vdc (Using only electronic/brushless insulation tester).

TD

Creepage Distances and Clearances

Per IEC 60255-5: 2000
Pollution degree 3,
Overvoltage category III,
Impulse test voltage 5 kV.

High Voltage (Dielectric) Withstand

EIA(RS)232 ports excepted.
(i) Per IEC 60255-5: 2000, 2 kV rms AC, 1 minute:
Between all case terminals connected together, and the case earth.
Also, between all terminals of independent circuits.
1kV rms AC for 1 minute, across open watchdog contacts.
1kV rms AC for 1 minute, across open contacts of changeover output relays.
(ii) Per ANSI/IEEE C37.90-1989 (reaffirmed 1994):
1.5 kV rms AC for 1 minute, across open contacts of changeover output relays.

Impulse Voltage Withstand Test

Per IEC 60255-5: 2000
Front time: 1.2 µs, Time to half-value: 50 µs,
Peak value: 5 kV, 0.5J
Between all terminals, and all terminals and case earth.

Electromagnetic Compatibility (EMC)

1 MHz Burst High Frequency Disturbance Test

Per IEC 60255-22-1: 1988, Class III,
Common-mode test voltage: 2.5 kV,
Differential test voltage: 1.0 kV,
Test duration: 2s, Source impedance: 200Ω
EIA(RS)232 ports excepted.

Immunity to Electrostatic Discharge
Per IEC 60255-22-2: 1996, Class 4,
15kV discharge in air to user interface, display, and exposed metalwork.
Per IEC 60255-22-2: 1996, Class 3,
8kV discharge in air to all communication ports.
6kV point contact discharge to any part of the front of the product.

Electrical Fast Transient or Burst Requirements
Per IEC 60255-22-4: 2002. Test severity Class III and IV:
Amplitude: 2 kV, burst frequency 5kHz (Class III),
Amplitude: 4 kV, burst frequency 2.5kHz (Class IV).
Applied directly to auxiliary supply, and applied to all other inputs. EIA(RS)232 ports excepted.

Surge Withstand Capability
IEEE/ANSI C37.90.1: 2002:
4kV fast transient and 2.5kV oscillatory applied common mode and differential mode to opto inputs (filtered), output relays, CTs, VTs, power supply, field voltage.
4kV fast transient and 2.5kV oscillatory applied common mode to communications, IRIG-B.

Surge Immunity Test
EIA(RS)232 ports excepted.
Per IEC 61000-4-5: 2002 Level 4,
Time to half-value: 1.2/50 µs,
Amplitude: 4kV between all groups and case earth,
Amplitude: 2kV between terminals of each group.

Immunity to Radiated Electromagnetic Energy
Per IEC 60255-22-3: 2000, Class III:
Test field strength, frequency band 80 to 1000 MHz:
10 V/m,
Test using AM: 1 kHz / 80%,
Spot tests at 80, 160, 450, 900 MHz
Per IEEE/ANSI C37.90.2: 1995:
25MHz to 1000MHz, zero and 100% square wave modulated.
Field strength of 35V/m.

Radiated Immunity from Digital Communications
Per EN61000-4-3: 2002, Level 4:
Test field strength, frequency band 800 to 960 MHz, and 1.4 to 2.0 GHz:
30 V/m,
Test using AM: 1 kHz / 80%.

Radiated Immunity from Digital Radio Telephones
Per ENV 50204: 1995
10 V/m, 900MHz and 1.89GHz.

Immunity to Conducted Disturbances Induced by Radio Frequency Fields
Per IEC 61000-4-6: 1996, Level 3,
Disturbing test voltage: 10 V

Power Frequency Magnetic Field Immunity
Per IEC 61000-4-8: 1994, Level 5,
100A/m applied continuously,
1000A/m applied for 3s.
Per IEC 61000-4-9: 1993, Level 5,
1000A/m applied in all planes.
Per IEC 61000-4-10: 1993, Level 5,
100A/m applied in all planes at 100kHz/1MHz with a burst duration of 2s.

Conducted Emissions
Per EN 55022: 1998:
0.15 - 0.5MHz, 79dBµV (quasi peak) 66dBµV (average)
0.5 - 30MHz, 73dBµV (quasi peak) 60dBµV (average).

Radiated Emissions
Per EN 55022: 1998:
30 - 230MHz, 40dBµV/m at 10m measurement distance
230 - 1GHz, 47dBµV/m at 10m measurement distance.

EU Directives

EMC Compliance
Per 89/336/EEC:
Compliance to the European Commission Directive on EMC is claimed via the Technical Construction File route. Product Specific Standards were used to establish conformity:
EN50263: 2000

Product Safety
Per 73/23/EEC:
Compliance with European Commission Low Voltage Directive.
Compliance is demonstrated by reference to generic safety standards:
EN61010-1: 2001
EN60950-1: 2002

CE 73/23/EEC

R&TTE COMPLIANCE
Radio and Telecommunications Terminal Equipment (R & TTE) directive 95/5/EC.Compliance demonstrated by compliance to the Low Voltage Directive, 73/23/EEC amended by 93/68/EEC, down to zero volts by reference to safety standards. Applicable to rear communications ports.

ATEX COMPLIANCE
ATEX Potentially Explosive Atmospheres directive 94/9/EC, for equipment. The equipment is compliant with Article 1(2) of European directive 94/9/EC. It is approved for operation outside an ATEX hazardous area. It is however approved for connection to Increased Safety, “Ex e”, motors with rated ATEX protection, Equipment Category 2, to ensure their safe operation in gas Zones 1 and 2 hazardous areas.

CAUTION - Equipment with this marking is not itself suitable for operation within a potentially explosive atmosphere.

Compliance demonstrated by Notified Body certificates of compliance.

II (2) G

Mechanical Robustness

Vibration Test
Per IEC 60255-21-1: 1996
Response Class 2
Endurance Class 2

Shock and Bump
Per IEC 60255-21-2: 1995
Shock response Class 2
Shock withstand Class 1
Bump Class 1

Seismic Test
Per IEC 60255-21-3: 1995
Class 2

P14x Third Party Compliances (UL/CUL)

File Number: E20251 Original Issue Date: 21-04-2005 (Complies with Canadian and US requirements).

TD

Protection Functions

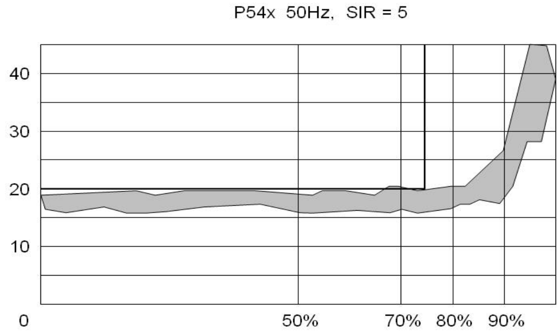
Phase Current Differential Protection

Accuracy
Pick-up: Formula ±10%
Drop-off: 0.75 x Formula ±10%
IDMT characteristic shape: ±5% or
40ms whichever is greater
DT operation: ±2% or 20ms whichever
is greater
Instantaneous Operation: <30ms
Reset time: <60ms
Repeatability: ±2.5%
Characteristic:
UK curves IEC 60255-3 – 1998
US curves IEEE C37.112 – 1996
Vector compensation:
No affect on accuracy
Current transformer ratio
Compensation
No affect on accuracy
High set characteristic setting:
No affect on accuracy
Two ended scheme operation:
No affect on accuracy
Three ended scheme operation:
No affect on accuracy

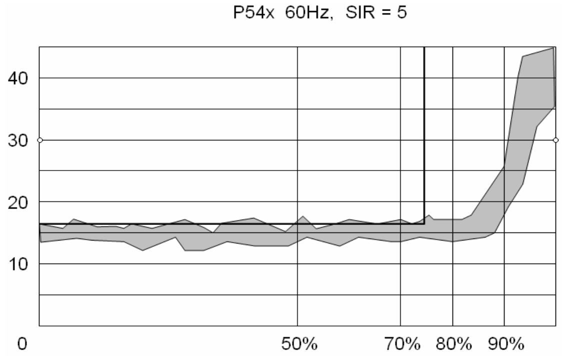
Distance Protection

All quoted operating times include the closure of the trip output contact.

50Hz Operation



60Hz Operation



Accuracy
Characteristic shape, up to SIR = 30:
±5% for on-angle fault (the set line angle)
±10% off-angle
(Example: For a 70 degree set line angle, injection testing at 40 degrees would be referred to as "off-angle").
Zone time delay deviations:
±20ms or 2%, whichever is greater.

Sensitivity
Settings < 5/In Ω: (0.05In*5/(setting*In)) ±5%
Settings > 5/In Ω: 0.05 In ±5%

Out of Step

Accuracy of zones and timers as per distance
Operating range: up to 7Hz

Phase and Ground (Earth) Overcurrent

Accuracy
Pick-up: Setting ±5%
Drop-off: 0.95 x setting ±5%
Minimum trip level for IDMT elements:
1.05 x Setting ± 5%
Inverse time stages:
±40ms or 5%, whichever is greater
Definite time stages:
±40ms or 2%, whichever is greater
Repeatability: 5%
Directional boundary accuracy:
±2° with hysteresis <3°
Additional tolerance due to increasing X/R ratios:
±5% over the X/R ratio from 1 to 90.
Overshoot of overcurrent elements: <30ms

SEF
Pick-up: Setting ±5%
Drop-off: 0.95 x Setting ±5%
Minimum trip level of IDMT elements:
1.05 x Setting ±5%
IDMT characteristic shape:
±5% or 40ms whichever is greater*
IEEE reset: ±17.5% or 60ms
whichever is greater
DT operation: ±2% or 50ms
whichever is greater
DT reset: ±5% or 50ms whichever is
greater
Repeatability: 5%
* Reference conditions TMS = 1, TD = 1, and IN> setting of 100mA, accuracy operating range 2-20Is

Wattmetric SEF
Pick-up P=0W: ISEF> ±5% or 5mA
Pick-up P>0W: P> ±5%
Drop-off P=0W: (0.95 x ISEF >) ±5% or 5mA
Drop-off P>0W: 0.9 x P> ±5%
Boundary accuracy: ±5% with 1° hysteresis
Repeatability: 1%

Polarizing Quantities
VN> and V2> Level detectors:
Pick-up: ±10%
Resetting ratio: 0.9
I2> Level detector:
Pick-up: ±10%
Resetting ratio: 0.9

Negative Sequence Overcurrent

Accuracy
Pick-up: Setting ±5%
Drop-off: 0.95 x setting
Definite time operation:
±60ms or 2%, whichever is greater
Repeatability: 1%
Directional boundary accuracy:
±2° with hysteresis <1°
Reset: <35ms

Under Voltage

Accuracy
DT Pick-up: Setting ±2%
IDMT Pick-up: 0.98 x setting ±2%
Drop-off: 1.02 x setting ±2%
Definite time operation:
±40ms or 2%, whichever is greater
Repeatability: 1%
IDMT characteristic shape:
±40ms or 2%, whichever is greater
Reset: <75ms

Over Voltage

Accuracy
DT Pick-up: Setting ±1%
IDMT Pick-up: 1.02 x setting ±2%
Drop-off: 0.98 x setting ±2%
Definite time operation:
±40ms or 2%, whichever is greater
Repeatability: 1%
IDMT characteristic shape:
±40ms or 2%, whichever is greater
Reset: <75ms

Neutral Displacement/Residual Over Voltage

Accuracy
DT Pick-up: Setting ±5%
IDMT Pick-up: 1.05 x setting ±5%
Drop-off: 0.95 x setting ±5%
Definite time operation:
±20ms or 2%, whichever is greater
Instantaneous operation: <50ms
Repeatability: 10%
IDMT characteristic shape:
±60ms or 5%, whichever is greater
Reset: <35ms

Circuit Breaker Fail and Undercurrent

Accuracy
Pick-up: ±10% or 0.025In, whichever is greater
Operating time: <12ms
Timers: ±40ms or 2%, whichever is greater
Reset: <15ms

Broken Conductor Logic

Accuracy
Pick-up: Setting ±2.5%
Drop-off: 0.95 x setting ±2.5%
Definite time operation:
±50ms or 2%, whichever is greater
Reset: <25ms

Thermal Overload

Accuracy
Thermal alarm pick-up:
Calculated trip time ±10%
Thermal overload pick-up:
Calculated trip time ±10%
Cooling time accuracy ±15% of theoretical
Repeatability: <5%
* *Operating time measured with applied current of 20% above thermal setting.*

Voltage Transformer Supervision

Accuracy
Fast block operation: <1 cycle
Fast block reset: <1.5 cycles
Time delay:
±20ms or 2%, whichever is greater

Current Transformer Supervision

Standard CTS

Accuracy
IN> Pick-up: Setting ±5%
VN< Pick-up: Setting ±5%
IN> Drop-off: 0.9 setting ±5%
VN< Drop-off:
(1.05 x setting) ±5% or 1V, whichever is greater
Time delay operation:
Setting ±2% or 20ms, whichever is greater
CTS block operation: <1 cycle
CTS reset: <35ms

TD

Differential CTS

Accuracy
I1 Pick-up: Setting 5%
I1 Drop-off: (0.9 x setting) 5%
I2/I1> Pick-up: Setting 5%
I2/I1> Drop-off: (0.9 x setting) 5%
I2/I1>> Pick-up: Setting 5%
I2/I1>> Drop-off: (0.9 x setting) 5%
Time delay operation:
Setting 2% or 20ms, whichever is greater
CTS block operation: <1 cycle
CTS block diff operation <1 cycle
CTS reset: <35ms

CB State Monitoring and Condition Monitoring

Accuracy
Timers:
±20ms or 2%, whichever is greater
Broken current accuracy: ±5%

Programmable Scheme Logic

Accuracy
Output conditioner timer:
Setting ±20ms or 2%, whichever is greater

Dwell conditioner timer:
Setting ±20ms or 2%, whichever is greater
Pulse conditioner timer:
Setting ±20ms or 2%, whichever is greater

Auto-reclose and Check Synchronism

Accuracy
Timers:
Setting ±20ms or 2%, whichever is greater

Measurements and Recording Facilities

Accuracy
Typically ±1%, but ±0.5% between 0.2 - 2In/Vn
Current: 0.05 to 3In
Accuracy: ±1.0% of reading
Voltage: 0.05 to 2Vn
Accuracy: ±1.0% of reading
Power (W): 0.2 to 2Vn and 0.05 to 3In
Accuracy: ±5.0% of reading at unity power factor
Reactive power (Vars): 0.2 to 2Vn to 3In
Accuracy: ±5.0% of reading at zero power factor
Apparent power (VA): 0.2 to 2Vn 0.05 to 3In
Accuracy: ±5.0% of reading
Energy (Wh): 0.2 to 2Vn 0.2 to 3In
Accuracy: ±5.0% of reading at zero power factor
Energy (Varh): 0.2 to 2Vn 0.2 to 3In
Accuracy: ±5.0% of reading at zero power factor
Phase accuracy: 0° to 360°
Accuracy: ±0.5%
Frequency: 45 to 65Hz
Accuracy: ±0.025Hz

IRIG-B and Real Time Clock

Performance Accuracy
(for modulated and un-modulated versions)
Real time clock accuracy: < ±2 seconds/day

Disturbance Records

Maximum record duration: 10.5sec.
No of records: Typically a minimum of 50 records at 1.5 seconds (no of records dependent on record duration setting).
VDEW standard supports 8 records of 3 sec. duration each.

Accuracy
Magnitude and relative phases:
±5% of applied quantities
Duration: ±2%
Trigger position: ±2% (minimum Trigger 100ms)

Fault Locator

Accuracy
Fault location: ±2% of line length (under reference conditions)*
* Reference conditions solid fault applied on line

Event, Fault & Maintenance Records

The most recent records are stored in battery-backed memory, and can be extracted via the communication port or be viewed on the front panel display.

No of Event Records: Up to 512 time tagged event records.

No of Fault Records: Up to 5

No of Maintenance Records: Up to 5

Plant Supervision

Accuracy

Timers: ±2% or 20ms whichever is greater
Broken current accuracy: ±5%

Timer Accuracy

Timers: ±2% or 40ms whichever is greater
Reset time: <30ms

Undercurrent Accuracy

Pick-up: ±10% or 25mA whichever is greater
Operating time: <20ms
Reset: <25ms

InterMiCOM^{64} Fiber Optic Teleprotection

End-end operation. Table below shows minimum and maximum transfer time for InterMiCOM^{64} (IM64).

The times are measured from opto initialization (with no opto filtering) to relay standard output and include a small propagation delay for back-back test (2.7ms for 64kbits/s and 3.2ms for 56kbits/s).

IDiff IM64 indicates InterMiCOM^{64} signals working in conjunction with the differential protection fiber optic communications channel. IM64 indicates InterMiCOM^{64} signals working as a standalone feature.

Configuration	Permissive Op Times (ms)	Direct Op Times (ms)
IM64 at 64k	13 - 18	17 - 20
IM64 at 56k	15 - 20	19 - 22
IDiff IM64 at 64k	22 - 24	23 - 25
IDiff IM64 at 56k	24 - 26	25 - 27

IEC 61850 Ethernet Data

100 Base FX Interface

Transmitter Optical Characteristics

(T_A = 0°C to 70°C, V_{CC} = 4.75 V to 5.25 V)

Parameter	Sym	Min.	Typ.	Max.	Unit
Output Optical Power BOL 62.5/125 µm, NA = 0.275 Fiber EOL	PO	-19 -20	-16.8	-14	dBm avg.
Output Optical Power BOL 50/125 µm, NA = 0.20 Fiber EOL	PO	-22.5 -23.5	-20.3	-14	dBm avg.
Optical Extinction Ratio				10 -10	% dB
Output Optical Power at Logic “0” State	PO (“0”)			-45	dBm avg.

BOL - Beginning of life

EOL - End of life

Receiver Optical Characteristics

(T_A = 0°C to 70°C, V_{CC} = 4.75 V to 5.25 V)

Parameter	Sym	Min.	Typ.	Max.	Unit
Input Optical Power Minimum at Window Edge	PIN Min. (W)		-33.5	–31	dBm avg.
Input Optical Power Minimum at Eye Center	PIN Min. (C)		-34.5	-31.8	Bm avg.
Input Optical Power Maximum	PIN Max.	-14	-11.8		dBm avg.

Note: The 10BaseFL connection will no longer be supported as IEC 61850 does not specify this interface

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Settings, Measurements and Records List

Settings List

Global Settings (System Data):

Language: English/French/German/Spanish
Frequency: 50/60Hz

Circuit Breaker Control (CB Control):

CB Control by:
- Disabled
- Local
- Remote
- Local+remote
- Opto
- Opto+local
- Opto+remote
- Opto+rem+local

Close pulse time: 0.10…10.00s
Trip pulse time: 0.10…5.00s
Man close t max: 0.01…9999.00s
Man close delay: 0.01…600.00s
CB healthy time: 0.01…9999.00s
Check sync time: 0.01…9999.00s
Reset lockout by: User interface/CB close
Man close RstDly: 0.10…600.00s
Single pole A/R: Disabled/Enabled
Three pole A/R: Disabled/Enabled
CB Status Input:
- None
- 52A 3 pole
- 52B 3 pole
- 52A & 52B 3 pole
- 52A 1 pole
- 52B 1 pole
- 52A & 52B 1 pole

Date and Time

IRIG-B Sync: Disabled/Enabled
Battery Alarm: Disabled/Enabled

Configuration

Setting Group:
- Select via Menu
- Select via Opto

Active Settings: Group 1/2/3/4
Setting Group 1: Disabled/Enabled
Setting Group 2: Disabled/Enabled
Setting Group 3: Disabled/Enabled
Setting Group 4: Disabled/Enabled
Distance: Disabled/Enabled
Directional E/F: Disabled/Enabled
Tripping Mode: 3 Pole
Phase Diff: Disabled/Enabled
Overcurrent: Disabled/Enabled
Neg Sequence O/C: Disabled/Enabled
Broken Conductor: Disabled/Enabled
Earth Fault: Disabled/Enabled
Sensitive E/F: Disabled/Enabled
Residual O/V NVD: Disabled/Enabled
Thermal Overload: Disabled/Enabled
Power Swing Block: Disabled/Enabled
Volt Protection: Disabled/Enabled
CB Fail: Disabled/Enabled
Supervision: Disabled/Enabled
System Checks: Disabled/Enabled
Auto-Reclose: Disabled/Enabled
Input Labels: Invisible/Visible
Output Labels: Invisible/Visible
CT & VT Ratios: Invisible/Visible
Record Control: Invisible/Visible
Disturb Recorder: Invisible/Visible
Measure’t Setup: Invisible/Visible
Comms Settings: Invisible/Visible
Commission Tests: Invisible/Visible
Setting Values: Primary/Secondary
Control Inputs: Invisible/Visible
Ctrl I/P Config: Invisible/Visible
Ctrl I/P Labels: Invisible/Visible
Direct Access: Disabled/Enabled
InterMiCOM^{64} Fiber: Disabled/Enabled
Function Key: Invisible/Visible
LCD Contrast: *(Factory pre-set)*

CT and VT Ratios

Main VT Primary: 100V...1MV
Main VT Sec'y: 80...140V
C/S VT Primary: 100V...1MV
C/S VT Secondary: 80...140V
Phase CT Primary: 1A…30kA
Phase CT Sec'y: 1A/5A
SEF CT Primary: 1A…30kA
SEF CT Sec'y: 1A/5A
MComp CT Primary: 1A…30kA
MComp CT Sec'y: 1A/5A
C/S Input:
- A-N
- B-N
- C-N
- A-B
- B-C
- C-A

Main VT Location: Line/Bus
CT Polarity: Standard /Inverted
CT2 Polarity: Standard /Inverted
SEF CT Polarity: Standard /Inverted
M CT Polarity: Standard /Inverted
VTs Connected: Yes/No

Sequence of Event Recorder (Record Control)

Alarm Event: Disabled/Enabled
Relay O/P Event: Disabled/Enabled
Opto Input Event: Disabled/Enabled
General Event: Disabled/Enabled
Fault Rec Event: Disabled/Enabled
Maint Rec Event: Disabled/Enabled
Protection Event: Disabled/Enabled
DDB 31 - 0:
(up to):
DDB 1407 - 1376:
Binary function link strings, selecting which DDB signals will be stored as events, and which will be filtered out.

Oscillography (Disturb Recorder)

Duration: 0.10…10.50s
Trigger Position: 0.0…100.0%
Trigger Mode: Single/Extended
Analog Channel 1:
(up to):
Analog Channel 12:
Disturbance channels selected from:
IA, IB, IC, IN, IN Sensitive, VA, VB, VC, IM, V CheckSync (only for P543 and P545) and IA2, IB2, IC2 (only for P544 and P546)

Digital Input 1:
(up to):
Digital Input 32:
Selected binary channel assignment from any DDB status point within the relay (opto input, output contact, alarms, starts, trips, controls, logic…).
Input 1 Trigger: No Trigger/Trigger
(up to):
Input 32 Trigger: No Trigger/Trigger

Measured Operating Data (Measure't Setup)

Default Display:
3Ph + N Current
3Ph Voltage
Power
Date and Time
Description
Plant Reference
Frequency
Access Level
Local Values: Primary/Secondary
Remote Values: Primary/Secondary
Measurement Ref: VA/VB/VC/IA/IB/IC
Measurement Mode: 0/1/2/3
Fix Dem Period: 1…99mins
Roll Sub Period: 1…99mins
Num Sub Periods: 1…15
Distance Unit: Miles/Kilometers
Fault Location:
Distance
Ohms
% of Line

Remote 2 Values: Primary/Secondary

Communications

RP1 Protocol:
Courier
IEC870-5-103
DNP 3.0
RP1 Address: *(Courier or IEC870-5-103):*
0…255
RP1 Address: *(DNP3.0):*
0…65519
RP1 InactivTimer: 1…30mins
RP1 Baud Rate: *(IEC870-5-103):*
9600/19200 bits/s
RP1 Baud Rate: *(DNP3.0):*
1200 bits/s
2400 bits/s
4800 bits/s
9600 bits/s
19200 bits/s
38400 bits/s
RP1 Parity:
Odd/Even/None
RP1 Meas Period: 1…60s
RP1 PhysicalLink:
RS485
Fiber Optic *(IEC870-5-103 only)*
K-Bus *(Courier only)*
RP1 Time Sync: Disabled/Enabled
Function Type: Differential 192/
Distance 128
RP1 CS103 Blocking:
Disabled
Monitor Blocking
Command Blocking
RP1 Port Config: (Courier):
K Bus
EIA485 (RS485)
RP1 Comms Mode:
IEC60870 FT1.2 Frame
IEC60870 10-Bit Frame
RP1Bauds rate: 1200 bits/s, 2400 bits/s, 4800 bits/s, 9600 bits/s, 19200 bits/s or 38400 bits/s

Optional Ethernet Port

NIC Tunl Timeout: 1...30mins
NIC Link Report: Alarm, Event, None
NIC Link Timeout: 0.1...60s

Optional Additional Second Rear Communication (Rear Port2 (RP2))

RP2 Protocol: Courier (fixed)
RP2 Port Config:
Courier over EIA(RS)232
Courier over EIA(RS)485
K-Bus
RP2 Comms. Mode:
IEC60870 FT1.2 Frame
10-Bit NoParity
RP2 Address: 0…255
RP2 InactivTimer: 1…30mins

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RP2 Baud Rate:
9600 bits/s
19200 bits/s
38400 bits/s

Commission Tests

Monitor Bit 1:
(up to):
Monitor Bit 8:
Binary function link strings, selecting which DDB signals have their status visible in the Commissioning menu, for test purposes
Test Mode:
Disabled
Test Mode
Blocked Contacts
Test Pattern:
Configuration of which output contacts are to be energized when the contact test is applied.
Static Test Mode: Disabled/Enabled
Static Test: Disabled/Enabled
Loopback Mode: Disabled/Internal/External
IM^{64} Test Mode: Disabled/Enabled

Circuit Breaker Condition Monitoring (CB Monitor Setup)

Broken I^: 1.0…2.0
I^ Maintenance: Alarm
Disabled/Enabled
I^ Maintenance: 1…25000
I^ Lockout: Alarm Disabled/Enabled
I^ Lockout: 1…25000
No. CB Ops Maint: Alarm
Disabled/Enabled
No. CB Ops Maint: 1…10000
No. CB Ops Lock: Alarm
Disabled/Enabled
No. CB Ops Lock: 1…10000
CB Time Maint: Alarm
Disabled/Enabled
CB Time Maint: 0.005…0.500s
CB Time Lockout: Alarm
Disabled/Enabled
CB Time Lockout: 0.005…0.500s
Fault Freq. Lock: Alarm
Disabled/Enabled
Fault Freq. Count: 1…9999
Fault Freq. Time: 0…9999s

Optocoupled Binary Inputs (Opto Config.)

Global threshold:
24 - 27V
30 - 34V
48 - 54V
110 - 125V
220 - 250V
Custom
Opto Input 1:
(up to):
Opto Input #. *(# = max. opto no. fitted):*
Custom options allow independent thresholds to be set per opto, from the same range as above.
Filter Control:
Binary function link string, selecting which optos will have an extra 1/2 cycle noise filter, and which will not.
Characteristics:
Standard 60% - 80%
50% - 70%

Control Inputs into PSL (Ctrl. I/P Config.)

Hotkey Enabled:
Binary function link string, selecting which of the control inputs will be driven from Hotkeys.
Control Input 1: Latched/Pulsed
(up to):
Control Input 32: Latched/Pulsed
Ctrl Command 1:
(up to):
Ctrl Command 32:
ON/OFF
SET/RESET
IN/OUT
ENABLED/DISABLED

Function Keys

Fn. Key Status 1:
(up to):
Fn. Key Status 10
Disable
Lock
Unlock/Enable
Fn. Key 1 Mode: Toggled/Normal
(up to):
Fn. Key 10 Mode: Toggled/Normal
Fn. Key 1 Label:
(up to):
Fn. Key 10 Label:
User defined text string to describe the function of the particular function key

IED Configurator

Switch Conf. Bank: No Action/Switch Banks

IEC 61850 GOOSE

GoEna: Disabled/Enabled
Test Mode: Disabled/Pass Through/Forced
VOP Test Pattern: 0x00000000...
0xFFFFFFFF
Ignore Test Flag: No/Yes

Prot Comms/IM64

Scheme Setup:2 Terminal/Dual Redundant/3 Terminal
Address: 0-0, 1-A…20-A, 1-B….20-B
Address: 0-0, 1-A…20-A, 1-B….20-B, 1-C…20-C
Comm Mode: Standard/IEEE C37.94
Baud Rate Ch 1: 56kbits/s or 64kbits/s
Baud Rate Ch 2: 56kbits/s or 64kbits/s
Clock Source Ch1: Internal/External
Clock Source Ch2: Internal/External
Ch1 N*64kbits/s: Auto, 1, 2, 3... 12
Ch2 N*64kbits/s: Auto, 1, 2, 3... 12
Comm Delay Tol: 0.001s...0.00005s
Comm Fail Timer: 0.1s...600s
Comm Fail Mode: Ch 1 Failure/Ch 2 Failure/ Ch 1 or Ch 2 Fail/Ch 1 and Ch 2 Fail
GPS Sync: Enabled or Disabled
Char Mod Time: 0...2s
Prop Delay Equal: No operation/Restore CDiff
Re-Configuration: Three Ended/Two Ended (R1&R2)/Two Ended (L&R2)/Two Ended (L&R1)
Channel Timeout: 0.1s...10s
IM Msg Alarm: 0%...100%
IM1 Cmd Type: Direct/Permissive
IM1 FallBackMode: Default/Latching
IMx(x=1 to 8) DefaultValue: 0 or 1
IM9 to IM16: Any mode for IMx (x = 1 to 8) automatically applies for IMx+8

Control Input User Labels (Ctrl. I/P Labels)

Control Input 1:
(up to):
Control Input 32:
User defined text string to describe the function of the particular control input

Settings in Multiple Groups

Note: All settings here onwards apply for setting groups # = 1 to 4.

TD

Protection Functions

Line Parameters

GROUP # (for # = 1 to 4)
Line Length (km): 0.30…1000.00km
Line Length (miles): 0.20…625.00mi
Line Impedance: 0.05…500.00/In Ω
Line Angle: 20…90°
Residual Comp: 0.00…10.00
Residual Angle: -180…90°
Mutual Comp: Disabled/Enabled
Mutual Comp: 0.00…10.00
Mutual Angle: -180…90°
Mutual cut-off (k): 0.0…2.0
Phase Rotation:
  Standard ABC
  Reverse ACB
Trip Mode:
  3 Pole
  1 and 3 Pole

Distance Setup

Setting Mode: Simple/Advanced

Phase Distance

Phase Chars.: Mho/Quadrilateral Quad	
Resistance:	Common/Proportional
Fault Resistance:	0.05…500.00/In Ω
Zone 1 Ph Status:	Disabled/Enabled
Zone 1 Ph Reach:	10…1000% of line
Zone 2 Ph Status:	Disabled/Enabled
Zone 2 Ph Reach:	10…1000% of line
Zone 3 Ph Status:	Disabled/Enabled
Zone 3 Ph Reach:	10…1000% of line
Zone 3 Ph Offset:	Disabled/Enabled
Z3Ph Rev Reach:	10…1000% of line
Zone P Ph Status:	Disabled/Enabled
Zone P Ph Dir.:	Forward/Reverse
Zone P Ph Reach:	10…1000% of line
Zone 4 Ph Status:	Disabled/Enabled
Zone 4 Ph Reach:	10…1000% of line

Ground Distance

Ground Chars.:	Mho/Quadrilateral
Quad Resistance:	Common/Proportional
Fault Resistance:	0.05…500.00/In Ω
Zone1 Gnd Status:	Disabled/Enabled
Zone1 Gnd Reach:	10…1000% of line
Zone2 Gnd Status:	Disabled/Enabled
Zone2 Gnd Reach:	10…1000% of line
Zone3 Gnd Status:	Disabled/Enabled
Zone3 Gnd Reach:	10…1000% of line
Zone3 Gnd Offset:	Disabled/Enabled
Z3Gnd Rev Reach:	10…1000% of line
ZoneP Gnd Status:	Disabled/Enabled
ZoneP Gnd Direction:	Forward/Reverse
ZoneP Gnd Reach:	10…1000% of line
Zone4 Gnd Status:	Disabled/Enabled
Zone4 Gnd Reach:	10…1000% of line

Digital Filter:
  Standard
  Special Applics
CVT Filters:
  Disabled
  Passive
  Active
SIR Setting: *(for CVT)*: 5…60
Load Blinders: Disabled/Enabled
Load/B Impedance:
  0.10…500.00/In Ω
Load/B Angle: 15…65°
Load Blinder V<: 1.0…70.0V (ph-g)
Distance Polarizing: 0.2…5.0
Delta Status: Disabled/Enabled
Delta Char Angle: 0°...90°

Distance Elements - Phase Distance

Z1 Ph. Reach: 0.05…500.00/In Ω
Z1 Ph. Angle: 20…90°
R1 Ph. Resistive: 0.05…500.00/In Ω
Z1 Tilt Top Line: -30…30°
Z1 Ph. Sensit. Iph>1: 0.050…2.000 In
Z2 Ph. Reach: 0.05…500.00/In Ω
Z2 Ph. Angle: 20…90°
Z2 Ph Resistive: 0.05…500.00/In Ω
Z2 Tilt Top Line: -30…30°
Z2 Ph. Sensit. Iph>2: 0.050…2.000 In
Z3 Ph. Reach: 0.05…500.00/In Ω
Z3 Ph. Angle: 20…90°
Z3' Ph Rev Reach: 0.05…500.00/In Ω
R3 Ph Res. Fwd.: 0.05…500.00/In Ω
R3' Ph Res. Rev.: 0.05…500.00/In Ω
Z3 Tilt Top Line: -30…30°
Z3 Ph. Sensit. Iph>3: 0.050…2.000 In
ZP Ph. Reach: 0.05…500.00/In Ω
ZP Ph. Angle: 20…90°
ZP Ph Resistive: 0.05…500.00/In Ω
ZP Tilt Top line: -30…30°
ZP Ph. Sensit. Iph>P: 0.050…2.000In
Z4 Ph. Reach: 0.05…500.00/In Ω
Z4 Ph. Angle: 20…90°
Z4 Ph Resistive: 0.05…500.00/In Ω
Z4 Tilt Top line: -30…30°
Z4 Ph. Sensit. Iph>4: 0.050…2.000 In

Ground Distance

Z1 Gnd. Reach: 0.05…500.00/In Ω
Z1 Gnd. Angle: 20…90°
kZN1 Res. Comp.: 0.00…10.00
kZN1 Res. Angle: -180…90°
kZm1 Mut. Comp.: 0.00…10.00
kZm1 Mut. Angle: -180…90°
R1 Gnd. Resistive: 0.05…500.00/In Ω
Z1 Sensit Ignd>1: 0.050…2.000 In
Z2 Gnd. Reach: 0.05…500.00/In Ω
Z2 Gnd. Angle: 20…90°
kZN2 Res. Comp.: 0.00…10.00
kZN2 Res. Angle: -180…90°
kZm2 Mut. Comp: 0.00…10.00
kZm2 Mut. Angle: -180…90°
R2 Gnd Resistive: 0.05…500.00/In Ω
Z2 Sensit Ignd>2: 0.050…2.000 In

Z3 Gnd. Reach: 0.05…500.00/In Ω
Z3 Gnd. Angle: 20…90°
Z3' Gnd Rev Rch: 0.05…500.00/In Ω
kZN3 Res. Comp.: 0.00…10.00
kZN3 Res. Angle: -180…90°
kZm3 Mut. Comp.: 0.00…10.00
kZm3 Mut. Angle: -180…90°
R3 Gnd Res. Fwd: 0.05…500.00/In Ω
R3 Gnd Res. Rev: 0.05…500.00/In Ω
Z3 Sensit Ignd>3: 0.050…2.000 In
ZP Ground Reach: 0.05…500.00/In Ω
ZP Ground Angle: 20…90°
kZNP Res. Comp.: 0.00…10.00
kZNP Res. Angle: -180…90°
kZmP Mut. Comp.: 0.00…10.00
kZmP Mut. Angle: -180…90°
RP Gnd Resistive: 0.05…500.00/In Ω
ZP Sensit Ignd>P: 0.050…2.000 In
Z4 Gnd. Reach: 0.05…500.00/In Ω
Z4 Gnd. Angle: 20…90°
kZN4 Res. Comp.: 0.00…10.00
kZN4 Res. Angle: -180…90°
kZm4 Mut. Comp.: 0.00…10.00
kZm4 Mut. Angle: -180…90°
R4 Gnd. Resistive: 0.05…500.00/In Ω
Z4 Gnd Sensitivity: 0.050…2.000 In

Phase Current Differential Protection

Phase Diff: Enabled or Disabled
Phase Is1:0.2In...2In
Phase Is2:1In...30In
Phase k1:30%...150%
Phase k2: 30%...150%
Phase Char: DT/IEC S Inverse/IEC V Inverse/ IEC E inverse/UK LT Inverse/IEEE M Inverse/IEEE V Inverse/IEEE E Inverse/US Inverse/US ST Inverse
Phase Time Delay: 0s...100s
Phase TMS: 0.025...1.2
Phase Time Dial: 0.01...100
PIT Time: 0s...0.2s
Ph CT Corr'tion:1...8
Compensation: None/Cap Charging/Vector Group
Susceptance: 1E-8*In...10*In
Inrush Restraint: Enabled/Disabled
Id High Set: 4*In...32*In
Vectorial Comp:Yy0 (0 deg)/Yd1 (-30 deg)/ Yy2 (-60 deg)/Yd3 (-90 deg)/Yy4 (-120 deg)/ Yd5 (-150 deg)/Yy6 (180 deg)/Yd7 (+150 deg)/Yy8 (+120 deg)/Yd9 (+90 deg)/Yy10 (+60 deg)/Yd11 (+30 deg)/Ydy0 (0 deg)/ Ydy6 (180 deg)
Phase Is1 CTS: 0.2*In...4*In

Scheme Logic

Basic Scheme

Zone 1 Tripping: Disabled/ Phase only/Ground only/Phase and Ground
tZ1 Ph. Delay: 0s...10s
tZ1 Gnd. Delay: 0s...10s
Zone 2 Tripping: Disabled/Phase only/ Ground only/Phase and Ground
tZ2 Ph. Delay: 0s...10s
tZ2 Gnd. Delay: 0s…10s
Zone 3 Tripping: Disabled/Phase only/ Ground only/Phase and Ground
tZ3 Ph. Delay: 0s...10s
tZ2 Gnd. Delay: 0s...10s
Zone P Tripping: Disabled/Phase only/ Ground only/Phase and Ground
tZP Ph. Delay: 0s...10s
tZP Gnd. Delay: 0s...10s
Zone 4 Tripping: Disabled/Phase only/ Ground only/Phase and Ground
tZ4 Ph. Delay: 0s...10s
tZ4 Gnd. Delay: 0s...10s

Aided Scheme 1

Aid 1 Selection: Disabled/PUR/PUR Unblocking/POR/POR/Unblocking/ Blocking 1/Blocking 2/ Prog Unblocking/Programmable
Aid 1 Distance: Disabled/ Phase Only/ Ground only/Phase and Ground
Aid 1 Dist. Dly: 0s...1s
Unblocking Delay: 0s...0.1s
Aid 1 DEF: Disabled/Enabled
Aid 1 DEF Dly: 0s...1s
Aid 1 DEF Trip: 1/3 Pole
tREV Guard: 0s...0.15s
Send on Trip: Aided / Z1, Any Trip or None
Weak Infeed: Disabled/ Echo/Echo and Trip
WI Sngl Pole Trp: Disabled/Enabled
WI V< Thresh: 10V...70V
WI Trip Delay: 0s...1s
Custom Send Mask: Bit 0 = Z1 Gnd/Bit 1 = Z2 Gnd/Bit 2 = Z4 Gnd/Bit 3 = Z1 Ph/Bit 4 = Z2 Ph/Bit 5 = Z4 Ph/Bit 6 = DEF Fwd/Bit 7 = DEF Rev/Bit
Custom Time PU: 0s...1s
Custom Time DO: 0s...1s

Aided Scheme 2

(As per Aided Scheme 1 Trip on Close)

SOTF Status: Disabled/Enabled Pole Dead/Enabled ExtPulse/En Pdead + Pulse
SOTF Delay: 0.2s...1000s
SOTF Tripping: Bit 0 = Zone 1/Bit 1 = Zone 2/Bit 2 = Zone 3/Bit 3 = Zone P/Bit 4 = Zone 4
T/Status: Disabled/Enabled
T/Tripping: Bit 0 = Zone 1/Bit 1 = Zone 2/Bit 2 = Zone 3/Bit 3 = Zone P/Bit 4 = Zone 4
TOC Reset Delay: 0.1s...2s

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SOTF Pulse: 0.1s...10s

Z1 Extension
Z1 Ext Scheme: Disabled/Enabled/En. on Ch1 Fail/En. On Ch2 Fail/En All Ch Fail/En. anyCh Fail
Z1 Ext Ph: 100%...200%
Z1 Ext Gnd: 100%...200%

Loss of Load
LOL Scheme: Disabled/Enabled/En. on Ch1 Fail/En. On Ch2 Fail/En All Ch Fail/En. Any Ch Fail
LOL <I: 0.05 x In...1 x In
LOL Window: 0.01s 0.1s Phase

TD

Phase Overcurrent (Overcurrent)

I>1 Status:
- Disabled
- Enabled
- Enabled VTS
- Enabled Ch Fail
- En VTSorCh Fail
- En VTSandCh Fail

I>1 Function:
- DT
- IEC S Inverse
- IEC V Inverse
- IEC E Inverse
- UK LT Inverse
- IEEE M Inverse
- IEEE V Inverse
- IEEE E Inverse
- US Inverse
- US ST Inverse

I>1 Directional:
- Non-Directional
- Directional Fwd
- Directional Rev

I>1 Current Set: 0.08…4.00 In
I>1 Time Delay: 0.00…100.00s
I>1 TMS: 0.025…1.200
I>1 Time Dial: 0.01…100.00
I>1 Reset Char: DT/Inverse
I>1 tRESET: 0.00…100.00s
I>2 Status
(up to):
I>2 tRESET
All settings and options chosen from the same ranges as per the first stage overcurrent, I>1.
I>3 Status:
Disabled
- Enabled
- Enabled VTS
- Enabled Ch Fail
- En VTSorCh Fail
- En VTSandCh Fail

I>3 Directional:
- Non-Directional
- Directional Fwd
- Directional Rev

I>3 Current Set: 0.08…32.00 In
I>3 Time Delay: 0.00…100.00s
I>4 Status
(up to):
I>4 Time Delay
All settings and options chosen from the same ranges as per the third stage overcurrent, I>3.
I> Char Angle: -95…95°
I> Blocking:
Binary function link string, selecting which overcurrent elements (stages 1 to 4) will be blocked if VTS detection of fuse failure occurs.

Negative Sequence Overcurrent (Neg Seq O/C)

I2> Status: Disabled/Enabled
I2> Directional:
- Non-Directional
- Directional Fwd
- Directional Rev

I2> VTS:
- Block
- Non-Directional

I2> Current Set: 0.08…4.00 In
I2> Time Delay: 0.00…100.00s
I2> Char Angle: -95…95°
IN> V2pol Set: 0.5…25.0V

Broken Conductor

Broken Conductor: Disabled/Enabled
I2/I1 Setting: 0.20…1.00
I2/I1 Time Delay: 0.0…100.0s

Ground Overcurrent (Earth Fault)

IN>1 Status:
- Disabled
- Enabled
- Enabled VTS
- Enabled Ch Fail
- En VTSorCh Fail
- En VTSandCh Fail

IN>1 Function:
- DT
- IEC S Inverse
- IEC V Inverse
- IEC E Inverse
- UK LT Inverse
- IEEE M Inverse
- IEEE V Inverse
- IEEE E Inverse
- US Inverse
- US ST Inverse

IN>1 Directional:
- Non-Directional
- Directional Fwd
- Directional Rev

IN>1 Current Set: 0.08…4.00 In
IN>1 Time Delay: 0.00…100.00s
IN>1 TMS: 0.025…1.200
IN>1 Time Dial: 0.01…100.00
IN>1 Reset Char: DT/Inverse
IN>1 tRESET: 0.00…100.00s

IN>2 Status
(up to):
IN>2 tRESET
All settings and options chosen from the same ranges as per the first stage ground overcurrent, IN>1.
IN>3 Status:
Disabled
Enabled
Enabled VTS
Enabled Ch Fail
En VTSorCh Fail
En VTSandCh Fail
IN>3 Directional:
Non-Directional
Directional Fwd
Directional Rev
IN>3 Current Set: 0.08…32.00 In
IN>3 Time Delay: 0.00…100.00s
IN>4 Status
(up to):
IN>4 Time Delay
All settings and options chosen from the same ranges as per the third stage ground overcurrent, IN>3.
IN> Blocking:
Binary function link string, selecting which ground overcurrent elements (stages 1 to 4) will be blocked if VTS detection of fuse failure occurs.
IN> DIRECTIONAL
IN> Char Angle: -95…95°
IN> Polarization:
Zero Sequence
Neg Sequence
IN> VNpol Set: 0.5…40.0V
IN> V2pol Set: 0.5…25.0V
IN> I2pol Set: 0.08…1.00 In

Directional Aided Schemes - DEF Settings

DEF Status: Disabled/Enabled
DEF Polarizing:
Zero Sequence *(virtual current pol)*
Neg Sequence
DEF Char Angle: -95…95°
DEF VNpol Set: 0.5…40.0V
DEF V2pol Set: 0.5…25.0V
DEF Threshold: 0.08…1.00 In

Group 1 Sensitive E/F

Sens E/F Options: SEF Enabled
Wattmetric SEF
ISEF>1 Function: IDMT Curve Type
Disabled
DT
IEC S Inverse
IEC V Inverse
IEC E Inverse
UK LT Inverse
IEEE M Inverse
IEEE V Inverse
IEEE E Inverse
US Inverse
US ST Inverse
ISEF>1 Directional:
Non-Directional
Directional Fwd
Directional Rev
ISEF>1 Current Set: 0.005…0.1 In_{SEF}
ISEF>1 Time Delay: 0 s…..200s
ISEF>1 TMS: 0.025…1.2
ISEF>1 Time Dial: 0.01…100
ISEF>1 Reset Char: DT/Inverse
ISEF>1 tRESET: 0 s-100s
ISEF>2 as ISEF>1
ISEF>3 Status:
Disabled
Enabled
ISEF>3 Directional:
Non-Directional
Directional Fwd
Directional Rev
ISEF>3 Current Set: 0.05…0.8 In_{SEF}
ISEF>3 Time Delay: 0 s…200s
ISEF>3 Intertrip: Enabled/Disabled
ISEF>4 as ISEF>3
ISEFN> Blocking
Bit 0 VTS Blks ISEF>1
Bit 1 VTS Blks ISEF>2
Bit 2 VTS Blks ISEF>3
Bit 3 VTS Blks ISEF>4
Bit 4 A/R Blks ISEF>3
Bit 5 A/R Blks ISEF>4
Bit 6 Not Used
Bit 7 Not Used
ISEF> Directional
ISEF> Char Angle: -95°…95° deg
ISEF> VNpol Set: 0.5…80V
Wattmetric SEF
PN> Setting: 0...20In_{SEF} W

Neutral Voltage Displacement (Residual O/V NVD)

VN>1 Function:
Disabled
DT
IDMT
VN>1 Voltage Set: 1…50V
VN>1 Time Delay: 0.00…100.00s
VN>1 TMS: 0.5…100.0
VN>1 tReset: 0.00…100.00s
VN>2 Status: Disabled/Enabled
VN>2 Voltage Set: 1…50V
VN>2 Time Delay: 0.00…100.00s

Thermal Overload

Characteristic:
Disabled
Single
Dual
Thermal Trip: 0.08…4.00 In
Thermal Alarm: 50…100%
Time Constant 1: 1…200mins

Time Constant 2: 1…200mins

Power Swing/Out Of Step (Power Swing)

Power Swing:
  Blocking
  Indication
PSB Reset Delay: 0.05…2.00s
Zone 1 Ph PSB: Blocking/Allow Trip
  (up to):
Zone 4 Ph PSB: Blocking/Allow Trip
Zone 1 Gnd PSB: Blocking/Allow Trip
  (up to):
Zone 4 Gnd PSB: Blocking/Allow Trip
PSB Timeout: Disabled/Enabled
PSB Timeout Set: 0.1…10.0s

Out of Step

OST (Out of Step Tripping) mode:
  Disabled
  Predictive and OST Trip
  OST Trip
  Predictive OST
Z5 Fwd Reach: 0.1…500.00/In Ω
Z6 Fwd Reach: 0.1…500.00/In Ω
Z5' Rev Reach: 0.1…500.00/In Ω
Z6' Rev Reach: 0.1…500.00/In Ω
R5 Res. Fwd: 0.1…200.00/In Ω
R6 Res. Fwd: 0.1…200.00/In Ω
R5' Res. Rev: -0.1…-200.00/In Ω
R6' Res. Rev: -0.1…-200.00/In Ω
α Blinder Angle: 20…90°
Delta t Time Setting: 0.02s…1s
Tost Time Delay Setting: 0s…1s

Undervoltage Protection

V< Measur't Mode:
  Phase-Phase
  Phase-Neutral
V< Operate Mode:
  Any Phase
  Three Phase
V<1 Function:
  Disabled
  DT
  IDMT
V<1 Voltage Set: 10…120V
V<1 Time Delay: 0.00…100.00s
V<1 TMS: 0.5…100.0
V<1 Poledead Inh: Disabled/Enabled
V<2 Status: Disabled/Enabled
V<2 Voltage Set: 10…120V
V<2 Time Delay: 0.00…100.00s
V<2 Poledead Inh: Disabled/Enabled

Overvoltage Protection

V> Measur't Mode:
  Phase-Phase
  Phase-Neutral
V> Operate Mode:
  Any Phase
  Three Phase
V>1 Function:
  Disabled
  DT
  IDMT
V>1 Voltage Set: 60…185V
V>1 Time Delay: 0.00…100.00s
V>1 TMS: 0.5…100.0
V>2 Status: Disabled/Enabled
V>2 Voltage Set: 60…185V
V>2 Time Delay: 0.00…100.00s

Circuit Breaker Fail

CB Fail 1 Status: Disabled/Enabled
CB Fail 1 Timer: 0.00…10.00s
CB Fail 2 Status: Disabled/Enabled
CB Fail 2 Timer: 0.00…10.00s
Volt Prot Reset:
  I< Only
  CB Open & I<
  Prot Reset & I<
Ext Prot Reset:
  I< Only
  CB Open & I<
  Prot Reset & I<
WI Prot Reset: Disabled/Enabled
  Undercurrent
I< Current Set: 0.02…3.20 In
ISEF< Current Set: 0.001…0.8 In_{SEF}

Supervision

VT Supervision
VTS Mode: Measured + MCB, Measured Only
  or MCB Only
VTS Status: Blocking/Indication
VTS Reset Mode: Manual/Auto
VTS Time Delay: 1s...10s
VTS I> Inhibit: 0.08....32 x □n
VTS I2> Inhibit: 0.05...0.5 x □n
CT Supervision (CTS)
CTS Status: Disabled/Standard/I Diff
Standard CTS
CTS VN< Inhibit: 0.5V...22V
CTS IN> Set: 0.08...4 x □n
CTS Time Delay: 0s...10s
Inrush Detection
I> 2nd Harmonic: 10%...100%
Weak Infeed Blk
WI Inhibit: Disabled/Enabled
I0/I2 Setting: 2...3
I Diff CTS
CTS Status (Diff): Restrain/Indication
CTS Reset Mode: Manual/Auto
CTS i1>: 0.05*In...4.0*In
CTS i2/i1>: 0.05...1
CTS i2/i1>>: 0.05...1

CTS Time Delay: 0...10

Systems Check (Models P543 and P545)

Bus-Line Synchronism and Voltage Checks (System Checks)
Voltage Monitors
Live Voltage: 1.0…132.0V
Dead Voltage: 1.0…132.0V
Synchrocheck (Check Synch)
CS1 Status: Disabled/Enabled
CS1 Phase Angle: 5…90°
CS1 Slip Control:
 None
 Timer
 Frequency
 Both
CS1 Slip Freq: 0.02…1.00Hz
CS1 Slip Timer: 0.0…99.0s
CS2 Status
(up to):
CS2 Slip Timer
All settings and options chosen from the same ranges as per the first stage CS1 element.
CS Undervoltage: 10.0…132.0V
CS Overvoltage: 60.0…185.0V
CS Diff Voltage: 1.0…132.0V
CS Voltage Block:
 None
 Undervoltage
 Overvoltage
 Differential
 UV & OV
 UV & DiffV
 OV & DiffV
 UV, OV & DiffV
System Split
SS Status: Disabled/Enabled
SS Phase Angle: 90…175°
SS Under V Block: Disabled/Enabled
SS Undervoltage: 10.0…132.0V
SS Timer: 0.0…99.0s

Auto-reclose (Models P543 and P545)

Single Pole Shot: 1/2/3/4
Three Pole Shot: 1/2/3/4
1 Pole Dead Time: 0.20…5.00s
Dead Time 1: 0.20…100.00s
Dead Time 2: 1…1800s
Dead Time 3: 1…3600s
Dead Time 4: 1…3600s
CB Healthy Time: 1…3600s
Reclaim Time: 1…600s
AR Inhibit Time: 0.01…600.00s
Check Sync Time: 0.01…9999.00s
Z2T AR:
 (up to):
Z4T AR:
 No Action
 Initiate AR
 Block AR
 All time-delayed distance zones can be independently set not to act upon AR logic, to initiate a cycle, or to block.
DEF Aided AR:
 No Action
 Initiate AR
 Block AR
TOR:
 No Action
 Initiate AR
 Block AR
I>1 AR:
 (up to):
I>4 AR:
 No Action
 Initiate AR
 Block AR
 All overcurrent stages can be independently set not to act upon AR logic, to initiate a cycle, or to block.
IN>1 AR:
 (up to):
IN>4 AR:
 No Action
 Initiate AR
 Block AR
 All ground/earth overcurrent stages can be independently set not to act upon AR logic, to initiate a cycle, or to block.
ISEF>1 AR:
 (up to):
ISEF>4 AR:
 No Action
 Initiate AR
 Block AR
 All ground/earth overcurrent stages can be independently set not to act upon AR logic, to initiate a cycle, or to block.
Mult Phase AR:
 Allow Autoclose
 BAR 2 and 3Ph
 BAR 3 Phase
Dead Time Start:
 Protection Op
 Protection Reset
Discrim Time: 0.10…5.00s
System Checks
CheckSync1 Close: Disabled/Enabled
CheckSync2 Close: Disabled/Enabled
LiveLine/DeadBus: Disabled/Enabled
DeadLine/LiveBus: Disabled/Enabled
DeadLine/DeadBus: Disabled/Enabled
CS AR Immediate: Disabled/Enabled
SysChk on Shot 1: Disabled/Enabled

Opto Input Labels

Opto Input 1:
 (up to):
Opto Input 24:
 User defined text string to describe the function of the particular opto input.

TD

TD

Output Labels

Relay 1:
(up to):
Relay 32:
User defined text string to describe the function of the particular relay output contact.

Measurements List

Measurements 1

Iφ Magnitude
Iφ Phase Angle
Per phase (φ = A, B, C) current measurements
IN derived Mag
IN derived Angle
ISEF Mag
ISEF Angle
I1 Magnitude
I2 Magnitude
I0 Magnitude
Iφ RMS
Per phase (φ = A, B, C) RMS current measurements
IN RMS
Vφ-φ Magnitude
Vφ-φ Phase Angle
Vφ Magnitude
Vφ Phase Angle
All phase-phase and phase-neutral voltages (φ = A, B, C).
VN Mag
VN Ang
V1 Magnitude
V2 Magnitude
V0 Magnitude
Vφ RMS
Vφ-φ RMS
All phase-phase and phase-neutral voltages (φ = A, B, C).
Frequency
C/S Voltage Mag
C/S Voltage Ang
C/S Bus-Line Ang
Slip Frequency
IM Magnitude
IM Phase Angle
I1 Magnitude
I1 Phase Angle
I2 Magnitude
I2 Phase Angle
I0 Magnitude
I0 Phase Angle
V1 Magnitude
V1 Phase Angle
V2 Magnitude
V2 Phase Angle
V0 Magnitude
V0 Phase Angle

Measurements 2

φ Phase Watts
φ Phase VArs
φ Phase VA
All phase segregated power measurements, real, reactive and apparent (φ = A, B, C).
3 Phase Watts
3 Phase VArs
3 Phase VA
Zero Seq Power
3Ph Power Factor
φPh Power Factor
Independent power factor measurements for all three phases (φ = A, B, C).
3Ph WHours Fwd
3Ph WHours Rev
3Ph VArHours Fwd
3Ph VArHours Rev
3Ph W Fix Demand
3Ph VArs Fix Dem
Iφ Fixed Demand
Maximum demand currents measured on a per phase basis (φ = A, B, C).
3Ph W Roll Dem
3Ph VArs Roll Dem
Iφ Roll Demand
Maximum demand currents measured on a per phase basis (φ = A, B, C).
3Ph W Peak Dem
3Ph VAr Peak Dem
Iφ Peak Demand
Maximum demand currents measured on a per phase basis (φ = A, B, C).
Thermal State

Measurements 3

IA Local
IA Angle Local
IB Local
IB Angle Local
IC Local
IC Angle Local
IA remote 1
IA Ang remote 1
IB remote 1
IB Ang remote 1
IC remote 1
IC Ang remote 1
IA remote 2
IA Ang remote 2
IB remote 2
IB Ang remote 2
IC remote 2
IC Ang remote 2
IA Differential
IB Differential
IC Differential
IA Bias
IB Bias
IC Bias

Measurements 4

Ch 1 Prop Delay
Ch 2 Prop Delay
Ch1 Rx Prop Delay
Ch1 Tx Prop Delay
Ch2 Rx Prop Delay
Ch2 Tx Prop Delay
Channel 1 Status
Channel 2 Status
Channel Status:
Bit 0= Rx
Bit 1= Tx
Bit 2= Local GPS
Bit 3= Remote GPS
Bit 4= Mux Clk F Error
Bit 5= Signal Lost
Bit 6= Path Yellow
Bit 7= Mismatch RxN
Bit 8= Timeout
Bit 9= Message Level
Bit 10= Passthrough

Binary function link strings denoting channel errors, and when self-healing has been initiated in 3-terminal applications.

IM64 Rx Status
Statistics
Last Reset on
Date/Time
Ch1 No. Vald Mess
Ch1 No. Err Mess
Ch1 No. Errored s
Ch1 No. Sev Err s
Ch1 No. Dgraded m
Ch2 No. Vald Mess
Ch2 No. Err Mess
Ch2 No. Errored s
Ch2 No. Sev Err s
Ch2 No. Dgraded m

Circuit Breaker Monitoring Statistics

CB Operations
CB φ Operations

Circuit breaker operation counters on a per phase basis (φ = A, B, C).

Total Iφ Broken

Cumulative breaker interruption duty on a per phase basis (φ = A, B, C).

CB Operate Time
CB Control
Total Reclosures

Fault Record Proforma

The following data is recorded for any relevant elements that operated during a fault, and can be viewed in each fault record.

Time & Date
Model Number:
Address:
Event Type: Fault record
Event Value
Faulted Phase:

Binary data strings for fast polling of which phase elements started or tripped for the fault recorded.

Start Elements
Trip Elements

Binary data strings for fast polling of which protection elements started or tripped for the fault recorded.

Fault Alarms

Binary data strings for fast polling of alarms for the fault recorded.

Fault Time
Active Group: 1/2/3/4
System Frequency: Hz
Fault Duration: s
CB Operate Time: s
Relay Trip Time: s
Fault Location: km/miles/Ω/%
I φPre Flt
Iφ Angle Pre Flt

Per phase record of the current magnitudes and phase angles stored before the fault inception.

IN Prefault Mag
IN Prefault Ang
IM Prefault Mag
IM Prefault Ang
Vφ Prefault Mag
Vφ Prefault Ang

Per phase record of the voltage magnitudes and phase angles stored before the fault inception.

VN Prefault Mag
VN Prefault Ang
Iφ Fault Mag
Iφ Fault Ang

Per phase record of the current magnitudes and phase angles during the fault.

IN Fault Mag
IN Fault Ang
IM Fault Mag
IM Fault Ang
Vφ Fault Mag
Vφ Fault Ang

Per phase record of the voltage magnitudes and phase angles during the fault.

VN Fault Mag
VN Fault Ang
IB local
IC local
IA remote 1
IB remote 1
IC remote 1
IA remote 2
IB remote 2
IC remote 2
IA Differential
IB Differential
IC Differential
IA Bias
IB Bias
IC Bias

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GETTING STARTED

Date:	**7th August 2006**
Hardware Suffix:	**K**
Software Version:	**41 and 51**
Connection Diagrams:	**10P54302xx (xx = 01 to 02) & 10P54303xx (xx = 01 to 02)**
	10P54402xx (xx = 01 to 02) & 10P54403xx (xx = 01 to 02)
	10P54502xx (xx = 01 to 02) & 10P54503xx (xx = 01 to 02)
	10P54602xx (xx = 01 to 02) & 10P54603xx (xx = 01 to 02)

CONTENTS

FIGURES

1. GETTING STARTED

1.1 User interfaces and menu structure

The settings and functions of the MiCOM protection relay can be accessed both from the front panel keypad and LCD, and via the front and rear communication ports. Information on each of these methods is given in this section to describe how to start using the relay.

1.2 Introduction to the relay

The front panel of the relay is shown in Figure 1, with the hinged covers at the top and bottom of the relay shown open. Extra physical protection for the front panel can be provided by an optional transparent front cover. With the cover in place read only access to the user interface is possible. Removal of the cover does not compromise the environmental withstand capability of the product, but allows access to the relay settings. When full access to the relay keypad is required, for editing the settings, the transparent cover can be unclipped and removed when the top and bottom covers are open. If the lower cover is secured with a wire seal, this will need to be removed. Using the side flanges of the transparent cover, pull the bottom edge away from the relay front panel until it is clear of the seal tab. The cover can then be moved vertically down to release the two fixing lugs from their recesses in the front panel.

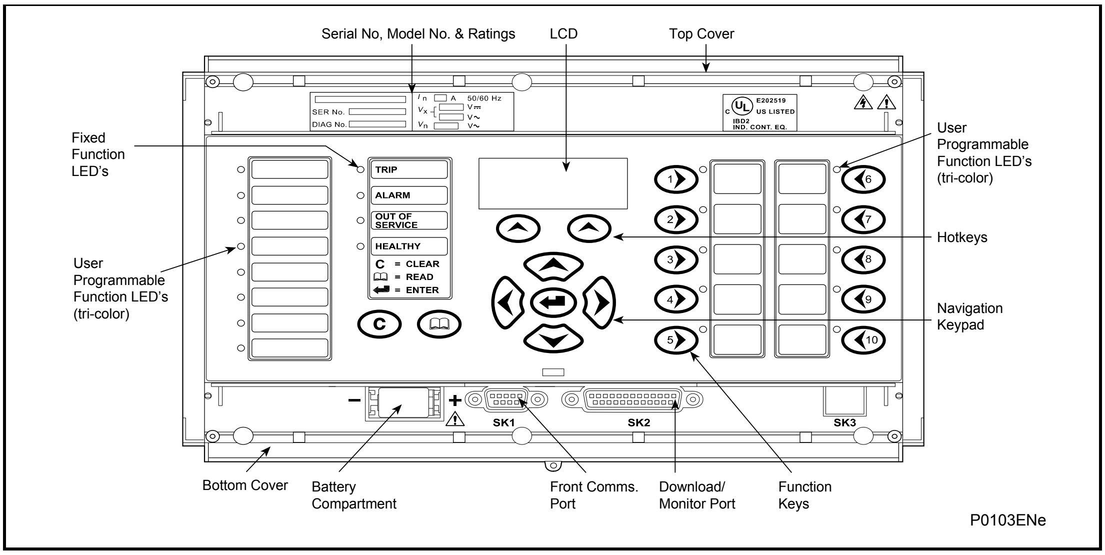

Figure 1: Relay front view

The front panel of the relay includes the following, as indicated in Figure 1:

– A 16-character by 3-line alphanumeric liquid crystal display (LCD)

– A 19-key keypad comprising 4 arrow keys (◄, ►, ▲ and ▼), an enter key (↵), a clear key (C), a read key (📖), 2 hot keys (7) and 10 (1 – 10) programmable function keys

– Function key functionality:

  – The relay front panel features control pushbutton switches with programmable LEDs that facilitate local control. Factory default settings associate specific relay functions with these 10 direct-action pushbuttons and LEDs e.g. Enable/Disable the auto-recloser function. Using programmable scheme logic, the user can readily change the default direct-action pushbutton functions and LED indications to fit specific control and operational needs.

– Hotkey functionality:

  – SCROLL

  – Starts scrolling through the various default displays.

  - STOP
  - Stops scrolling the default display.
  - For control of setting groups, control inputs and circuit breaker operation
- 22 LEDs; 4 fixed function LEDs, 8 tri-color programmable function LEDs on the left hand side of the front panel and 10 tri-color programmable function LEDs on the right hand side associated with the function keys
- Under the top hinged cover:
  - The relay serial number, and the relay's current and voltage rating information
- Under the bottom hinged cover:
  - Battery compartment to hold the 1/2 AA size battery which is used for memory back-up for the real time clock, event, fault and disturbance records
  - A 9-pin female D-type front port for communication with a PC locally to the relay (up to 15m distance) via an EIA(RS)232 serial data connection
  - A 25-pin female D-type port providing internal signal monitoring and high speed local downloading of software and language text via a parallel data connection

GS

1.2.1 LED indications

Fixed Function

The 4 fixed function LEDs on the left-hand side of the front panel are used to indicate the following conditions:

Trip (Red) indicates that the relay has issued a trip signal. It is reset when the associated fault record is cleared from the front display. (Alternatively the trip LED can be configured to be self-resetting)*.

Alarm (Yellow) flashes to indicate that the relay has registered an alarm. This may be triggered by a fault, event or maintenance record. The LED will flash until the alarms have been accepted (read), after which the LED will change to constant illumination, and will extinguish, when the alarms have been cleared.

Out of service (Yellow) indicates that the relay's protection is unavailable.

Healthy (Green) indicates that the relay is in correct working order, and should be on at all times. It will be extinguished if the relay's self-test facilities indicate that there is an error with the relay's hardware or software. The state of the healthy LED is reflected by the watchdog contact at the back of the relay.

To improve the visibility of the settings via the front panel, the LCD contrast can be adjusted using the "LCD Contrast" setting in the CONFIGURATION column. This should only be necessary in very hot or cold ambient temperatures.

Programmable LEDs

All the programmable LEDs are tri-color and can be programmed to indicate RED, YELLOW or GREEN depending on the requirements. The 8 programmable LEDs on the left are suitable for programming alarm indications and the default indications and functions are indicated in the table below. The 10 programmable LEDs physically associated with the function keys, are used to indicate the status of the associated pushbutton's function and the default indications are shown below:

The default mappings for each of the programmable LEDs are as shown in the following table:

LED Number	Default Indication	P543	P544	P545	P546
1	Red	Diff Trip	Diff Trip	Diff Trip	Diff Trip
2	Red	Dist Inst Trip	Dist Inst Trip	Dist Inst Trip	Dist Inst Trip
3	Red	Dist Delay Trip	Dist Delay Trip	Dist Delay Trip	Dist Delay Trip
4	Red	Signaling Fail	Signaling Fail	Signaling Fail	Signaling Fail
5	Red	Any Start	Any Start	Any Start	Any Start
6	Red	AR in Progress	Not Used	AR in Progress	Not Used
7	Green	AR Lockout	Not Used	AR Lockout	Not Used
8	Red	Test Loopback	Test Loopback	Test Loopback	Test Loopback
F1		Not Used	Not Used	Not Used	Not Used
F2		Not Used	Not Used	Not Used	Not Used
F3		Not Used	Not Used	Not Used	Not Used
F4		Not Used	Not Used	Not Used	Not Used
F5		Not Used	Not Used	Not Used	Not Used
F6		Not Used	Not Used	Not Used	Not Used
F7		Not Used	Not Used	Not Used	Not Used
F8		Not Used	Not Used	Not Used	Not Used
F9		Not Used	Not Used	Not Used	Not Used
F10		Not Used	Not Used	Not Used	Not Used

1.2.2 Relay rear panel

The rear panel of the relay is shown in Figure 2. All current and voltage signals, digital logic input signals and output contacts are connected at the rear of the relay. Figure 2 shows:

Slot A: Optional IRIG-B and ETHERNET - IEC 61850 - board

Slot B: Fiber communication board for differential teleprotection including GPS sampling synchronization

Slot C: Analogue (CT& VT) Input Board

Slot D and F: Opto-isolated inputs boards

Slot G and H: Relay output contacts boards

Slot J: Power Supply/EIA(RS)485 Communications board

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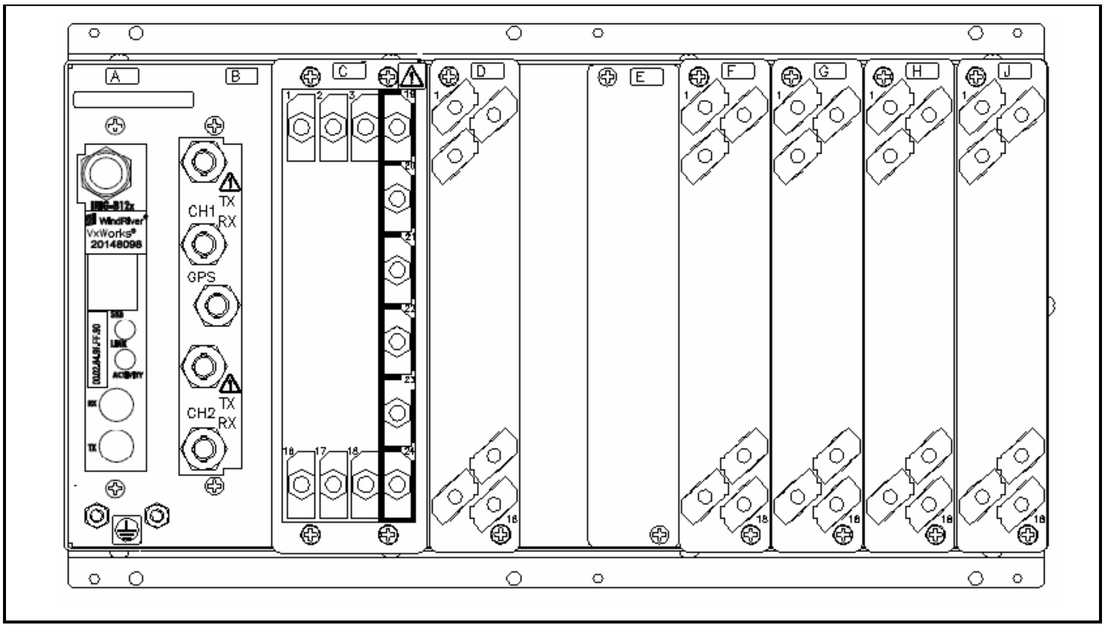

Figure 2: P543 relay rear view (60TE)

Note: Above diagram indicates example P543 60TE case layout for information purposes, exact layout will vary depending on model configuration and case size.

Refer to the wiring diagram in section P54x/EN IN/A11 for complete connection details.

1.3 Relay connection and power-up

Before powering-up the relay, confirm that the relay power supply voltage and nominal ac signal magnitudes are appropriate for your application. The relay serial number, and the relay's current and voltage rating, power rating information can be viewed under the top hinged cover. The relay is available in the following auxiliary voltage versions and these are specified in the table below.

Nominal Ranges	Operative dc Range	Operative ac Range
24 - 48V dc	19 to 65V	-
48 - 110V dc (30 - 100V ac rms) **	37 to 150V	24 to 110V
110 - 250V dc (100 - 240V ac rms) **	87 to 300V	80 to 265V

** rated for ac or dc operation

Please note that the label does not specify the logic input ratings. The P54x relay is fitted with universal opto isolated logic inputs that can be programmed for the nominal battery voltage of the circuit of which they are a part. See 'Universal Opto input' in the Firmware section for more information on logic input specifications. Please note that the opto inputs have a maximum input voltage rating of 300V dc at any setting.

Once the ratings have been verified for the application, connect external power capable of delivering the power requirements specified on the label to perform the relay familiarization procedures. Figure 2 indicates the location of the power supply terminals but please refer to the wiring diagrams in the Installation section for complete installation details ensuring that the correct polarities are observed in the case of dc supply.

1.4 Introduction to the user interfaces and settings options

The relay has three user interfaces:

– The front panel user interface via the LCD and keypad

– The front port which supports Courier communication

– The rear port which supports K-Bus or IEC60870-5-103 or DNP3.0 or IEC 61850 + Courier via rear EIA(RS)485 port or IEC 61850 + IEC60870-5-103 via rear EIA(RS)485 port. The protocol for the rear port must be specified when the relay is ordered

The measurement information and relay settings which can be accessed from the three interfaces are summarized in Table 1.

	Keypad/ LCD	**Courier**	**IEC 61850**	**IEC870-5-103**	**DNP3.0**
Display & modification of all settings	•	•			
Digital I/O signal status	•	•	•	•	•
Display/extraction of measurements	•	•	•	•	•
Display/extraction of fault records	•	•		•	•
Extraction of disturbance records		•	•	•	
Programmable scheme logic settings		•			
Reset of fault & alarm records	•	•		•	•
Clear event & fault records	•	•			•
Time synchronization		•	•	•	•
Control commands	•	•		•	•

Table 1

1.5 Menu structure

The relay’s menu is arranged in a tabular structure. Each setting in the menu is referred to as a cell, and each cell in the menu may be accessed by reference to a row and column address. The settings are arranged so that each column contains related settings, for example all of the disturbance recorder settings are contained within the same column. As shown in Figure 3, the top row of each column contains the heading that describes the settings contained within that column. Movement between the columns of the menu can only be made at the column heading level. A complete list of all of the menu settings is given in the Menu Content Map at the end of this section.

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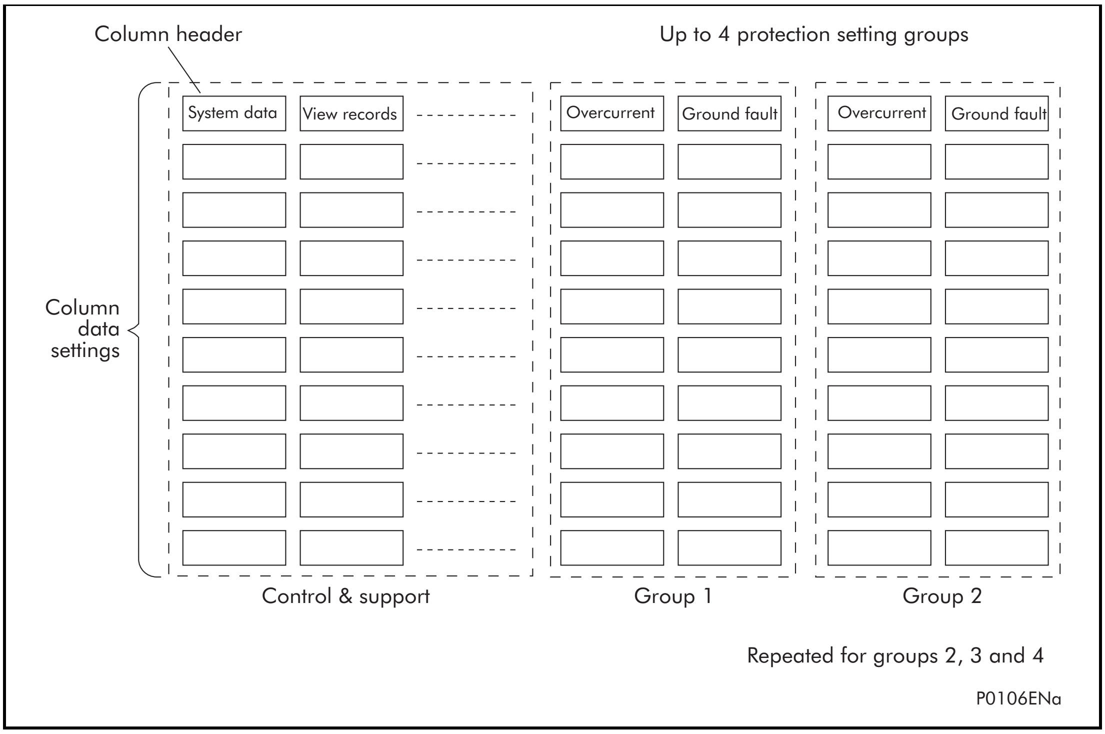

Figure 3: Menu structure

All of the settings in the menu fall into one of three categories; protection settings, disturbance recorder settings, or control and support (C&S) settings. One of two different methods is used to change a setting depending on which category the setting falls into. Control and support settings are stored and used by the relay immediately after they are entered. For either protection settings or disturbance recorder settings, the relay stores the new setting values in a temporary 'scratchpad'. It activates all the new settings together, but only after it has been confirmed that the new settings are to be adopted. This technique is employed to provide extra security, and so that several setting changes that are made within a group of protection settings will all take effect at the same time.

1.5.1 Protection settings

The protection settings include the following items:

– Protection element settings

– Scheme logic settings

There are four groups of protection settings, with each group containing the same setting cells. One group of protection settings is selected as the active group, and is used by the protection elements.

1.5.2 Disturbance recorder settings

The disturbance recorder settings include the record duration and trigger position, selection of analog and digital signals to record, and the signal sources that trigger the recording.

1.5.3 Control and support settings

The control and support settings include:

– Relay configuration settings

– VT ratio settings

– Reset LEDs

– Active protection setting group

– Password & language settings

– Communications settings

– Measurement settings

– Event & fault record settings

– User interface settings

– Commissioning settings

1.6 Password protection

The menu structure contains three levels of access. The level of access that is enabled determines which of the relay's settings can be changed and is controlled by entry of two different passwords. The levels of access are summarized in Table 2.

Access level	Operations enabled
Level 0 No password required	Read access to all settings, alarms, event records and fault records
Level 1 Password 1 or 2 required	As level 0 plus: Control commands, e.g. Circuit breaker open/close. Reset of fault and alarm conditions. Reset LEDs. Clearing of event and fault records.
Level 2 Password 2 required	As level 1 plus: All other settings

Table 2

Each of the two passwords are 4 characters of upper case text. The factory default for both passwords is AAAA. Each password is user-changeable once it has been correctly entered. Entry of the password is achieved either by a prompt when a setting change is attempted, or by moving to the 'Password' cell in the 'System data' column of the menu. The level of access is independently enabled for each interface, that is to say if level 2 access is enabled for the rear communication port, the front panel access will remain at level 0 unless the relevant password is entered at the front panel. The access level enabled by the password entry will time-out independently for each interface after a period of inactivity and revert to the default level. If the passwords are lost an emergency password can be supplied - contact Schneider Electric with the relay's serial number. The current level of access enabled for an interface can be determined by examining the 'Access level' cell in the 'System data' column, the access level for the front panel User Interface (UI), can also be found as one of the default display options.

The relay is supplied with a default access level of 2, such that no password is required to change any of the relay settings. It is also possible to set the default menu access level to either level 0 or level 1, preventing write access to the relay settings without the correct password. The default menu access level is set in the 'Password control' cell which is found in the 'System data' column of the menu (note that this setting can only be changed when level 2 access is enabled).

1.7 Relay configuration

The relay is a multi-function device that supports numerous different protection, control and communication features. In order to simplify the setting of the relay, there is a configuration settings column which can be used to enable or disable many of the functions of the relay. The settings associated with any function that is disabled are made invisible, i.e. they are not shown in the menu. To disable a function change the relevant cell in the 'Configuration' column from 'Enabled' to 'Disabled'.

The configuration column controls which of the four protection settings groups is selected as active through the 'Active settings' cell. A protection setting group can also be disabled in the configuration column, provided it is not the present active group. Similarly, a disabled setting group cannot be set as the active group.

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1.8 Front panel user interface (keypad and LCD)

When the keypad is exposed it provides full access to the menu options of the relay, with the information displayed on the LCD.

The ⟨, ⟩, ⌃ and ⌄ keys which are used for menu navigation and setting value changes include an auto-repeat function that comes into operation if any of these keys are held continually pressed. This can be used to speed up both setting value changes and menu navigation; the longer the key is held depressed, the faster the rate of change or movement becomes.

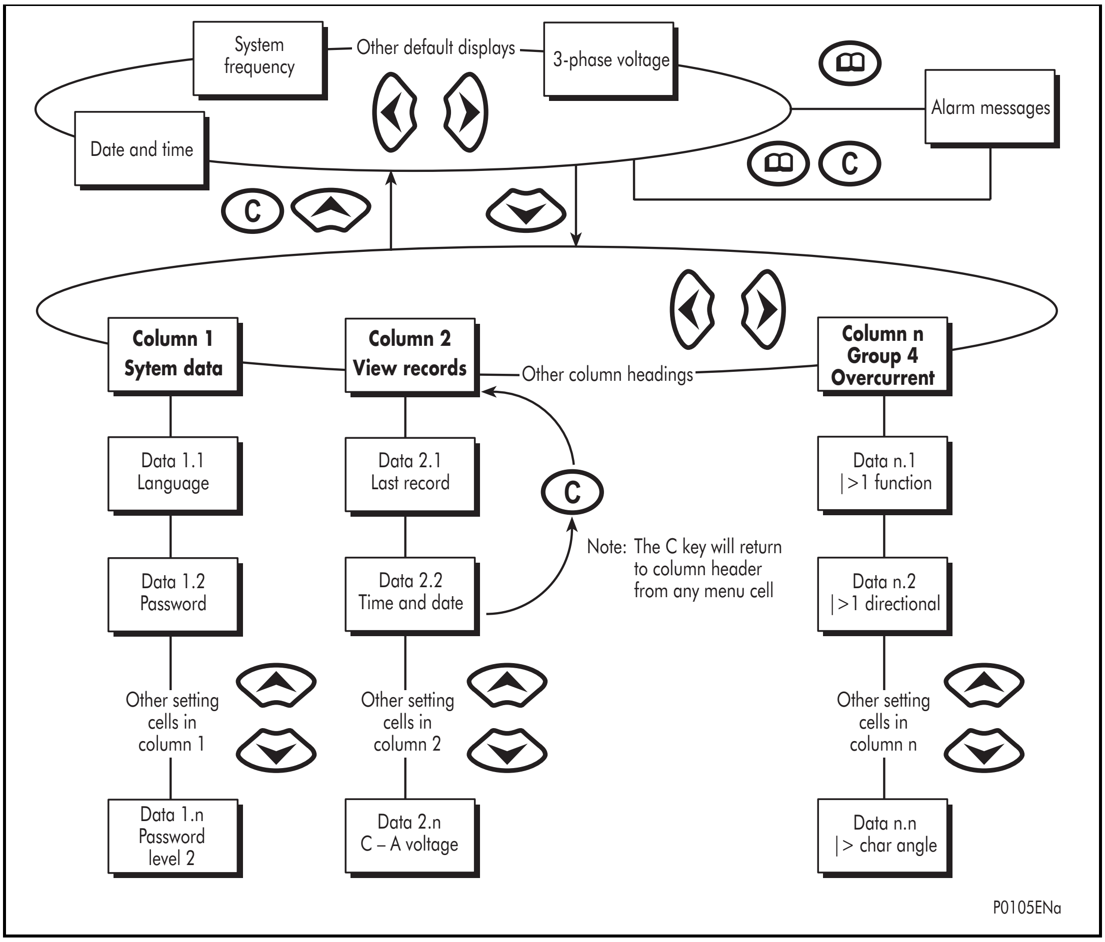

Figure 4: Front panel user interface

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1.8.1 Default display and menu time-out

The front panel menu has a default display, the contents of which can be selected from the following options in the 'default display' cell of the 'Measure't setup' column:

– Date and time

– Relay description (user defined)

– Plant reference (user defined)

– System frequency

– 3 phase voltage

– Access level

From the default display it is also possible to view the other default display options using the and keys. However, if there is no keypad activity for the 15 minute timeout period, the default display will revert to that selected by the setting and the LCD backlight will turn off. If this happens any setting changes that have not been confirmed will be lost and the original setting values maintained.

Whenever there is an uncleared alarm present in the relay (e.g. fault record, protection alarm, control alarm etc.) the default display will be replaced by:

Alarms/Faults Present

Entry to the menu structure of the relay is made from the default display and is not affected if the display is showing the 'Alarms/Faults present' message.

1.8.2 Menu navigation and setting browsing

The menu can be browsed using the four arrow keys, following the structure shown in Figure 6. Thus, starting at the default display the key will display the first column heading. To select the required column heading use the and keys. The setting data contained in the column can then be viewed by using the and keys. It is possible to return to the column header either by holding the [up arrow symbol] key down or by a single press of the clear key C. It is only possible to move across columns at the column heading level. To return to the default display press the key or the clear key C from any of the column headings. It is not possible to go straight to the default display from within one of the column cells using the auto-repeat facility of the key, as the auto-repeat will stop at the column heading. To move to the default display, the key must be released and pressed again.

1.8.3 Hotkey menu navigation

The hotkey menu can be browsed using the two keys directly below the LCD. These are known as direct access keys. The direct access keys perform the function that is displayed directly above them on the LCD. Thus, to access the hotkey menu from the default display the direct access key below the "HOTKEY" text must be pressed. Once in the hotkey menu the ⇐ and ⇒ keys can be used to scroll between the available options and the direct access keys can be used to control the function currently displayed. If neither the ⇐ or ⇒ keys are pressed with 20 seconds of entering a hotkey sub menu, the relay will revert to the default display. The clear key C will also act to return to the default menu from any page of the hotkey menu. The layout of a typical page of the hotkey menu is described below:

- The top line shows the contents of the previous and next cells for easy menu navigation
- The center line shows the function
- The bottom line shows the options assigned to the direct access keys

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The functions available in the hotkey menu are listed below:

1.8.3.1 Setting group selection

The user can either scroll using <<NXT GRP>> through the available setting groups or <<SELECT>> the setting group that is currently displayed.

When the SELECT button is pressed a screen confirming the current setting group is displayed for 2 seconds before the user is prompted with the <<NXT GRP>> or <<SELECT>> options again. The user can exit the sub menu by using the left and right arrow keys.

For more information on setting group selection refer to “Changing setting group” section in the Operation section (P54x/EN OP).

1.8.3.2 Control inputs - user assignable functions

The number of control inputs (user assignable functions - USR ASS) represented in the hotkey menu is user configurable in the “CTRL I/P CONFIG” column. The chosen inputs can be SET/RESET using the hotkey menu.

For more information refer to the “Control Inputs” section in the Operation section (P54x/EN OP).

1.8.3.3 CB control

The CB control functionality varies from one Px40 relay to another. For a detailed description of the CB control via the hotkey menu refer to the “Circuit breaker control” section of the Operation section (P54x/EN OP).

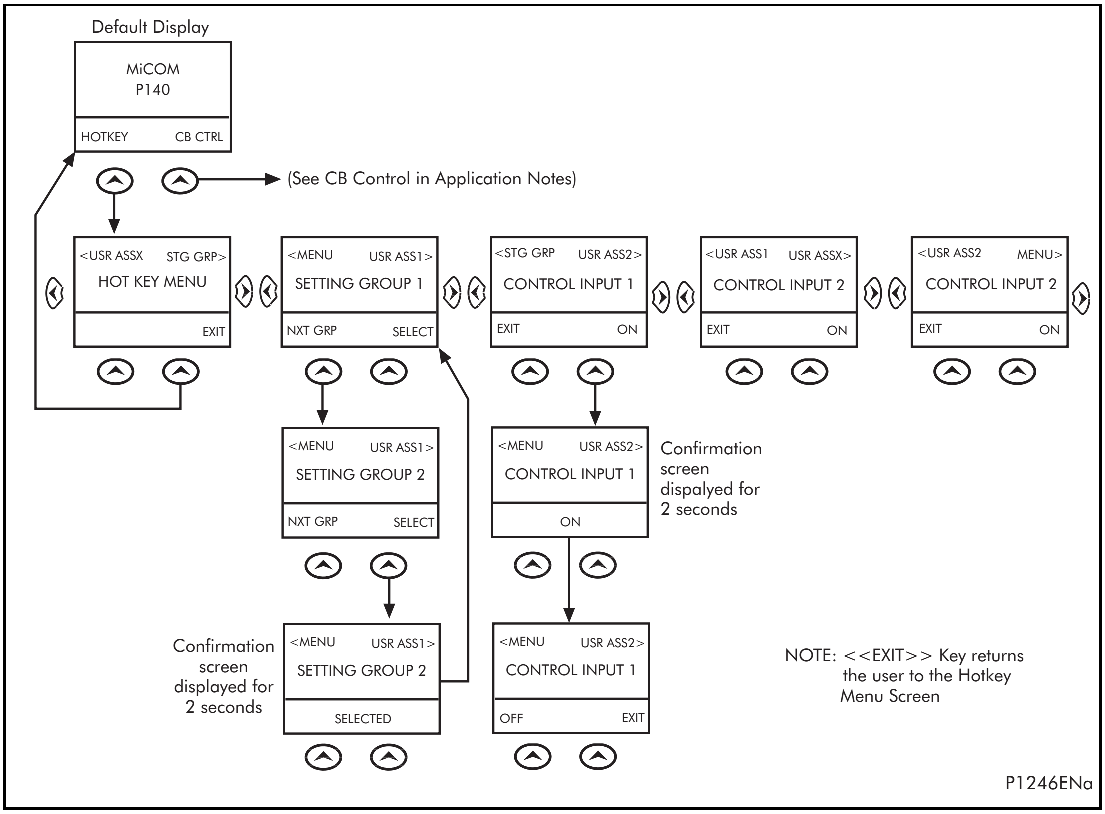

Figure 5: Hotkey menu navigation

1.8.4 Password entry

When entry of a password is required the following prompt will appear:

Enter password
**** Level 2

Note: The password required to edit the setting is the prompt as shown above.

A flashing cursor will indicate which character field of the password may be changed. Press the and keys to vary each character between A and Z. To move between the character fields of the password, use the and keys. The password is confirmed by pressing the enter key . The display will revert to 'Enter Password' if an incorrect password is entered. At this point a message will be displayed indicating whether a correct password has been entered and if so what level of access has been unlocked. If this level is sufficient to edit the selected setting then the display will return to the setting page to allow the edit to continue. If the correct level of password has not been entered then the password prompt page will be returned to. To escape from this prompt press the clear key . Alternatively, the password can be entered using the 'Password' cell of the 'System data' column.

For the front panel user interface the password protected access will revert to the default access level after a keypad inactivity time-out of 15 minutes. It is possible to manually reset the password protection to the default level by moving to the 'Password' menu cell in the 'System data' column and pressing the clear key instead of entering a password.

1.8.5 Reading and clearing of alarm messages and fault records

The presence of one or more alarm messages will be indicated by the default display and by the yellow alarm LED flashing. The alarm messages can either be self-resetting or latched, in which case they must be cleared manually. To view the alarm messages press the read key . When all alarms have been viewed, but not cleared, the alarm LED will change from flashing to constant illumination and the latest fault record will be displayed (if there is one). To scroll through the pages of this use the key. When all pages of the fault record have been viewed, the following prompt will appear:

Press clear to
reset alarms

To clear all alarm messages press ; to return to the alarms/faults present display and leave the alarms uncleared, press . Depending on the password configuration settings, it may be necessary to enter a password before the alarm messages can be cleared (see section on password entry). When the alarms have been cleared the yellow alarm LED will extinguish, as will the red trip LED if it was illuminated following a trip.

Alternatively it is possible to accelerate the procedure, once the alarm viewer has been entered using the key, the key can be pressed, and this will move the display straight to the fault record. Pressing again will move straight to the alarm reset prompt where pressing once more will clear all alarms.

1.8.6 Setting changes

To change the value of a setting, first navigate the menu to display the relevant cell. To change the cell value press the enter key , which will bring up a flashing cursor on the LCD to indicate that the value can be changed. This will only happen if the appropriate password has been entered, otherwise the prompt to enter a password will appear. The setting value can then be changed by pressing the or keys. If the setting to be changed is a binary value or a text string, the required bit or character to be changed must first be selected using the and keys. When the desired new value has been reached it is confirmed as the new setting value by pressing ⏎. Alternatively, the new value will be discarded either if the clear button Ⓒ is pressed or if the menu time-out occurs.

For protection group settings and disturbance recorder settings, the changes must be confirmed before they are used by the relay. To do this, when all required changes have been entered, return to the column heading level and press the ⌃ key. Prior to returning to the default display the following prompt will be given:

Update settings? Enter or clear

Pressing ⏎ will result in the new settings being adopted, pressing Ⓒ will cause the relay to discard the newly entered values. It should be noted that, the setting values will also be discarded if the menu time out occurs before the setting changes have been confirmed. Control and support settings will be updated immediately after they are entered, without the 'Update settings?' prompt.

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1.9 Front communication port user interface

The front communication port is provided by a 9-pin female D-type connector located under the bottom hinged cover. It provides EIA(RS)232 serial data communication and is intended for use with a PC locally to the relay (up to 15m distance) as shown in Figure 6. This port supports the Courier communication protocol only. Courier is the communication language developed by Schneider Electric to allow communication with its range of protection relays. The front port is particularly designed for use with the relay settings program MiCOM S1 that is a Windows 98, Windows NT4.0, Windows 2000 or Windows XP based software package.

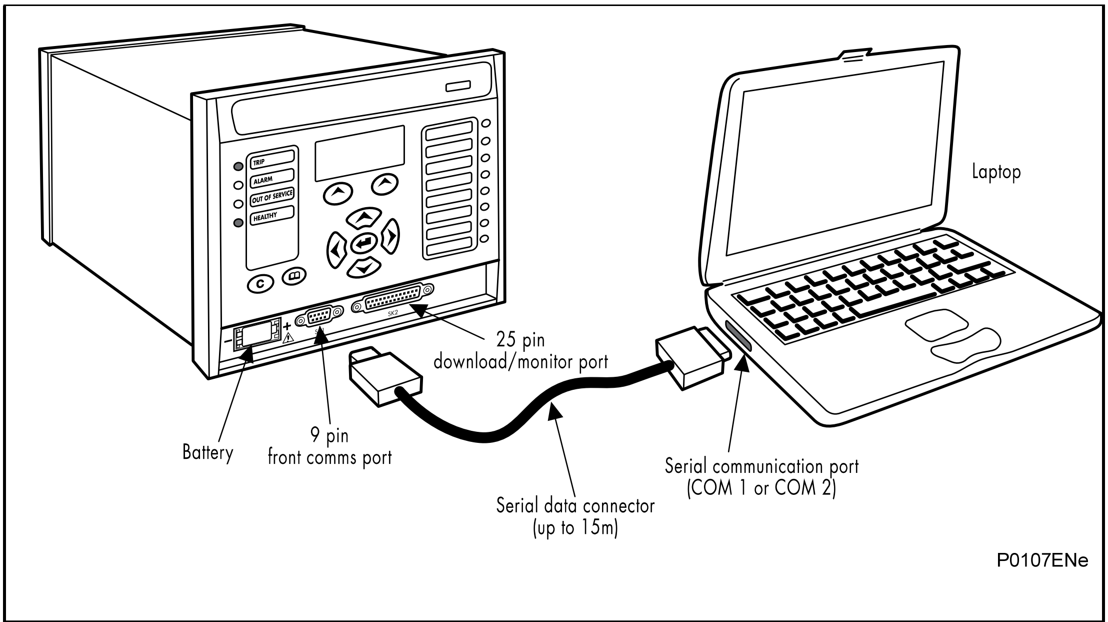

Figure 6: Front port connection

The relay is a Data Communication Equipment (DCE) device. Thus the pin connections of the relay's 9-pin front port are as follows:

Pin no. 2	Tx Receive data
Pin no. 3	Rx Transmit data
Pin no. 5	0V Zero volts common

None of the other pins are connected in the relay. The relay should be connected to the serial port of a PC, usually called COM1 or COM2. PCs are normally Data Terminal Equipment (DTE) devices which have a serial port pin connection as below (if in doubt check your PC manual):

	25 Way	9 Way	
Pin no. 2	3	2	Rx Receive data
Pin no. 3	2	3	Tx Transmit data
Pin no. 5	7	5	0V Zero volts common

For successful data communication, the Tx pin on the relay must be connected to the Rx pin on the PC, and the Rx pin on the relay must be connected to the Tx pin on the PC, as shown in Figure 7. Therefore, providing that the PC is a DTE with pin connections as given above, a 'straight through' serial connector is required, i.e. one that connects pin 2 to pin 2, pin 3 to pin 3, and pin 5 to pin 5. Note that a common cause of difficulty with serial data communication is connecting Tx to Tx and Rx to Rx. This could happen if a 'cross-over' serial connector is used, i.e. one that connects pin 2 to pin 3, and pin 3 to pin 2, or if the PC has the same pin configuration as the relay.

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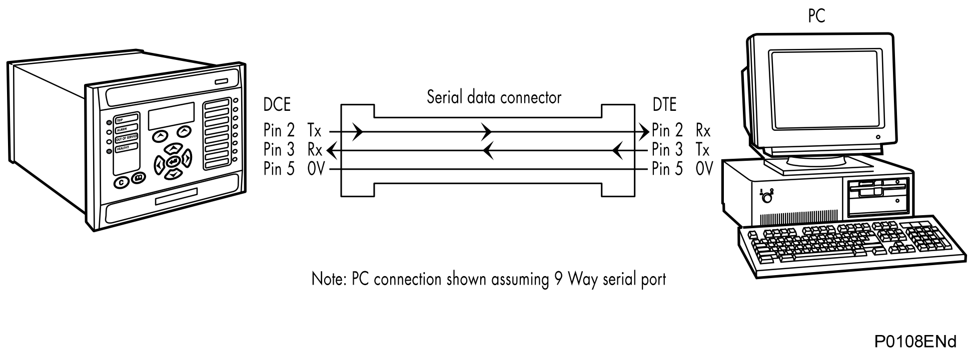


Figure 7: PC - relay signal connection

Having made the physical connection from the relay to the PC, the PC's communication settings must be configured to match those of the relay. The relay's communication settings for the front port are fixed as shown in the table below:

Protocol	Courier
Baud rate	19,200 bits/s
Courier address	1
Message format	11 bit - 1 start bit, 8 data bits, 1 parity bit (even parity), 1 stop bit

The inactivity timer for the front port is set at 15 minutes. This controls how long the relay will maintain its level of password access on the front port. If no messages are received on the front port for 15 minutes then any password access level that has been enabled will be revoked.

1.9.1 Front courier port

The front EIA(RS)232[1] 9 pin port supports the Courier protocol for one to one communication. It is designed for use during installation and commissioning/maintenance and is not suitable for permanent connection. Since this interface will not be used to link the relay to a substation communication system, some of the features of Courier are not implemented. These are as follows:

Automatic Extraction of Event Records:

– Courier Status byte does not support the Event flag

[1] This port is actually compliant to EIA(RS)574; the 9-pin version of EIA(RS)232, see www.tiaonline.org.

– Send Event/Accept Event commands are not implemented

Automatic Extraction of Disturbance Records:

– Courier Status byte does not support the Disturbance flag

Busy Response Layer:

– Courier Status byte does not support the Busy flag, the only response to a request will be the final data

Fixed Address:

– The address of the front courier port is always 1, the Change Device address command is not supported.

Fixed Baud Rate:

– 19200 bps

It should be noted that although automatic extraction of event and disturbance records is not supported it is possible to manually access this data via the front port.

1.10 MiCOM S1 relay communications basics

The front port is particularly designed for use with the relay settings program MiCOM S1 that is a Windows 98, Windows NT4.0, Windows 2000 or Windows XP based software package. MiCOM S1 is the universal MiCOM IED Support Software and provides users a direct and convenient access to all stored data in any MiCOM IED using the EIA(RS)232 front communication port.

MiCOM S1 provides full access to:

- MiCOM Px20, Px30, Px40 relays
- MiCOM Mx20 measurements units

1.10.1 PC requirements

The following minimum requirements must be met for the MiCOM S1 software to properly work on a PC.

- IBM computer or 100% compatible,
- WindowsTM 98 or NT 4.0 (Not WindowsTM 95)
- Pentium II 300 Mhz minimum,
- Screen VGA 256 colors minimum,
- Resolution 640 x 400 minimum (1024 x 768 recommended),
- 48Mb RAM minimum,
- 500Mb free on computer hard-disk.

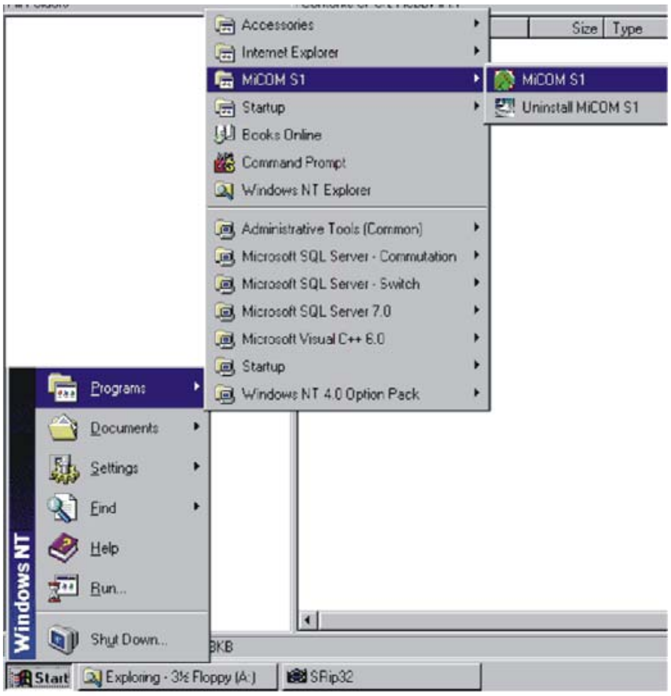
1.10.2 Connecting to the P54x relay using MiCOM S1

Before starting, verify that the EIA(RS)232 serial cable is properly connected to the EIA(RS)232 port on the front panel of the relay. Please follow the instructions in section 1.9 to ensure a proper connection is made between the PC and the relay before attempting to communicate with the relay.

This section is intended as a quick start guide to using MiCOM S1. Please refer to the MiCOM S1 User Manual for more detailed information.

To start MiCOM S1, click on the icon: 

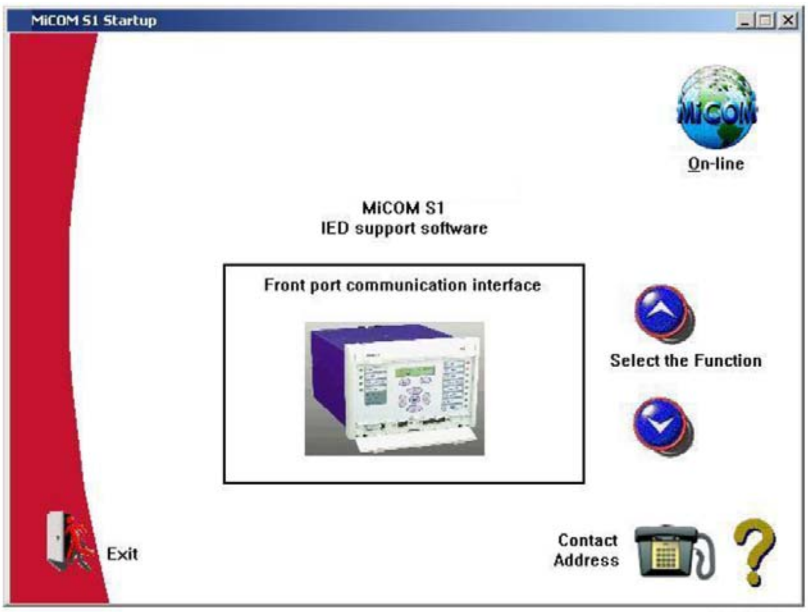
In the "Programs" menu, select "MiCOM S1" then "MiCOM S1 Start-up".



S0013ENa

WARNING: Clicking on "UninstalL MICOM S1", will uninstall MICOM S1, and all data and records used in MICOM S1.

You access the MiCOM S1 launcher screen.

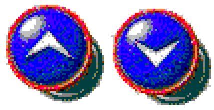


S0114ENb

The MiCOM S1 launcher is the software that gives access to the different application programs:

- MiCOM S1 for MiCOM M/Px20 IEDs
- MiCOM S1 for MiCOM Px30 IEDs
- MiCOM S1 for MiCOM Px40 IEDs
- MiCOM S1 disturbance application

GS

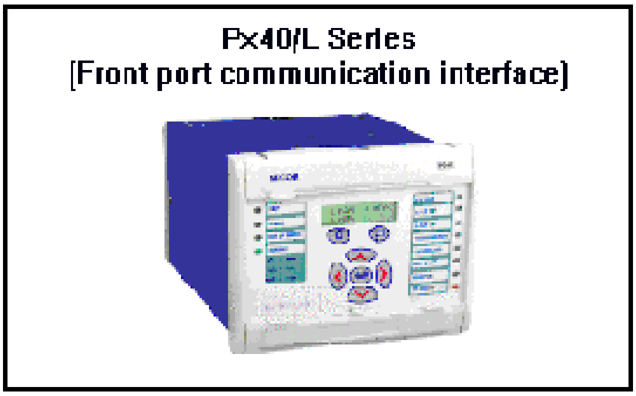
To access these different programs, use the blue arrows, 

Click on the desired type of access

IED front port access


S0015ENb

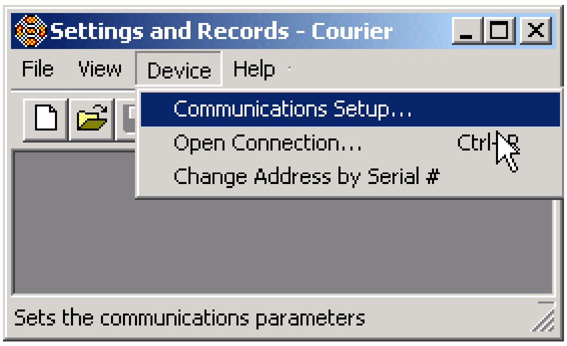
and click on the required MiCOM Px40 series



1.10.3 Open communication link with relay

To open the communications link from S1 to the P54x relay the following procedure must be followed:

First the communication setup must be adjusted if necessary. In the "Device" menu, select "Communications Setup…"



This brings up the following screen:

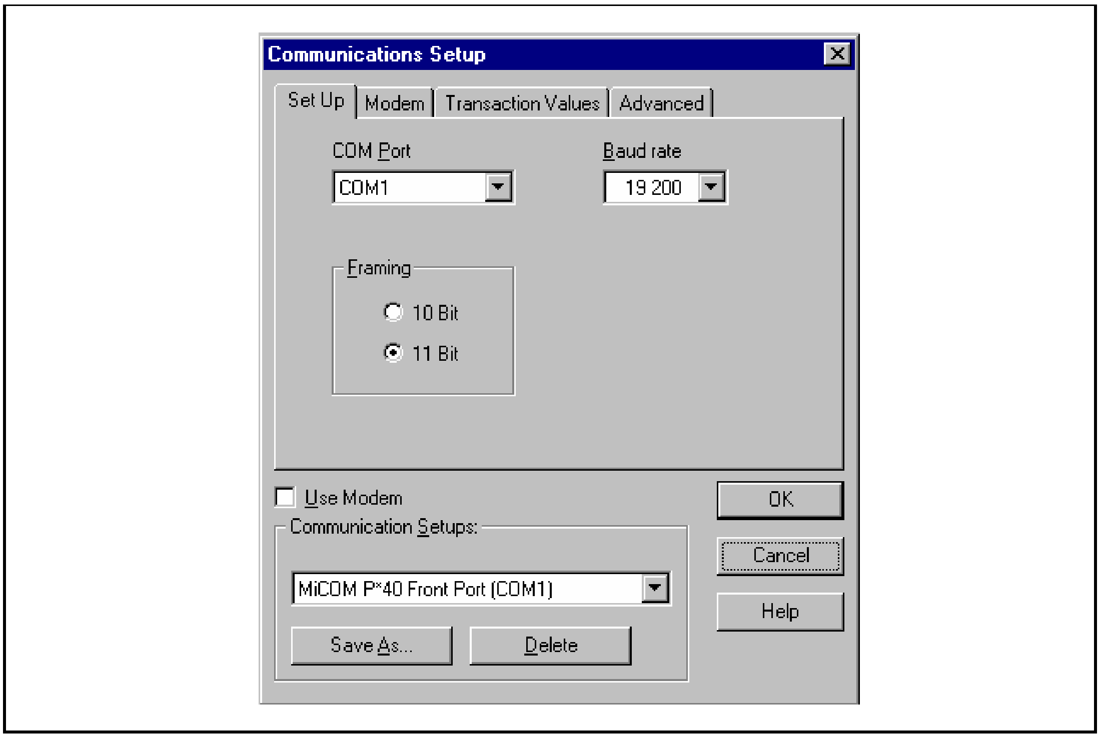
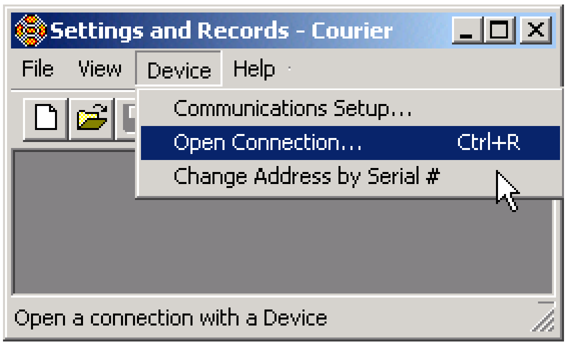
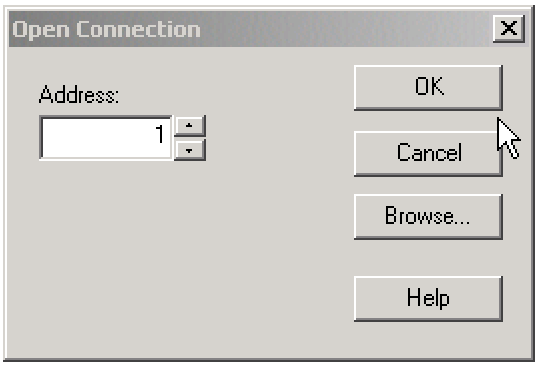


Figure 8: Communication set-up screen

When the communications setup is correct the link with the relay can be initialized. In the "Device" menu, select "Open Connection…"



This brings up a prompt for the address of the relay to be interrogated (for front port access, the relay address is always “1” - regardless of any address settings for the rear ports).



When this has been entered a prompt for the password appears.

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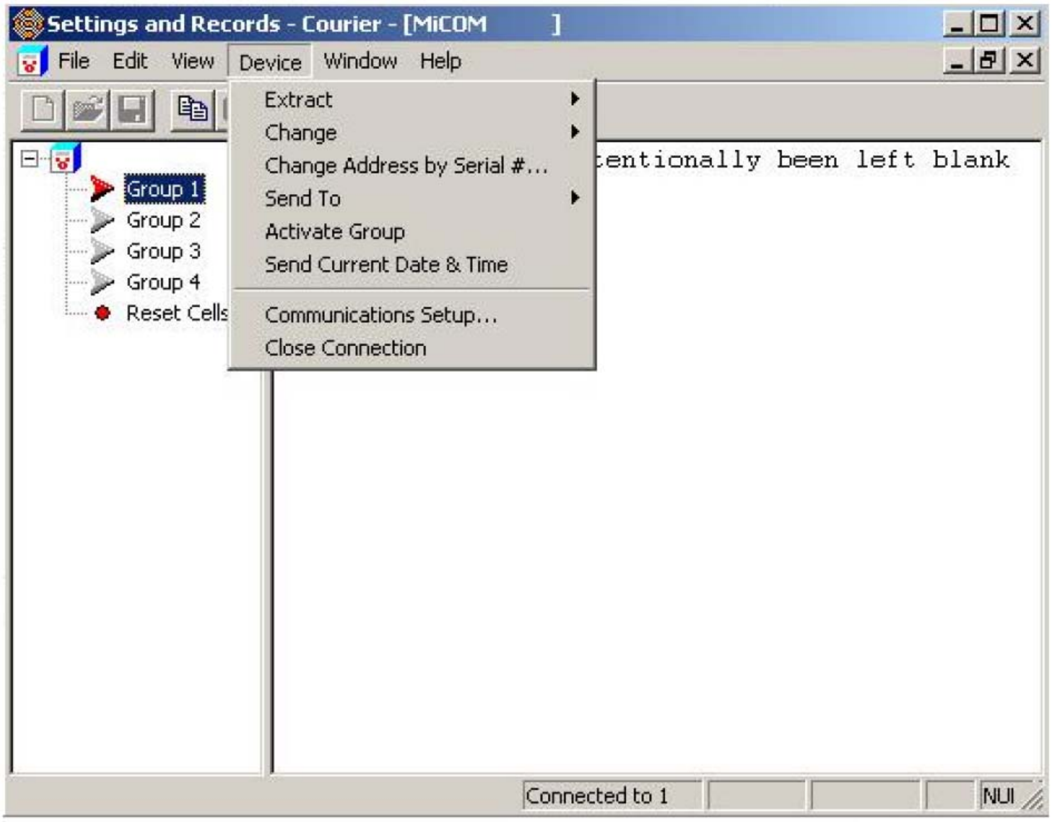
When these have been entered satisfactorily the relay is then able to communicate with MiCOM S1. When a communication link has been established between the PC and a MiCOM IED, both are said to be online. Data and information can be directly transferred from and to the IED using the menu available under the “DEVICE” menu.

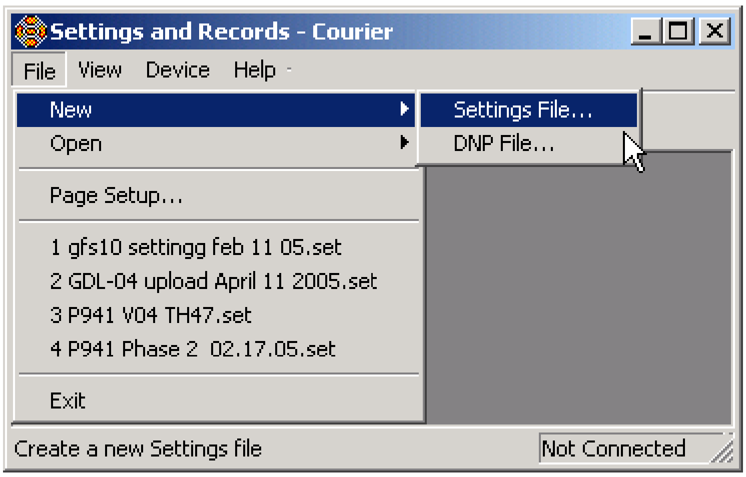


S0057ENc

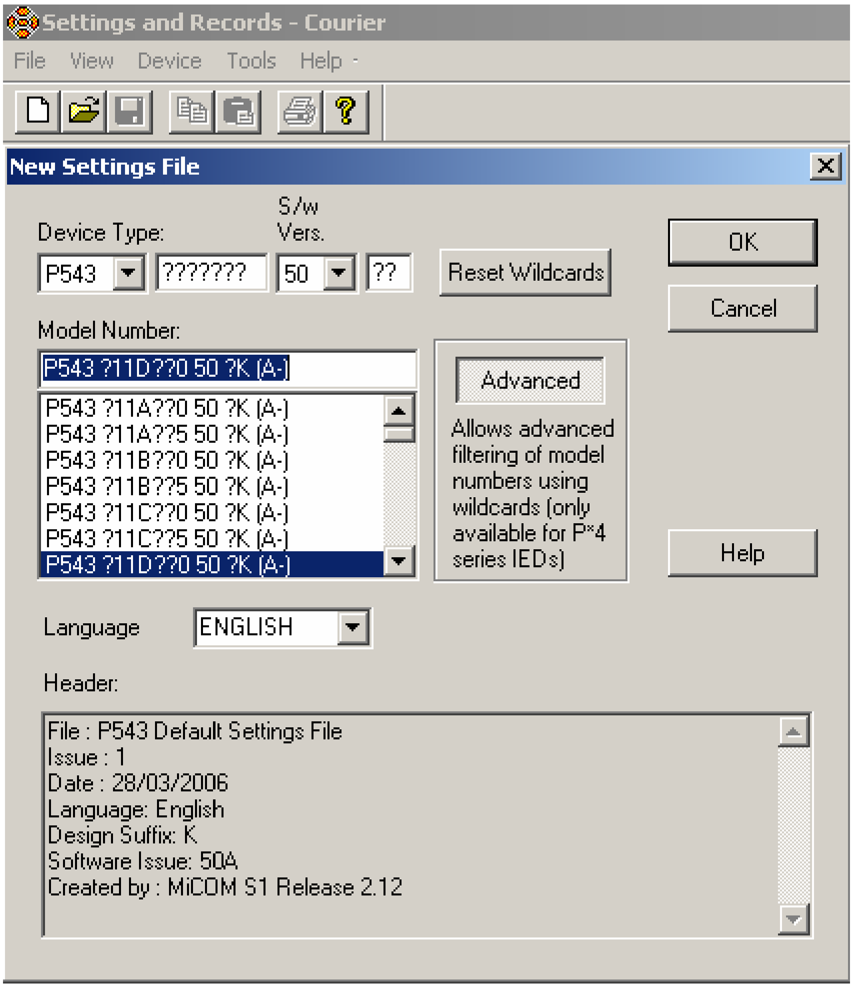
For further instruction on how to extract, download and modify settings files, please refer to the MiCOM S1 User Manual.

1.10.4 Off-line use of MiCOM S1

As well as being used for the on-line editing of settings, MiCOM S1 can also be used as an off-line tool to prepare settings without access to the relay. In order to open a default setting file for modification, in the “File” menu, select “New” and then “Settings File…”



This brings up a prompt for the relay model type where you can select the correct relay for your application:



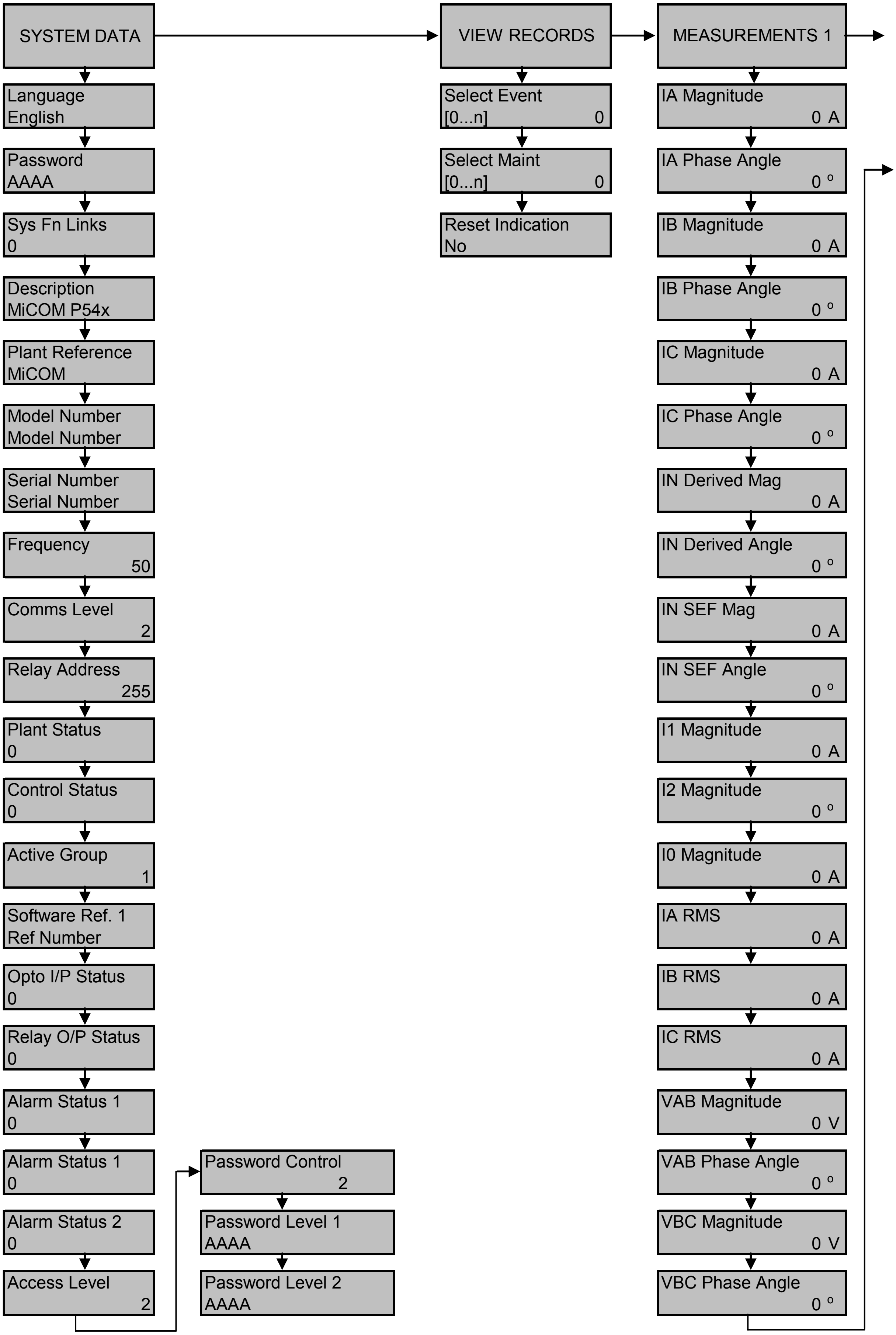
Clicking on OK will open the default file and you can start to edit settings. For further instruction on how to extract, download and modify settings files, please refer to the MiCOM S1 User Manual.

Appendix - Relay Menu Map (Default)

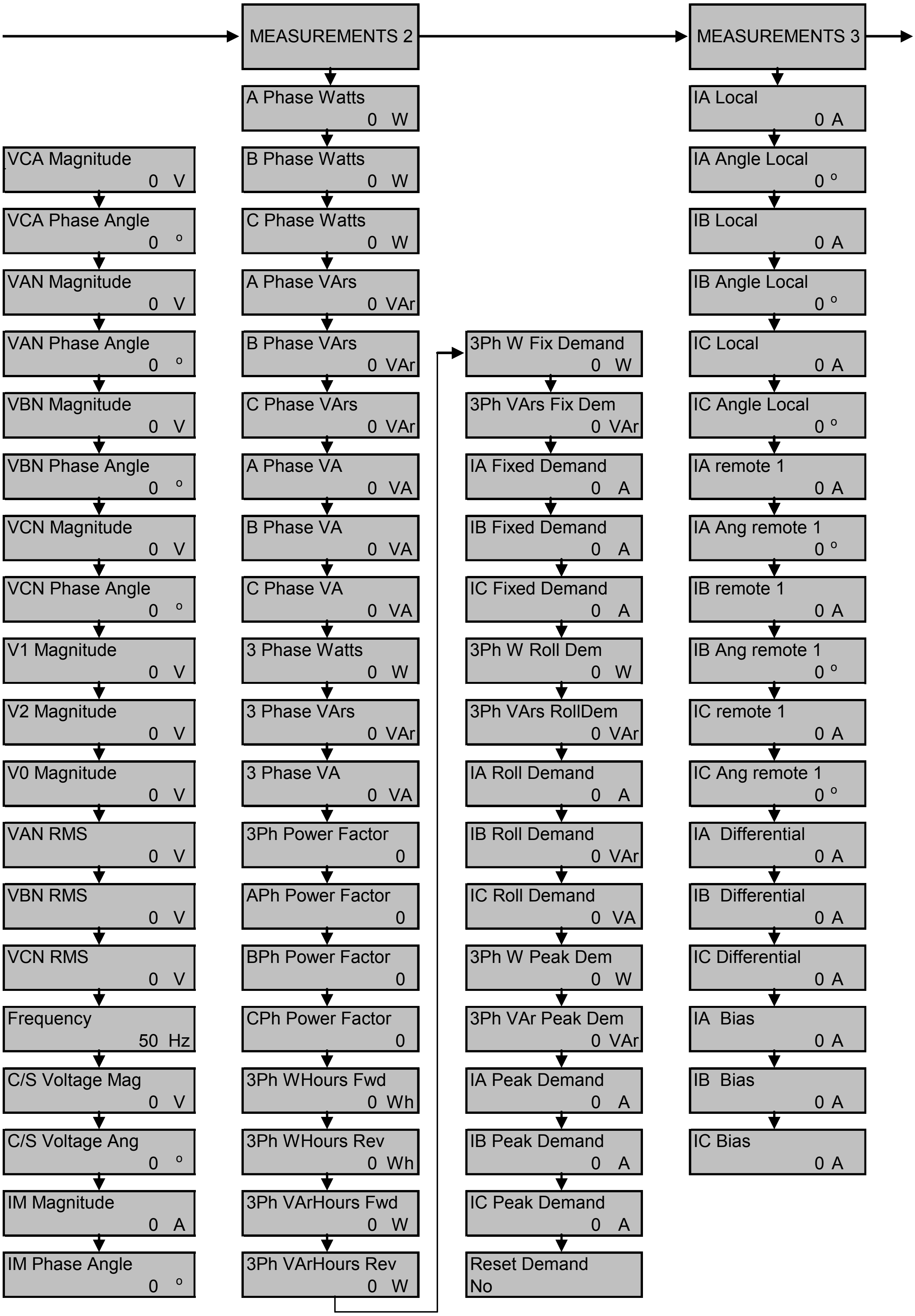
Note 1: This specific menu map relates to the MiCOM P543 modes with distance option.

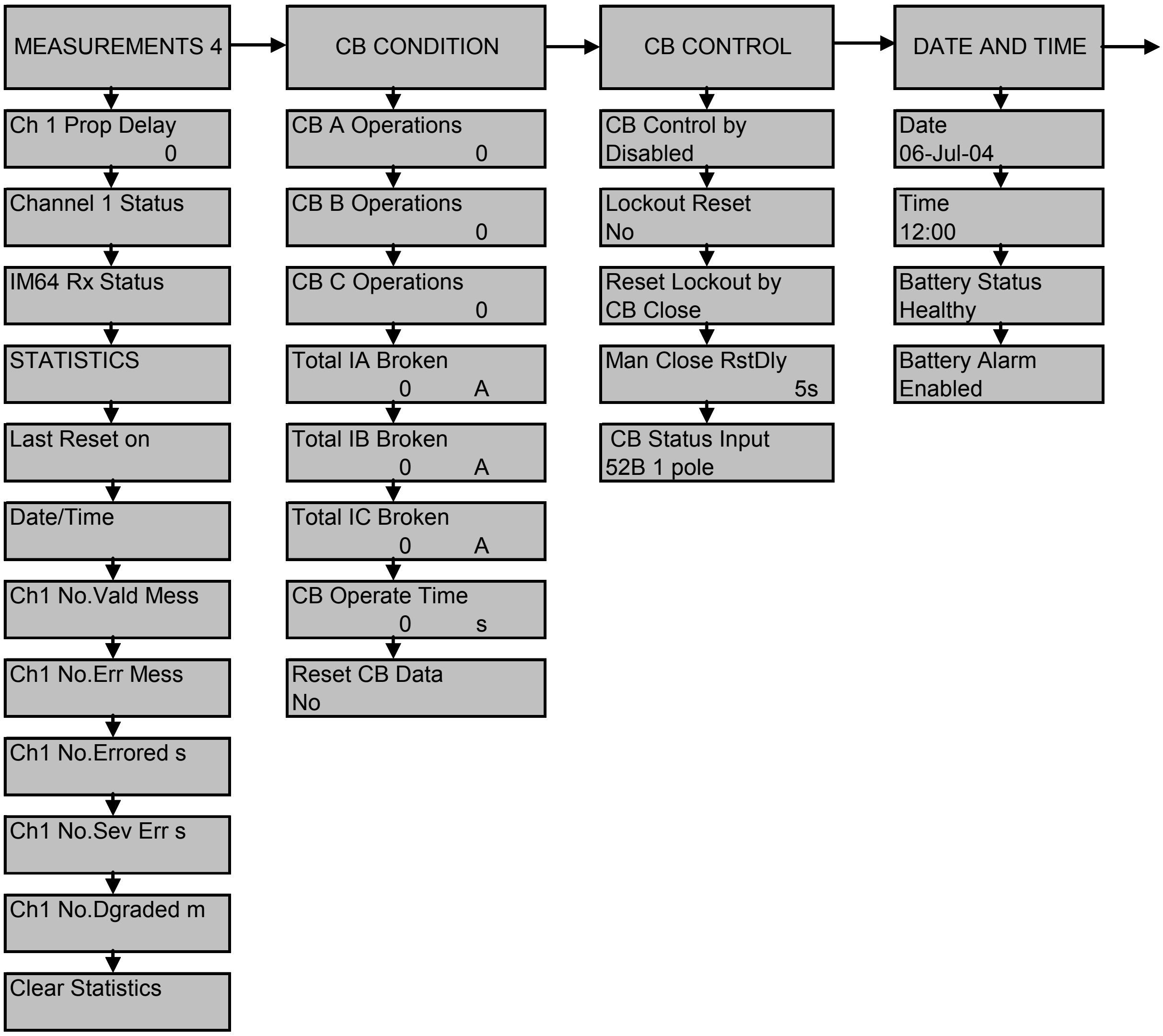
Note 2: * Group 1 is shown on the menu map, Groups 2, 3 and 4 are identical to Group 1 and therefore omitted.

Note 3: These menu cells are dependent on the relay model selected and thus may differ from that shown.

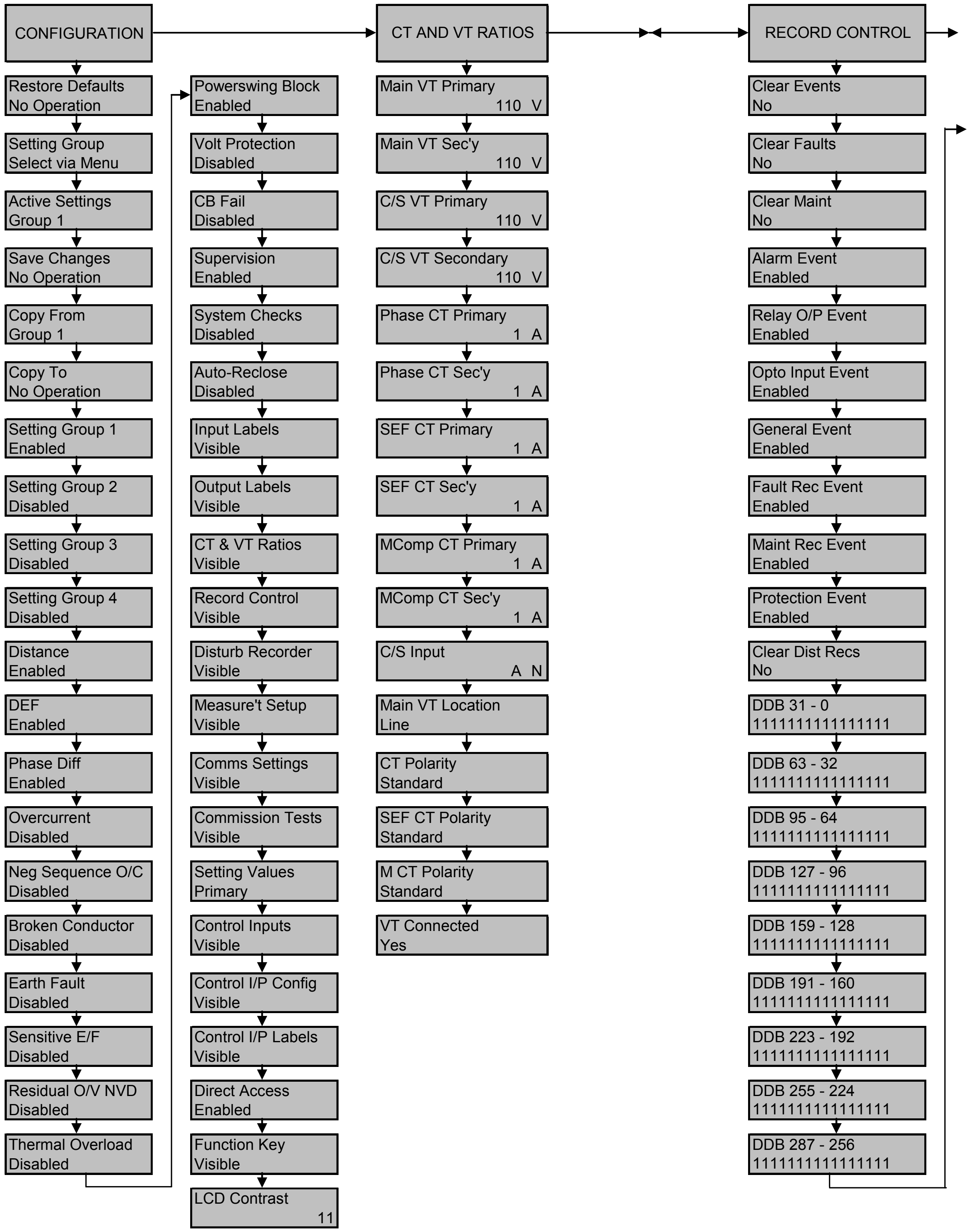

SYSTEM DATA
Language
English
Password
AAAA
Sys Fn Links
0
Description
MiCOM P54x
Plant Reference
MiCOM
Model Number
Model Number
Serial Number
Serial Number
Frequency
50
Comms Level
2
Relay Address
255
Plant Status
0
Control Status
0
Active Group
1
Software Ref. 1
Ref Number
Opto I/P Status
0
Relay O/P Status
0
Alarm Status 1
0
Alarm Status 1
0
Alarm Status 2
0
Access Level
2
Password Control
2
Password Level 1
AAAA
Password Level 2
AAAA
VIEW RECORDS
Select Event
[0...n] 0
Select Maint
[0...n] 0
Reset Indication
No
MEASUREMENTS 1
IA Magnitude
0 A
IA Phase Angle
0 °
IB Magnitude
0 A
IB Phase Angle
0 °
IC Magnitude
0 A
IC Phase Angle
0 °
IN Derived Mag
0 A
IN Derived Angle
0 °
IN SEF Mag
0 A
IN SEF Angle
0 °
I1 Magnitude
0 A
I2 Magnitude
0 °
I0 Magnitude
0 A
IA RMS
0 A
IB RMS
0 A
IC RMS
0 A
VAB Magnitude
0 V
VAB Phase Angle
0 °
VBC Magnitude
0 V
VBC Phase Angle
0 °

GS


VCA Magnitude
0 V
VCA Phase Angle
0 °
VAN Magnitude
0 V
VAN Phase Angle
0 °
VBN Magnitude
0 V
VBN Phase Angle
0 °
VCN Magnitude
0 V
VCN Phase Angle
0 °
V1 Magnitude
0 V
V2 Magnitude
0 V
V0 Magnitude
0 V
VAN RMS
0 V
VBN RMS
0 V
VCN RMS
0 V
Frequency
50 Hz
C/S Voltage Mag
0 V
C/S Voltage Ang
0 °
IM Magnitude
0 A
IM Phase Angle
0 °
MEASUREMENTS 2
A Phase Watts
0 W
B Phase Watts
0 W
C Phase Watts
0 W
A Phase VArs
0 VAr
B Phase VArs
0 VAr
C Phase VArs
0 VAr
A Phase VA
0 VA
B Phase VA
0 VA
C Phase VA
0 VA
3 Phase Watts
0 W
3 Phase VArs
0 VAr
3 Phase VA
0 VA
3Ph Power Factor
0
APh Power Factor
0
BPh Power Factor
0
CPh Power Factor
0
3Ph WHours Fwd
0 Wh
3Ph WHours Rev
0 Wh
3Ph VArHours Fwd
0 W
3Ph VArHours Rev
0 W
3Ph W Fix Demand
0 W
3Ph VArs Fix Dem
0 VAr
IA Fixed Demand
0 A
IB Fixed Demand
0 A
IC Fixed Demand
0 A
3Ph W Roll Dem
0 W
3Ph VArs RollDem
0 VAr
IA Roll Demand
0 A
IB Roll Demand
0 VAr
IC Roll Demand
0 VA
3Ph W Peak Dem
0 W
3Ph VAr Peak Dem
0 VAr
IA Peak Demand
0 A
IB Peak Demand
0 A
IC Peak Demand
0 A
Reset Demand
No
MEASUREMENTS 3
IA Local
0 A
IA Angle Local
0 °
IB Local
0 A
IB Angle Local
0 °
IC Local
0 A
IC Angle Local
0 °
IA remote 1
0 A
IA Ang remote 1
0 °
IB remote 1
0 A
IB Ang remote 1
0 °
IC remote 1
0 A
IC Ang remote 1
0 °
IA Differential
0 A
IB Differential
0 A
IC Differential
0 A
IA Bias
0 A
IB Bias
0 A
IC Bias
0 A


MEASUREMENTS 4
Ch 1 Prop Delay 0
Channel 1 Status
IM64 Rx Status
STATISTICS
Last Reset on
Date/Time
Ch1 No.Vald Mess
Ch1 No.Err Mess
Ch1 No.Errored s
Ch1 No.Sev Err s
Ch1 No.Dgraded m
Clear Statistics
CB CONDITION
CB A Operations 0
CB B Operations 0
CB C Operations 0
Total IA Broken 0 A
Total IB Broken 0 A
Total IC Broken 0 A
CB Operate Time 0 s
Reset CB Data No
CB CONTROL
CB Control by Disabled
Lockout Reset No
Reset Lockout by CB Close
Man Close RstDly 5s
CB Status Input 52B 1 pole
DATE AND TIME
Date 06-Jul-04
Time 12:00
Battery Status Healthy
Battery Alarm Enabled

GS


CONFIGURATION
Restore Defaults
No Operation
Setting Group
Select via Menu
Active Settings
Group 1
Save Changes
No Operation
Copy From
Group 1
Copy To
No Operation
Setting Group 1
Enabled
Setting Group 2
Disabled
Setting Group 3
Disabled
Setting Group 4
Disabled
Distance
Enabled
DEF
Enabled
Phase Diff
Enabled
Overcurrent
Disabled
Neg Sequence O/C
Disabled
Broken Conductor
Disabled
Earth Fault
Disabled
Sensitive E/F
Disabled
Residual O/V NVD
Disabled
Thermal Overload
Disabled
Powerswing Block
Enabled
Volt Protection
Disabled
CB Fail
Disabled
Supervision
Enabled
System Checks
Disabled
Auto-Reclose
Disabled
Input Labels
Visible
Output Labels
Visible
CT & VT Ratios
Visible
Record Control
Visible
Disturb Recorder
Visible
Measure't Setup
Visible
Comms Settings
Visible
Commission Tests
Visible
Setting Values
Primary
Control Inputs
Visible
Control I/P Config
Visible
Control I/P Labels
Visible
Direct Access
Enabled
Function Key
Visible
LCD Contrast
11
CT AND VT RATIOS
Main VT Primary
110 V
Main VT Sec'y
110 V
C/S VT Primary
110 V
C/S VT Secondary
110 V
Phase CT Primary
1 A
Phase CT Sec'y
1 A
SEF CT Primary
1 A
SEF CT Sec'y
1 A
MComp CT Primary
1 A
MComp CT Sec'y
1 A
C/S Input
A N
Main VT Location
Line
CT Polarity
Standard
SEF CT Polarity
Standard
M CT Polarity
Standard
VT Connected
Yes
RECORD CONTROL
Clear Events
No
Clear Faults
No
Clear Maint
No
Alarm Event
Enabled
Relay O/P Event
Enabled
Opto Input Event
Enabled
General Event
Enabled
Fault Rec Event
Enabled
Maint Rec Event
Enabled
Protection Event
Enabled
Clear Dist Recs
No
DDB 31 - 0
1111111111111111
DDB 63 - 32
1111111111111111
DDB 95 - 64
1111111111111111
DDB 127 - 96
1111111111111111
DDB 159 - 128
1111111111111111
DDB 191 - 160
1111111111111111
DDB 223 - 192
1111111111111111
DDB 255 - 224
1111111111111111
DDB 287 - 256
1111111111111111

DISTURB RECORDER

DDB 319 - 288
1111111111111111

DDB 351 - 320
1111111111111111

DDB 383 - 352
1111111111111111

DDB 415 - 384
1111111111111111

DDB 447 - 416
1111111111111111

DDB 479 - 448
1111111111111111

DDB 511 - 480
1111111111111111

DDB 543 - 512
1111111111111111

DDB 575 - 544
1111111111111111

DDB 607 - 576
1111111111111111

DDB 639 - 608
1111111111111111

DDB 671 - 640
1111111111111111

DDB 703 - 672
1111111111111111

DDB 735 - 704
1111111111111111

DDB 767 - 736
1111111111111111

DDB 799 - 768
1111111111111111

DDB 831 - 800
1111111111111111

DDB 863 - 832
1111111111111111

DDB 895 - 864
1111111111111111

DDB 927 - 896
1111111111111111

DDB 959 - 928
1111111111111111

DDB 991 - 960
1111111111111111

DDB 1023 - 992
1111111111111111

DDB 1055 - 1024
1111111111111111

DDB 1087 - 1056
1111111111111111

DDB 1119 - 1088
1111111111111111

DDB 1151 - 1120
1111111111111111

DDB 1183 - 1152
1111111111111111

DDB 1215 - 1184
1111111111111111

DDB 1247 - 1216
1111111111111111

DDB 1279 - 1248
1111111111111111

DDB 1311 - 1280
1111111111111111

DDB 1343 - 1312
1111111111111111

DDB 1375 - 1344
1111111111111111

DDB 1407 - 1376
1111111111111111

Duration
1.5 s

Trigger Position
33.3 %

Trigger Mode
Single

Analog Channel 1
VA

Analog Channel 2
VB

Analog Channel 3
VC

Analog Channel 4
IA

Analog Channel 5
IB

Analog Channel 6
IC

Analog Channel 7
IN

Analog Channel 8
IM Sensitive

Digital Input 1
Relay 1

Input 1 Trigger
No Trigger

Digital Input 2
Relay 2

Input 2 Trigger
No Trigger

Digital Input 3
Relay 3

Input 3 Trigger
Trigger L/H

Digital Input 4
Relay 4

Input 4 Trigger
No Trigger

Digital Input 5
Relay 5

Input 5 Trigger
No Trigger

Digital Input 6
Relay 6

Input 6 Trigger
No Trigger

Digital Input 7 *
Relay 7

Input 7 Trigger *
No Trigger

* Continue as above for "Digital Input_X" and "Input_X Trigger" 7 - 16

Digital Input 17
Opto 1

Input 17 Trigger
No Trigger

Digital Input 18
Opto 2

Digital Input 18
No trigger

Digital Input 19
Opto 3

Input 19 Trigger
No Trigger

Digital Input 20
Opto 4

Input 20 Trigger
No Trigger

Digital Input 21
Opto 5

Input 21 Trigger
No Trigger

Digital Input 22
Opto 6

Input 22 Trigger
No Trigger

Digital Input 23
Opto 7

GS

GS

MEASURE'T SETUP

- Default Display: Description
- Local Values: Primary
- Remote Values: Primary
- Measurement Ref: VA
- Measurement Mode: 0
- Fix Dem Period: 30 mins
- Roll Sub Period: 30 mins
- Num Sub Periods: 1
- Distance Unit: Miles
- Fault Location: Distance
- Remote2 Values: Primary

COMMUNICATIONS

- RP1 Protocol: Courier
- RP1 Address: 255
- RP1 InactivTimer: 15 mins
- RP1 Card Status: K Bus OK
- RP1 Port Config: K Bus
- Rear Port2 (RP2)
- RP2 Protocol: Courier
- RP2 Card Status: EIA232 OK
- RP2 Port Config: EIA232 (RS232)
- RP2 Comms Mode: IEC60870 FT1.2
- RP2 Address: 255
- RP2 InactivTimer: 15 mins
- RP2 Baud Rate: 19200

COMMISSION TESTS

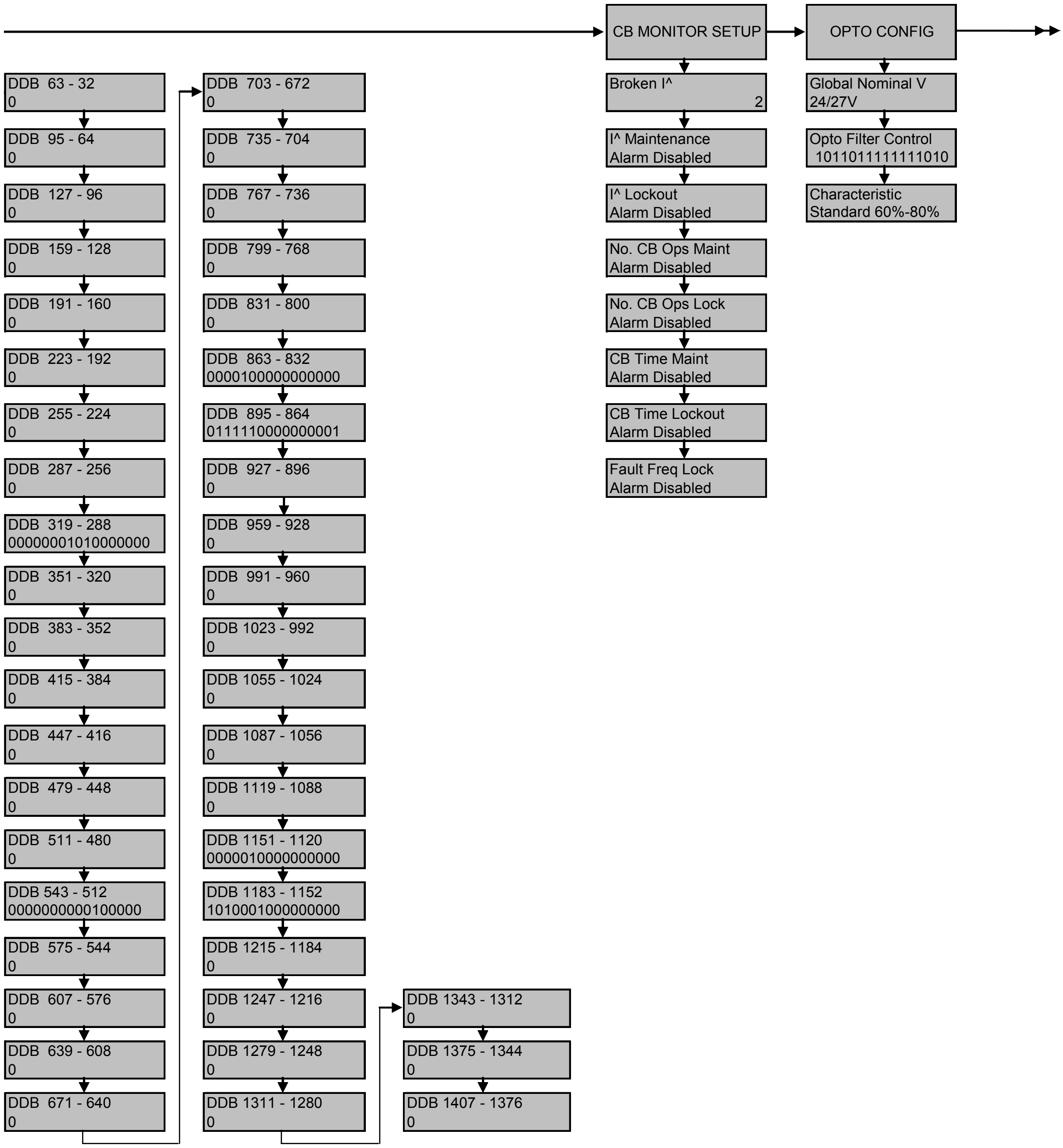
- Opto I/P Status: 0
- Relay O/P Status: 00000000001010
- Test Port Status: 00001000
- Monitor Bit 1: 1060
- Monitor Bit 2: 1062
- Monitor Bit 3: 1064
- Monitor Bit 4: 1066
- Monitor Bit 5: 1068
- Monitor Bit 6: 1070
- Monitor Bit 7: 1072
- Monitor Bit 8: 1074
- Test Mode: Disabled
- Test LEDs: No Operation
- Static Test: Disabled
- Test Loopback: Disabled
- IM64 TestPattern: 0000000000000000
- IM64 Test Mode: Disabled
- Red LED Status: 0000000000000010
- Green LED Status: 0000000000000010
- DDB 31 - 0: 0

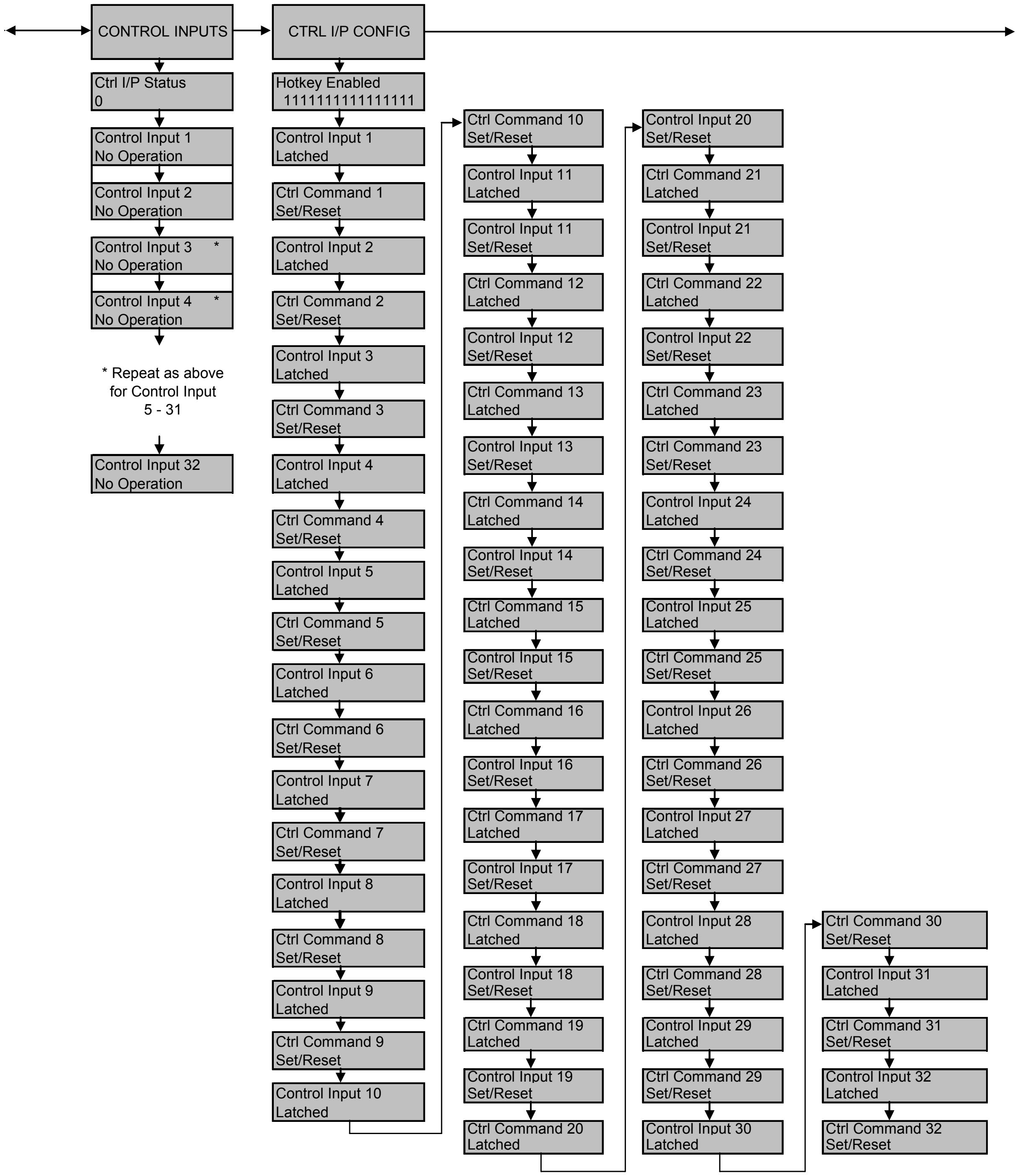
(continued)

- Input 23 Trigger: No Trigger
- Digital Input 24 *: Opto 8

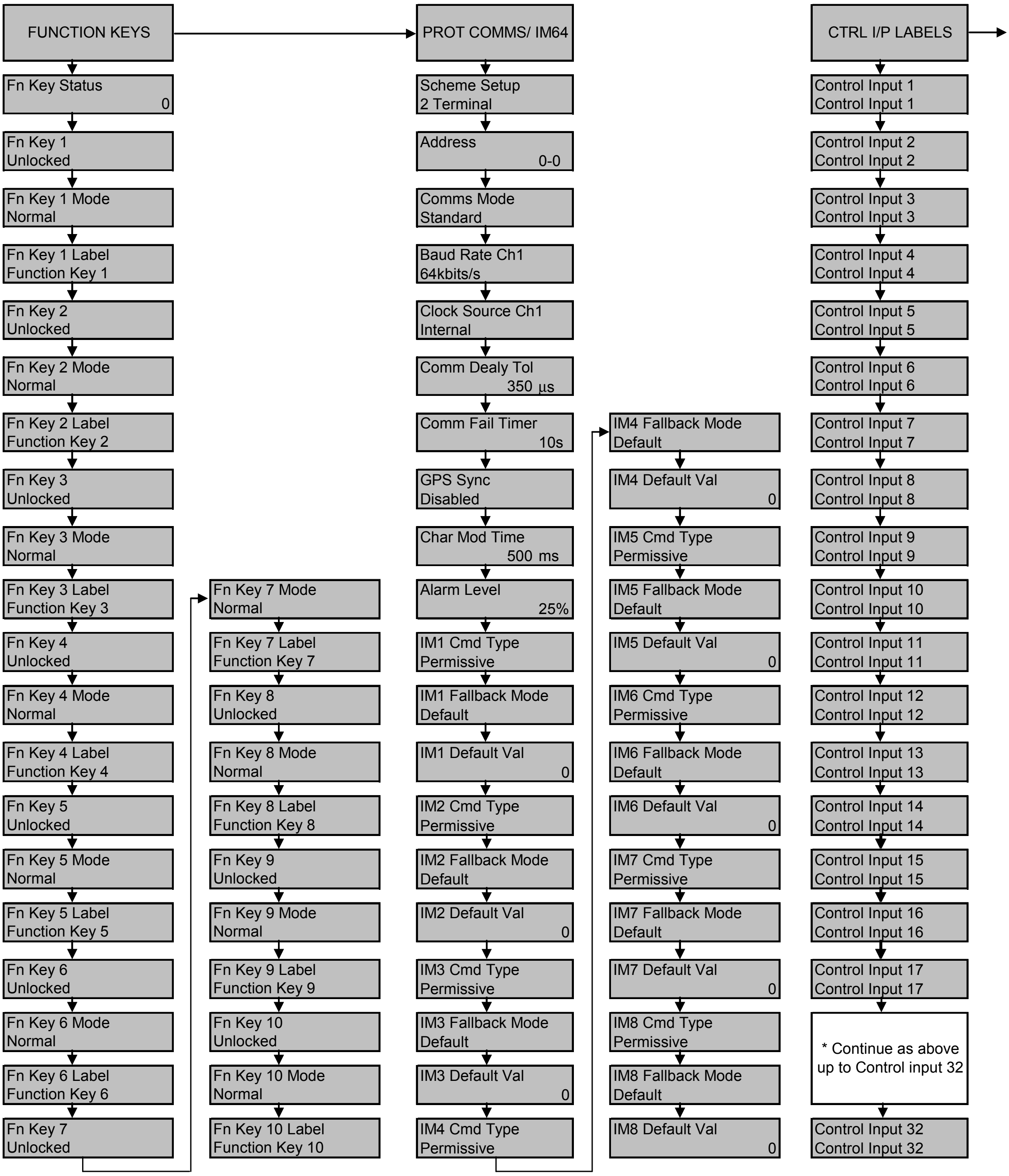
* Continue as above for "Digital Input_X" and "Input_X Trigger" 24 - 31

- Digital Input 32: Opto 16
- Input 32 Trigger: No Trigger
- Analog Channel 9: V Checksync
- Analog Channel 10: IM
- Analog Channel 11: IN
- Analog Channel 12: IN


CB MONITOR SETUP
OPTO CONFIG
DDB 63 - 32
0
DDB 95 - 64
0
DDB 127 - 96
0
DDB 159 - 128
0
DDB 191 - 160
0
DDB 223 - 192
0
DDB 255 - 224
0
DDB 287 - 256
0
DDB 319 - 288
00000001010000000
DDB 351 - 320
0
DDB 383 - 352
0
DDB 415 - 384
0
DDB 447 - 416
0
DDB 479 - 448
0
DDB 511 - 480
0
DDB 543 - 512
0000000000100000
DDB 575 - 544
0
DDB 607 - 576
0
DDB 639 - 608
0
DDB 671 - 640
0
DDB 703 - 672
0
DDB 735 - 704
0
DDB 767 - 736
0
DDB 799 - 768
0
DDB 831 - 800
0
DDB 863 - 832
0000100000000000
DDB 895 - 864
0111110000000001
DDB 927 - 896
0
DDB 959 - 928
0
DDB 991 - 960
0
DDB 1023 - 992
0
DDB 1055 - 1024
0
DDB 1087 - 1056
0
DDB 1119 - 1088
0
DDB 1151 - 1120
0000010000000000
DDB 1183 - 1152
1010001000000000
DDB 1215 - 1184
0
DDB 1247 - 1216
0
DDB 1279 - 1248
0
DDB 1311 - 1280
0
DDB 1343 - 1312
0
DDB 1375 - 1344
0
DDB 1407 - 1376
0
Broken I^
2
I^ Maintenance
Alarm Disabled
I^ Lockout
Alarm Disabled
No. CB Ops Maint
Alarm Disabled
No. CB Ops Lock
Alarm Disabled
CB Time Maint
Alarm Disabled
CB Time Lockout
Alarm Disabled
Fault Freq Lock
Alarm Disabled
Global Nominal V
24/27V
Opto Filter Control
1011011111111010
Characteristic
Standard 60%-80%

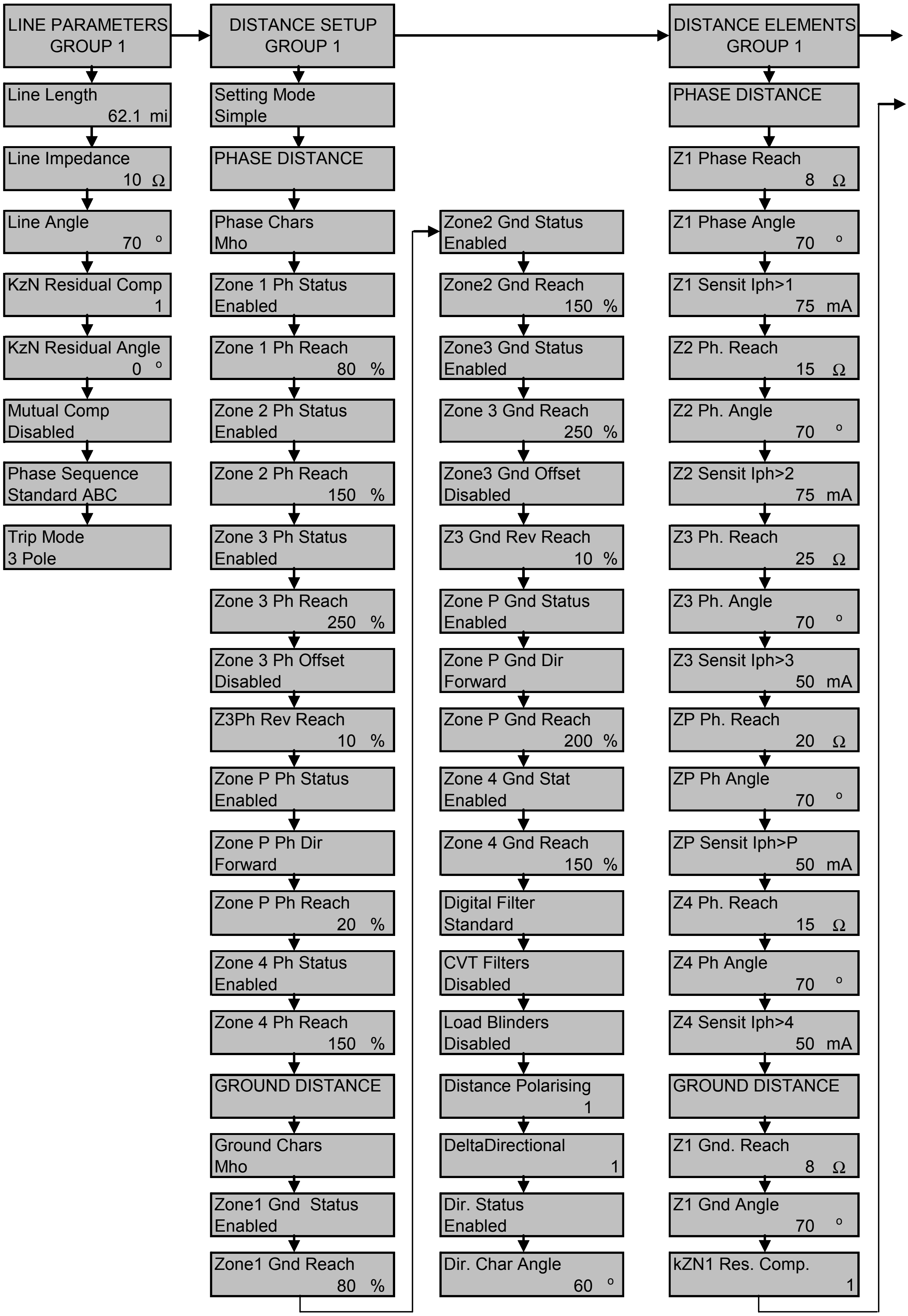

CONTROL INPUTS
Ctrl I/P Status 0
Control Input 1 No Operation
Control Input 2 No Operation
Control Input 3 * No Operation
Control Input 4 * No Operation
* Repeat as above for Control Input 5 - 31
Control Input 32 No Operation
CTRL I/P CONFIG
Hotkey Enabled 1111111111111111
Control Input 1 Latched
Ctrl Command 1 Set/Reset
Control Input 2 Latched
Ctrl Command 2 Set/Reset
Control Input 3 Latched
Ctrl Command 3 Set/Reset
Control Input 4 Latched
Ctrl Command 4 Set/Reset
Control Input 5 Latched
Ctrl Command 5 Set/Reset
Control Input 6 Latched
Ctrl Command 6 Set/Reset
Control Input 7 Latched
Ctrl Command 7 Set/Reset
Control Input 8 Latched
Ctrl Command 8 Set/Reset
Control Input 9 Latched
Ctrl Command 9 Set/Reset
Control Input 10 Latched
Ctrl Command 10 Set/Reset
Control Input 11 Latched
Control Input 11 Set/Reset
Ctrl Command 12 Latched
Control Input 12 Set/Reset
Ctrl Command 13 Latched
Control Input 13 Set/Reset
Ctrl Command 14 Latched
Control Input 14 Set/Reset
Ctrl Command 15 Latched
Control Input 15 Set/Reset
Ctrl Command 16 Latched
Control Input 16 Set/Reset
Ctrl Command 17 Latched
Control Input 17 Set/Reset
Ctrl Command 18 Latched
Control Input 18 Set/Reset
Ctrl Command 19 Latched
Control Input 19 Set/Reset
Ctrl Command 20 Latched
Control Input 20 Set/Reset
Ctrl Command 21 Latched
Control Input 21 Set/Reset
Ctrl Command 22 Latched
Control Input 22 Set/Reset
Ctrl Command 23 Latched
Ctrl Command 23 Set/Reset
Control Input 24 Latched
Ctrl Command 24 Set/Reset
Control Input 25 Latched
Ctrl Command 25 Set/Reset
Control Input 26 Latched
Ctrl Command 26 Set/Reset
Control Input 27 Latched
Ctrl Command 27 Set/Reset
Control Input 28 Latched
Ctrl Command 28 Set/Reset
Control Input 29 Latched
Ctrl Command 29 Set/Reset
Control Input 30 Latched
Ctrl Command 30 Set/Reset
Control Input 31 Latched
Ctrl Command 31 Set/Reset
Control Input 32 Latched
Ctrl Command 32 Set/Reset

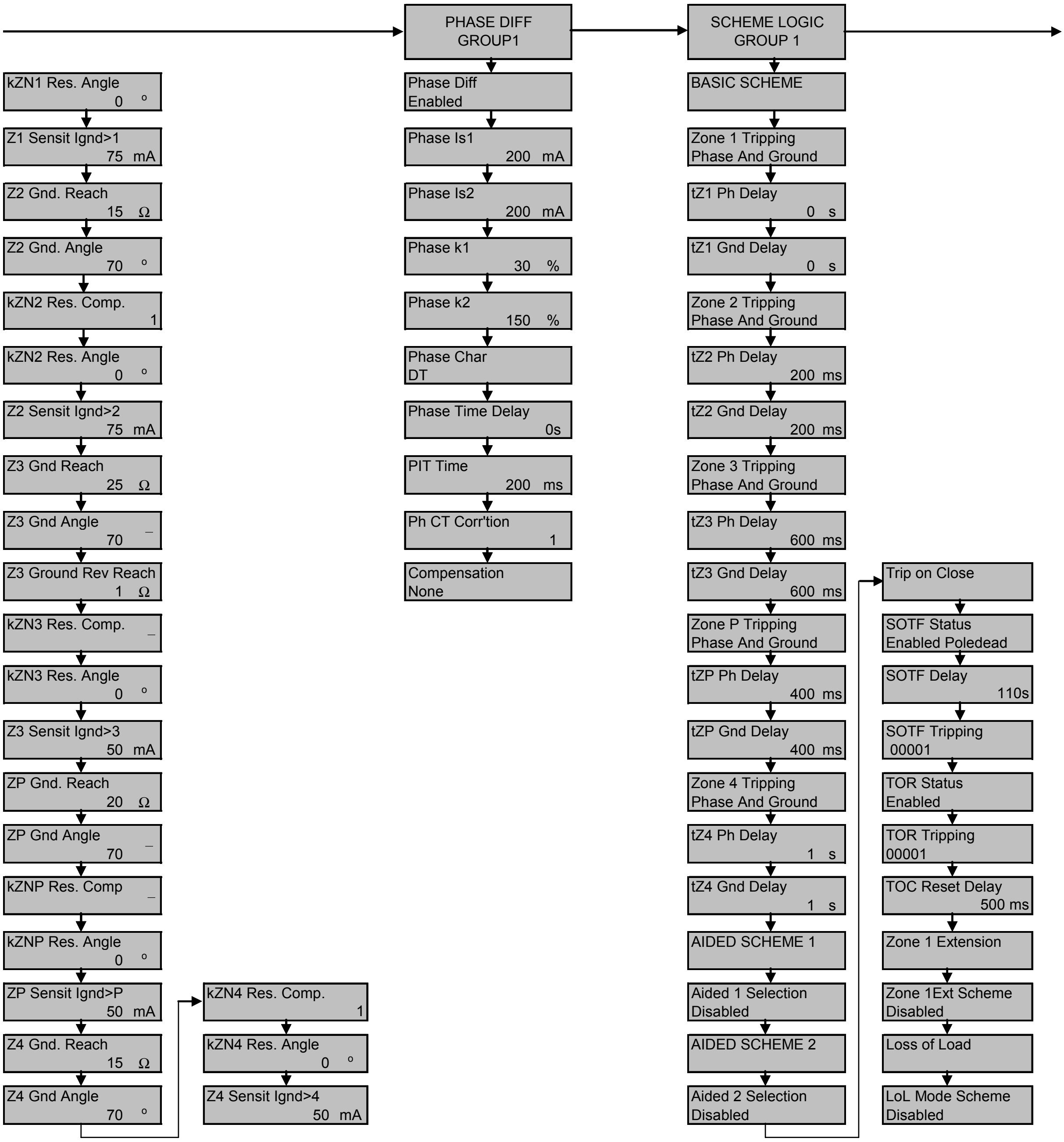
GS


FUNCTION KEYS
Fn Key Status 0
Fn Key 1 Unlocked
Fn Key 1 Mode Normal
Fn Key 1 Label Function Key 1
Fn Key 2 Unlocked
Fn Key 2 Mode Normal
Fn Key 2 Label Function Key 2
Fn Key 3 Unlocked
Fn Key 3 Mode Normal
Fn Key 3 Label Function Key 3
Fn Key 4 Unlocked
Fn Key 4 Mode Normal
Fn Key 4 Label Function Key 4
Fn Key 5 Unlocked
Fn Key 5 Mode Normal
Fn Key 5 Label Function Key 5
Fn Key 6 Unlocked
Fn Key 6 Mode Normal
Fn Key 6 Label Function Key 6
Fn Key 7 Unlocked
Fn Key 7 Mode Normal
Fn Key 7 Label Function Key 7
Fn Key 8 Unlocked
Fn Key 8 Mode Normal
Fn Key 8 Label Function Key 8
Fn Key 9 Unlocked
Fn Key 9 Mode Normal
Fn Key 9 Label Function Key 9
Fn Key 10 Unlocked
Fn Key 10 Mode Normal
Fn Key 10 Label Function Key 10
PROT COMMS/ IM64
Scheme Setup 2 Terminal
Address 0-0
Comms Mode Standard
Baud Rate Ch1 64kbits/s
Clock Source Ch1 Internal
Comm Dealy Tol 350 µs
Comm Fail Timer 10s
GPS Sync Disabled
Char Mod Time 500 ms
Alarm Level 25%
IM1 Cmd Type Permissive
IM1 Fallback Mode Default
IM1 Default Val 0
IM2 Cmd Type Permissive
IM2 Fallback Mode Default
IM2 Default Val 0
IM3 Cmd Type Permissive
IM3 Fallback Mode Default
IM3 Default Val 0
IM4 Cmd Type Permissive
IM4 Fallback Mode Default
IM4 Default Val 0
IM5 Cmd Type Permissive
IM5 Fallback Mode Default
IM5 Default Val 0
IM6 Cmd Type Permissive
IM6 Fallback Mode Default
IM6 Default Val 0
IM7 Cmd Type Permissive
IM7 Fallback Mode Default
IM7 Default Val 0
IM8 Cmd Type Permissive
IM8 Fallback Mode Default
IM8 Default Val 0
CTRL I/P LABELS
Control Input 1 Control Input 1
Control Input 2 Control Input 2
Control Input 3 Control Input 3
Control Input 4 Control Input 4
Control Input 5 Control Input 5
Control Input 6 Control Input 6
Control Input 7 Control Input 7
Control Input 8 Control Input 8
Control Input 9 Control Input 9
Control Input 10 Control Input 10
Control Input 11 Control Input 11
Control Input 12 Control Input 12
Control Input 13 Control Input 13
Control Input 14 Control Input 14
Control Input 15 Control Input 15
Control Input 16 Control Input 16
Control Input 17 Control Input 17
* Continue as above up to Control input 32
Control Input 32 Control Input 32

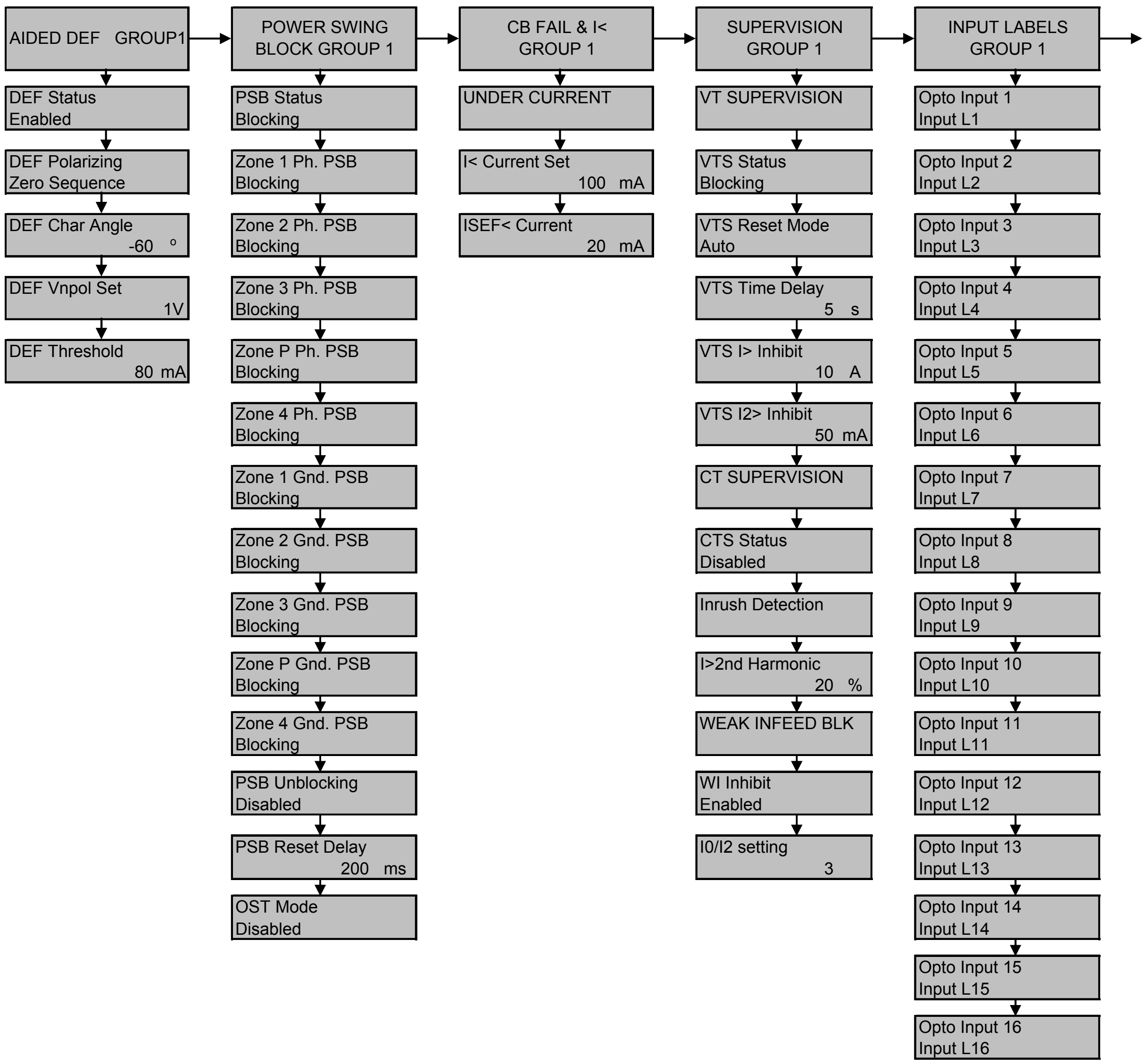
GS

GS

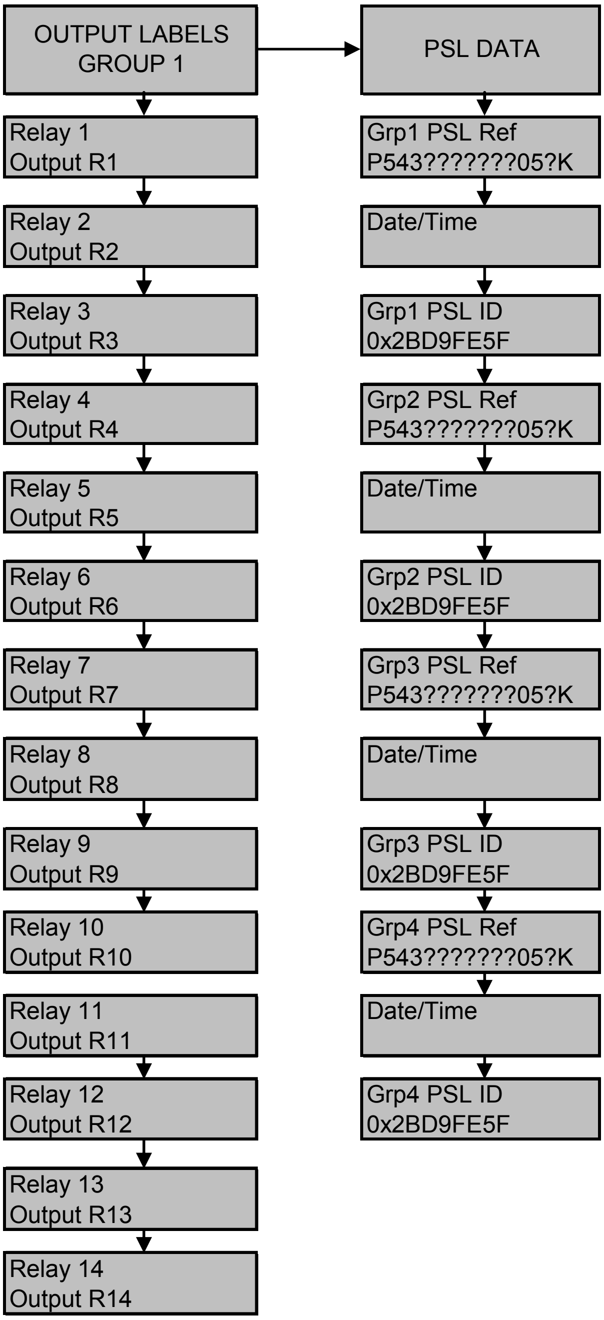

LINE PARAMETERS GROUP 1
Line Length 62.1 mi
Line Impedance 10 Ω
Line Angle 70 °
KzN Residual Comp 1
KzN Residual Angle 0 °
Mutual Comp Disabled
Phase Sequence Standard ABC
Trip Mode 3 Pole
DISTANCE SETUP GROUP 1
Setting Mode Simple
PHASE DISTANCE
Phase Chars Mho
Zone 1 Ph Status Enabled
Zone 1 Ph Reach 80 %
Zone 2 Ph Status Enabled
Zone 2 Ph Reach 150 %
Zone 3 Ph Status Enabled
Zone 3 Ph Reach 250 %
Zone 3 Ph Offset Disabled
Z3Ph Rev Reach 10 %
Zone P Ph Status Enabled
Zone P Ph Dir Forward
Zone P Ph Reach 20 %
Zone 4 Ph Status Enabled
Zone 4 Ph Reach 150 %
GROUND DISTANCE
Ground Chars Mho
Zone1 Gnd Status Enabled
Zone1 Gnd Reach 80 %
Zone2 Gnd Status Enabled
Zone2 Gnd Reach 150 %
Zone3 Gnd Status Enabled
Zone 3 Gnd Reach 250 %
Zone3 Gnd Offset Disabled
Z3 Gnd Rev Reach 10 %
Zone P Gnd Status Enabled
Zone P Gnd Dir Forward
Zone P Gnd Reach 200 %
Zone 4 Gnd Stat Enabled
Zone 4 Gnd Reach 150 %
Digital Filter Standard
CVT Filters Disabled
Load Blinders Disabled
Distance Polarising 1
DeltaDirectional 1
Dir. Status Enabled
Dir. Char Angle 60 °
DISTANCE ELEMENTS GROUP 1
PHASE DISTANCE
Z1 Phase Reach 8 Ω
Z1 Phase Angle 70 °
Z1 Sensit Iph>1 75 mA
Z2 Ph. Reach 15 Ω
Z2 Ph. Angle 70 °
Z2 Sensit Iph>2 75 mA
Z3 Ph. Reach 25 Ω
Z3 Ph. Angle 70 °
Z3 Sensit Iph>3 50 mA
ZP Ph. Reach 20 Ω
ZP Ph Angle 70 °
ZP Sensit Iph>P 50 mA
Z4 Ph. Reach 15 Ω
Z4 Ph Angle 70 °
Z4 Sensit Iph>4 50 mA
GROUND DISTANCE
Z1 Gnd. Reach 8 Ω
Z1 Gnd Angle 70 °
kZN1 Res. Comp. 1


PHASE DIFF GROUP1
SCHEME LOGIC GROUP 1
kZN1 Res. Angle 0 °
Z1 Sensit Ignd>1 75 mA
Z2 Gnd. Reach 15 Ω
Z2 Gnd. Angle 70 °
kZN2 Res. Comp. 1
kZN2 Res. Angle 0 °
Z2 Sensit Ignd>2 75 mA
Z3 Gnd Reach 25 Ω
Z3 Gnd Angle 70
Z3 Ground Rev Reach 1 Ω
kZN3 Res. Comp.
kZN3 Res. Angle 0 °
Z3 Sensit Ignd>3 50 mA
ZP Gnd. Reach 20 Ω
ZP Gnd Angle 70
kZNP Res. Comp
kZNP Res. Angle 0 °
ZP Sensit Ignd>P 50 mA
Z4 Gnd. Reach 15 Ω
Z4 Gnd Angle 70 °
kZN4 Res. Comp. 1
kZN4 Res. Angle 0 °
Z4 Sensit Ignd>4 50 mA
Phase Diff Enabled
Phase Is1 200 mA
Phase Is2 200 mA
Phase k1 30 %
Phase k2 150 %
Phase Char DT
Phase Time Delay 0s
PIT Time 200 ms
Ph CT Corr'tion 1
Compensation None
BASIC SCHEME
Zone 1 Tripping Phase And Ground
tZ1 Ph Delay 0 s
tZ1 Gnd Delay 0 s
Zone 2 Tripping Phase And Ground
tZ2 Ph Delay 200 ms
tZ2 Gnd Delay 200 ms
Zone 3 Tripping Phase And Ground
tZ3 Ph Delay 600 ms
tZ3 Gnd Delay 600 ms
Zone P Tripping Phase And Ground
tZP Ph Delay 400 ms
tZP Gnd Delay 400 ms
Zone 4 Tripping Phase And Ground
tZ4 Ph Delay 1 s
tZ4 Gnd Delay 1 s
AIDED SCHEME 1
Aided 1 Selection Disabled
AIDED SCHEME 2
Aided 2 Selection Disabled
Trip on Close
SOTF Status Enabled Poledead
SOTF Delay 110s
SOTF Tripping 00001
TOR Status Enabled
TOR Tripping 00001
TOC Reset Delay 500 ms
Zone 1 Extension
Zone 1Ext Scheme Disabled
Loss of Load
LoL Mode Scheme Disabled

GS


AIDED DEF GROUP1
DEF Status
Enabled
DEF Polarizing
Zero Sequence
DEF Char Angle
-60 °
DEF Vnpol Set
1V
DEF Threshold
80 mA
POWER SWING BLOCK GROUP 1
PSB Status
Blocking
Zone 1 Ph. PSB
Blocking
Zone 2 Ph. PSB
Blocking
Zone 3 Ph. PSB
Blocking
Zone P Ph. PSB
Blocking
Zone 4 Ph. PSB
Blocking
Zone 1 Gnd. PSB
Blocking
Zone 2 Gnd. PSB
Blocking
Zone 3 Gnd. PSB
Blocking
Zone P Gnd. PSB
Blocking
Zone 4 Gnd. PSB
Blocking
PSB Unblocking
Disabled
PSB Reset Delay
200 ms
OST Mode
Disabled
CB FAIL & I< GROUP 1
UNDER CURRENT
I< Current Set
100 mA
ISEF< Current
20 mA
SUPERVISION GROUP 1
VT SUPERVISION
VTS Status
Blocking
VTS Reset Mode
Auto
VTS Time Delay
5 s
VTS I> Inhibit
10 A
VTS I2> Inhibit
50 mA
CT SUPERVISION
CTS Status
Disabled
Inrush Detection
I>2nd Harmonic
20 %
WEAK INFEED BLK
WI Inhibit
Enabled
I0/I2 setting
3
INPUT LABELS GROUP 1
Opto Input 1
Input L1
Opto Input 2
Input L2
Opto Input 3
Input L3
Opto Input 4
Input L4
Opto Input 5
Input L5
Opto Input 6
Input L6
Opto Input 7
Input L7
Opto Input 8
Input L8
Opto Input 9
Input L9
Opto Input 10
Input L10
Opto Input 11
Input L11
Opto Input 12
Input L12
Opto Input 13
Input L13
Opto Input 14
Input L14
Opto Input 15
Input L15
Opto Input 16
Input L16

GS


OUTPUT LABELS GROUP 1
Relay 1 Output R1
Relay 2 Output R2
Relay 3 Output R3
Relay 4 Output R4
Relay 5 Output R5
Relay 6 Output R6
Relay 7 Output R7
Relay 8 Output R8
Relay 9 Output R9
Relay 10 Output R10
Relay 11 Output R11
Relay 12 Output R12
Relay 13 Output R13
Relay 14 Output R14
PSL DATA
Grp1 PSL Ref P543???????05?K
Date/Time
Grp1 PSL ID 0x2BD9FE5F
Grp2 PSL Ref P543???????05?K
Date/Time
Grp2 PSL ID 0x2BD9FE5F
Grp3 PSL Ref P543???????05?K
Date/Time
Grp3 PSL ID 0x2BD9FE5F
Grp4 PSL Ref P543???????05?K
Date/Time
Grp4 PSL ID 0x2BD9FE5F

GS

ST

SETTINGS

Date:	**7th August 2006**
Hardware Suffix:	**K**
Software Version:	**41 and 51**
Connection Diagrams:	**10P54302xx (xx = 01 to 02) & 10P54303xx (xx = 01 to 02)**
	10P54402xx (xx = 01 to 02) & 10P54403xx (xx = 01 to 02)
	10P54502xx (xx = 01 to 02) & 10P54503xx (xx = 01 to 02)
	10P54602xx (xx = 01 to 02) & 10P54603xx (xx = 01 to 02)

ST

CONTENTS

ST

1. SETTINGS

The MiCOM P54x must be configured to the system and application by means of appropriate settings. The sequence in which the settings are listed and described in this chapter will be the protection setting, control and configuration settings and the disturbance recorder settings (see section P54x/EN GS for the detailed relay menu map). The relay is supplied with a factory-set configuration of default settings.

1.1 Relay settings configuration

The relay is a multi-function device that supports numerous different protection, control and communication features. In order to simplify the setting of the relay, there is a configuration settings column which can be used to enable or disable many of the functions of the relay. The settings associated with any function that is disabled are made invisible; i.e. they are not shown in the menu. To disable a function change the relevant cell in the 'Configuration' column from 'Enabled' to 'Disabled'.

The configuration column controls which of the four protection settings groups is selected as active through the 'Active settings' cell. A protection setting group can also be disabled in the configuration column, provided it is not the present active group. Similarly, a disabled setting group cannot be set as the active group.

The column also allows all of the setting values in one group of protection settings to be copied to another group.

To do this firstly set the 'Copy from' cell to the protection setting group to be copied, and then set the 'copy to' cell to the protection group where the copy is to be placed. The copied settings are initially placed in the temporary scratchpad, and will only be used by the relay following confirmation.

Menu Text	Default Setting	Available Settings
Restore Defaults	No Operation	No Operation All Settings Setting Group 1 Setting Group 2 Setting Group 3 Setting Group 4
Setting to restore a setting group to factory default settings.		
Setting Group	Select via Menu	Select via Menu Select via Optos
Allows setting group changes to be initiated via Opto Input or via Menu.		
Active Settings	Group 1	Group 1, Group 2, Group 3, Group 4
Selects the active setting group.		
Save Changes	No Operation	No Operation, Save, Abort
Saves all relay settings.		
Copy from	Group 1	Group 1, 2, 3 or 4
Allows displayed settings to be copied from a selected setting group.		
Copy to	No Operation	No Operation Group 1, 2, 3 or 4
Allows displayed settings to be copied to a selected setting group (ready to paste).		
Setting Group 1	Enabled	Enabled or Disabled
If the setting group is disabled from the configuration, then all associated settings and signals are hidden, with the exception of this setting (paste).		
Setting Group 2 (as above)	Disabled	Enabled or Disabled

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Menu Text	Default Setting	Available Settings
Setting Group 3 (as above)	Disabled	Enabled or Disabled
Setting Group 4 (as above)	Disabled	Enabled or Disabled
Distance	Enabled	Enabled or Disabled
Only in models with Distance option. To enable (activate) or disable (turn off) the Distance Protection: ANSI 21P/21G.		
Directional E/F	Enabled	Enabled or Disabled
Only in models with Distance option. To enable (activate) or disable (turn off) the Directional Earth Fault (DEF) Protection used in a pilot aided scheme: ANSI 67N. This protection is independent from back up Earth fault protection described below.		
Phase Diff	Enabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Differential Protection. To get the differential protection fully active, it is necessary also to enable the differential protection in the group. Note that Phase Diff setting and InterMiCOM^{64} Fiber setting are mutually exclusive as with Phase Diff enabled, the digital message exchanged has the structure of the differential message (i.e. currents are sent to the remote end, etc) and with InterMiCOM^{64} Fiber the digital message exchanged has the structure and properties of the InterMiCOM^{64} Fiber.		
Overcurrent	Enabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Phase Overcurrent Protection function. I> stages: ANSI 50/51/67P.		
Neg. Sequence O/C	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Negative Sequence Overcurrent Protection function. I2> stages: ANSI 46/67.		
Broken Conductor	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Broken Conductor function. I2/I1> stage: ANSI 46BC.		
Earth Fault	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the back up Earth Fault Protection function. IN >stages: ANSI 50/51/67N.		
Sensitive E/F	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Sensitive Earth Fault Protection function. ISEF >stages: ANSI 50/51/67N.		
Residual O/V NVD	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Residual Overvoltage Protection function. VN>stages: ANSI 59N.		
Thermal Overload	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Thermal Overload Protection function. ANSI 49.		
PowerSwing Block	Enabled	Enabled or Disabled
To enable (activate) or disable (turn off) the power swing blocking/out of step: ANSI 68/78.		
Volt Protection	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Voltage Protection (under/overvoltage) function. V<, V> stages: ANSI 27/59.		

Menu Text	Default Setting	Available Settings
CB Fail	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Circuit Breaker Fail Protection function. ANSI 50BF.		
Supervision	Enabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Supervision (VTS & CTS) functions. ANSI VTS/CTS.		
System Checks	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the System Checks (Check Sync. and Voltage Monitor) function: ANSI 25.		
Auto-reclose	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Auto-reclose function. ANSI 79.		
Input Labels	Visible	Invisible or Visible
Sets the Input Labels menu visible further on in the relay settings menu.		
Output Labels	Visible	Invisible or Visible
Sets the Output Labels menu visible further on in the relay settings menu.		
CT & VT Ratios	Visible	Invisible or Visible
Sets the Current & Voltage Transformer Ratios menu visible further on in the relay settings menu.		
Record Control	Invisible	Invisible or Visible
Sets the Record Control menu visible further on in the relay settings menu.		
Disturb. Recorder	Invisible	Invisible or Visible
Sets the Disturbance Recorder menu visible further on in the relay settings menu.		
Measure't. Set-up	Invisible	Invisible or Visible
Sets the Measurement Setup menu visible further on in the relay settings menu.		
Comms. Settings	Visible	Invisible or Visible
Sets the Communications Settings menu visible further on in the relay settings menu. These are the settings associated with the 2nd rear communications ports.		
Commission Tests	Visible	Invisible or Visible
Sets the Commissioning Tests menu visible further on in the relay settings menu.		
Setting Values	Primary	Primary or Secondary
This affects all protection settings that are dependent upon CT and VT ratios. All subsequent settings input must be based in terms of this reference.		
Control Inputs	Visible	Invisible or Visible
Activates the Control Input status and operation menu further on in the relay setting menu.		
Ctrl I/P Config.	Visible	Invisible or Visible
Sets the Control Input Configuration menu visible further on in the relay setting menu.		
Ctrl I/P Labels	Visible	Invisible or Visible
Sets the Control Input Labels menu visible further on in the relay setting menu.		
Direct Access	Enabled	Enabled/Disabled/Hotkey only/CB Cntrl. only
Defines what CB control direct access is allowed. Enabled implies control via menu, hotkeys etc.		

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Menu Text	Default Setting	Available Settings
InterMiCOM^{64} Fiber	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) InterMiCOM64 (integrated 56/64kbit/s teleprotection). Note that Phase Diff setting and InterMiCOM64 Fiber setting are mutually exclusive as with Phase Diff enabled, the digital message exchanged has the structure of the differential message (i.e. currents are sent to the remote end, etc) and with InterMiCOM64 Fiber the digital message exchanged has the structure and properties of the InterMiCOM64 Fiber.		
Function Key	Visible	Invisible or Visible
Sets the Function Key menu visible further on in the relay setting menu.		
LCD Contrast	11	0…31
Sets the LCD contrast.		

1.1.1 Default settings restore

To restore the default values to the settings in any protection settings group, set the 'restore defaults' cell to the relevant group number. Alternatively it is possible to set the 'restore defaults' cell to 'all settings' to restore the default values to all of the relay's settings, not just the protection groups' settings. The default settings will initially be placed in the scratchpad and will only be used by the relay after they have been confirmed. Note that restoring defaults to all settings includes the rear communication port settings, which may result in communication via the rear port being disrupted if the new (default) settings do not match those of the master station.

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1.2 Protection communication configuration

The column "PROT COMMS/ IM64" is used to set up all the differential protection communications parameters required by differential protection and also the parameters required for teleprotection when Differential function is disabled and the relay is working as a Distance relay using InterMiCOM^{64} for teleprotection purposes.

Each setting below that refers to Channel 2 is visible only when 3 Terminal or Dual redundant teleprotection configuration is set.

InterMiCOM^{64} input and output mapping has to be done in the Programmable Scheme Logic (PSL).

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
PROT COMMS/IM64				
Scheme Setup	2 Terminal	2 Terminal, Dual Redundant, or 3 Terminal		
Settings to determine how many relay ends are connected in the differential zone or how many relays are connected to the teleprotection scheme for the protected line, with two or three ends possible. For a plain two terminal line, there is an additional option to use dual communication channels, to implement redundancy (i.e. employ a parallel “hot-standby” path).				
Address	0-0	0-0, 1-A…20-A, 1-B….20-B		
Setting for the unique relay address that is encoded in the Differential message and in the InterMiCOM^{64} sent message. The aim of setting the address is to establish pairs of relays which will only communicate with each other. Should an inadvertent fiber/MUX misrouting or spurious loopback occur, an error will be logged, and the erroneous received data will be rejected. As an example, in a 2 ended scheme the following address setting would be correct: Local relay: 1-A Remote relay: 1-B Address 0-0 is a universal address, whereby any relay will be free to communicate with any other (equivalent to disabling of the unique addressing). When PROT COMMS/IM64 is set to loop back mode, the address 0-0 will replace any existing address in the relay.				
Address	0-0	0-0, 1-A…20-A, 1-B….20-B, 1-C…20-C		
In 3 terminal schemes, communicating groups of three relays may be configured.				
Comm Mode	Standard	Standard or IEEE C37.94		
Setting that defines the data format that will be transmitted on the fiber outputs from the relay. If the Multiplexer accepts direct fiber inputs according to IEEE C37.94, the ‘IEEE C37.94’ setting is selected. For a direct fiber link between relays, and where the MUX connection is in electrical format (G.703 or V.35 or X.21), the ‘Standard’ message format needs to be set. For a setting change to take effect, rebooting of the relay will be required. The Comm Mode setting applies to both channels.				
Baud Rate Ch 1	64kbits/s	56kbits/s or 64kbits/s		
Channel 1 data rate setting for signaling between ends. The setting will depend on the MUX electrical interface, set 64kbit/s for G.703 and X.21, or generally 56kbit/s for V.35. For direct fiber connection between relays, 64kbit/s will offer slightly faster data transmission. The setting is invisible when IEEE C37.94 Comm Mode is selected.				
Baud Rate Ch 2	64kbits/s	56kbits/s or 64kbits/s		
As ‘Baud Rate Ch1’ cell.				
Clock Source Ch1	Internal	Internal or External		
Setting that defines which clock source is used to synchronize data transmissions over channel 1. The setting will depend on communications configuration and external clock source availability. If relays are connected direct fiber over channel 1, ‘Internal’ setting should be selected. If channel 1 is routed via a multiplexer, either setting may be required (see Application Notes).				
Clock Source Ch2	Internal	Internal or External		
Setting that matches the clock source being used for data synchronization over channel 2.				

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<table>
<tr><th rowspan="2">Menu Text</th><th rowspan="2">Default Setting</th><th colspan="2">Setting Range</th><th rowspan="2">Step Size</th></tr>
<tr><th>Min.</th><th>Max.</th></tr>
<tr><td>Ch1 N*64kbits/s</td><td>1</td><td colspan="3">Auto, 1, 2, 3, …..or 12</td></tr>
<tr><td colspan="5">Setting for channel 1 when connected to MUX. When set to ‘Auto’ P54x will configure itself to match the multiplexer.
The setting is visible only when IEEE C37.94 Comm Mode is selected.</td></tr>
<tr><td>Ch2 N*64kbits/s</td><td>1</td><td colspan="3">Auto, 1, 2, 3, …..or 12</td></tr>
<tr><td colspan="5">Setting for channel 2 when connected to Mux.
The setting is visible only when IEEE C37.94 Comm Mode is selected.</td></tr>
<tr><td>Comm Delay Tol</td><td>0.00025s</td><td>0.00025s</td><td>0.001s</td><td>0.00005s</td></tr>
<tr><td colspan="5">If successive calculated propagation times exceed this time delay setting, the relay will initiate a change in relay setting for a short time period (“Char Mod Time” setting) and will raise a Comm Delay Alarm.</td></tr>
<tr><td>Fail Timer</td><td>10s</td><td>0.1s</td><td>600s</td><td>0.1s</td></tr>
<tr><td colspan="5">Time delay after which the ‘Channel Fail Alarm’ will be issued providing that no messages were received during the ‘Channel Timeout’ period or the ‘Alarm Level’ is exceeded.</td></tr>
<tr><td>Comm Fail Mode</td><td>Ch 1 and 2 Fail</td><td colspan="3">Ch 1 Failure/ Ch 2 Failure/ Ch 1 or Ch 2 Fail/ Ch 1 and Ch 2 Fail</td></tr>
<tr><td colspan="5">Fail mode setting that triggers the ‘Channel Fail Alarm’, providing that the Dual Redundancy or 3 ended scheme is set.
Normally the alarm would be raised for any loss of an operational channel (logical “OR” combination). However, when relays in a 3 ended scheme are deliberately operated in Chain topology “AND” logic may be used, for indication when the scheme becomes finally inoperative, with no self-healing (signal rerouting) mode possible.</td></tr>
<tr><td>GPS Sync</td><td>Disabled</td><td colspan="3">Enabled or Disabled</td></tr>
<tr><td colspan="5">To enable (activate) or disable (turn off) the time alignment of current vectors via GPS.</td></tr>
<tr><td>Char Mod Time</td><td>0.5s</td><td>0</td><td>2s</td><td>0.0001s</td></tr>
<tr><td colspan="5">Time delay during which the setting characteristic k1 is increased to 200% after successive calculated propagation delay time exceed the time delay setting “Comm Delay Tol”</td></tr>
<tr><td>Prop Delay Equal</td><td>No Operation</td><td colspan="3">No operation or Restore CDiff</td></tr>
<tr><td colspan="5">If a P54x relay working with GPS sample synchronization loses GPS and there is a further switch in the protection communications network, the relay becomes Inhibit. If GPS become active again, the relay will automatically reset. But if not, the user can remove the inhibited condition by using this setting as long as it is ensured that propagation delay times are equal.
The setting is invisible when GPS Sync mode is enabled.</td></tr>
<tr><td>Re-Configuration</td><td>Three Ended</td><td colspan="3">Three Ended, Two Ended (R1&R2) , Two Ended (L&R2) or Two Ended (L&R1)</td></tr>
<tr><td colspan="5">This setting is to change the scheme from three ended scheme to two ended scheme or vice versa. An in deep explanation of relay performance for each case is given in section P54x/EN_OP
The setting is invisible when 3 Terminal Scheme Setup is selected.</td></tr>
</table>

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<table>
<tr><th rowspan="2">Menu Text</th><th rowspan="2">Default Setting</th><th colspan="2">Setting Range</th><th rowspan="2">Step Size</th></tr>
<tr><th>Min.</th><th>Max.</th></tr>
<tr><td>Channel Timeout</td><td>0.1s</td><td>0.1s</td><td>10s</td><td>0.1s</td></tr>
<tr><td colspan="5">A rolling time window beyond which any of the 8 IM signals that are set to ‘Default’ will be replaced by the corresponding ’IM_X Default Value’ setting, providing that no valid message is received on that channel in the meantime. The ‘Chnl Fail Alarm’ timer will be also initiated.

If only one channel is used, each out of 16 IM signals available that is set to ‘Default’ will convert to corresponding ‘IM_X Default Value’

If a Dual redundant or 3 ended scheme is selected, each out of 8 IM signals available that is set to ‘Default’ will convert to corresponding ‘IM_X Default Value’, but only for the affected channel.</td></tr>
<tr><td>IM Msg Alarm Lvl</td><td>25%</td><td>0%</td><td>100%</td><td>1%</td></tr>
<tr><td colspan="5">Setting that is used to alarm for poor channel quality. If during a fixed 100ms rolling window the number of invalid messages divided by the total number of messages that should be received (based upon the ‘Baud Rate’ setting) increase above the threshold, a ‘Channel Fail Alarm’ timer will be initiated.</td></tr>
<tr><td>IM1 Cmd Type</td><td>Permissive</td><td colspan="3">Direct or Permissive</td></tr>
<tr><td colspan="5">Setting that defines the operative mode of the received InterMiCOM_1 signal.

When ‘Direct’ tripping is chosen, for security reasons 2 consecutive valid messages have to be received before a change in the signal status will be acknowledged. That will impose an additional 1-2ms delay comparing to ‘Permissive’ mode.

Set ‘Direct’ in Direct Transfer Tripping (Intertripping) applications.

Set ‘Permissive’ to accommodate any Permissive or Blocking scheme.</td></tr>
<tr><td>IM1 FallBackMode</td><td>Default</td><td colspan="3">Default or Latching</td></tr>
<tr><td colspan="5">Setting that defines the status of IM1 signal in case of heavy noise and message synchronization being lost.

If set to ‘Latching’ the last valid IM1 status will be maintained until the new valid message is received.

If set to ‘Default’, the IM1 status, pre-defined by the user in ‘IM1 Default Value’ cell will be set. A new valid message will replace ‘IM1 Default Value’, once the channel recovers.</td></tr>
<tr><td>IM1 Default Value</td><td>0</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td colspan="5">Setting that defines the IM1 fallback status.</td></tr>
<tr><td>IM2 to IM8</td><td colspan="4">Cell as for IM1 above</td></tr>
<tr><td>IM9 to IM16</td><td colspan="4">Any mode for IMx (x = 1 to 8) automatically applies for IMx+8</td></tr>
</table>

1.3 Protection GROUP settings

The protection settings include all the following items that become active once enabled in the configuration column of the relay menu database:

- Protection element settings
- Programmable Scheme logic (PSL) that also includes InterMiCOM^{64} signals mapping
- Protection Schemes
- Auto-reclose and check synchronization settings
- Fault locator settings.

There are four groups of protection settings, with each group containing the same setting cells. One group of protection settings is selected as the active group, and is used by the protection elements. The settings for group 1 is shown. The settings are discussed in the same order in which they are displayed in the menu.

1.3.1 Line parameters

The column “GROUP x LINE PARAMETERS” is used to enter the characteristics of the protected line or cable. These settings are used by the fault locator as the base data for input to the distance to fault algorithm, and also as the reference for all distance zones when the Distance set up is preferred in the ‘Simple’ setting mode. It also accommodates the system phase rotation and defines the single or three pole tripping mode.

<table>
<tr><th rowspan="2">Menu Text</th><th rowspan="2">Default Setting</th><th colspan="2">Setting Range</th><th rowspan="2">Step Size</th></tr>
<tr><th>Min.</th><th>Max.</th></tr>
<tr><td>Line Length (km)</td><td>100</td><td>0.01</td><td>1,000</td><td>0.01</td></tr>
<tr><td colspan="5">Setting of the protected line/cable length in km. This setting is available if MEASURE’T SETUP column is selected as ‘Visible’ in the CONFIGURATION column and if ‘Distance unit’ in the MEASURE’T SETUP column is selected as ‘kilometers’.</td></tr>
<tr><td>Line Length (miles)</td><td>62.10</td><td>0.005</td><td>621</td><td>0.005/0.01</td></tr>
<tr><td colspan="5">Setting of the protected line/cable length in miles. This setting is available if MEASURE’T SETUP column is selected as ‘Visible’ in the CONFIGURATION column and if ‘Distance unit’ in the MEASURE’T SETUP column is selected as ‘miles’. Dual step size is provided, for cables/short lines up to 10 miles the step size is 0.005 miles, 0.01 miles otherwise.</td></tr>
<tr><td>Line Impedance</td><td>10/In Ω</td><td>0.05/In Ω</td><td>500Ω÷ (In x percentage reach setting of furthest reaching zone)</td><td>0.01/In Ω</td></tr>
<tr><td colspan="5">Setting for protected line/cable positive sequence impedance in either primary or secondary terms, depending on the “Setting Values” reference chosen in the CONFIGURATION column. The set value is used for Fault locator, and for all distance zone reaches calculation if ‘Simple’ setting mode under “GROUP x LINE PARAMETERS” is selected.</td></tr>
<tr><td>Line Angle</td><td>70°</td><td>20°</td><td>90°</td><td>1°</td></tr>
<tr><td colspan="5">Setting of the line angle (line positive sequence impedance angle).</td></tr>
<tr><td>kZN Residual Comp</td><td>1</td><td>0</td><td>10</td><td>0.01</td></tr>
<tr><td colspan="5">Setting of the residual compensation factor magnitude, used to extend the ground loop reach by a multiplication factor of (1+ kZN), is calculated as ratio:
$|kZN| = (Z_0 – Z_1)/3Z_1$ where,
Z_1 = positive sequence impedance for the protected line or cable.
Z_0 = zero sequence impedance for the protected line or cable.</td></tr>
<tr><td>kZN Residual Angle</td><td>0°</td><td>-180°</td><td>90°</td><td>1°</td></tr>
<tr><td colspan="5">Setting of the residual compensation factor angle (in degrees) is calculated as:
$\angle kZN = \angle (Z_0 – Z_1)/3Z_1$ where,
Z_1 = positive sequence impedance for the protected line or cable.
Z_0 = zero sequence impedance for the protected line or cable.</td></tr>
<tr><td>Mutual Comp</td><td>Disabled</td><td colspan="3">Enabled or Disabled</td></tr>
<tr><td colspan="5">To enable (activate) or disable (turn off) the Mutual compensation replica used in both, Distance and Fault locator ground fault loops.</td></tr>
</table>

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
kZm Mutual Set	1	0		10
Setting of the mutual compensation factor kZm magnitude is calculated as a ratio: $\lvert kZm \rvert = ZM_0/3Z_1$ where, ZM_0 = zero sequence mutual impedance for the protected line or cable. Z_1 = positive sequence impedance for the protected line or cable. Setting kZm is visible if ‘Mutual Comp’ is enabled.				
kZm Mutual Angle	0°	-180°	90°	1°
Setting of the mutual compensation angle (in degrees) is calculated as: $\angle kZm = \angle ZM_0/3Z_1$ Angle setting $\angle$kZm is visible if ‘Mutual Comp’ is enabled.				
Mutual Cut-off	0	2		0.01
Only in models with Distance option. Setting used to eliminate the mutual compensation replica in case when the ratio of neutral current of the parallel line to the neutral current of the protective line (I_{MUTUAL}/IN) exceeds the setting. This setting is visible only if ‘Mutual Comp’ is enabled.				
Phase Sequence	Standard ABC	Standard ABC, Reverse ACB		Phase Rotation
This setting is used to select whether the 3 phase quantities (V and I) are rotating in the standard ABC sequence, or whether the rotation is in reverse ACB order. The appropriate selection is required to ensure that all derived sequence components and faulted phase flagging/targeting are correct.				
Trip Mode	3 Pole	3 pole, 1 and 3 pole		Trip Mode
This setting is used to select the tripping mode. The selection “1 and 3 pole” allows single pole tripping for single phase to ground faults, whilst selection “3 pole” converts any trip command(s) to three pole tripping.				

1.3.2 Distance setup (only for models with distance option)

The column “GROUP x DISTANCE SETUP” is used to:

- Select the Distance setting mode (Simple or Advanced)
- Select the operating characteristic (Mho or Quad) for phase and ground measuring loops independently
- Enable or Disable each phase and ground zone independently
- Define the reach (in Ohms) for each phase and ground zone independently by simply setting the percentage required reach with reference to the line impedance (taken as the 100% reference basis)
- Other settings related to application of the “Basic” distance scheme

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Menu Text	Default Setting	Setting Range		Step Size
		Min.	**Max.**	
Setting Mode	Simple	Simple or Advanced		Setting Mode
Setting to select setting mode for Distance protection, depending on type of application and user preferences. **'Simple' mode:** 'Simple' setting mode is the default setting mode, suitable for the majority of applications. Instead of entering distance zone impedance reaches in ohms, zone settings are simply entered in terms of percentage of the protected line data specified in the 'GROUP x LINE PARAMETERS/Line Impedance' setting. The setting assumes that the residual compensation factor is equal for all zones. The relay auto calculates the required reaches from the percentages. The calculated zone reaches are available for viewing but a user can not alter/change the value as long as 'Simple' mode setting remains active. **Advanced setting mode:** 'Advanced' setting mode allows individual distance ohmic reaches and residual compensation factors to be entered for each zone. When 'Advanced' mode is selected, all 'percentage' settings that are associated to 'Simple' setting mode in the column "GROUP x DISTANCE SETUP" will be hidden and the Distance zone settings need to be entered for each zone in the 'GROUP x DIST. ELEMENTS' column.				
PHASE DISTANCE				
Phase chars.	Mho	Disabled or Mho or Quad		21P char.
Setting to disable (turn off) phase distance protection or to set Mho or Quad operating characteristic: ANSI 21P. The chosen setting is applicable to all phase distance zones.				
Quad Resistance	Proportional	Common or Proportional		
Setting to define the mode of resistive reach coverage. If 'Common' mode is selected, all phase distance zones will have the equal resistive coverage. If 'Proportional' mode is selected, the zones will have resistive coverage according to the % reach set for the zone, multiplied by the 'Fault Resistance' R_{PH} setting. This setting is visible only when 'Simple' setting mode and quad characteristic are set.				
Fault Resistance	10/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting used to specify the fault arc resistance that can be detected for faults between phases. The set value determines the right hand side of the quadrilaterals. This setting is visible only when 'Simple' setting mode and quad characteristic are set.				
Z1 Ph Status	Enabled	Enabled or Disabled or Enabled on CH Fail		
To enable (activate) or disable (turn off) or enable (only in the case that differential protection communication channel is lost) Z1 for phase faults. This setting is invisible if 'Phase Char.' is disabled.				
Z1 Phase Reach	80%	10%	1000%	10%
Setting entry as percentage of the line impedance that sets Zone 1 reach in ohms.				
Z2 Ph Status	Enabled	Enabled or Disabled or Enabled on CH Fail		
As per Z1, but applicable to Zone 2.				
Z2 Phase Reach	120%	10%	1000%	10%
Setting entry as percentage of the line impedance that sets Zone 2 reach in ohms.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Z3 Ph Status	Enabled	Enabled or Disabled or Enabled on CH Fail		
As per Z1, but applicable to Zone 3.				
Z3 Phase Reach	250%	10%	1000%	10%
Setting entry as percentage of the line impedance that sets Zone 3 forward reach in ohms.				
Z3 Ph Offset	Enabled	Enabled or Disabled or Enabled on CH Fail		
To enable (activate) or disable (turn off) or enable (only in the case that differential protection communication channel is lost) Zone 3 offset reach for phase faults. By default, Z3 Mho phase characteristic is offset (partly reverse directional), thus not memory/cross polarized. 'If Z3 Gnd Offset' is disabled, Z3 Mho characteristic becomes memory/cross polarized like all other zones.				
Z3 Rev Reach	10%	10%	1000%	1%
Setting entry as percentage of the line impedance that sets Zone 3 reverse reach in ohms.				
ZP Ph Status	Enabled	Enabled or Disabled or Enabled on CH Fail		
As per Z1, but applicable to Zone P.				
ZP Ph Dir.	Forward	Forward/ Reverse		
To directionalize Zone P forward or reverse.				
ZP Phase Reach	200%	10%	1000%	10%
Setting entry as percentage of the line impedance that sets Zone P forward or reverse reach in ohms.				
Z4 Ph Status	Enabled	Enabled or Disabled or Enabled on CH Fail		
As per Z1, but applicable to Zone 4.				
Z4 Phase Reach	150%	10%	1000%	10%
Setting entry as percentage of the line impedance that sets reverse Zone 4 reach in ohms.				
GROUND DISTANCE				
Ground Chars.	Mho	Disabled or Mho or Quad		21G char.
Setting to disable (turn off) ground distance protection or to set Mho or Quad operating characteristic: ANSI 21G. The chosen setting is applicable to all ground distance zones.				
Quad Resistance	Proportional	Common or Proportional		
Setting to define the mode of resistive reach coverage. If 'Common' mode is selected, all ground distance zones will have the equal resistive coverage. If 'Proportional' mode is selected, the zones will have resistive coverage according to the % reach set for the zone, multiplied by the 'Fault Resistance' R_G setting. This setting is visible only when 'Simple' setting mode and quad characteristic are set.				
Fault Resistance	10/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting used to specify the fault arc resistance that can be detected for faults phase - ground. The set value determines the right hand side of the quadrilaterals. This setting is visible only when 'Simple' setting mode and quad characteristic are set.				

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Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Z1 Gnd Status	Enabled	Enabled or Disabled or Enabled on CH Fail		
To enable (activate) or disable (turn off) or enable (only in the case that differential protection communication channel is lost) Zone 1 for ground faults. This setting is invisible if 'Ground Char.' is disabled.				
Z1 Ground Reach	80%	10%	1000%	10%
Setting entry as percentage of the line impedance that sets Zone 1 reach in ohms.				
Z2 Gnd Status	Enabled	Enabled or Disabled or Enabled on CH Fail		
As per Z1, but applicable to Zone 2.				
Z2 Ground Reach	120%	10%	1000%	10%
Setting entry as percentage of the line impedance that sets Zone 2 reach in ohms.				
Z3 Gnd Status	Enabled	Enabled or Disabled or Enabled on CH Fail		
As per Z1, but applicable to Zone 3.				
Z3 Ground Reach	250%	10%	1000%	10%
Setting entry as percentage of the line impedance that sets Zone 3 forward reach in ohms.				
Z3 Gnd Offset	Enabled	Enabled or Disabled or Enabled on CH Fail		
To enable (activate) or disable (turn off) or enable (only in the case that differential protection communication channel is lost) Zone 3 offset reach for ground faults. By default, Z3 Mho ground characteristic is offset (partly reverse directional), thus not memory/cross polarized. 'If Z3 Gnd Offset' is disabled, Z3 Mho characteristic becomes memory/cross polarized like all other zones.				
Z3 Rev Reach	10%	10%	1000%	1%
Setting entry as percentage of the line impedance that sets Zone 3 reverse reach in ohms.				
ZP Gnd Status	Enabled	Enabled or Disabled or Enabled on CH Fail		
As per Z1, but applicable to Zone P.				
ZP Gnd Dir.	Forward	Forward/ Reverse		
To directionalize ZP forward or reverse.				
ZP Ground Reach	200%	10%	1000%	10%
Setting entry as percentage of the line impedance that sets Zone P forward or reverse reach in ohms.				
Z4 Gnd Status	Enabled	Enabled or Disabled or Enabled on CH Fail		
As per Z1, but applicable to Zone 4.				
Z4 Ground Reach	150%	10%	1000%	10%
Setting entry as percentage of the line impedance that sets reverse Zone 4 reach in ohms.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Digital Filter	Standard	Standard or Special Application		
Setting to enable (activate) ‘Standard’ or ‘Special Application’ filters. ‘Standard’ filters are the default setting and should be applied in the majority of applications. It is only the case when the fault currents and voltages may become very distorted by non-fundamental harmonics that extra filtering is necessary to avoid transient over-reach. In such system conditions the ‘Special Applications’ setting should be applied.				
CVT Filters	Disabled	Disabled, Passive or Active		
Setting that accommodates the type of voltage transformer being used to prevent transient over-reach and preserve sub-cycle operating time whenever possible. In case of conventional wound VTs, the transients due to voltage collapse during faults are very small and no extra filtering is required, therefore the setting should be ‘Disabled’ as per default. For a CVT with active Ferro resonance damping, the voltage distortions may be severe and risk transient over-reach. For that reason, the ‘CVT Filters’ should be set to ‘Active’. Trip times increase proportionally (subcycle up to SIR = 2, gradually lengthening for SIR up to 30). For a CVT with passive Ferro resonance damping, the voltage distortions are generally small up to SIR of 30. For such applications, ‘CVT Filters’ should be set ‘Passive’. The relay calculates the SIR and will take marginally longer to trip if the infeed is weak (exceeds the relay’s SIR setting).				
SIR Setting	30	5	60	1
Setting that determines when extra filtering will be applied. If on fault inception the calculated SIR exceeds the ‘SIR Setting’ the relay will marginally slow down, as otherwise there would be a risk of over-reach. This setting is visible only when ‘CVT Filters’ is set to ‘Passive’.				
Load Blinder	Disabled	Disabled or Enabled		
Setting used to activate (enable) or turn off (disable) load blinders. Load blinders, when enabled, have two main purposes: to prevent tripping due to load encroachment under heavy load condition and detect very slow moving power swings.				
Z< Blinder Imp	15/In Ω	0.1/In Ω	500/In Ω	0.01/In Ω
Setting of radius of under-impedance circle.				
Load B/Angle	45°	15°	65°	1°
Angle setting for the two blinder lines boundary with the gradient of the rise or fall with respect to the resistive axis.				
Load Blinder V<	15V	1V	70V	0.5V
Load blinder phase to ground under-voltage setting that overrides the blinder if the measured voltage in the affected phase falls below setting. Also overrides blinding of phase-phase loops where the phase-phase voltage falls below √3 x (V< setting).				
Dist. Polarizing	1	0.2	5	0.1
The setting defines the composition of polarizing voltage as a mixture of ‘Self’ and ‘Memory’ polarizing voltage. ‘Self’ polarized voltage is fixed to 1pu and could be mixed with ‘Memory’ polarizing voltage ranging from 0.2pu up to 5pu. The default setting of 1 means that half of the polarizing voltage is made up from ‘Self’ and the other half from clean ‘Memory’ voltage. Adding more ‘Memory’ voltage will enhance the resistive coverage of Mho characteristics, whose expansion is defined as: Mho expansion = [(Dist. Polarizing)/ (Dist. Polarizing + 1)] x Zs Where Zs is the source impedance.				

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Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
DELTA DIRECTION				
Delta Status	Enabled	Disabled or Enabled		
Setting used to activate (enable) or turn off (disable) Delta Direction. To enable (activate) or disable (turn off) delta direction decision used by distance elements. If disabled, the relay uses conventional (non delta) directional line.				
Delta Char Angle	60°	0°	90°	1°
Setting for the relay characteristic angle used for the delta directional decision.				

1.3.3 Distance elements (only for models with distance option)

The column “GROUP x DISTANCE ELEMENTS” is used to individually set reaches, line angles, neutral compensation factors, minimum current operating levels and line tilting for resistive phase faults for each zone if the setting mode is set to ‘Advanced’. In ‘Simple’ setting mode, ‘Distance Elements’ setting can be **viewed**, but not edited here.

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Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
PHASE DISTANCE				
Z1 Ph. Reach	8/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z1 reach.				
Z1 Ph. Angle	70°	20°	90°	1°
Setting of line angle for zone 1.				
R1 Ph. Resistive	8/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z1 resistive reach. This setting is only visible if Quad is selected.				
Z1 Tilt Top Line	-3°	-30°	30°	1°
Setting of Z1 top reactance line gradient to avoid over-reach for resistive phase faults under heavy load. Minus angle tilts the reactance line downwards.				
Z1 Sensit. Iph>1	0.075 x In	0.05 x In	2 x In	0.01 x In
Current sensitivity setting for Z1 that must be exceeded in faulted phases if Z1 is to operate.				
Z2 Ph. Reach	15/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z2 reach.				
Z2 Ph. Angle	70°	20°	90°	1°
Setting of line angle for zone 2.				
R2 Ph. Resistive	15/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z2 resistive reach.				
Z2 Tilt Top Line	-3°	-30°	30°	1°
Setting of Z2 top reactance line gradient.				
Z2 Sensit. Iph>2	0.075 x In	0.05 x In	2 x In	0.01 x In
Zone 2 current sensitivity.				
Z3 Ph. Reach	25/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z3 reach.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Z3 Ph. Angle	70°	20°	90°	1°
Setting of line angle for zone 3.				
Z3' Ph. Rev Reach	1/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z3 offset (reverse) reach. This setting is only visible if 'Z3 Offset' is enabled in 'GROUP x DISTANCE SETUP'.				
R3 Ph. Res Fwd.	25/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z3 resistive reach that defines Quad's right hand line.				
R3 Ph. Res Rev.	1/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z3 resistive reach that defines Quad's left hand line. This is settable only if Phase Chars. is Quad and Z3 offset is enabled otherwise is fixed to 25% of the right hand blinder.				
Z3 Tilt Top Line	-3°	-30°	30°	1°
Setting of Z3 top reactance line gradient.				
Z3 Sensit. Iph>3	0.050 x In	0.05 x In	2 x In	0.01 x In
Zone 3 current sensitivity.				
ZP Ph. Reach	20/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for ZP reach.				
ZP Ph. Angle	70°	20°	90°	1°
Setting of line angle for zone P.				
RP Ph. Resistive	20/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for ZP resistive reach.				
ZP Tilt Top Line	-3°	-30°	30°	1°
Setting of ZP top reactance line gradient.				
ZP Sensit. Iph>P	0.05 x In	0.05 x In	2 x In	0.01 x In
Zone P current sensitivity.				
Z4 Ph. Reach	15/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z4 reach. This is a common setting for Z4 time delayed and Z4 high speed elements used in blocking schemes and for current reversal guard.				
Z4 Ph. Angle	70°	20°	90°	1°
Setting of line angle for zone 4.				
R4 Ph. Resistive	15/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for ZP resistive reach.				
Z4 Tilt Top Line	-3°	-30°	30°	1°
Setting of Z4 top reactance line gradient.				
Z4 Sensit. Iph>4	0.05 x In	0.05 x In	2 x In	0.01 x In
Zone P current sensitivity.				
GROUND DISTANCE				
Z1 Gnd. Reach	8/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z1 reach.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Z1 Gnd. Angle	70°	20°	90°	1°
Setting of line angle (positive sequence) for zone 1.				
kZN1 Res. Comp.	1	0	10	0.001
Setting of Z1 residual compensation magnitude.				
kZN1 Res. Angle	0	-180°	90°	1°
Setting of Z1 residual compensation angle.				
R1 Gnd. Resistive	8/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z1 ground resistive reach. This setting is only visible if Quad is selected.				
Z1 Sensit. Ignd>1	0.075 x In	0.05 x In	2 x In	0.01 x In
Current sensitivity setting for Z1 that must be exceeded in faulted phase **and** the neutral if Z1 is to operate.				
Z2 Gnd. Reach	15/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z2 reach.				
Z2 Gnd. Angle	70°	20°	90°	1°
Setting of line angle (positive sequence) for zone 2.				
kZN2 Res. Comp.	1	0	10	0.001
Setting of Z2 residual compensation magnitude.				
kZN2 Res. Angle	0	-180°	90°	1°
Setting of Z2 residual compensation angle.				
R2 Gnd. Resistive	15/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z2 ground resistive reach.				
Z2 Sensit. Ignd>2	0.075 x In	0.05 x In	2 x In	0.01 x In
Zone 2 current sensitivity.				
Z3 Gnd. Reach	25/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z3 reach.				
Z3 Gnd. Angle	70°	20°	90°	1°
Setting of line angle (positive sequence) for zone 3.				
Z3’ Gnd. Rev Rch	1/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z3 offset (reverse) reach. This setting is only visible if ‘Z3 Offset’ is enabled in ‘GROUP x DISTANCE SETUP’.				
kZN3 Res. Comp.	1	0	10	0.001
Setting of Z3 residual compensation magnitude.				
kZN3 Res. Angle	0	-180°	90°	1°
Setting of Z3 residual compensation angle.				
R3 Gnd. Res. Fwd	25/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z3 resistive reach that defines Quad’s right hand line.				
R3 Gnd. Res. Rev	1/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z3 resistive reach that defines Quad’s left hand line. This is settable only if Ground Chars. is Quad and Z3 offset is enabled otherwise is fixed to 25% of the right hand blinder.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Z3 Sensit. Ignd>3	0.05 x In	0.05 x In	2 x In	0.01 x In
Zone 3 current sensitivity.				
ZP Gnd. Reach	20/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for ZP reach.				
ZP Gnd. Angle	70°	20°	90°	1°
Setting of line angle (positive sequence) for zone P.				
kZNP Res. Comp.	1	0	10	0.001
Setting of ZP residual compensation magnitude.				
kZNP Res. Angle	0	-180°	90°	1°
Setting of ZP residual compensation angle.				
RP Gnd. Resistive	20/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for ZP ground resistive reach.				
ZP Sensit. Ignd>P	0.05 x In	0.05 x In	2 x In	0.01 x In
Zone P current sensitivity.				
Z4 Gnd. Reach	15/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z4 reach. This is a common setting for Z4 time delayed and Z4 high speed elements used in blocking schemes and for current reversal guard.				
Z4 Gnd. Angle	70°	20°	90°	1°
Setting of line angle (positive sequence) for zone 4.				
kZN4 Res. Comp.	1	0	10	0.001
Setting of Z4 residual compensation magnitude.				
kZN4 Res. Angle	0	-180°	90°	1°
Setting of Z4 residual compensation angle.				
R4 Gnd. Resistive	15/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z4 ground resistive reach.				
Z4 Sensit. Ignd>4	0.05 x In	0.05 x In	2 x In	0.01 x In
Zone 4 current sensitivity.				

1.3.4 Phase differential

The column “GROUP x PHASE DIFF” is used to:

- Select the settings of the phase differential characteristic
- Define CT correction factors
- Define type of compensation (Capacitive Charging current or phase shift compensation). If charging current is selected, to set the value of susceptance and if phase shift is chosen, to set the value of vector compensation (P543 and P545 models only)
- Enable or Disable inrush restrain in the case of transformers in zone (P543 and P545 models only)
- Set the amount of positive sequence current required for Differential current transformer supervision

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The column “GROUP x PHASE DIFF” is invisible if disabled in ‘CONFIGURATION’ column.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Phase Diff	Enabled	Enabled or Disabled		
To enable (activate) or disable (turn off) the Differential protection function in the group.				
Phase Is1	0.2In	0.2In	2In	0.05In
Setting that defines the minimum pick-up level of the relay.				
Phase Is2	2In	1In	30In	0.05In
This setting defines the bias current threshold, above which the higher percentage bias k2 is used.				
Phase k1	30%	30%	150%	5%
The lower percentage bias setting used when the bias current is below Is2. This provides stability for small CT mismatches, whilst ensuring good sensitivity to resistive faults under heavy load conditions.				
Phase k2	150% (2 end or dual redundant) 100% (3 end)	30%	150%	5%
The higher percentage bias setting used to improve relay stability under heavy through fault current conditions.				
Phase Char	DT	DT, IEC S Inverse, IEC V Inverse, IEC E inverse, UK LT Inverse IEEE M Inverse, IEEE V Inverse, IEEE E Inverse, US Inverse, US ST Inverse		
Setting for the tripping characteristic for differential protection element.				
Phase Time Delay	0s	0s	100s	0.01s
Setting for the time-delay for the definite time setting if selected. The setting is visible only when DT function is selected.				
Phase TMS	1	0.025	1.2	0.025
Setting for the time multiplier setting to adjust the operating time of the IEC IDMT characteristic.				
Phase Time Dial	0.01	0.01	100	0.01
Setting for the time multiplier setting to adjust the operating time of the IEEE/US IDMT curves. The Time Dial (TD) is a multiplier on the standard curve equation, in order to achieve the required tripping time. The reference curve is based on TD = 1. **Care:** Certain manufacturer's use a mid-range value of TD = 5 or 7, so it may be necessary to divide by 5 or 7 to achieve parity.				
PIT Time	0.2s	0s	0.2s	0.005s
This timer is initiated upon receipt of PIT flag in the message. Once this timer elapses, and as long as the current is above of Is1 setting, the relay closes its three phase differential trip contacts.				
Ph CT Corr'tion	1	1	8	0.01
Setting used to compensate CT ratios mismatch between terminals.				

<table>
<tr><th rowspan="2">Menu Text</th><th rowspan="2">Default Setting</th><th colspan="2">Setting Range</th><th rowspan="2">Step Size</th></tr>
<tr><th>Min.</th><th>Max.</th></tr>
<tr><td>Compensation</td><td>None</td><td colspan="3">None, Cap Charging, Vector group</td></tr>
<tr><td colspan="5">Setting to define type of compensation.
If set to “None”, “Susceptance” “Inrush Restraint”, “Id High Set” and ”Vectorial Comp” are invisible.
If set to “Cap Charging”, “Susceptance” setting becomes visible and “Inrush Restraint”, “Id High Set” and ”Vectorial Comp” are invisible.
If set to “Vector group”, “Inrush Restraint”, “Id High Set” and ”Vectorial Comp” settings become visible while “Susceptance” setting is invisible.
“Inrush Restraint”, “Id High Set” and ”Vectorial Comp” are only applicable in relay models P543 and P545.</td></tr>
<tr><td>Susceptance</td><td>1E-8*In</td><td>1E-8*In</td><td>10*In</td><td>1E-8*In</td></tr>
<tr><td colspan="5">Visible when” Compensation” is set to “Cap Charging”. Setting to define the positive sequence susceptance value of the circuit for capacitive charging current compensation</td></tr>
<tr><td>Inrush Restraint</td><td>Disabled</td><td colspan="3">Enabled or Disabled</td></tr>
<tr><td colspan="5">Only models P543 and P545 when” Compensation” is set to “Vector group”. To enable (activate) or disable (turn off) the additional bias inrush restrain. When set to enable “Id High Set” becomes visible.
Note: It must be ensure that this function is enabling at each end to avoid maloperation.</td></tr>
<tr><td>Id High Set</td><td>4*In</td><td>4*In</td><td>32*In</td><td>0.01*In</td></tr>
<tr><td colspan="5">Only in models P543 and P545 when “Inrush Restraint” is enable. Pick-up setting for high set differential protection</td></tr>
<tr><td>Vectorial Comp</td><td>Yy0 (0 deg)</td><td colspan="3">Yy0 (0 deg), Yd1 (-30 deg), Yy2 (-60 deg), Yd3 (-90 deg), Yy4 (-120 deg), Yd5 (-150 deg), Yy6 (180 deg), Yd7 (+150 deg), Yy8 (+120 deg), Yd9 (+90 deg), Yy10 (+60 deg), Yd11 (+30 deg), Ydy0 (0 deg), Ydy6 (180 deg)</td></tr>
<tr><td colspan="5">Only in models P543 and P545 when” Vectorial Comp” is enable. To define the vector compensation to account for phase shift correction and zero sequence current filtering (for transformer applications)</td></tr>
<tr><td>Phase Is1 CTS</td><td>1.2*In</td><td>0.2*In</td><td>4*In</td><td>0.05*In</td></tr>
<tr><td colspan="5">Setting that defines the minimum pick-up level of the relay when a current transformer supervision CTS is declared</td></tr>
</table>

1.3.5 Scheme logic (basic and aided scheme logic). Only in models with distance option

The column “GROUP x SCHEME LOGIC” is used to:

- Set operating mode and associated timers for each distance zone when distance operates in the Basic scheme
- Select aided schemes via one or two available signaling channels
- Define operating zones during Trip On Close (TOC)

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Menu Text	**Default Setting**	**Setting Range**		**Step Size**
		Min.	**Max.**	
BASIC SCHEME				
Zone 1 Tripping	Phase and Ground	Disabled, Phase only, Ground only, or Phase and Ground		
Setting to select for which types of fault Zone 1 elements will be applied.				
tZ1 Ph. Delay	0s	0s	10s	0.01s
Time delay for Z1 phase element.				
tZ1 Gnd. Delay	0s	0s	10s	0.01s
Time delay for Z1 ground element.				
Zone 2 Tripping	Phase and Ground	Disabled, Phase only, Ground only, or Phase and Ground		
Setting to select for which types of fault Zone 2 elements will be applied.				
tZ2 Ph. Delay	0.2s	0s	10s	0.01s
Time delay for Z2 phase element.				
tZ2 Gnd. Delay	0.2s	0s	10s	0.01s
Time delay for Z2 ground element.				
Zone 3 Tripping	Phase and Ground	Disabled, Phase only, Ground only, or Phase and Ground		
Setting to select for which types of fault Zone 3 elements will be applied.				
tZ3 Ph. Delay	0.6s	0s	10s	0.01s
Time delay for Z3 phase element.				
tZ2 Gnd. Delay	0.6s	0s	10s	0.01s
Time delay for Z3 ground element.				
Zone P Tripping	Phase and Ground	Disabled, Phase only, Ground only, or Phase and Ground		
Setting to select for which types of fault Zone P elements will be applied.				
tZP Ph. Delay	0.4s	0s	10s	0.01s
Time delay for ZP phase element.				
tZP Gnd. Delay	0.4s	0s	10s	0.01s
Time delay for ZP ground element.				
Zone 4 Tripping	Phase and Ground	Disabled, Phase only, Ground only, or Phase and Ground		
Setting to select for which types of fault Zone 4 elements will be applied.				
tZ4 Ph. Delay	1s	0s	10s	0.01s
Time delay for Z4 phase element.				
tZ4 Gnd. Delay	1s	0s	10s	0.01s
Time delay for Z4 ground element.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
AIDED SCHEME 1				
Aid. 1 Selection	Disabled	Disabled, PUR, PUR Unblocking, POR, POR Unblocking, Blocking 1, Blocking 2, Prog. Unblocking or Programmable		
Selection of the generic scheme type for aided channel 1. Note: POR is equivalent to POTT (permissive overreach transfer trip), PUR is equivalent to PUTT (permissive underreach transfer trip).				
Aid 1 Distance	Phase and Ground	Disabled, Phase Only, Ground Only, or Phase and Ground		
Setting to select whether distance elements should key the scheme selected as per the previous setting. If set to Disabled, no distance zones interact with this aided scheme, and basic scheme tripping only applies.				
Aid. 1 Dist. Dly	0s	0s	1s	0.002s
Trip time delay for Aided 1 Distance schemes.				
Unblocking Delay	0.05s	0s	0.1s	0.002s
Time delay after Loss of Guard until unblocking occurs. After the set delay, the relay will respond as though an aided signal has been received from the remote end. This setting is visible only when PUR Unblocking, POR Unblocking or Programmable Unblocking schemes are chosen.				
Aid. 1 DEF	Enabled	Disabled or Enabled		
Setting to select whether a DEF scheme should be mapped to Aided scheme 1. (Not applicable where a Permissive Underreaching scheme selection has been made).				
Aid. 1 DEF Dly	0s	0s	1s	0.002s
Time delay for Aided 1 DEF tripping.				
Aid. 1 DEF Trip	3 Pole	1 or 3 Pole		
Setting that defines the tripping mode for Aided 1 DEF. This setting is visible only if tripping mode under GROUP x LINE PARAMETERS/Trip Mode is set to 1 and 3 pole.				
tREV. Guard	0.02s	0s	0.15s	0.002s
Setting for the current reversal guard timer. Intended to keep stability on a healthy line, whilst breakers open on a faulted parallel line to clear the fault. This setting is visible only when over-reaching or Blocking schemes are selected.				
Send on Trip	Aided/Z1	Aided/Z1, Any Trip or None		
Setting that defines the reinforced trip signal for POR Aided 1 scheme. If selected to: "None": No reinforced signal is issued "Aided/Z1": The reinforced signal is issued with aided trip or with Z1 if aided distance scheme is enabled "Any Trip": Signal is reinforced with Any trip (DDB 522)				
Weak Infeed	Disabled	Disabled, Echo, or Echo and Trip		
Setting that defines Aided 1 scheme operation in case of weak infeed conditions, where no protection elements detect the fault at the local end, but an aided channel has been received from the remote end. Setting “Echo” will allow the received signal to be returned to the remote relay, “Trip” will allow local end tripping after a set delay.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
WI Sngl Pole Trp	Disabled	Disabled or Enabled		
Setting that defines the Weak Infeed tripping mode. When disabled, any WI trip will be converted to a 3 phase trip.				
WI V< Thresh.	45V	10V	70V	5V
Setting of Weak Infeed level detector. If phase - ground voltage in any phase drops below the threshold and with insufficient phase current for the protection to operate, the end is declared as a weak infeed terminal.				
WI Trip Delay	0.06s	0s	1s	0.002s
Setting for the weak infeed trip time delay.				
Custom Send Mask	0000000001	Bit 0 = Z1 Gnd, Bit 1 = Z2 Gnd, Bit 2 = Z4 Gnd, Bit 3 = Z1 Ph, Bit 4 = Z2 Ph, Bit 5 = Z4 Ph, Bit 6 = DEF Fwd, Bit 7 = DEF Rev, Bit		
Logic Settings that determine the element or group of elements that are sending a permissive signal to the other line end. For the signal to be sent, the element must operate and a corresponding bit in the matrix must be set to “1” (High). The above mapping is part of a custom made Aided 1 scheme, and unlike all other schemes that are factory tested, the customer must take the responsibility for testing and the operation of the scheme. This setting is visible only if a Programmable or Prog. Unblocking scheme is selected.				
Custom Time PU	0s	0s	1s	0.002s
Pick up time delay of DDB signal ‘Aid1 CustomT in’, available in the PSL logic. Once the time delay elapses, the DDB signal ‘Aid1 CustomT out’ will become high.				
Custom Time DO	0s	0s	1s	0.002s
Drop off time delay of DDB signal ‘Aid1 CustomT in’. Once the time delay elapses, the DDB signal ‘Aid1 CustomT out’ will become low. Note that the timer is a combined hard coded PU/DO timer for Custom Aided scheme 1.				
AIDED SCHEME 2				
All the settings are similar to AIDED SCHEME 1 above. Elements are mapped to the second scheme when they are wished to run independent of Aided Scheme 1.				
Trip On Close				
SOTF Status	Enabled Pole Dead	Disabled, Enabled Pole Dead, Enabled ExtPulse, En Pdead + Pulse		
Setting that enables [note] (turns on) or disables (turns off) a special protection logic which can apply upon line energization. SOTF = Switch on to Fault. Note: SOTF can be enabled in three different manners: 1. Enabled Pole Dead. By using pole dead logic detection logic 2. Enabled ExtPulse. By using an external pulse 3. En Pdead + Pulse. By using both				
SOTF Delay	110s	0.2s	1000s	0.2s
The SOTF Delay is a pick up time delay that starts after opening all 3 poles of a CB. If the CB is then closed after the set time delay has expired, SOTF protection will be active. SOTF provides enhanced protection for manual closure of the breaker (not for auto-reclosure). This setting is visible only if Pole Dead or Pdead + Pulse are selected to enable SOTF.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
SOTF Tripping	00001	Bit 0 = Zone 1, Bit 1 = Zone 2, Bit 2 = Zone 3, Bit 3 = Zone P, Bit 4 = Zone 4		
Logic Settings that determine the Distance zones that are allowed to operate instantaneously upon line energization. If, for example, Bit 1 is set to "1" (High), Z2 will operate without waiting for the usual tZ2 time delay should a fault lie within Z2 upon CB closure. SOTF tripping is 3 phase and auto-reclose will be blocked.				
TOR Status	Enabled	Disabled or Enabled		
Setting that enables (turns on) or disables (turns off) special protection following auto-reclosure. When set Enabled, TOR will be activated 200ms after CB opening, ready for application when an auto-reclose shot occurs. TOR = Trip on (auto)Reclose.				
TOR Tripping	00001	Bit 0 = Zone 1, Bit 1 = Zone 2, Bit 2 = Zone 3, Bit 3 = Zone P, Bit 4 = Zone 4		
Logic Settings that determine the Distance zones that are allowed to operate instantaneously upon line energization. If, for example, Bit 1 is set to "1" (High), Z2 will operate without waiting for the usual tZ2 time delay should a fault lie within Z2 upon CB closure. TOR tripping is 3 phase and auto-reclose will be blocked.				
TOC Reset Delay	0.5s	0.1s	2s	0.1s
The TOC Reset Delay is a user settable time window during which TOC protection is available. The time window starts timing upon CB closure and it is common for SOTF and TOR protection. Once this timer expires after a successful (re)closure, all protection reverts to normal.				
SOTF Pulse	0.5s	0.1s	10s	0.01s
The SOTF Pulse is a user settable time window during which the SOTF protection is available. This setting is visible only if ExtPulse or Pdead + Pulse are selected to enable SOTF				
Z1 Extension				
Z1 Ext Scheme	Disabled	Disabled, Enabled, En. on Ch1 Fail, En. On Ch2 Fail, En All Ch Fail, or En. Any Ch Fail		
Setting that enables (turns on) or disables (turns off) the Zone 1 Extension scheme. When Enabled, extended Zone 1 will apply unless the Reset Zone 1 Extension DDB signal is energized. Otherwise, it is possible to enable Z1X when aided scheme channel(s) fail.				
Z1 Ext Ph	150%	100%	200%	1%
Extended Z1X phase reach as a percentage of the Z1 phase reach. (Phase resistive reach for Z1X is the same as for Zone 1.)				
Z1 Ext Gnd	150%	100%	200%	1%
Extended Z1X ground reach as a percentage of Z1 ground reach. (Ground resistive reach and residual compensation for Z1X is the same as for Zone 1.)				
Loss of Load				
LOL Scheme	Disabled	Disabled, Enabled, En. on Ch1 Fail, En. On Ch2 Fail, En All Ch Fail, or En. Any Ch Fail		
Setting that enables (turns on) or disables (turns off) the Loss of Load scheme. When Enabled, accelerated tripping can apply as the remote end opens (3-pole trip applications only). Otherwise, it is possible to enable Z1X when aided scheme channel(s) fail.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
LOL <I	0.5 x In	0.05 x In	1 x In	0.05 x In
LOL undercurrent detector that indicates a loss of load condition on the unfaulted phases, indicating that the remote end has just opened.				
LOL Window	0.04s	0.01s	0.1s	0.01s
Length of LOL window - the time window in which Zone 2 accelerated tripping can occur following LOL undercurrent detector operation.				

1.3.6 Power swing blocking

The column “GROUP x POWER SWING Blk.” is used to set either blocking or indication for out of step conditions. If blocking mode is selected, a user can individually select for each zone to be either blocked or allow tripping.

The power swing detection is based on superimposed current, and is essentially “settings free”.

ST

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
PSB Status	Blocking	Blocking or Indication		
To enable (activate) Indication or Blocking mode. This setting is invisible if disabled in ‘CONFIGURATION’ column. If Indication status is selected, the alarm will be issued but tripping by distance protection will be unaffected. When Blocking status is selected, the user is presented with further options as to which zones do/do not require blocking.				
Zone 1 Ph. PSB	Blocking	Blocking, Delayed Unblocking, or Allow trip		
Setting that defines the Z1 phase element operation should any swing impedance enter and remains inside the Z1 phase characteristic for more then ‘tZ1 Ph. Delay’. If Blocking is selected, the Z1 phase element operation will be disabled for the duration of the swing. If Unblocking is chosen, the Z1 phase element block will be removed after drop off timer ‘PSB Unblocking Dly’ has expired, even if the swing is still present. This allows system separation when swings fail to stabilize. In ‘Allow trip’ mode, the Z1 phase element is unaffected by PSB detection.				
Zone x Ph. PSB	Blocking	Blocking, Delayed Unblocking, or Allow trip		
Individual Zone setting options all as per Zone 1 Ph. (x = 2, 3, 4, P).				
Zone 1 Gnd. PSB	Blocking	Blocking, Delayed Unblocking, or Allow trip		
Setting that defines the Z1 ground element operation should any swing impedance enter and remains inside the Z1 ground characteristic for more then ‘tZ1 Gnd. Delay’. If Blocking is selected, the Z1 ground element operation will be disabled for the duration of the swing. If Unblocking is chosen, the Z1 ground element block will be removed after drop off timer ‘PSB Unblocking Dly’ has expired, even if the swing is still present. This allows system separation when swings fail to stabilize. In ‘Allow trip’ mode, the Z1 ground element is unaffected by PSB detection.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Zone x Gnd. PSB	Blocking	Blocking, Delayed Unblocking, or Allow trip		
Individual Zone setting options all as per Zone 1 Gnd. (x = 2, 3, 4, P).				
PSB Unblocking	Disabled	Disabled or Enabled		
To enable (activate) or disable (turn off) the PSB Unblocking delay timer. This setting is common to all zones and it is visible if any distance zone is set to 'PSB Unblocking Dly'. For swing durations longer than this setting, blocking can be selectively removed.				
PSB Unblock dly	2s	0.1s	10s	0.1s
Unblock timer setting - on expiry, power swing blocking can optionally be removed.				
PSB Reset Delay	0.2s	0.05s	2s	0.05s
Setting to maintain the power swing detection for a period after the delta current detection has reset. ΔI will naturally reset momentarily twice in each swing cycle, and a short setting ensures continued PSB pick-up, to ride through the gaps.				
OST Mode	Disabled	Disabled, Predictive & OST Trip, OST Trip, Predictive OST Trip		
To enable (activate) or disable (turn off) Out of Step protection. This setting (and all related settings below) is invisible if PowerSwing Block is disabled in 'CONFIGURATION' column. If 'OST Trip' is selected, relay will operate after Tost time delay if the measured positive sequence impedance has passed the Z6-Z5 region slower than 25ms (@ 50 or 60Hz) and if the polarity of the resistive component has changed between entering and exiting zone 5. If 'Predictive OST Trip' is selected, relay will operate after Tost time delay if the positive sequence impedance has passed the Z6-Z5 region faster than 25ms but slower than 'Delta t' set time. If 'Predictive & OST Trip' is selected, it will operate if any of two above criteria is satisfied.				
Z5	30/In Ω	0.1/In Ω	500/In Ω	0.01/In Ω
Setting for Z5 forward reactance reach.				
Z6	32/In Ω	0.1/In Ω	500/In Ω	0.01/In Ω
Setting for Z6 forward reactance reach.				
Z5'	-30/In Ω	-0.1/In Ω	-500/In Ω	0.01/In Ω
Setting for Z5 reverse reactance reach.				
Z6'	-32/In Ω	-0.1/In Ω	-500/In Ω	0.01/In Ω
Setting for Z6 reverse reactance reach.				
R5	20/In Ω	0.1/In Ω	200/In Ω	0.01/In Ω
Setting for Z5 positive resistive reach.				
R6	22/In Ω	0.1/In Ω	200/In Ω	0.01/In Ω
Setting for Z6 positive resistive reach.				
R5'	-20/In Ω	-0.1/In Ω	-200/In Ω	0.01/In Ω
Setting for Z5 negative resistive reach.				
R6'	-22/In Ω	-0.1/In Ω	-200/In Ω	0.01/In Ω
Setting for Z6 negative resistive reach.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Blinder Angle	80°	20°	90°	1°
Setting of blinder angle, common for both Z5 and Z6.				
Delta t	0.03s	0.03s	1s	0.001s
Time setting that is compared with the measured time between positive sequence impedance entering Z6 and entering Z5.				
Tost	0s	0s	1s	0.01s
Tripping time delay common for any OST setting option.				

1.3.7 Phase overcurrrent protection

The overcurrent protection included in the MiCOM P54x provides four stage non-directional/ directional phase segregated overcurrent protection with independent time delay characteristics. All overcurrent and directional settings apply to each phase but are independent for each of the four stages. To arrange a single pole tripping by overcurrent protection, the default PSL needs to be modified.

ST

The first two stages of overcurrent protection have time-delayed characteristics which are selectable between inverse definite minimum time (IDMT), or definite time (DT). The third and fourth stages have definite time characteristics only.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
I>1 Status	Enabled	Disabled, Enabled, Enabled VTS, Enabled Ch Fail, En VTSorCh Fail, En VTSandCh Fail		
Setting that defines first stage overcurrent operating status. Depending of this setting, I>1 will be enabled permanently or in case of Voltage Transformer Supervision (fuse fail) operation, or in case of communication channel fail, or a combination (and /or) of both.				
I>1 Function	IEC S Inverse	DT, IEC S Inverse, IEC V Inverse, IEC E inverse, UK LT Inverse IEEE M Inverse, IEEE V Inverse, IEEE E Inverse, US Inverse, US ST Inverse		
Setting for the tripping characteristic for the first stage overcurrent element.				
I>1 Directional	Non-directional	Non-directional Directional Fwd Directional Rev		
This setting determines the direction of measurement for first stage element.				
I>1 Current Set	1 x In	0.08 x In	4.0 x In	0.01 x In
Pick-up setting for first stage overcurrent element.				
I>1 Time Delay	1s	0s	100s	0.01s
Setting for the time-delay for the definite time setting if selected for first stage element. The setting is visible only when DT function is selected.				
I>1 TMS	1	0.025	1.2	0.025
Setting for the time multiplier setting to adjust the operating time of the IEC IDMT characteristic.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
I>1 Time Dial	1	0.01	100	0.01
Setting for the time multiplier setting to adjust the operating time of the IEEE/US IDMT curves. The Time Dial (TD) is a multiplier on the standard curve equation, in order to achieve the required tripping time. The reference curve is based on TD = 1. **Care:** Certain manufacturer's use a mid-range value of TD = 5 or 7, so it may be necessary to divide by 5 or 7 to achieve parity.				
I>1 Reset Char.	DT	DT or Inverse		N/A
Setting to determine the type of reset/release characteristic of the IEEE/US curves.				
I>1 tRESET	0s	0s	100s	0.01s
Setting that determines the reset/release time for definite time reset characteristic.				
I>2 Cells as for I>1 above				
Setting the same as for the first stage overcurrent element.				
I>3 Status	Disabled	Disabled, Enabled, Enabled VTS, Enabled Ch Fail, En VTSorCh Fail, En VTSandCh Fail		
Setting that defines first stage overcurrent operating status. Depending of this setting, I>3 will be enabled permanently or in case of Voltage Transformer Supervision (fuse fail) operation, or in case of communication channel fail, or a combination (and /or) of both.				
I>3 Directional	Non-directional	Non-directional Directional Fwd Directional Rev		N/A
This setting determines the direction of measurement for the overcurrent element.				
I>3 Current Set	10 x In	0.08 x In	32 x In	0.01 x In
Pick-up setting for third stage overcurrent element.				
I>3 Time Delay	0s	0s	100s	0.01s
Setting for the operating time-delay for third stage overcurrent element.				
I>4 Cells as for I>3 Above				
Settings the same as the third stage overcurrrent element.				
I> Char. Angle	30°	–95°	+95°	1°
Setting for the relay characteristic angle used for the directional decision. The setting is visible only when ‘Directional Fwd’ or ‘Directional Rev’ is set.				
I> Blocking	00001111	Bit 0 = VTS Blocks I>1, Bit 1 = VTS Blocks I>2, Bit 2 = VTS Blocks I>3, Bit 3 = VTS Blocks I>4, Bits 5 to 7 are not used.		
Logic Settings that determine whether blocking signals from VT supervision affect certain overcurrent stages. VTS Block – only affects directional overcurrent protection. With the relevant bit set to 1, operation of the Voltage Transformer Supervision (VTS), will block the stage. When set to 0, the stage will revert to Non-directional upon operation of the VTS. If I> Status is set ‘Enabled VTS’, no blocking should be selected in order to provide fault clearance by overcurrent protection during the VTS condition.				

1.3.8 Negative sequence overcurrent

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
I2> Status	Disabled	Disabled or Enabled		N/A
Setting to enable or disable the negative sequence definite time element.				
I2> Direction	Non-directional	Non-directional Directional Fwd Directional Rev		N/A
This setting determines the direction of measurement for this element.				
I2> VTS	Block	Block or Non-Directional		
Setting that determines whether VT supervision blocks negative sequence overcurrent protection, or whether it reverts non-directional on VTS detection.				
I2> Current Set	0.2 x In	0.08 x In	4 x In	0.01 x In
Pick-up setting for the negative sequence overcurrent element.				
I2> Time Delay	10	0s	100s	0.01s
Setting for the operating time-delay for the negative sequence overcurrent element.				
I2> Char. Angle	–60°	–95°	+95°	1°
Setting for the relay characteristic angle used for the directional decision. The setting is visible only when ‘Directional Fwd’ or ‘Directional Rev’ is set.				
I2> V2pol Set	5V	0.5V	25V	0.5V
Setting determines the minimum negative sequence voltage threshold that must be present to determine directionality. The setting is visible only when ‘Directional Fwd’ or ‘Directional Rev’ is set.				

1.3.9 Broken conductor

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Broken Conductor	Disabled	Enabled/Disabled		N/A
Enables or disables the broken conductor function.				
I2/I1	0.2	0.2	1	0.01
Setting to determine the pick- up level of the negative to positive sequence current ratio.				
I2/I1 Time Delay	60s	0s	100s	1s
Setting for the function operating time delay.				

1.3.10 Earth fault

The back-up earth fault overcurrent protection included in the MiCOM P54x provides four stage non-directional/directional three-phase overcurrent protection with independent time delay characteristics. All earth fault overcurrent and directional settings apply to all three phases but are independent for each of the four stages.
The first two stages of earth fault overcurrent protection have time-delayed characteristics which are selectable between inverse definite minimum time (IDMT), or definite time (DT). The third and fourth stages have definite time characteristics only.

ST

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
IN>1 Status	Enabled	Disabled, Enabled, Enabled VTS, Enabled Ch Fail, En VTSorCh Fail, En VTSandCh Fail		
Setting that defines first stage overcurrent operating status. Depending of this setting, IN>1 will be enabled permanently or in case of Voltage Transformer Supervision (fuse fail) operation, or in case of communication channel fail, or a combination (and /or) of both.				
IN>1 Function	IEC S Inverse	DT, IEC S Inverse, IEC V Inverse, IEC E inverse, UK LT Inverse IEEE M Inverse, IEEE V Inverse, IEEE E Inverse, US Inverse, US ST Inverse		
Setting for the tripping characteristic for the first stage earth fault overcurrent element.				
IN>1 Directional	Non-directional	Non-directional Directional Fwd Directional Rev		
This setting determines the direction of measurement for first stage element.				
IN>1 Current Set	0.2 x In	0.08 x In	4.0 x In	0.01 x In
Pick-up setting for first stage overcurrent element.				
IN>1 Time Delay	1	0	100	0.01
Setting for the time-delay for the definite time setting if selected for first stage element. The setting is available only when DT function is selected.				
IN>1 TMS	1	0.025	1.2	0.025
Setting for the time multiplier setting to adjust the operating time of the IEC IDMT characteristic.				
IN>1 Time Dial	1	0.01	100	0.01
Setting for the time multiplier setting to adjust the operating time of the IEEE/US IDMT curves. The Time Dial (TD) is a multiplier on the standard curve equation, in order to achieve the required tripping time. The reference curve is based on TD = 1. **Care:** Certain manufacturer's use a mid-range value of TD = 5 or 7, so it may be necessary to divide by 5 or 7 to achieve parity.				
IN>1 Reset Char.	DT	DT or Inverse		N/A
Setting to determine the type of reset/release characteristic of the IEEE/US curves.				
IN>1 tRESET	0s	0s	100s	0.01s
Setting that determines the reset/release time for definite time reset characteristic.				
IN>2 Cells as for IN>1 above				
Setting the same as for the first stage earth fault overcurrent element.				
IN>3 Status	Enabled	Disabled, Enabled, Enabled VTS, Enabled Ch Fail, En VTSorCh Fail, En VTSandCh Fail		
Setting that defines first stage overcurrent operating status. Depending of this setting, IN>3 will be enabled permanently or in case of Voltage Transformer Supervision (fuse fail) operation, or in case of communication channel fail, or a combination (and /or) of both.				

ST

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
IN>3 Directional	Non-directional	Non-directional Directional Fwd Directional Rev		N/A
This setting determines the direction of measurement for the earth fault overcurrent element.				
IN>3 Current Set	10 x In	0.08 x In	32 x In	0.01 x In
Pick-up setting for third stage earth fault overcurrent element.				
IN>3 Time Delay	0s	0s	100s	0.01s
Setting for the operating time-delay for third stage earth fault overcurrent element.				
IN>4 Cells as for IN>3 Above				
Settings the same as the third stage earth fault overcurrrent element.				
IN> Blocking	00001111	Bit 0 = VTS Blocks I>1, Bit 1 = VTS Blocks I>2, Bit 2 = VTS Blocks I>3, Bit 3 = VTS Blocks I>4, Bits 5 & 6 are not used.		
Logic Settings that determine whether blocking signals from VT supervision affect certain earth fault overcurrent stages. VTS Block - only affects directional earth fault overcurrent protection. With the relevant bit set to 1, operation of the Voltage Transformer Supervision (VTS), will block the stage. When set to 0, the stage will revert to Non-directional upon operation of the VTS. If IN> Status is set 'Enabled VTS', no blocking should be selected in order to provide earth fault clearance by earth fault overcurrent protection during VTS condition.				
IN> DIRECTIONAL				
IN> Char. Angle	-60°	–95°	+95°	1°
Setting for the relay characteristic angle used for the directional decision. The setting is visible only when 'Directional Fwd' or 'Directional Rev' is set.				
IN>Pol	Zero Sequence	Zero Sequence or Neg. Sequence		N/A
Setting that determines whether the directional function uses zero sequence or negative sequence voltage polarizing.				
IN>VNpol Set	1V	0.5V	80V	0.5V
Setting for the minimum zero sequence voltage polarizing quantity for directional decision. Setting is visible only when 'Zero Sequence' polarization is set.				
IN>V2pol Set	1V	0.5V	25V	0.5V
Setting for the minimum negative sequence voltage polarizing quantity for directional decision. Setting is visible only when 'Negative Sequence' polarization is set.				
IN>I2pol Set	0.08 x In	0.08 x In	1 x In	0.01x In
Setting for the minimum negative sequence current polarizing quantity for directional decision. Setting is visible only when 'Negative Sequence' polarization is set.				

1.3.11 Aided DEF

The column "GROUP x AIDED DEF" is used to set all parameters for operation of DEF (Directional Earth Fault aided scheme thresholds). As this configuration merely assigns pick up at the local end only, they need to be further configured to a selected Aided channel scheme under "GROUP x SCHEME LOGIC" to provide unit protection.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
DEF SCHEME				
DEF Status	Enabled	Enabled or Disabled		
To enable (activate) or disable (turn off) the Directional Earth Fault element that is used in an aided scheme (= ground overcurrent pilot scheme). This setting is invisible if disabled in 'CONFIGURATION' column.				
DEF Polarizing	Zero Sequence	Neg. Sequence or Zero Sequence		
Setting that defines the method of DEF polarization. Either zero, or negative sequence voltage can be taken as the directional reference. When Zero Sequence is selected, this arms the *"Virtual Current Polarizing".*				
DEF Char Angle	-60°	-95°	95°	1°
Setting for the relay characteristic angle used for the directional decision.				
DEF VNpol Set	1V	0.5V	40V	0.5V
Setting that must be exceeded by generated neutral displacement voltage VN (= 3.Vo) in order for the DEF function to be operational. As Virtual Current Polarizing will be in force when Zero sequence polarizing is used, this setting will normally have no relevance. If the relay phase selector (delta sensitivity typically 4% In) detects the faulted phase, this will artificially generate a large VNpol, typically equal to Vn (phase-ground). Only if the phase selector cannot phase select will this setting be relevant, as VNpol will then measure true VN. The setting is invisible if 'Neg. Sequence' polarization is set.				
DEF V2pol Set	1V	0.5V	25V	0.5V
Setting that must be exceeded by generated negative sequence voltage V2 in order for the DEF function to be operational. The setting is invisible if 'Zero Sequence' polarization is set.				
DEF Threshold	0.08 x In	0.08 x In	1 x In	0.01 x In
Setting the forward pickup current sensitivity for residual current (= 3.Io). The reverse detector automatically adopts half of this value.				

1.3.12 Sensitive earth fault

If a system is earthed through a high impedance, or is subject to high ground fault resistance, the earth fault level will be severely limited. Consequently, the applied earth fault protection requires both an appropriate characteristic and a suitably sensitive setting range in order to be effective. A separate four-stage sensitive earth fault element is provided within the P54x relay for this purpose, which has a dedicated input.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Sens E/F Options	SEF	SEF Enabled, Wattmetric SEF		
Setting to select the type of sensitive earth fault protection function and the type of high-impedance function to be used.				
ISEF>1 Function	DT	Disabled, DT, IEC S Inverse, IEC V Inverse, IEC E inverse, UK LT Inverse IEEE M Inverse, IEEE V Inverse, IEEE E Inverse, US Inverse, US ST Inverse		
Setting for the tripping characteristic for the first stage sensitive earth fault element.				

ST

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
ISEF>1 Direction	Non-directional	Non-directional Direction Fwd Direction Rev		N/A
This setting determines the direction of measurement for the first stage sensitive earth fault element.				
ISEF>1 Current	0.05 x In_{SEF}	0.005 x In_{SEF}	0.1x In_{SEF}	0.00025 x In_{SEF}
Pick-up setting for the first stage sensitive earth fault element.				
ISEF>1 Delay	1	0	200s	0.01s
Setting for the time delay for the first stage definite time element.				
ISEF>1 TMS	1	0.025	1.2	0.025
Setting for the time multiplier to adjust the operating time of the IEC IDMT characteristic.				
ISEF>1 Time Dial	1	0.1	100	0.1
Setting for the time multiplier to adjust the operating time of the IEEE/US IDMT curves.				
ISEF>1 Reset Char.	DT	DT or Inverse		N/A
Setting to determine the type of reset/release characteristic of the IEEE/US curves.				
ISEF>1 tRESET	0	0s	100s	0.01s
Setting to determine the reset/release time for definite time reset characteristic.				
ISEF>2 Cells as for ISEF>1 Above				
ISEF>3 Status	Disabled	Disabled or Enabled		N/A
Setting to enable or disable the third stage definite time sensitive earth fault element.				
ISEF>3 Direction	Non-directional	Non-directional Directional Fwd Directional Rev		N/A
This setting determines the direction of measurement for the third stage element.				
ISEF>3 Current	0.2 x In_{SEF}	0.005 x In_{SEF}	2.0 x In_{SEF}	0.001 x In_{SEF}
Pick-up setting for the third stage sensitive earth fault element.				
ISEF>3 Delay	1	0s	200s	0.01s
Setting for the operating time delay for third stage sensitive earth fault element.				
ISEF>4 Cells as for ISEF>3 Above				
ISEF> Func. Link	001111	Bit 0 = Bit 3=VTS Blks ISEF>4, Bit 4= A/R Blks ISEF>3, Bit 5=A/R Blks ISEF>4, Bit 6=Not Used, Bit 7=Not Used		
Settings that determine whether VT supervision and auto-reclose logic signals blocks selected sensitive earth fault stages.				
ISEF DIRECTIONAL				
ISEF> Char. Angle	90°	–95°	+95°	1°
Setting for the relay characteristic angle used for the directional decision.				

ST

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
ISEF>VNpol Set	5	0.5V	88V	0.5V
Setting for the minimum zero sequence voltage polarizing quantity required for directional decision.				
WATTMETRIC SEF	Sub-heading in menu			
PN> Setting	$9In_{SEF}$ W	0	$20In_{SEF}$ W	$0.05In_{SEF}$ W
Setting for the threshold for the wattmetric component of zero sequence power. The power calculation is as follows: The PN> setting corresponds to: Vres x Ires x Cos ($\phi - \phi c$) = 9 x Vo x Io x Cos ($\phi - \phi c$) Where; ϕ = Angle between the Polarizing Voltage (-Vres) and the Residual Current ϕc = Relay Characteristic Angle (RCA) Setting (ISEF> Char Angle) Vres = Residual Voltage Ires = Residual Current Vo = Zero Sequence Voltage Io = Zero Sequence Current				

1.3.13 Residual overvoltage (neutral voltage displacement)

The NVD element within the MiCOM P54x is of two-stage design, each stage having separate voltage and time delay settings. Stage 1 may be set to operate on either an IDMT or DT characteristic, whilst stage 2 may be set to DT only.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
VN>1 Function	DT	Disabled or DT or IDMT		N/A
Setting for the tripping characteristic of the first stage residual overvoltage element.				
VN>1 Voltage Set	5V	1V	80V	1V
Pick-up setting for the first stage residual overvoltage characteristic.				
VN>1 Time Delay	5s	0s	100s	0.01s
Operating time delay setting for the first stage definite time residual overvoltage element.				
VN>1 TMS	1	0.5	100	0.5
Setting for the time multiplier setting to adjust the operating time of the IDMT characteristic. The characteristic is defined as follows: t = K / (M – 1) Where: K = Time multiplier setting t = Operating time in seconds M = Derived residual voltage/relay setting voltage (VN> Voltage Set)				
VN>1 tReset	0s	0s	100s	0.01s
Setting to determine the reset/release definite time for the first stage characteristic				
VN>2 Status	Disabled	Disabled or Enabled		N/A
Setting to enable or disable the second stage definite time residual overvoltage element.				

ST

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
VN>2 Voltage Set	10V	1V	80V	1V
Pick-up setting for the second stage residual overvoltage element.				
VN>2 Time Delay	10s	0s	100s	0.01s
Operating time delay for the second stage residual overvoltage element.				

1.3.14 Thermal overload

The thermal overload function within the MiCOM P54x is capable of being selected as a single time constant or dual time constant characteristic, dependent on the type of plant to be protected.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Characteristic	Single	Disabled, Single or Dual		
Setting for the operating characteristic of the thermal overload element.				
Thermal Trip	1 x In	0.08 x In	4 x In	0.01 x In
Sets the maximum full load current allowed and the pick-up threshold of the thermal characteristic.				
Thermal Alarm	70%	50%	100%	1%
Setting for the thermal state threshold corresponding to a percentage of the trip threshold at which an alarm will be generated.				
Time Constant 1	10 minutes	1 minute	200 minutes	1 minute
Setting for the thermal time constant for a single time constant characteristic or the first time constant for the dual time constant characteristic.				
Time Constant 2	5 minutes	1 minute	200 minutes	1 minute
Setting for the second thermal time constant for the dual time constant characteristic.				

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1.3.15 Voltage protection

Under and overvoltage protection included within the MiCOM P54x consists of two independent stages. These are configurable as either phase to phase or phase to neutral measuring by means of the "V<Measur't mode" cell.

Stage 1 may be selected as IDMT, DT or Disabled, within the "V<1 function" cell. Stage 2 is DT only and is enabled/disabled in the "V<2 status" cell.

Two stages are included to provide both alarm and trip stages, where required.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
UNDERVOLTAGE				
V< Measur't. Mode	Phase-Phase	Phase to Phase Phase to Neutral		N/A
Sets the measured input voltage that will be used for the undervoltage elements.				
V< Operate Mode	Any Phase	Any Phase Three Phase		N/A
Setting that determines whether any phase or all three phases has to satisfy the undervoltage criteria before a decision is made.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
V<1 Function	DT	Disabled DT IDMT		N/A
Tripping characteristic for the first stage undervoltage function. The IDMT characteristic available on the first stage is defined by the following formula: $t = K / (1 - M)$ Where: K = Time multiplier setting t = Operating time in seconds M = Measured voltage/relay setting voltage (V< Voltage Set)				
V<1 Voltage Set	80V	10V	120V	1V
Sets the pick-up setting for first stage undervoltage element.				
V<1 Time Delay	10s	0s	100s	0.01s
Setting for the operating time-delay for the first stage definite time undervoltage element.				
V<1 TMS	1	0.5	100	0.5
Setting for the time multiplier setting to adjust the operating time of the IDMT characteristic.				
V<1 Poledead Inh	Enabled	Enabled or Disabled		N/A
If the cell is enabled, the relevant stage will become inhibited by the pole dead logic. This logic produces an output when it detects either an open circuit breaker via auxiliary contacts feeding the relay opto inputs or it detects a combination of both undercurrent and undervoltage on any one phase. It allows the undervoltage protection to reset when the circuit breaker opens to cater for line or bus side VT applications.				
V<2 Status	Disabled	Enabled or Disabled		N/A
Setting to enable or disable the second stage undervoltage element.				
V<2 Voltage Set	60V	10V	120V	1V
This setting determines the pick-up setting for second stage undervoltage element.				
V<2 Time Delay	5s	0s	100s	0.01s
Setting for the operating time-delay for the second stage definite time undervoltage element.				
V<2 Poledead Inh	Enabled	Enabled Disabled		N/A
Similar function to V<1 Poledead Inhibit.				
OVERVOLTAGE				
V> Measur't. Mode	Phase-Phase	Phase to Phase Phase to Neutral		N/A
Sets the measured input voltage that will be used for the overvoltage elements.				
V> Operate Mode	Any Phase	Any Phase Three Phase		N/A
Setting that determines whether any phase or all three phases has to satisfy the overvoltage criteria before a decision is made.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
V>1 Function	DT	Disabled, DT or IDMT		N/A
Tripping characteristic setting for the first stage overvoltage element. The IDMT characteristic available on the first stage is defined by the following formula: t = K/(M - 1) Where: K = Time multiplier setting t = Operating time in seconds M = Measured voltage/relay setting voltage (V<>Voltage Set)				
V>1 Voltage Set	130V	60V	185V	1V
Sets the pick-up setting for first stage overvoltage element.				
V>1 Time Delay	10s	0s	100s	0.01s
Setting for the operating time-delay for the first stage definite time overvoltage element.				
V>1 TMS	1	0.5	100	0.5
Setting for the time multiplier setting to adjust the operating time of the IDMT characteristic.				
V>2 Status	Disabled	Enabled or Disabled		N/A
Setting to enable or disable the second stage overvoltage element.				
V>2 Voltage Set	150V	60V	185V	1V
This setting determines the pick-up setting for the second stage overvoltage element.				
V>2 Time Delay	0.5s	0s	100s	0.01s
Setting for the operating time-delay for the second stage definite time overvoltage element.				

1.3.16 Circuit breaker fail and undercurrent function

This function consists of a two-stage circuit breaker fail function that can be initiated by:

- Current based protection elements
- Voltage based protection elements
- External protection elements.

For current-based protection, the reset condition is based on undercurrent operation to determine that the CB has opened. For the non-current based protection, the reset criteria may be selected by means of a setting for determining a CB Failure condition.

It is common practice to use low set undercurrent elements in protection relays to indicate that circuit breaker poles have interrupted the fault or load current, as required.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
BREAKER FAIL				
CB Fail 1 Status	Enabled	Enabled or Disabled		
Setting to enable or disable the first stage of the circuit breaker function.				
CB Fail 1 Timer	0.2s	0s	10s	0.01s
Setting for the circuit breaker fail timer stage 1, during which breaker opening must be detected. There are timers per phase to cope with evolving faults, but the timer setting is common.				
CB Fail 2 Status	Disabled	Enabled or Disabled		
Setting to enable or disable the second stage of the circuit breaker function.				
CB Fail 2 Timer	0.4s	0s	10s	0.01s
Setting for the circuit breaker fail timer stage 2, during which breaker opening must be detected.				
Volt Prot. Reset	CB Open & I<	I< Only, CB Open & I<, Prot. Reset & I<		
Setting which determines the elements that will reset the circuit breaker fail time for voltage protection function initiated circuit breaker fail conditions.				
Ext. Prot. Reset	CB Open & I<	I< Only, CB Open & I<, Prot. Reset & I<		
Setting which determines the elements that will reset the circuit breaker fail time for external protection function initiated circuit breaker fail conditions.				
WI Prot. Reset	Disabled	Disabled or Enabled		
When Enabled, CB Fail timers will be reset by drop off of a weak infeed trip condition, providing that WI trip logic is activated.				
UNDERCURRENT				
I< Current Set	0.1x In	0.02 x In	3.2 x In	0.01 x In
Setting that determines the circuit breaker fail timer reset current for overcurrent based protection circuit breaker fail initiation. This setting is also used in the pole dead logic to determine the status of the pole (dead or live).				
ISEF< Current	0.02x In_{SEF}	0.001x In_{SEF}	0.8x In_{SEF}	0.00005 x In
Setting that determines the circuit breaker fail timer reset current for Sensitive earth fault (SEF) protection circuit breaker fail initiation.				

1.3.17 Supervision (VTS, CTS, Inrush detection and special weak infeed blocking)

The VTS feature within the relay operates on detection of negative phase sequence (nps) voltage without the presence of negative phase sequence current.

The CT supervision feature operates on detection of derived zero sequence current, in the absence of corresponding derived zero sequence voltage that would normally accompany it.

The Special Weak Infeed Blocking is not normally applied, and is described in detail later in this service manual.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
VT SUPERVISION				
VTS Mode	Measured + MCB	Measured + MCB, Measured Only or MCB Only		
Setting that determines the method to be used to declare VT failure.				
VTS Status	Blocking	Blocking, Indication		
This setting determines whether the following operations will occur upon detection of VTS. - VTS set to provide alarm indication only. - Optional blocking of voltage dependent protection elements. - Optional conversion of directional overcurrent elements to non-directional protection (available when set to blocking mode only). These settings are found in the function links cell of the relevant protection element columns in the menu.				
VTS Reset Mode	Manual	Manual, Auto		
The VTS block will be latched after a user settable time delay 'VTS Time Delay'. Once the signal has latched then two methods of resetting are available. The first is manually via the front panel interface (or remote communications) and secondly, when in 'Auto' mode, provided the VTS condition has been removed and the 3 phase voltages have been restored above the phase level detector settings for more than 240ms.				
VTS Time Delay	5s	1s	10s	0.1s
Setting that determines the operating time-delay of the element upon detection of a voltage supervision condition.				
VTS I> Inhibit	10 x In	0.08 x In	32 x In	0.01 x In
The setting is used to override a voltage supervision block in the event of a phase fault occurring on the system that could trigger the voltage supervision logic.				
VTS I2> Inhibit	0.05 x In	0.05 x In	0.5 x In	0.01 x In
The setting is used to override a voltage supervision block in the event of a fault occurring on the system with negative sequence current above this setting which could trigger the voltage supervision logic.				
CT SUPERVISION (CTS)				
CTS Status	Disabled	Disabled, Standard, I Diff		N/A
Setting to disable, enable the standard (voltage dependant) CTS or enable the I diff (non voltage dependant, communication dependant) CTS				
STANDARD CTS				
CTS VN< Inhibit	5V	0.5V	22V	0.5V
This setting is used to inhibit the current transformer supervision element should the zero sequence voltage exceed this setting.				
CTS IN> Set	0.1 x In	0.08 x In	4 x In	0.01 x In
This setting determines the level of zero sequence current that must be present for a valid current transformer supervision condition.				
CTS Time Delay	5s	0s	10s	1s
Setting that determines the operating time-delay of the element upon detection of a current transformer supervision condition.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
INRUSH DETECTION				
I> 2nd Harmonic	20%	10%	100%	5%
If the level of second harmonic in any phase current or neutral current exceeds the setting, inrush conditions will be recognized by changing the status of four DDB signals from low to high in the Programmable Scheme Logic (PSL). The user then has a choice to use them further in the PSL in accordance with the application.				
WEAK INFEED BLK				
WI Inhibit	Disabled	Disabled or Enabled		
This setting enables (turns on) or disables (turns off) a special feature to cover scenarios when there is a very weak positive or negative sequence source behind the relay, but the zero sequence infeed is large. Special to stub-end transformer feeding, where the stub end has no generation, but has solid earthing at a Yd transformer neutral.				
I0/I2 Setting	3	2	3	0.1
If the ratio of zero sequence current to negative sequence current exceeds the setting, all protection elements such as Distance, DEF and Delta that could potentially operate during a genuine weak infeed condition will be inhibited. This setting will be visible only if ‘WI Inhibit’ is enabled.				
I Diff CTS				
CTS Status (Diff)	Restrain	Restrain, Indication		
This setting determines whether the following operations will occur upon detection of CTS. - CTS set to provide alarm indication only. - CTS set to restrain the differential protection				
CTS Reset Mode	Manual	Manual or Auto		
The CTS block will be latched after a user settable time delay ‘CTS Time Delay’. Once the signal has latched then two methods of resetting are available. The first is manually via the front panel interface (or remote communications) and secondly, when in ‘Auto’ mode, provided the CTS condition has been removed.				
CTS i1>	0.1*In	0.05*In	4.0*In	0.01*In
Setting that determines if the circuit is loaded. If the positive sequence current calculated by the relay exceed this value, the relay declares load condition at relay end.				
CTS i2/i1>	0.05	0.05	1	0.01
Setting above which an asymmetrical fault condition or a CT problem is declared.				
CTS i2/i1>>	0.4	0.05	1	0.01
Setting above which a CT failure is declared providing that CTS i2/i1> threshold at any other CT set connected to the differential zone relay has not been exceed.				
CTS Time Delay	5	0	10	0.01
Time delay after which the ‘CTS Alarm’ or ‘Remote CTS Alarm’ will be issued providing that CT failure is declared				

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1.3.18 System checks (check sync. function)

The MiCOM P54x has a two stage Check Synchronization function that can be set independently.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
VOLTAGE MONITORING				
Live Voltage	32V	1V	132V	0.5V
Sets the minimum voltage threshold above which a line or bus is to be recognized as being 'Live'.				
Dead Voltage	13V	1V	132V	0.5V
Sets the voltage threshold below which a line or bus to be recognized as being 'Dead'.				
CHECK SYNC.				
Stage 1	Enabled	Enabled or Disabled		
Setting to enable or disable the first stage check sync. element.				
CS1 Phase Angle	20°	0°	90°	1°
Sets the maximum phase angle difference between the line and bus voltage for the first stage check sync. element phase angle criteria to be satisfied.				
CS1 Slip Control	Frequency	Frequency/Both/Timer/None		
Setting that determines whether slip control is by slip frequency only, frequency + timer or timer only criteria to satisfy the first stage check sync. conditions. If slip control by timer or frequency + timer is selected, the combination of phase angle and timer settings determines an effective maximum slip frequency, calculated as: $\frac{2 \times A}{T \times 360}$ Hz. for Check Sync. 1, or Where: A = Phase angle setting (°) T = Slip timer setting (seconds)				
CS1 Slip Freq.	50mHz	10mHz	1Hz	10mHz
Sets the maximum frequency difference between the line and bus voltage for the first stage check sync. element slip frequency to be satisfied.				
CS1 Slip Timer	1s	0s	99s	0.01s
Minimum operating time-delay setting for the first stage check sync. element.				
CS2 Status	Enabled	Enabled or Disabled		
Setting to enable or disable the second stage check sync. element.				
CS2 Phase Angle	20°	0°	90°	1°
Sets the maximum phase angle difference between the line and bus voltage for the second stage check sync. element phase angle criteria to be satisfied.				

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Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
CS2 Slip Control	Frequency	Frequency/Both/Timer/None		
Setting that determines whether slip control is by slip frequency only, frequency + timer or timer only criteria to satisfy the CS1 conditions. If Slip Control by Timer or Frequency + Timer is selected, the combination of Phase Angle and Timer settings determines an effective maximum slip frequency, calculated as: $\frac{A}{T \times 360}$ Hz. for Check Sync. 2, or Where: A = Phase angle setting (°) T = Slip timer setting (seconds) Unlike Check Sync. 1, Check Sync. 2 only permits closure for decreasing angles of slip, therefore the circuit breaker should always close within the limits defined by Check Sync. 2.				
CS2 Slip Freq.	50mHz	10mHz	1Hz	10mHz
Slip frequency setting for the second stage check sync. element.				
CS2 Slip Timer	1s	0s	99s	0.01s
Setting for the second stage Check Sync. slip timer.				
CS Undervoltage	54V	10V	132V	0.5V
Sets an undervoltage threshold above which the line and bus voltage must be to satisfy the Check Sync. condition if selected in the 'CS Voltage Block' cell.				
CS Overvoltage	130V	60V	185V	0.5V
Sets an overvoltage threshold above below which the line and bus voltage must be to satisfy the Check Sync. condition if selected in the 'CS Voltage Block' cell.				
CS Diff. Voltage	6.5V	1V	132V	0.5V
Sets the voltage magnitude threshold between the line and bus volts below that the line and bus voltage difference must be to satisfy the Check Sync. condition if selected in the 'CS Voltage Block' cell.				
CS Voltage Block	V<	V</V>/Vdiff.>/V< and V>/V< and Vdiff>/ V> and Vdiff>/V< V> and Vdiff>/None		
Selects whether an undervoltage, overvoltage and voltage difference thresholds for the line and bus voltages must be satisfied in order for the Check Sync. conditions to be satisfied.				
SYSTEM SPLIT				
SS Status	Enabled	Enabled or Disabled		
Setting to enable or disable the system split function - to detect a line and bus which are not possible to synchronize.				
SS Phase Angle	120°	90°	175°	1°
Sets the maximum phase angle difference between the line and bus voltage, which must be exceeded, for the System Split condition to be satisfied.				
SS Under V Block	Enabled	Enabled or Disabled		
Activates and undervoltage block criteria				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
SS Undervoltage	54V	10V	132V	0.5V
Sets an undervoltage threshold above which the line and bus voltage must be to satisfy the System Split condition.				
SS Timer	1s	0s	99s	0.01s
The System Split output remains set for as long as the System Split criteria are true, or for a minimum period equal to the System Split Timer setting, whichever is longer.				

1.3.19 Auto-reclose function

The MiCOM P54x will initiate auto-reclose for fault clearances by any instantaneous trip allocated in the PSL to DDB Trip Inputs A,B or C (DDB 530,531 or 532 respectively). The default PSL includes differential trip, Zone 1 trip and aided trips. In addition, other distance zones, Aided DEF, Directional comparison, phase and earth overcurrent protection and Trip On Reclose (TOR) may be set to initiate auto-reclose, when required. This is done in the settings (shown here after). Protection such as voltage, frequency, thermal etc. will block auto-reclose.

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The following shows the relay settings for the auto-reclose function, which must be set in conjunction with the Circuit Breaker Control settings under main Menu. The available setting ranges and factory defaults are shown:

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Single Pole Shot	1	1	4	1
Sets the number of auto-reclose shots/cycles applicable for single phase faults. **Care:** This setting also applies when auto-reclose is configured in 3 pole tripping applications**.** Even though the trip mode may be 3 pole only, the fact that the *initiation* was a single phase fault type is memorized. In single pole tripping applications, for a setting of “N” shots, the full cycle will allow one single pole trip and reclosure, plus (N-1) subsequent three phase shots. When the number of recurrent single pole faults exceeds the setting, the AR will lockout.				
3 Pole Shot	1	1	4	1
Sets the number of auto-reclose shots/cycles applicable for a multiphase fault. Where the phase selector has identified more than one faulted phase, or has been unable to phase select only a single phase, the applicable sequence is “3 Pole”. When the number of 3ph trips exceeds the setting, the AR will lock out.				
1 Pole Dead Time	0.5s	0.05s	5s	0.01s
Sets the dead time (CB open interval) for a single pole auto-reclose cycle, first shot.				
Dead Time 1	0.3s	0.05s	30s	0.01s
Sets the dead time for the first auto-reclose cycle, except where a single pole trip has occurred.				
Dead Time 2	60s	1s	1800s	1s
Sets the dead time for the second auto-reclose cycle.				
Dead Time 3	60s	1s	3600s	1s
Sets the dead time for the third auto-reclose cycle.				
Dead Time 4	60s	1s	3600s	1s
Sets the dead time for the fourth auto-reclose cycle.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
CB Healthy Time	5s	1s	3600s	1s
If on completion of the dead time, the "CB Healthy" input is low, and remains low for a period given by the "CB Healthy Time" timer, lockout will result and the circuit breaker will remain open.				
Reclaim Time	180s	1s	600s	1s
Sets the auto-reclose reclaim timer – the time after which the sequence counter will reset to zero.				
AR Inhibit Time	5s	0.01s	600s	0.01s
With this setting, auto-reclose initiation is inhibited for a period equal to setting "A/R Inhibit Time" following a manual circuit breaker closure.				
Check Sync Time	5s	0.01s	9999s	0.01s
Time window during which set System Check conditions must be satisfied for a successful reclose. If not, AR will lockout after time has elapsed.				
Z2T AR	Block AR	No action, Block AR or Initiate AR		
Setting that determines impact of time delayed zone 2 on AR operation. Set "Initiate AR" if the trip should initiate a cycle, and "Block AR" if a time delayed trip should cause lockout. Set "No action" if Zone 2 tripping should exert no specific logic control on the re-closer.				
Z3T AR	Block AR	No action, Block AR or Initiate AR		
Similar application to Z3T AR. Selection for Zone 3 trips.				
ZPT AR	Block AR	No action, Block AR or Initiate AR		
Similar application to ZPT AR. Selection for Zone 3 trips.				
Z4T AR	Block AR	No action, Block AR or Initiate AR		
Similar application to Z4T AR. Selection for Zone 4 trips.				
DEF Aided AR	Block AR	Block AR or Initiate AR		
Setting that determines impact of aided Directional Earth Fault protection (DEF) on AR operation.				
TOR AR	Block AR	Block AR or Initiate AR		
Setting that determines impact of Trip On Reclose (TOR) on AR operation.				
I>1 AR	No Action	No action, Block AR or Initiate AR		
Setting that determines impact of the first stage overcurrent protection on AR operation.				
I>2 to I>4 Cells as for I>1 Above				
IN>1 AR	No Action	No action, Block AR or Initiate AR		
Setting that determines impact of the first stage earth fault overcurrent protection on AR operation.				
IN>2 to IN>4 Cells as for IN>1 Above				

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Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Mult Phase AR	BAR 3 Phase	BAR 3 Phase/BAR 2 and 3 Phase/Allow AR		
Setting that determines impact of any multiphase fault on AR operation. If, for example, ‘BAR 2 and 3 Phase’ is selected, the AR will be blocked for any multiphase fault. If ‘BAR 3 Phase’ is selected, the AR will be blocked only for faults affecting all three phases together (A-B-C). The ‘Allow AR’ selection is used where all faulted phase combinations may be permitted to initiate an auto-reclose sequence.				
Dead Time Start	Protection Operation	Protection Operation or Protection Reset		N/A
Setting that determines whether the dead time is started when the protection operates or when the protection trip command resets.				
Discrim. Timer	0.1s	0.1s	5s	0.01s
Pick up time delay after which any evolving fault during the dead time will be considered as a second (new) fault. If an evolving fault occurs while the timer is still running, the force 3 ph trip internal signal will be issued and the ‘1 Pole Dead Time’ that is running following the initial single pole trip will stop and start ‘Dead Time 1’ instead.				
ISEF>1 AR	No Action	No action, Block AR or Initiate AR		
Setting that determines impact of the first stage sensitive earth fault overcurrent protection on AR operation.				
ISEF>2 to ISEF>4 Cells as for ISEF>1 Above				
SYSTEM CHECKS				
CS1 Close Enable	Disabled	Enabled or Disabled		N/A
Enables auto-reclose with check synchronization. Only allows auto-reclose when the system satisfies the “Check Sync. Stage 1” settings.				
CS2 Close Enable	Disabled	Enabled or Disabled		N/A
Enables auto-reclose with check synchronization. Only allows auto-reclose when the system satisfies the “Check Sync. Stage 2” settings				
LiveLine/Dead Bus	Disabled	Enabled or Disabled		N/A
Enables auto-reclose with Live (“hot”) line and Dead busbar.				
DeadLine/LiveBus	Disabled	Enabled or Disabled		N/A
Enables auto-reclose with Dead line and Live (“hot”) busbar.				
DeadLine/Dead Bus	Disabled	Enabled or Disabled		N/A
Enables auto-reclose with Dead line and Dead busbar.				
C/S AR Immediate	Disabled	Enabled or Disabled		N/A
When enabled this setting allows the set dead time to be bypassed, by implementing a repeat re-closer function. Provided that both line ends have cleared the fault, the line will have gone dead. If the line is then energized from the remote end first, the line will become live again. On detection of a live line, in synchronism with the local bus, immediate re-closing can be permitted.				
Sys. Chk. on Shot 1	Enabled	Enabled or Disabled		N/A
Can be used to disable system checks on the first auto-reclose shot.				

1.3.20 Input labels

The column "GROUP x INPUT LABELS" is used to individually label each opto input that is available in the relay. The text is restricted to 16 characters and is available if 'Input Labels' are set visible under CONFIGURATION column.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Opto Input 1	Input L1	16 characters custom name		
Label for Opto Input 1				
Opto Input x	Input Lx	16 characters custom name		
Label for other Opto Inputs. x = up to 24, depending on relay model.				

1.3.21 Output labels

The column "GROUP x OUTPUT LABELS" is used to individually label each output relay that is available in the relay. The text is restricted to 16 characters and is available if 'Output Labels' are set visible under CONFIGURATION column.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Relay 1	Output R1	16 characters custom name		
Label for output relay 1				
Relay x	Output Rx	16 characters custom name		
Label for other output relays. x = up to 32, depending on relay model.				

1.4 Control and support settings

The control and support settings are part of the main menu and are used to configure the relays global configuration. It includes submenu settings as below:

- Relay function configuration settings
- Open/close circuit breaker
- CT & VT ratio settings
- Reset LEDs
- Active protection setting group
- Password & language settings
- Circuit breaker control & monitoring settings
- Communications settings
- Measurement settings
- Event & fault record settings
- User interface settings
- Commissioning settings

1.4.1 System data

This menu provides information for the device and general status of the relay.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Language	English			
The default language used by the device. Selectable as English, French, German, Spanish.				
Password	****			
Device default password.				
Sys. Fn. Links	0			1
Setting to allow the fixed function trip LED to be self resetting (set to 1 to extinguish the LED after a period of healthy restoration of load current).				
Description	MiCOM P54x			
16 character relay description. Can be edited.				
Plant Reference	MiCOM			
Associated plant description and can be edited.				
Model Number	P54??1???M???0K			
Relay model number. This display cannot be altered.				
Serial Number	123456J			
Relay model number. This display cannot be altered.				
Frequency	50 Hz	50Hz or 60Hz		
Relay set frequency. Settable either 50 or 60Hz				
Comms. Level 2				
Displays the conformance of the relay to the Courier Level 2 comms.				
Relay Address 1	255	0	255	1
Sets the first rear port relay address.				
Plant Status	0000000000000010			
Displays the circuit breaker plant status.				
Control Status	0000000000000000			
Not used.				
Active Group	1	1	4	1
Displays the active settings group.				
CB Trip/Close	No Operation	No Operation/ Trip/Close		
Supports trip and close commands if enabled in the Circuit Breaker Control menu.				
Software Ref. 1	P54x____1__051_K			
Software Ref. 2	P54x____1__051_K			
Displays the relay software version including protocol and relay model. Software Ref. 2 is displayed for relay with IEC 61850 protocol only and this will display the software version of the Ethernet card.				
Opto I/P Status	000000000000000000000000			
Display the status of the available opto inputs fitted.				

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Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Relay O/P Status	00000000000000000000000000000000			
Displays the status of all available output relays fitted.				
Alarm Status 1	00000000000000000000000000000000			
32 bit field gives status of first 32 alarms. Includes fixed and user settable alarms.				
Alarm Status 2	00000000000000000000000000000000			
Next 32 alarm status defined.				
Access Level	2			
Displays the current access level. Level 0 - No password required - Read access to all settings, alarms, event records and fault records Level 1 - Password 1 or 2 required - As level 0 plus: Control commands, e.g. circuit breaker open/close Reset of fault and alarm conditions, Reset LEDs Clearing of event and fault records Level 2 - Password 2 required - As level 1 plus: All other settings				
Password Control	2			1
Sets the menu access level for the relay. This setting can only be changed when level 2 access is enabled.				
Password Level 1	****			
Allows user to change password level 1.				
Password Level 2	****			
Allows user to change password level 2.				

1.4.2 Circuit breaker control

The relay includes the following options for control of a single circuit breaker:

- Local tripping and closing, via the relay menu or hotkeys
- Local tripping and closing, via relay opto-isolated inputs
- Remote tripping and closing, using the relay communications

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
CB control by	Disabled	Disabled, Local, Remote, Local + Remote, Opto, Opto + local, Opto + Remote, Opto + Remote + local		
This Setting selects the type of circuit breaker control that be used in the logic				
Close Pulse Time	0.5s	0.01s	10s	0.01s
Defines the duration of the close pulse.				
Trip Pulse Time	0.5s	0.01s	5s	0.01s
Defines the duration of the trip pulse.				
Man Close Delay	10s	0.01s	600s	0.01s
This defines the delay time before the close pulse is executed.				

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Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
CB Healthy Time	5s	0.01s	9999s	0.01s
A settable time delay included for manual closure with this circuit breaker check. If the circuit breaker does not indicate a healthy condition in this time period following a close command then the relay will lockout and alarm.				
Check Sync. Time	5s	0.01s	9999s	0.01s
A user settable time delay is included for manual closure with check synchronizing. If the check sync. criteria are not satisfied in this time period following a close command the relay will lockout and alarm.				
Lockout Reset	No	No, Yes		
Displays if the Lockout condition has been reset.				
Reset Lockout By	CB Close	User Interface, CB Close		
Setting that determines if a lockout condition will be reset by a manual circuit breaker close command or via the user interface.				
Man Close RstDly	5s	0.01s	600s	0.01s
The manual close time, time delay, that is used to reset a lockout automatically from a manual close.				
Single Pole A/R	Disabled	Disabled or Enabled		
Enable or disable AR for single phase fault types. **Care:** This setting also applies when auto-reclose is configured in 3 pole tripping applications. Even though the trip mode may be 3 pole only, the fact that the *initiation* was a single phase fault type is memorized.				
Three Pole A/R	Disabled	Disabled or Enabled		
Enable or disable AR for multi-phase faults.				
Total Re-closures	Data			
Displays the number of successful re-closures.				
Reset Total A/R	No	No, Yes		
Allows user to reset the auto-reclose counters.				
CB Status Input	52B 1 pole	None, 52A 1 pole, 52B 1 pole, 52A & 52B 1 pole, 52A 3 pole, 52B 3 pole, 52A & 52B 3 pole		
Setting to define the type of circuit breaker contacts that will be used for the circuit breaker control logic. Form “A” contacts match the status of the circuit breaker primary contacts, form “B” are opposite to the breaker status. When “1 pole” is selected, individual contacts must be assigned in the Programmable Scheme Logic for phase A, phase B, and phase C. Setting “3 pole” means that only a single contact is used, common to all 3 poles.				

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1.4.3 Date and time

Displays the date and time as well as the battery condition.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Date/Time	Data			
Displays the relay's current date and time.				
IRIG-B Sync.	Disabled	Disabled or Enabled		
Enable IRIG-B time synchronization.				
IRIG-B Status	Data	Card not fitted/Card failed/ Signal healthy/No signal		
Displays the status of IRIG-B.				
Battery Status	Data			
Displays whether the battery is healthy or not.				
Battery Alarm	Enabled	Enabled or Disabled		
Setting that determines whether an unhealthy relay battery condition is alarmed or not.				
SNTP Status	Data			
Displays information about the SNTP time synchronization status: Disabled, Trying Server 1, Trying Server 2, Server 1 OK, Server 2 OK, No response, or No valid clock.				

1.4.4 CT/VT ratios

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Main VT Primary	110.0 V	100V	1000 kV	1
Sets the main voltage transformer input primary voltage.				
Main VT Sec'y	110.0 V	80V	140V	1
Sets the main voltage transformer input secondary voltage.				
C/S VT Primary	110.0 V	100V	1000 kV	1
Sets the check sync. voltage transformer input primary voltage.				
C/S VT Secondary	110.0 V	80V	140V	1
Sets the check sync. voltage transformer input secondary voltage.				
Phase CT Primary	1.000A	1A	30kA	1
Sets the phase current transformer input primary current rating.				
Phase CT Sec'y	1A	1A	5A	4
Sets the phase current transformer input secondary current rating.				
SEF CT Primary	1.000A	1A	30kA	1
Sets the sensitive earth fault current transformer input primary current rating.				
SEF CT Secondary	1A	1A	5A	4
Sets the sensitive earth fault current transformer input secondary current rating.				
MComp CT Primary	1.000A	1	30k	1
Sets the primary current rating of the neutral transformer that is located on the parallel line.				

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Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
MComp CT Secondary	1A	1A	5A	4
Sets the secondary current rating of the neutral transformer that is located on the parallel line.				
C/S Input	A-N	A-N, B-N, C-N, A-B, B-C, C-A		N/A
Selects the check sync. Input voltage measurement.				
Main VT Location	Line	Line, Bus		N/A
Selects the main voltage transformer location.				
CT Polarity	Standard	Standard or Inverted		
To invert polarity (180 °) of the CT				
CT2 Polarity	Standard	Standard or Inverted		
To invert polarity (180 °) of the CT2				
SEF CT Polarity	Standard	Standard or Inverted		
To invert polarity (180 °) of the SEF CT				
M CT Polarity	Standard	Standard or Inverted		
To invert polarity (180 °) of the M CT				
VTs Connected	Yes	Yes or No		
To indicate if voltage transformers are connected to the relay. This MUST be set properly to ensure Pole Dead logic works correctly. If set to yes, it will set VTS Slow Block and VTS Fast Block DDBs, but will not raise any alarms. It will also override the VTS enabled setting should the user set it. If set to No this setting will have no effect.				

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1.4.5 Record control

It is possible to disable the reporting of events from all interfaces that supports setting changes. The settings that control the various types of events are in the Record Control column. The effect of setting each to disabled is as follows:

Menu Text	Default Setting	Available Settings
Alarm Event	Enabled	Enabled or Disabled
Disabling this setting means that all the occurrences that produce an alarm will result in no event being generated.		
Relay O/P Event	Enabled	Enabled or Disabled
Disabling this setting means that no event will be generated for any change in logic input state.		
Opto Input Event	Enabled	Enabled or Disabled
Disabling this setting means that no event will be generated for any change in logic input state.		
General Event	Enabled	Enabled or Disabled
Disabling this setting means that no General Events will be generated		
Fault Rec. Event	Enabled	Enabled or Disabled
Disabling this setting means that no event will be generated for any fault that produces a fault record		

Menu Text	Default Setting	Available Settings
Maint. Rec. Event	Enabled	Enabled or Disabled
Disabling this setting means that no event will be generated for any occurrence that produces a maintenance record.		
Protection Event	Enabled	Enabled or Disabled
Disabling this setting means that any operation of protection elements will not be logged as an event.		
DDB 31 - 0	11111111111111111111111111111111	
Chooses whether any individual DDBs should be deselected as a stored event, by setting the relevant bit to “0” (zero). Typically used for repetitive recurrent changes such as an Opto input assigned for Minute Pulse clock synchronizing.		
Up to… DDB 1407 - 1376	11111111111111111111111111111111	
As above, for all DDBs through to 1407.		

1.4.6 Measurements

Menu Text	Default Settings	Available settings
MEASUREMENT SETUP		
Default Display	Description	Description/Plant Reference/ Frequency/Access Level/3Ph + N Current/3Ph Voltage/Power/Date and Time
This setting can be used to select the default display from a range of options, note that it is also possible to view the other default displays whilst at the default level using the ← and → keys. However once the 15 minute timeout elapses the default display will revert to that selected by this setting.		
Local Values	Primary	Primary/Secondary
This setting controls whether measured values via the front panel user interface and the front courier port are displayed as primary or secondary quantities.		
Remote Values	Primary	Primary/Secondary
This setting controls whether measured values via the rear communication port are displayed as primary or secondary quantities.		
Measurement Ref.	VA	VA/VB/VC/IA/IB/IC
Using this setting the phase reference for all angular measurements by the relay can be selected. This reference is for Measurements 1. Measurements 3 uses always IA local as a reference		
Measurement Mode	0	0 to 3 step 1
This setting is used to control the signing of the real and reactive power quantities; the signing convention used is defined in the Measurements and Recording section (P54x/EN MR).		
Fix Dem. Period	30 minutes	1 to 99 minutes step 1 minute
This setting defines the length of the fixed demand window.		
Roll Sub Period	30 minutes	1 to 99 minutes step 1 minute
These two settings are used to set the length of the window used for the calculation of rolling demand quantities.		
Num. Sub Periods	1	1 to 15 step 1
This setting is used to set the resolution of the rolling sub window.		

Menu Text	Default Settings	Available settings
MEASUREMENT SETUP		
Distance Unit*	km	km/miles
This setting is used to select the unit of distance for fault location purposes, note that the length of the line is preserved when converting from km to miles and vice versa.		
Fault Location*	Distance	Distance/Ohms/% of Line
The calculated fault location can be displayed using one of several options selected using this setting		
Remote2 Values	Primary	Primary or Secondary
The setting defines whether the values measured via the 2nd Rear Communication port are displayed in primary or secondary terms.		

1.4.7 Communications settings

The communications settings apply to the rear communications ports only and will depend upon the particular protocol being used. Further details are given in the SCADA communications section (P54x/EN SC).

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1.4.7.1 Communications settings for courier protocol

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
COMMUNICATIONS				
RP1 Protocol	Courier			
Indicates the communications protocol that will be used on the rear communications port.				
RP1 Remote Address	255	0	255	1
This cell sets the unique address for the relay such that only one relay is accessed by master station software.				
RP1 Inactivity Timer	15 mins.	1 min.	30 mins.	1 min.
This cell controls how long the relay will wait without receiving any messages on the rear port before it reverts to its default state, including resetting any password access that was enabled.				
RP1 Physical Link	Copper	Copper, Fiber Optic or KBus		
This cell defines whether an electrical EIA(RS)485, fiber optic or KBus connection is being used for communication between the master station and relay. If ‘Fiber Optic’ is selected, the optional fiber optic communications board will be required.				
RP1 Port Config.	KBus	KBus or EIA(RS)485		
This cell defines whether an electrical KBus or EIA(RS)485 is being used for communication between the master station and relay.				
RP1 Comms. Mode	IEC60870 FT1.2 Frame	IEC60870 FT1.2 Frame or 10-Bit No Parity		
The choice is either IEC60870 FT1.2 for normal operation with 11-bit modems, or 10-bit no parity.				
RP1 Baud Rate	19200 bits/s	9600 bits/s, 19200 bits/s or 38400 bits/s		
This cell controls the communication speed between relay and master station. It is important that both relay and master station are set at the same speed setting.				

1.4.7.2 Communications settings for IEC60870-5-103 protocol

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
COMMUNICATIONS				
RP1 Protocol	IEC60870-5-103			
Indicates the communications protocol that will be used on the rear communications port.				
RP1 Address	1	0	247	1
This cell sets the unique address for the relay such that only one relay is accessed by master station software.				
RP1 Inactivity Timer	15 mins.	1 min.	30 mins.	1 min.
This cell controls how long the relay will wait without receiving any messages on the rear port before it reverts to its default state, including resetting any password access that was enabled.				
RP1 Baud Rate	19200 bits/s	9600 bits/s or 19200 bits/s		
This cell controls the communication speed between relay and master station. It is important that both relay and master station are set at the same speed setting.				
RP1 Measure't. Period	15s	1s	60s	1s
This cell controls the time interval that the relay will use between sending measurement data to the master station.				
RP1 Physical Link	Copper	Copper or Fiber Optic		
This cell defines whether an electrical EIA(RS) 485 or fiber optic connection is being used for communication between the master station and relay. If 'Fiber Optic' is selected, the optional fiber optic communications board will be required.				
RP1 CS103 Blocking	Disabled	Disabled, Monitor Blocking, or Command Blocking		
There are three settings associated with this cell: Disabled - No blocking selected. Monitor Blocking - When the monitor blocking DDB Signal is active high, either by energizing an opto input or control input, reading of the status information and disturbance records is not permitted. When in this mode the relay returns a "termination of general interrogation" message to the master station. Command Blocking - When the command blocking DDB signal is active high, either by energizing an opto input or control input, all remote commands will be ignored (i.e. CB Trip/Close, change setting group etc.). When in this mode the relay returns a "negative acknowledgement of command" message to the master station.				

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1.4.7.3 Communications settings for DNP3.0 protocol

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
COMMUNICATIONS				
RP1 Protocol	DNP 3.0			
Indicates the communications protocol that will be used on the rear communications port.				
RP1 Address	3	0	65519	1
This cell sets the unique address for the relay such that only one relay is accessed by master station software.				
RP1 Baud Rate	19200 bits/s	1200 bits/s, 2400 bits/s, 4800 bits/s, 9600 bits/s, 19200 bits/s or 38400 bits/s		
This cell controls the communication speed between relay and master station. It is important that both relay and master station are set at the same speed setting.				
RP1 Parity	None	Odd, Even or None		
This cell controls the parity format used in the data frames. It is important that both relay and master station are set with the same parity setting.				
RP1 Physical Link	Copper	Copper or Fiber Optic		
This cell defines whether an electrical EIA(RS) 485 or fiber optic connection is being used for communication between the master station and relay. If ‘Fiber Optic’ is selected, the optional fiber optic communications board will be required.				
RP1 Time Sync.	Disabled	Disabled or Enabled		
If set to ‘Enabled’ the DNP3.0 master station can be used to synchronize the time on the relay. If set to ‘Disabled’ either the internal free running clock, or IRIG-B input are used.				
Message Gap (ms)	0	0	50	1
This setting allows the master station to have an interframe gap.				

1.4.7.4 Communications settings for Ethernet port

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
NIC Protocol	IEC61850			
Indicates that IEC61850 will be used on the rear Ethernet port.				
NIC MAC Address	*Ethernet MAC Address*			
Indicates the MAC address of the rear Ethernet port.				
NIC Tunl Timeout	5 mins	1 min	30 mins	1 min
Duration of time waited before an inactive tunnel to MiCOM S1 is reset.				
NIC Link Report	Alarm	Alarm, Event, None		
Configures how a failed/unfitted network link (copper or fiber) is reported: Alarm - an alarm is raised for a failed link Event - an event is logged for a failed link None - nothing reported for a failed link				
NIC Link Timeout	60s	0.1s	60s	0.1s
Duration of time waited, after failed network link is detected, before communication by the alternative media interface is attempted. See also the IED CONFIGURATOR column for IEC 61850 data.				

1.4.7.5 Rear port 2 connection settings

The settings shown are those configurable for the second rear port which is only available with the courier protocol.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
COMMUNICATIONS				
RP2 Protocol	Courier			
Indicates the communications protocol that will be used on the rear communications port.				
RP2 Port Config.	EIA(RS)232	EIA(RS)232, EIA(RS)485 or KBus		
This cell defines whether an electrical EIA(RS)232, EIA(RS)485 or KBus is being used for communication.				
RP2 Comms. Mode	IEC60870 FT1.2 Frame	IEC60870 FT1.2 Frame or 10-Bit No Parity		
The choice is either IEC60870 FT1.2 for normal operation with 11-bit modems, or 10-bit no parity.				
RP2 Address	255	0	255	1
This cell sets the unique address for the relay such that only one relay is accessed by master station software.				
RP2 Inactivity Timer	15 mins.	1 mins.	30 mins.	1 min.
This cell controls how long the relay will wait without receiving any messages on the rear port before it reverts to its default state, including resetting any password access that was enabled.				
RP2 Baud Rate	19200 bits/s	9600 bits/s, 19200 bits/s or 38400 bits/s		
This cell controls the communication speed between relay and master station. It is important that both relay and master station are set at the same speed setting.				

1.4.8 Commissioning tests

There are menu cells which allow the status of the opto-isolated inputs, output relay contacts, internal digital data bus (DDB) signals and user-programmable LEDs to be monitored. Additionally there are cells to test the operation of the output contacts, user-programmable LEDs and, where available, the auto-reclose cycles.

Menu Text	Default Setting	Available Settings
COMMISSION TESTS		
Opto I/P Status	0000000000000000	
This menu cell displays the status of the available relay's opto-isolated inputs as a binary string, a '1' indicating an energized opto-isolated input and a '0' a de-energized one		
Relay O/P Status	0000000000000000	
This menu cell displays the status of the digital data bus (DDB) signals that result in energization of the available output relays as a binary string, a '1' indicating an operated state and '0' a non-operated state. When the 'Test Mode' cell is set to 'Enabled' the 'Relay O/P Status' cell does not show the current status of the output relays and hence can not be used to confirm operation of the output relays. Therefore it will be necessary to monitor the state of each contact in turn.		
Test Port Status	00000000	
This menu cell displays the status of the eight digital data bus (DDB) signals that have been allocated in the 'Monitor Bit' cells.		

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Menu Text	Default Setting	Available Settings
Monitor Bit 1	1060 (LED 1)	0 to 1407 See PSL section for details of digital data bus signals
The eight ‘Monitor Bit’ cells allow the user to select the status of which digital data bus signals can be observed in the ‘Test Port Status’ cell or via the monitor/download port.		
Monitor Bit 8	1074 (LED 8)	0 to 1407
The eight ‘Monitor Bit’ cells allow the user to select the status of which digital data bus signals can be observed in the ‘Test Port Status’ cell or via the monitor/download port.		
Test Mode	Disabled	Disabled, Test Mode, Contacts Blocked
The Test Mode menu cell is used to allow secondary injection testing to be performed on the relay without operation of the trip contacts. It also enables a facility to directly test the output contacts by applying menu controlled test signals. To select test mode the Test Mode menu cell should be set to ‘Test Mode’, which takes the relay out of service and blocks operation of output contacts and maintenance, counters. It also causes an alarm condition to be recorded and the yellow ‘Out of Service’ LED to illuminate and an alarm message ‘Prot’n. Disabled’ is given. This also freezes any information stored in the Circuit Breaker Condition column and in IEC60870-5-103 builds changes the Cause of Transmission, COT, to Test Mode. To enable testing of output contacts the Test Mode cell should be set to Contacts Blocked. This blocks the protection from operating the contacts and enables the test pattern and contact test functions which can be used to manually operate the output contacts. Once testing is complete the cell must be set back to ‘Disabled’ to restore the relay back to service.		
Test Pattern	00000000000000000000000000000000	0 = Not Operated 1 = Operated
This cell is used to select the output relay contacts that will be tested when the ‘Contact Test’ cell is set to ‘Apply Test’.		
Contact Test	No Operation	No Operation, Apply Test, Remove Test
When the ‘Apply Test’ command in this cell is issued the contacts set for operation (set to ‘1’) in the ‘Test Pattern’ cell change state. After the test has been applied the command text on the LCD will change to ‘No Operation’ and the contacts will remain in the Test State until reset issuing the ‘Remove Test’ command. The command text on the LCD will again revert to ‘No Operation’ after the ‘Remove Test’ command has been issued. Note: When the ‘Test Mode’ cell is set to ‘Enabled’ the ‘Relay O/P Status’ cell does not show the current status of the output relays and hence can not be used to confirm operation of the output relays. Therefore it will be necessary to monitor the state of each contact in turn.		
Test LEDs	No Operation	No Operation Apply Test
When the ‘Apply Test’ command in this cell is issued the eighteen user-programmable LEDs will illuminate for approximately 2 seconds before they extinguish and the command text on the LCD reverts to ‘No Operation’.		
Test Auto-reclose	No Operation	No Operation, Trip 3 Pole, Trip Pole A, Trip Pole B, Trip Pole C
This is a command used to simulate a single pole or three phase tripping in order to test Auto-reclose cycle.		

Menu Text	Default Setting	Available Settings
Static Test	Disabled	Disabled or Enabled
When Static test is "Enabled", delta phase selectors and the delta directional line are bypassed to allow the user to test the relay with older injection test sets that are incapable of simulating real dynamic step changes in current and voltage. Resulting trip times will be slower, as extra filtering of distance comparators is also switched-in.		
Loopback Mode	Disabled	Disabled, Internal, External
Setting that allows communication loopback testing.		
IM64 TestPattern	0000000000000000	
This cell is used to set the DDB signals included in the User Defined Inter-Relay Commands IM64 when the 'IM64 Test Mode' cell is set to 'Enable'.		
IM64 Test Mode	Disabled	Disabled or Enabled
When the 'Enable" command in this cell is issued the DDB set for operation (set to '1') in the 'Test Pattern' cell change state.		
Red LED Status	000000000000000000	
This cell is an eighteen bit binary string that indicates which of the user-programmable LEDs on the relay are illuminated with the Red LED input active when accessing the relay from a remote location, a '1' indicating a particular LED is lit and a '0' not lit.		
Green LED Status	000000000000000000	
This cell is an eighteen bit binary string that indicates which of the user-programmable LEDs on the relay are illuminated with the Green LED input active when accessing the relay from a remote location, a '1' indicating a particular LED is lit and a '0' not lit.		
DDB 31 - 0	00000000000000000000001000000000	
Displays the status of DDB signals 0-31.		
… DDB 1407 - 1376	00000000000000000000000000000000	
... For monitoring all DDB signals up to 1407.		

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1.4.9 Circuit breaker condition monitor setup

The following table, detailing the options available for the Circuit Breaker condition monitoring, is taken from the relay menu. It includes the setup of the ruptured current facility and those features that can be set to raise an alarm, or lockout the CB.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Broken I^	2	1	2	0.1
This sets the factor to be used for the cumulative I^ counter calculation that monitors the cumulative severity of the duty placed on the interrupter. This factor is set according to the type of Circuit Breaker used.				
I^ Maintenance	Alarm Disabled	Alarm Disabled or Alarm Enabled		
Setting which determines if an alarm will be raised or not when the cumulative I^ maintenance counter threshold is exceeded.				
I^ Maintenance	1000In^	1In^	25000In^	1In^
Setting that determines the threshold for the cumulative I^ maintenance counter monitors.				
I^ Lockout	Alarm Disabled	Alarm Disabled or Alarm Enabled		
Setting which determines if an alarm will be raised or not when the cumulative I^lockout counter threshold is exceeded.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
I^ Lockout	2000In^	1In^	25000In^	1In^
Setting that determines the threshold for the cumulative I^ lockout counter monitor. Set that should maintenance not be carried out, the relay can be set to lockout the auto-reclose function on reaching a second operations threshold.				
No CB Ops. Maint.	Alarm Disabled	Alarm Disabled or Alarm Enabled		
Setting to activate the number of circuit breaker operations maintenance alarm.				
No CB Ops. Maint.	10	1	10000	1
Sets the threshold for number of circuit breaker operations maintenance alarm, indicating when preventative maintenance is due.				
No CB Ops. Lock	Alarm Disabled	Alarm Disabled or Alarm Enabled		
Setting to activate the number of circuit breaker operations lockout alarm.				
No CB Ops. Lock	20	1	10000	1
Sets the threshold for number of circuit breaker operations lockout. The relay can be set to lockout the auto-reclose function on reaching a second operations threshold.				
CB Time Maint.	Alarm Disabled	Alarm Disabled or Alarm Enabled		
Setting to activate the circuit breaker operating time maintenance alarm.				
CB Time Maint.	0.1s	0.005s	0.5s	0.001s
Setting for the circuit operating time threshold which is set in relation to the specified interrupting time of the circuit breaker.				
CB Time Lockout	Alarm Disabled	Alarm Disabled or Alarm Enabled		
Setting to activate the circuit breaker operating time lockout alarm.				
CB Time Lockout	0.2s	0.005s	0.5s	0.001s
Setting for the circuit breaker operating time threshold which is set in relation to the specified interrupting time of the circuit breaker. The relay can be set to lockout the auto-reclose function on reaching a second operations threshold.				
Fault Freq. Lock	Alarm Disabled	Alarm Disabled or Alarm Enabled		
Enables the excessive fault frequency alarm.				
Fault Freq. Count	10	1	9999	1
Sets a circuit breaker frequent operations counter that monitors the number of operations over a set time period.				
Fault Freq. Time	3600s	0s	9999s	1s
Sets the time period over which the circuit breaker operations are to be monitored. Should the set number of trip operations be accumulated within this time period, an alarm can be raised. Excessive fault frequency/trips can be used to indicate that the circuit may need maintenance attention (e.g. Tree-felling or insulator cleaning).				

1.4.10 Opto configuration

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
OPTO CONFIG.				
Global Nominal V	24 - 27	24 - 27, 30 - 34, 48 - 54, 110 - 125, 220 - 250, Custom		
Sets the nominal battery voltage for all opto inputs by selecting one of the five standard ratings in the Global Nominal V settings. If Custom is selected then each opto input can individually be set to a nominal voltage value.				
Opto Input 1	24 - 27	24 - 27, 30 - 34, 48 - 54, 110 - 125, 220 - 250		
Each opto input can individually be set to a nominal voltage value if custom is selected for the global setting.				
Opto Input 2 - 24	24 - 27	24 - 27, 30 - 34, 48 - 54, 110 - 125, 220 - 250		
Each opto input can individually be set to a nominal voltage value if custom is selected for the global setting. The number of inputs may be up to 24, depending on MiCOM P54x model and I/O configuration.				
Opto Filter Cntl.	111111110111011111111011			
Selects each input with a pre-set filter of ½ cycle that renders the input immune to induced noise on the wiring. The number of available bits may be 16 or 24, depending on the I/O configuration.				
Characteristics	Standard 60% - 80%	Standard 60% - 80%, 50% - 70%		
Selects the pick-up and drop-off characteristics of the optos. Selecting the standard setting means they nominally provide a Logic 1 or On value for Voltages ≥80% of the set lower nominal voltage and a Logic 0 or Off value for the voltages ≤60% of the set higher nominal voltage.				

1.4.11 Control inputs

The control inputs function as software switches that can be set or reset either locally or remotely. These inputs can be used to trigger any function that they are connected to as part of the PSL. The setting is not visible if ‘Control Inputs’ are set invisible under the CONFIGURATION column.

Menu Text	Default Setting	Setting Range	Step Size
CONTROL INPUTS			
Ctrl I/P Status	00000000000000000000000000000000		
Cell that is used to set (1) and reset (0) the selected Control Input by simply scrolling and changing the status of selected bits. This command will be then recognized and executed in the PSL. Alternatively, each of the 32 Control input can also be set and reset using the individual menu setting cells as follows:			
Control Input 1	No Operation	No Operation or Set or Reset	
Setting to allow Control Inputs 1 set/ reset.			
Control Input 2 to 32	No Operation	No Operation or Set or Reset	
Cell as for Control Input 1			

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1.4.12 Control input configuration

Instead of operating the control inputs as described in the above section, they could also be set to perform a pre-defined control function. This is achieved by mapping in the Hotkey menu. The operating mode for each of the 32 Control Inputs can be set individually.

Menu Text	Default Setting	Setting Range	Step Size
CTRL I/P CONFIG.			
Hotkey Enabled	11111111111111111111111111111111		
Setting to allow the control inputs to be individually assigned to the “Hotkey” menu by setting ‘1’ in the appropriate bit in the “Hotkey Enabled” cell. The hotkey menu allows the control inputs to be set, reset or pulsed without the need to enter the “CONTROL INPUTS” column			
Control Input 1	Latched	Latched, Pulsed	
Configures the control inputs as either ‘latched’ or ‘pulsed’. A latched control input will remain in the set state until a reset command is given, either by the menu or the serial communications. A pulsed control input, however, will remain energized for 10ms after the set command is given and will then reset automatically (i.e. no reset command required).			
Ctrl Command 1	Set/Reset	Set/Reset, In/Out, Enabled/Disabled, On/Off	
Allows the SET / RESET text, displayed in the hotkey menu, to be changed to something more suitable for the application of an individual control input, such as “ON / OFF”, “IN / OUT” etc.			
Control Input 2 to 32	Latched	Latched, Pulsed	
Configures the control inputs as either ‘latched’ or ‘pulsed’.			
Ctrl Command 2 to 32	Set/Reset	Set/Reset, In/Out, Enabled/Disabled, On/Off	
Allows the SET / RESET text, displayed in the hotkey menu, to be changed to something more suitable for the application of an individual control input, such as “ON / OFF”, “IN / OUT” etc.			

1.4.13 Function keys

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
FUNCTION KEYS				
Fn. Key Status	0000000000			
Displays the status of each function key.				
Fn. Key 1 Status	Unlock/Enable	Disable, Lock, Unlock/Enable		
Setting to activate function key. The ‘Lock’ setting allows a function key output that is set to toggle mode to be locked in its current active state.				
Fn. Key 1 Mode	Toggle	Toggle, Normal		
Sets the function key in toggle or normal mode. In ‘Toggle’ mode, a single key press will set/latch the function key output as ‘high’ or ‘low’ in programmable scheme logic. This feature can be used to enable/disable relay functions. In the ‘Normal’ mode the function key output will remain ‘high’ as long as key is pressed.				
Fn. Key 1 Label	Function Key 1			
Allows the text of the function key to be changed to something more suitable for the application.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Fn. Key 2 to 10 Status	Unlock/Enable	Disable, Lock, Unlock/Enable		
Setting to activate function key. The ‘Lock’ setting allows a function key output that is set to toggle mode to be locked in its current active position.				
Fn. Key 2 to 10 Mode	Toggle	Toggle, Normal		
Sets the function key in toggle or normal mode. In ‘Toggle’ mode, a single key press will set/latch the function key output as ‘high’ or ‘low’ in programmable scheme logic. This feature can be used to enable/disable relay functions. In the ‘Normal’ mode the function key output will remain ‘high’ as long as key is pressed.				
Fn. Key 2 to 10 Label	Function Key 2 to 10			
Allows the text of the function key to be changed to something more suitable for the application.				

1.4.14 IED configurator (for IEC61850 configuration)

The contents of the IED CONFIGURATOR column are mostly data cells, displayed for information but not editable. In order to edit the configuration, it is necessary to use the IED Configurator tool within MiCOM S1.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
IED CONFIGURATOR				
Switch Conf.Bank	No Action	No Action, Switch Banks		
Setting which allows the user to switch between the current configuration, held in the Active Memory Bank (and partly displayed below), to the configuration sent to and held in the Inactive Memory Bank.				
Active Conf.Name	Data			
The name of the configuration in the Active Memory Bank, usually taken from the SCL file.				
Active Conf.Rev	Data			
Configuration Revision number of the configuration in the Active Memory Bank, usually taken from the SCL file.				
Inact.Conf.Name	Data			
The name of the configuration in the Inactive Memory Bank, usually taken from the SCL file.				
Inact.Conf.Rev	Data			
Configuration Revision number of the configuration in the Inactive Memory Bank, usually taken from the SCL file.				
IP PARAMETERS				
IP Address	Data			
Displays the unique network IP address that identifies the relay.				
Subnet Mask	Data			
Displays the sub-network that the relay is connected to.				
Gateway	Data			
Displays the IP address of the gateway (proxy) that the relay is connected to, if any.				

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Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
SNTP PARAMETERS				
SNTP Server 1	Data			
Displays the IP address of the primary SNTP server.				
SNTP Server 2	Data			
Displays the IP address of the secondary SNTP server.				
IEC61850 SCL				
IED Name	Data			
8 character IED name, which is the unique name on the IEC 61850 network for the IED, usually taken from the SCL file.				
IEC61850 GOOSE				
GoID	Data			
64 character GOOSE Identifier, used for naming the published GOOSE message. Default GoID is TEMPLATESystem/LLN0GOgcbST.				
GoEna	Disabled	Disabled, Enabled		
Setting to enable GOOSE publisher settings.				
Test Mode	Disabled	Disabled, Pass Through, Forced		
The Test Mode cell allows the test pattern to be sent in the GOOSE message, for example for testing or commissioning. When 'Disabled' is selected, the test flag is not set. When 'Pass Through' is selected, the test flag is set, but the data in the GOOSE message is sent as normal. When 'Forced' is selected, the test flag is set, and the data sent in the GOOSE message is as per the 'VOP Test Pattern' setting below. Once testing is complete the cell must be set back to 'Disabled' to restore the GOOSE scheme back to normal service.				
VOP Test Pattern	0x00000000	0x00000000	0xFFFFFFFF	1
The 32 bit test pattern applied in 'Forced' test mode.				
Ignore Test Flag	No	No, Yes		
When set to 'Yes', the test flag in the subscribed GOOSE message is ignored, and the data treated as normal.				

1.4.15 Control input labels

Menu Text	Default Setting	Setting Range	Step Size
CTRL I/P LABELS			
Control Input 1	Control Input 1	16 Character Text	
Setting to change the text associated with each individual control input. This text will be displayed when a control input is accessed by the hotkey menu, or it can be displayed in the programmable scheme logic.			
Control Input 2 to 32	Control Input 2 to 32	16 Character Text	
Setting to change the text associated with each individual control input. This text will be displayed when a control input is accessed by the hotkey menu, or it can be displayed in the programmable scheme logic.			

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1.4.16 Direct access (breaker control and “hotkeys”)

The Direct Access keys are the “0” and “1” keys situated directly below the LCD display. The user may assign the function of these two keys, to signal direct commands into the PSL logic. Two modes of use exist:

- Tripping and Closing commands to the circuit breaker
- “Hotkey” functions, whereby a mini menu of frequently required commands and operations is accessed. Operators can then easily access the required command, without needing to navigate the full relay menu.

Menu Text	Default Setting	Setting Range	Step Size
CONFIGURATION			
Direct Access	Enabled	Disabled, Enabled, Hotkey only, or CB Ctrl Only	
The front direct access keys that are used as a short cut function of the menu may be: Disabled – No function visible on the LCD Enabled – All control functions mapped to the Hotkeys and Control Trip/Close are available Hotkey Only – Only control functions mapped to the Hotkeys are available on the LCD CB Ctrl Only – Only Control Trip/Control Close command will appear on the relay’s LCD			

1.5 Disturbance recorder settings (oscillography)

The disturbance recorder settings include the record duration and trigger position, selection of analog and digital signals to record, and the signal sources that trigger the recording.

The "DISTURBANCE RECORDER" menu column is shown in the following table:

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
DISTURB. RECORDER				
Duration	1.5s	0.1s	10.5s	0.01s
This sets the overall recording time.				
Trigger Position	33.3%	0	100%	0.1%
This sets the trigger point as a percentage of the duration. For example, the default settings show that the overall recording time is set to 1.5s with the trigger point being at 33.3% of this, giving 0.5s pre-fault and 1s post fault recording times.				
Trigger Mode	Single	Single or Extended		
If set to single mode, if a further trigger occurs whilst a recording is taking place, the recorder will ignore the trigger. However, if this has been set to "Extended", the post trigger timer will be reset to zero, thereby extending the recording time.				
Analog. Channel 1	VA	IA, IB, IC, IN, IN Sensitive, VA, VB, VC, IM V Checksync (only for P543 and P545) and IA2, IB2, IC2 (only for P544 and P546)		
Selects any available analog input to be assigned to this channel (including derived IN residual current).				
Analog. Channel 2	VB	As above		
Analog. Channel 3	VC	As above		
Analog. Channel 4	IA	As above		
Analog. Channel 5	IB	As above		

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Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Analog. Channel 6	IC	As above		
Analog. Channel 7	IN	As above		
Analog. Channel 8	IN Sensitive	As above		
Analog. Channel 9	V Checksync	As above		
Analog. Channel 10	IN	As above		
Analog. Channel 11	IN	As above		
Analog. Channel 12	IN	As above		
Digital Inputs 1 to 32	Relays 1 to 12 and Opto's 1 to 12	Any O/P Contact, Any Opto Inputs, or Internal Digital Signals		
The digital channels may monitor any of the opto isolated inputs or output contacts, in addition to a number of internal relay digital signals, such as protection starts, LEDs etc.				
Inputs 1 to 32 Trigger	No Trigger except Dedicated Trip Relay 3 operation which are set to Trigger L/H	No Trigger, Trigger L/H, Trigger H/L		
Any of the digital channels may be selected to trigger the disturbance recorder on either a low to high or a high to low transition.				

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OPERATION

Date:	**7th August 2006**
Hardware Suffix:	**K**
Software Version:	**41 and 51**
Connection Diagrams:	**10P54302xx (xx = 01 to 02) & 10P54303xx (xx = 01 to 02)**
	10P54402xx (xx = 01 to 02) & 10P54403xx (xx = 01 to 02)
	10P54502xx (xx = 01 to 02) & 10P54503xx (xx = 01 to 02)
	10P54602xx (xx = 01 to 02) & 10P54603xx (xx = 01 to 02)

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FIGURES

1. OPERATION OF INDIVIDUAL PROTECTION FUNCTIONS

The MiCOM P54x is a line protection relay that includes phase differential protection on a per phase basis and optionally comprehensive full scheme distance protection. Each one of these protection functions can be selected to work separately or simultaneously. The distance protection can also be set to operate upon failure of the relay protection communications. With the inclusion of Aided Directional Earth fault (DEF) the MiCOM P54x is a fully comprehensive and versatile line protection relay.

The following sections detail the individual protection functions.

1.1 Phase differential characteristics

MiCOM P54x calculates the difference between the currents entering and leaving a protected zone. The protection operates when this difference exceeds a set threshold.

Differential currents may also be generated during external fault conditions due to CT saturation. To provide stability for through fault conditions, the relay adopts a biasing technique. This method effectively raises the setting of the relay in proportion to the value of through fault current to prevent relay maloperation. Figure 1 shows the operating characteristics of the P54x phase differential element.

The differential current is calculated as the vector summation of the currents entering the protected zone. The bias current is the average of the measured current at each line end. It is found by the scalar sum of the current at each terminal, divided by two.

Each of these calculations is done on a phase by phase basis. The level of bias used for each element is the highest of the three calculated for optimum stability.

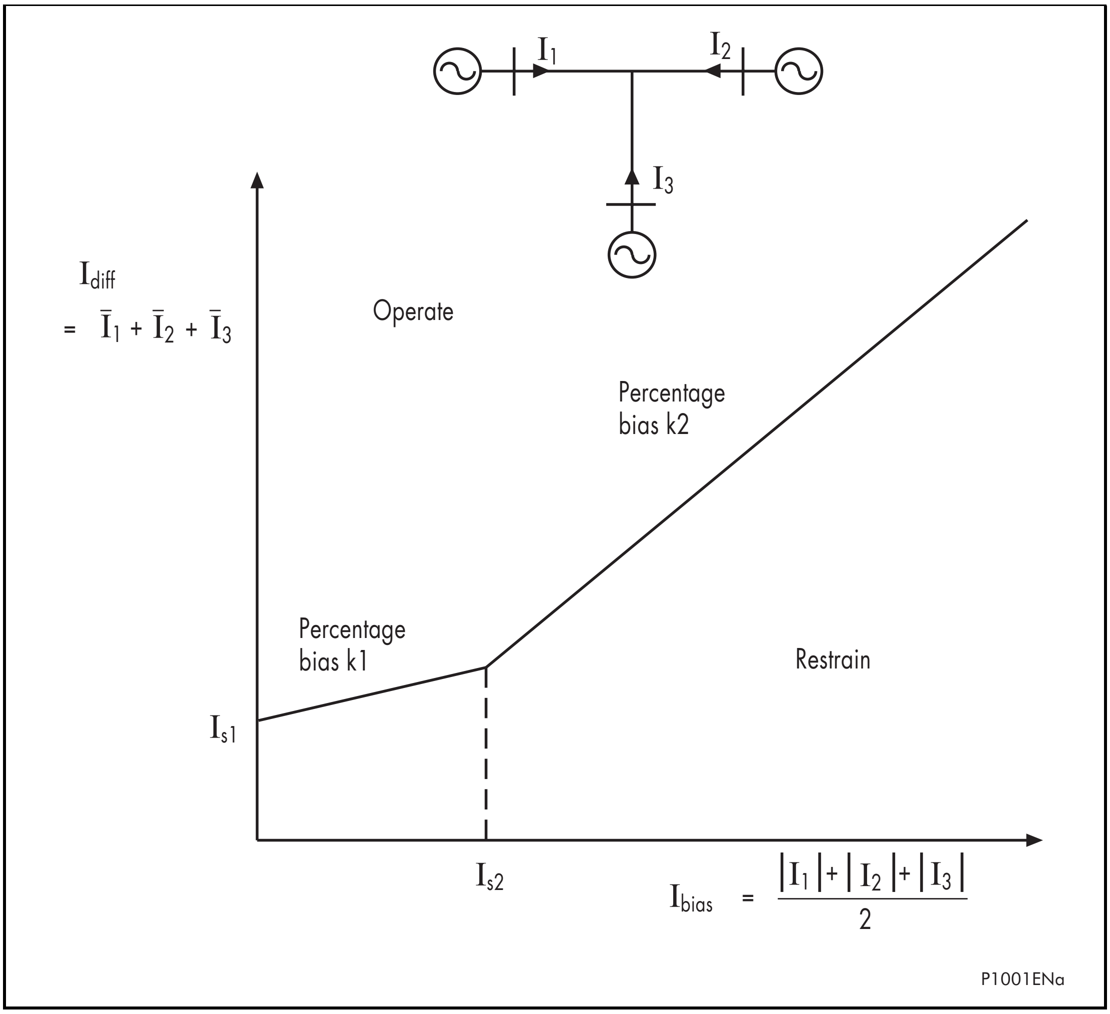

Figure 1: Relay bias characteristic

The characteristic is determined by four protection settings:

Is1 The basic differential current setting which determines the minimum pick-up level of the relay.

k1 The lower percentage bias setting used when the bias current is below Is2. This provides stability for small CT mismatches, whilst ensuring good sensitivity to resistive faults under heavy load conditions.

Is2 A bias current threshold setting, above which the higher percentage bias k2 is used.

k2 The higher percentage bias setting used to improve relay stability under heavy through fault current conditions.

The tripping criteria can be formulated as:

1. For |Ibias| < Is2,

   |Idiff| > k1.| Ibias| + Is1

2. For |Ibias| > Is2,

   |Idiff| > k2.| Ibias| - (k2 - k1). Is2 + Is1

When a trip is issued by the differential element, in addition to tripping the local breaker, the relay will send a differential intertrip signal to the remote terminals. This will ensure tripping of all ends of the protected line, even for marginal fault conditions.

The differential protection can be time delayed using either a definite or inverse time characteristic.

The Id High Set element is an unrestrained element designed to provide high speed operation in the event of CT saturation. Where transformer inrush restraint is used, the resultant second harmonic current produced from CT saturation may cause slow relay operation. The high set element will be automatically enabled when inrush restraint is enabled, otherwise it is not operational.

Logic Diagram for Differential protection is shown on Figure 2 here after:

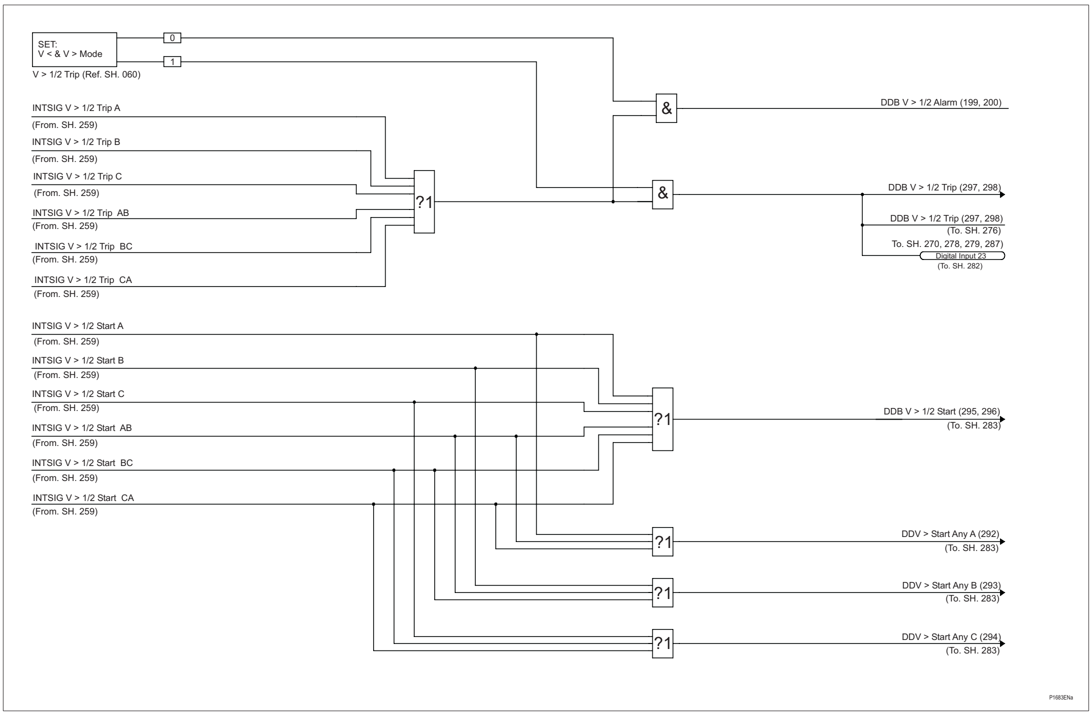

Figure 2: Differential logic diagram

1.1.1 Time alignment of current vectors

1.1.1.1 Time alignment of current vectors without GPS input (Traditional Technique)

This section relates to P54x relays when the GPS synchronization is not used.

To calculate differential current between line ends it is necessary that the current samples from each end are taken at the same moment in time. This can be achieved by time synchronizing the sampling, or alternatively, by the continuous calculation of the propagation delay between line ends. The P54x range of relays has adopted this second technique.

Consider a two-ended system as shown in Figure 3.

Two identical relays, A and B are placed at the two ends of the line. Relay A samples its current signals at time tA1, tA2 etc., and relay B at time tB1, tB2 etc. Note that the sampling instants at the two ends will not, in general, be coincidental or of a fixed relationship, due to slight drifts in sampling frequencies.

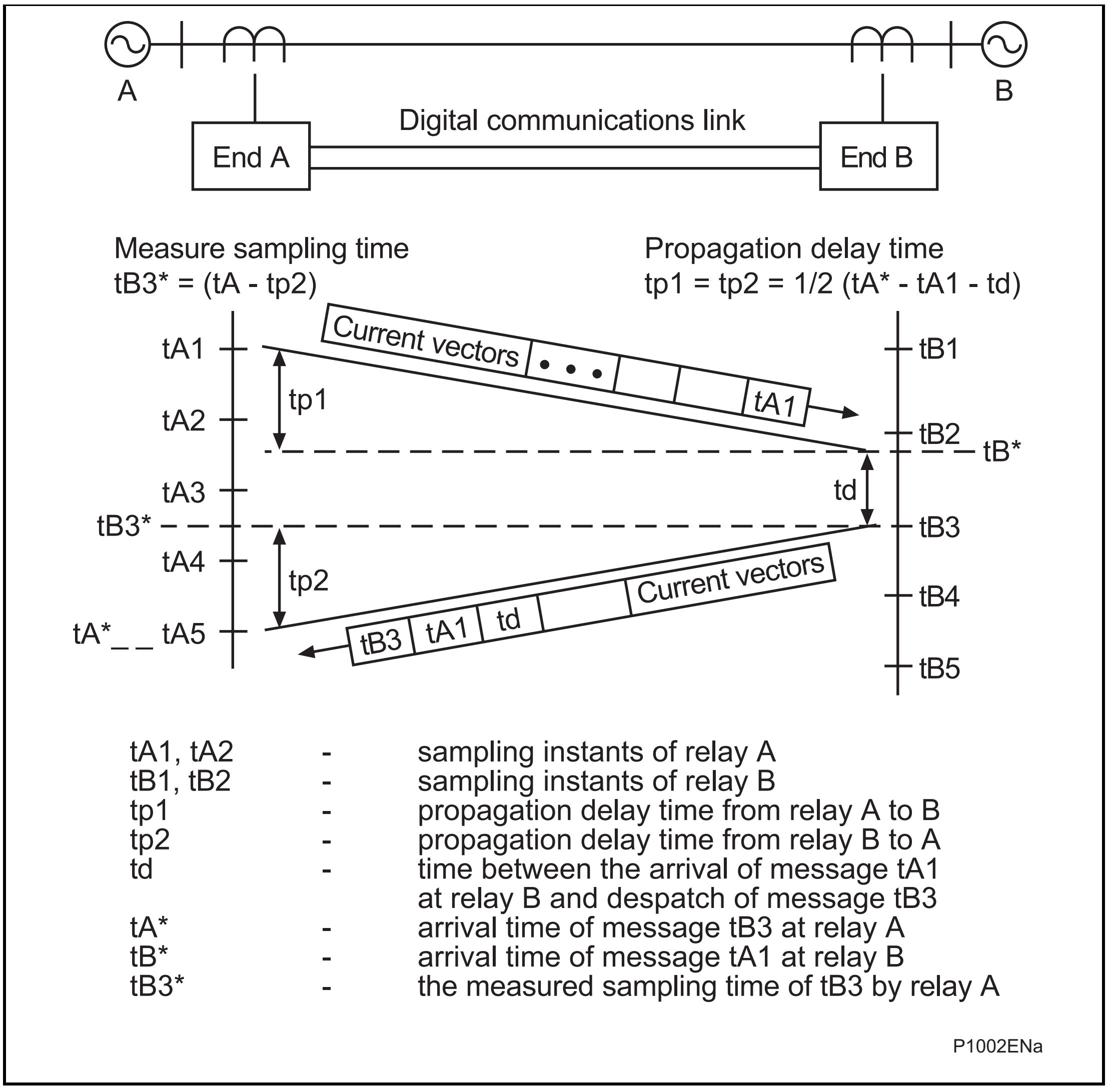

Figure 3: Propagation delay measurement

Assume that at time tA1, relay A sends a data message to relay B. The message contains a time tag, tA1, together with other timing and status information and the current vector values calculated at tA1. The message arrives at end B after a channel propagation delay time, tp1. Relay B registers the arrival time of the message as tB*.

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Since relays A and B are identical, relay B also sends out data messages to end A. Assume relay B sends out a data message at tB3. The message therefore contains the time tag tB3. It also returns the last received time tag from relay A (i.e. tA1) and the delay time, td, between the arrival time of the received message, tB*, and the sampling time, tB3, i.e. td = (tB3 - tB*).

The message arrives at end A after a channel propagation delay time, tp2. Its arrival time is registered by relay A as tA*. From the returned time tag, tA1, relay A can measure the total elapsed time as (tA* - tA1). This equals the sum of the propagation delay times tp1, tp2 and the delay time td at end B.

Hence,

$$(tA^* - tA1) = (td + tp1 + tp2)$$

The relay assumes that the transmit and receive channels follow the same path and so have the same propagation delay time. This time can therefore be calculated as:

$$tp1 = tp2 = \tfrac{1}{2}(tA^* - tA1 - td)$$

Note that the propagation delay time is measured for each received sample and this can be used to monitor any change on the communication link.

As the propagation delay time has now been deduced, the sampling instant of the received data from relay B (tB3*) can be calculated. As shown in Figure 3, the sampling time tB3* is measured by relay A as:

$$tB3^* = (tA^* - tp2)$$

In Figure 3, tB3* is between tA3 and tA4. To calculate the differential and bias currents, the vector samples at each line end must correspond to the same point in time. It is necessary therefore to time align the received tB3* data to tA3 and tA4. This can be achieved by rotating the received current vector by an angle corresponding to the time difference between tB3* and tA3 (and tA4). For example a time difference of 1ms would require a vector rotation of 1/20 * 360° = 18° for a 50Hz system.

As two data samples can be compared with each data message, the process needs to be done only once every two samples, thus reducing the communication bandwidth required. Note that the current vectors of the three phases need to be time aligned separately.

1.1.1.2 Time alignment of current vectors with GPS input (all models)

The effect of the deployment of switched SDH (Synchronous Digital Hierarchy) networks on telecommunications circuits used in the application of numerical current differential protection to transmission lines.

Such telecommunications networks can be deployed in flexible, self-healing topologies. Typically, ring network topologies are employed and these are characterized by the ability to self-heal in the event of a failure of an interconnection channel.

Consider a simple ring topology with 6 nodes, A - F, and consider two equipment situated at nodes B and C. Under healthy conditions equipment at B communicates with equipment at C directly between nodes B and C and equipment at C communicates with equipment at B directly between nodes C and B. In this condition the communications propagation time between nodes B and C will be the same as that between nodes C and B and so the traditional technique described in could be used to apply numerical current differential protection (see Figure 4).

If the link fails in one direction, say between the transmitter at node B and the receiver at node C, the self-healing ring can continue to transfer signals from node B to node C via the standby route through nodes B, A, F, E, D and then C (obviously a longer path). In this case the communication propagation delay times between nodes B and C differ in the two directions, and if the difference is greater than 1ms the traditional time alignment technique described in section 1.1.1.1 is no longer adequate.

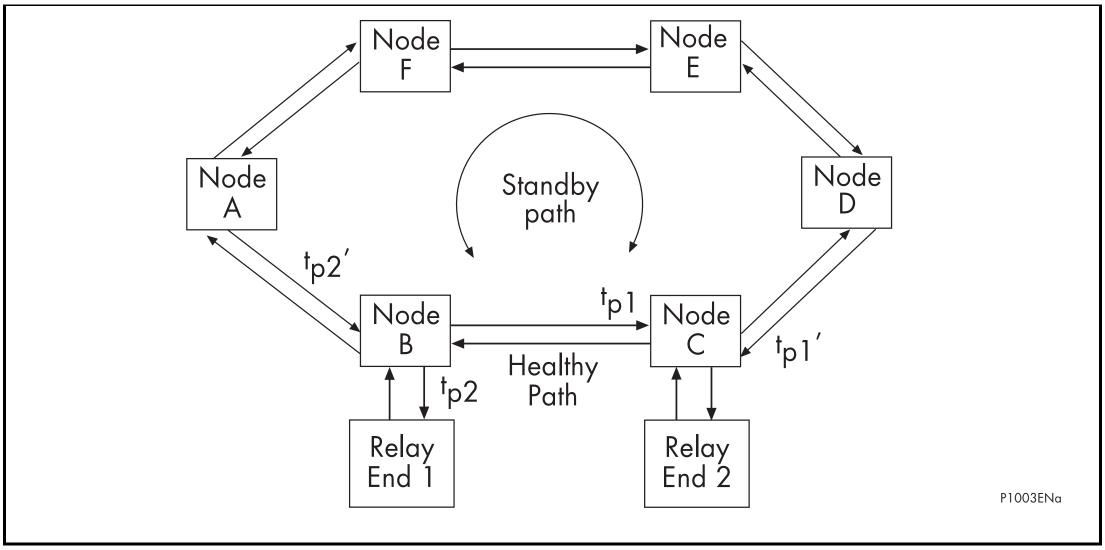

Figure 4: Example of switched synchronous digital hierarchy

P54x make use of the timing information available from the GPS system to overcome the limitation of the traditional technique, and thus allow application to communications that can provide a permanent or semi-permanent split path routing.

A 1 pulse per second output from a GPS receiver is used to ensure that the re-sampling of the currents at each relay occurs at the same instant in time. The technique is thus not dependant on equal transmit and receive propagation delay times; changes in one or both of the propagation delay times also do not cause problems. These factors make it suitable for use with switched SDH networks.

The GPS technique is taken further, however, to overcome concerns about the reliability of the GPS system. Consider a similar two ended system to that of Figure 3 where the re-sampling instants (tAn, tBn) are synchronized using the GPS timing information. Here the re-sampling instants at the two ends will be coincidental as shown in Figure 5. Note that Figure 5 demonstrates a case where the communications path propagation delay times are not the same.

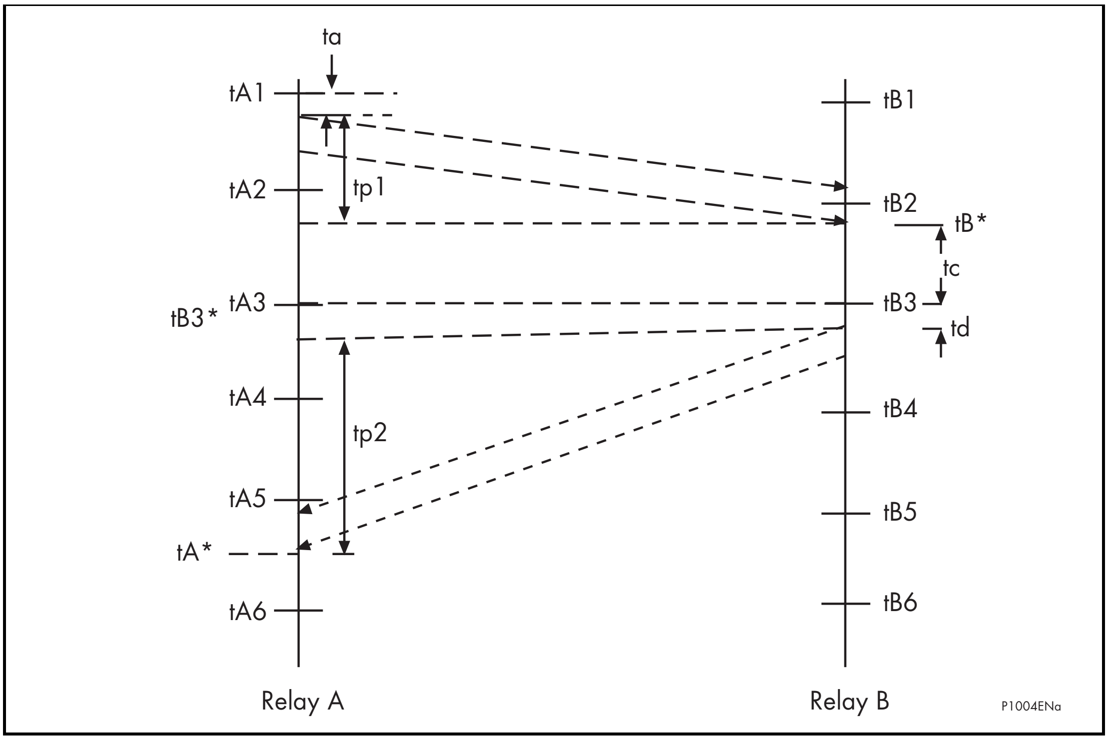

Figure 5: Data transmission

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Note : Relay A can measure the total elapsed time = (tA* - tA1). This equals the sum of the propagation delay times tp1 and tp2, the delay in sending out the initial message ta, and the delay time tc+td at end B. Hence

tp1 + tp2 = tA* - tA1 - ta - tc - td

However, because of the GPS synchronization of the re-sampling instants, tA3 is at the same instant as tB3 (therefore tB3* = tA3) we can use this knowledge to calculate the receive path delay

tp2= tA* - tA3 – td

And, by the same process the relay can also calculate tp1.

In the event of the GPS synchronizing signal becoming unavailable, the synchronization of the re-sampling instants at the different ends will be lost and the sampling will become asynchronous. However, time alignment of the current data will now be performed, by using the memorized value of propagation delay times prior to the GPS outage (tp2 in relay A and tp1 in relay B -Figure 4-). Each relay also keeps measuring the overall propagation delay, tp1+tp2. As long as the overall propagation delay does not exceed the setting value under PROT COMMS/IM64/Comm Delay Tol , it is considered that the communication path has not been switched, tp2 and tp1 at the two ends remains valid and the differential protection remains active. If the overall propagation delay exceeds the above mentioned setting, the differential protection will be inhibited. This patented “fallback” strategy ensures protection continuity even in the event of antenna vandalism, maintenance error, extremely adverse atmospheric conditions etc – all of which could result in GPS outage. Note that tp1 and tp2 do not need to be equal for the fallback strategy to become operational.

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1.1.2 Capacitive charging current (all models)

The charging current of a line or cable will be seen as differential current. If this current is of a sufficiently high magnitude, as is the case for cables and long feeders, then relay maloperation could occur. Two issues are apparent with charging current; the first being inrush during line energization and the second being steady state charging current.

Inrush charging current is predominately high order harmonics (9th and 11th for example). The Fourier filtering used by the P54x relays will remove these frequency components and hence provide stability.

Steady state charging current is nominally at fundamental frequency and hence may cause relay maloperation.

To overcome this problem the P54x relays include a feature to extract the charging current from the measured current before the differential quantity is calculated.

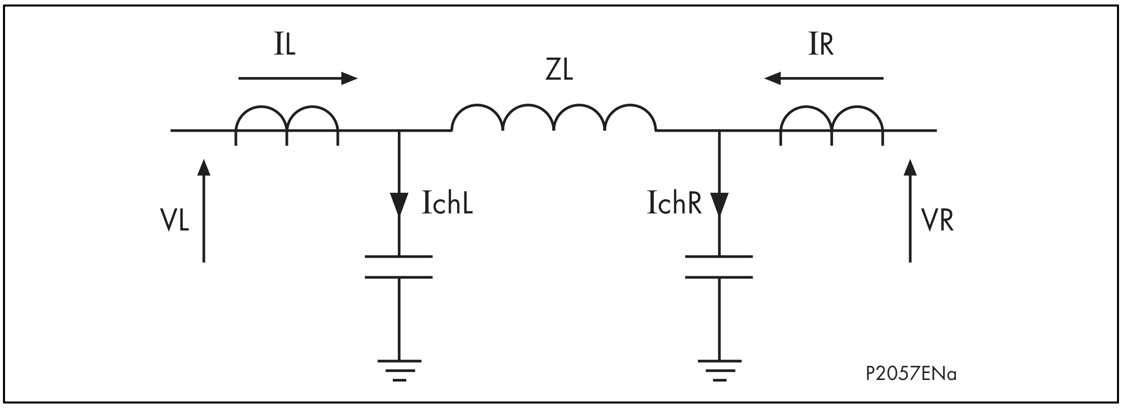

Figure 6: Capacitive charging current

IL = Local end line current

Ir = Remote end line current

VL = Local end voltage

VR = Remote end voltage

ZL = Line impedance

IchL = Local end charging current

IchR = Remote end charging current

By considering Figure 6 it is evident that the line charging current at a particular location is equal to the voltage at that location multiplied by the line positive sequence susceptance. It is therefore possible for the relays at each line end to calculate the respective line charging currents and compensate accordingly.

The differential current (Id) can be calculated as follows:

Id = IL + IR - (jVLBS/2) - (jVRBS/2)

Id = {IL - (jVLBS/2)} + {IR - (jVRBS/2)}

Id = Local relay current + remote relay current

Where BS is the line positive sequence susceptance.

This feature can be selectively enabled or disabled. If selected, the normal phase current data in the protection message is replaced by {I - (jVBS/2)}.

When applying a three end scheme with ends local (L), remote 1 (R1) and remote 2 (R2), the differential current is calculated as follows:

Id = IL + IR1 + IR2 - (jVL Bs/3) - (jVR1 Bs/3) - (jV R2 Bs/3)

Id = {IL - (jVL Bs/3) } + {I R1 - (jV R1 Bs/3) }+ {I R2 - (jV R2 Bs/3) }

Id = Local relay current + remote 1 relay current + remote 2 relay current

Where Bs is the total teed line positive sequence susceptance

i.e. Bs = Bs from L-Tee + Bs from R1 – Tee + Bs from R2 - Tee

The display of currents in the 'Measurements 3' column will be affected by this feature when selected.

1.1.3 CT ratio correction (all models)

To ensure correct operation of the differential element, it is important that under load and through fault conditions, the currents into the differential element of the relay balance. There are many cases where CT ratios at each end of the differential protection are different. Ratio correction factors are therefore provided. The CT ratio correction factors are applied to ensure that the signals to the differential algorithm are correct.

1.1.4 Protection of transformer feeders (P543 and P545)

MiCOM P54x relays can be applied when transformers are located in the differential zone. In order to obtain the correct performance of the relay for this application, MiCOM P54x is provided with:

- Phase compensation to take unto account any phase shift across the transformer, possible unbalance of signals from current transformers either side of windings, and the effects of the variety of earthing and winding arrangements. Within the P543 and P545, software interposing CTs (ICTs) are provided to give the required compensation.
- Inrush restrain to cater for high levels of magnetizing current during inrush conditions.

- CT ratio correction factor as mentioned in section 1.1.3 to match the transformer winding rated currents if needed.

Note that the P544 and P546 relays do not include any of the above features, except CT ratio mismatch compensation, and as such would not be suitable for the protection of in-zone transformer feeders.

On P543 or P545 relays where capacitive charging current compensation is available, there is a setting to select if capacitive charging current compensation is used or if interposing CTs are used.

1.1.4.1 Transformer magnetizing inrush and high set differential setting

The magnetizing inrush current to a transformer appears as a large operating signal to the differential protection. Special measures are taken with the relay design to ensure that no maloperation occurs during inrush.

Figure 7 shows a transformer magnetizing characteristic. To minimize material costs, weight and size, transformers are generally operated near to the 'knee point' of the magnetizing characteristic. Consequently, only a small increase in core flux above normal operating levels will result in a high magnetizing current.

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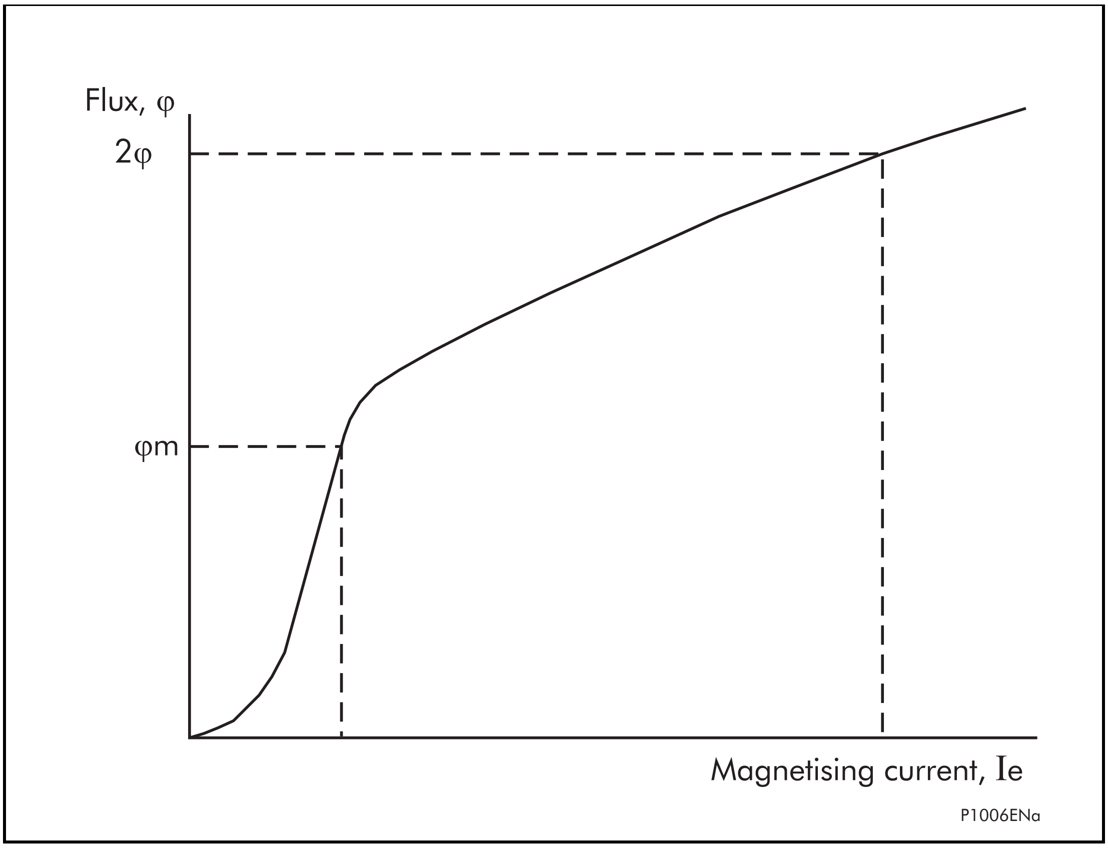

Figure 7: Transformer magnetizing characteristic

Under normal steady state conditions, the magnetizing current associated with the operating flux level is relatively small (usually less than 1% of rated current). However, if a transformer winding is energized at a voltage zero, with no remnant flux, the flux level during the first voltage cycle (2 x normal max. flux) will result in core saturation and in a high, non-sinusoidal magnetizing current waveform. This current is commonly referred to as magnetizing inrush current and may persist for several cycles. The magnitude and duration of magnetizing inrush current waveforms are dependent upon a number of factors, such as transformer design, size, system fault level, point on wave of switching, number of banked transformers, etc. Figure 8 shows typical transformer magnetizing currents for steady state and inrush conditions.

The magnetizing inrush current contains a high percentage of second harmonic. The P543 and P545 relays filter out this component of the waveform and use it as an additional bias quantity. The total bias used by the relay will therefore be a combination of the average load current on the line plus a multiple of the second harmonic component of the current. The multiplying factor is used to ensure stability and is a factory pre-set value.

Where P543 and P545 relays are used and inrush restrain function is enable, it must be ensure that this function is enabled at each end to avoid possible maloperation.

High set differential setting:

When inrush restrain is enabled, a high set differential protection becomes active. This unrestrained instantaneous ' Id High Set ' is provided to ensure rapid clearance for heavy internal faults with saturated CTs. The high set is not restrained by magnetizing inrush. A setting range 4In -32In (RMS values) is provided on P543 and P545

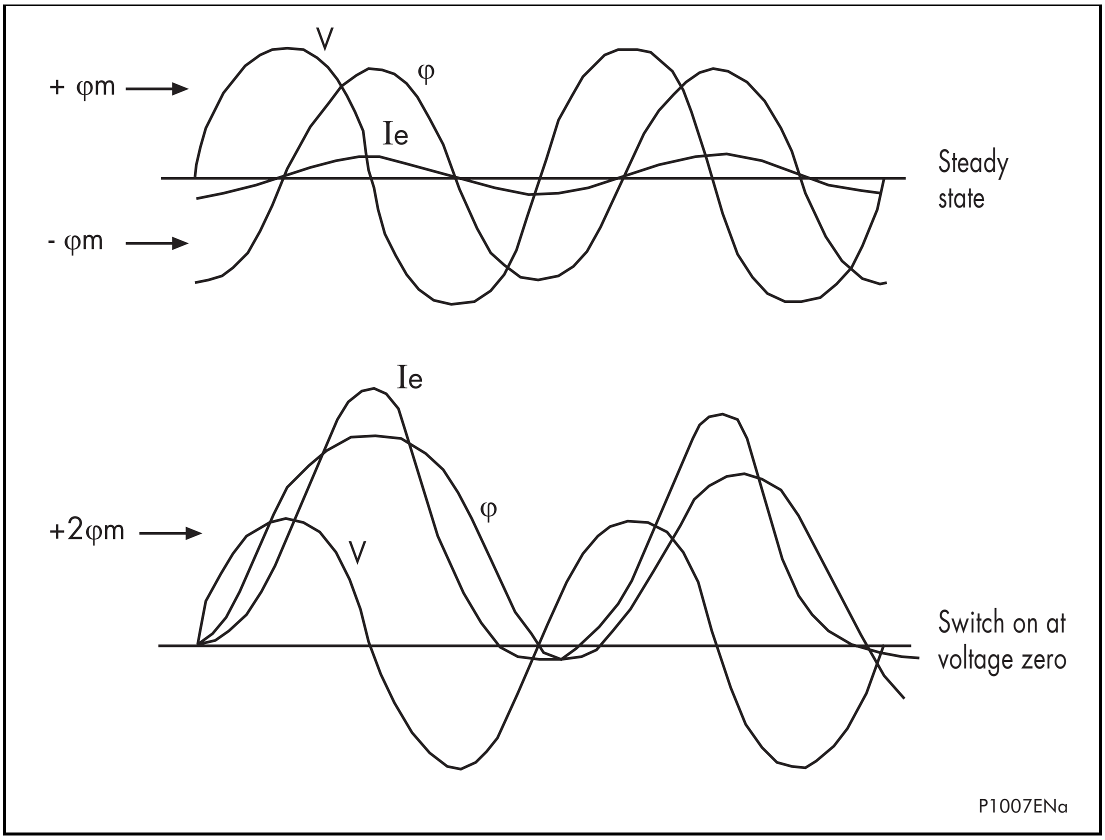

Figure 8: Magnetizing inrush waveforms

1.1.4.2 Phase correction and zero sequence current filtering

To compensate for any phase shift between two windings of a transformer, it is necessary to provide phase correction. This was traditionally provided by the appropriate delta connection of main line CTs. Phase correction is provided in the P54x relays via software interposing CTs.

In addition to compensating for the phase shift of the protected transformer, it is also necessary to mimic the distribution of primary zero sequence current in the protection scheme.

The advantage of having replica interposing CTs is that it gives the P54x relays the flexibility to cater for line CTs connected in either star or delta, as well as being able to compensate for a variety of system earthing arrangements

Figure 9 shows the need for zero sequence current filtering for differential protection across a transformer. The power transformer delta winding acts as a ‘trap’ to zero sequence current. This current is therefore only seen on the star connection side of the transformer and hence as differential current.

The filtering of zero sequence current has traditionally been provided by appropriate delta connection of main line CT secondary windings. In the P54x relays, zero sequence current filtering is automatically implemented in software when a delta connection is set for a software interposing CT. Where a transformer winding can pass zero sequence current to an external earth fault, it is essential that some form of zero sequence current filtering is employed. This would also be applicable where in zone earthing transformers are used.

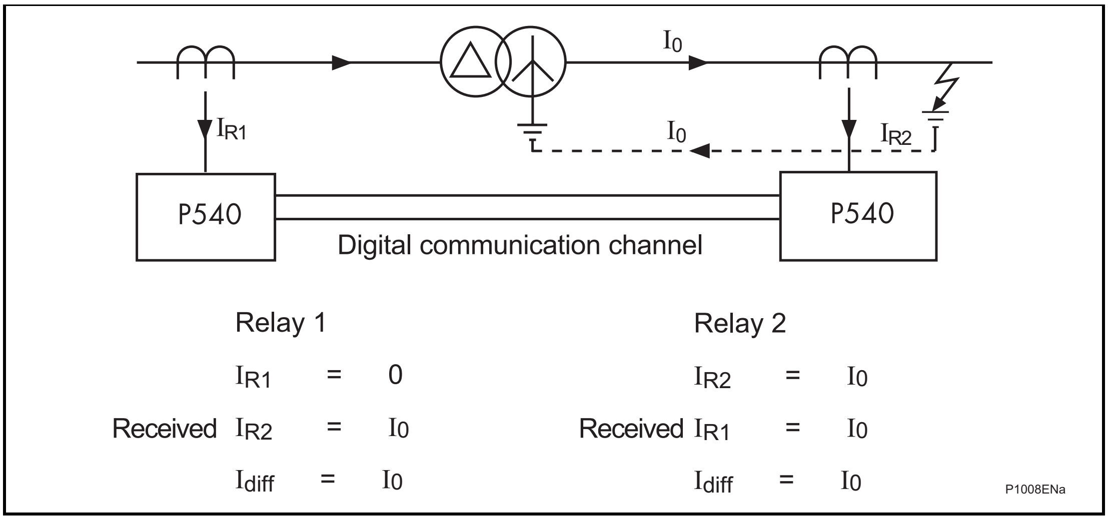

Figure 9: Need for zero-sequence current filtering

1.1.5 3 to 2 terminal reconfiguration

The P54x relays can be configured for the protection of two or three terminal lines. This allows any of the relays to be applied to a two-ended line which may be converted to a three terminal line at a later date. Since only the 'configuration' setting needs to be changed to configure the relay for two or three terminal operation, no hardware changes are required when the third terminal is added, provided that 2 channels of fiber optics are already fitted.

For operational reasons, it may be necessary, under certain circumstances, to switch out one line end and its associated relay on a three terminal circuit. By altering the 'Reconfiguration' setting at any end of the line, an operator can command any pair of relays to work as a two terminal system. The 'configured out' relay can then be switched off, leaving the line to be protected by the other two relays. A restore command can be issued to reconfigure the system back to three terminal operation.

Four reconfiguration settings are available:

- Three ended
- Two ended local and remote 1 (L & R1)
- Two ended local and remote 2 (L & R2)
- Two ended remote 1 and remote 2 (R1 & R2)

Before a configuration command can be successfully initiated, it is necessary to energize the 'reconfiguration interlock' and 'Inhibit Current Differential' opto isolated inputs. The latter input will disable tripping via the current differential elements from all three relays to ensure that the scheme will remain stable during reconfiguration.

It must be ensured that the line end to be 'configured out' is open before issuing a reconfiguration command. If this is not done, any current flowing in or out of the 'configured out' end will be seen as fault current and may cause the other relays to operate.

If the new configuration setting issued to the local relay is L & R1 or L & R2, the trip outputs of the two '2-ended' relays will remain inhibited by the 'Inhibit Current Differential' input at the

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local relay. The ‘inhibit trip/alarm outputs’ opto should be de-energized to enable the trip outputs reconfigured scheme. If the new configuration setting is R1 & R2, the output contacts of the two remote relays will not be inhibited as they will ignore all commands from the local relay.

The scheme may be restored to a three terminal configuration by selecting ‘three ended‘ at any terminal. This will occur irrespective of the status of the opto inputs but is subject to a healthy communications channel being detected.

1.1.6 Mesh corner and 1½ breaker switched substations

If differential protection is applied in a mesh corner or 1½ breaker switched substation, a P544 or P546 should be preferred to use it as they do have two independent CT inputs and therefore each one generates its own restrain. See also P54x/EN AP.

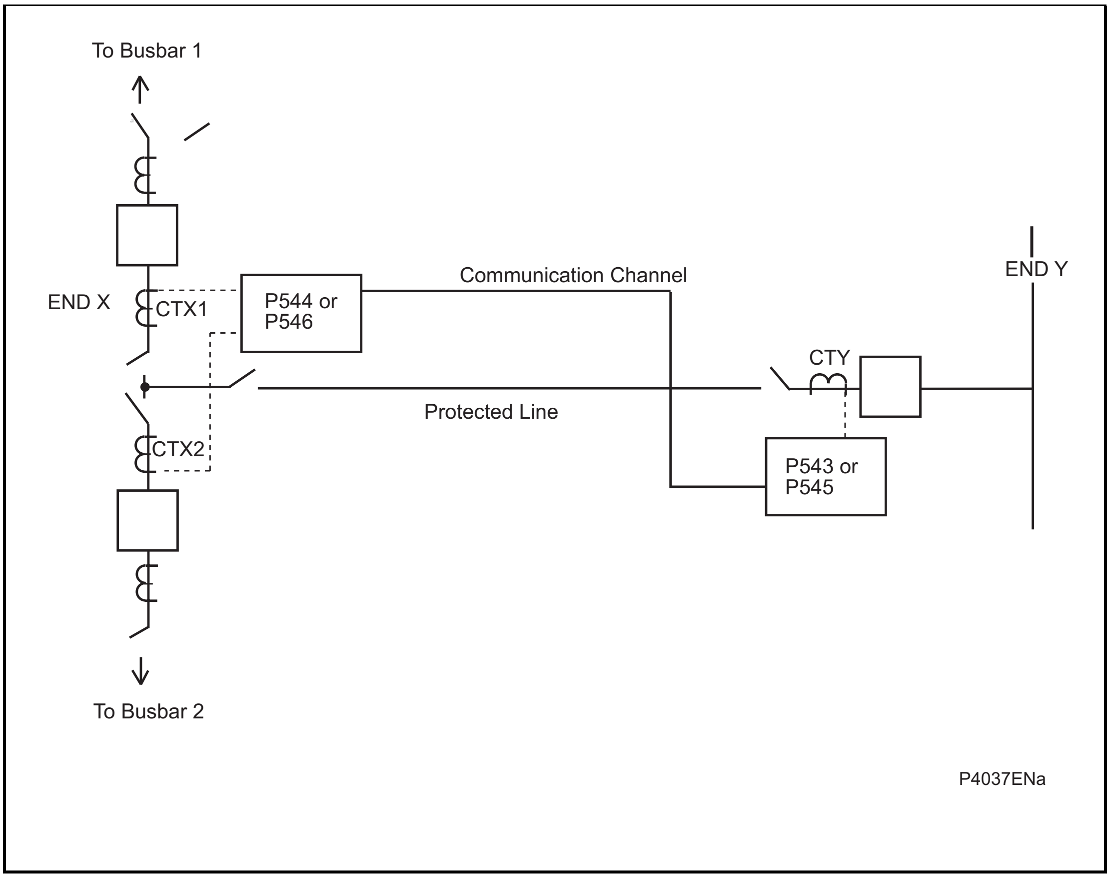

Figure 10: Breaker and a half application

As shown in Figure 10, a P544 or P546 relay should be used at the End X as the line is fed from a breaker and a half substation configuration. At End Y, a P543 or P545 should be installed.

Relay calculations for differential and bias currents are as follows for this case are as follows:

At End X

I diff = $\bar{I}_{CTX1} + \bar{I}_{CTX2} + \bar{I}_{CTY}$

I bias = $(|I_{CTX1}| + |I_{CTX2}|$ + (Additional bias if non zero) or $|I_{REMOTE}|)/2$

In this case Additional bias is zero as the P54x at the remote end has one single CT (P543 or P545).

Additional bias (to be sent to end Y) = is calculated on a per phase basis by scalar summing both local currents (ICTX1 and ICTX2) and selecting the largest of the three calculated. This current is included in the transmitted message.

At End Y

I diff = $\bar{I}_{CTY} + \bar{I}_{CTX1} + \bar{I}_{CTX2}$

I bias = ($|I_{CTY}|$ + (Additional bias if non zero) or $|I_{REMOTE}|$)/2

In this case Additional bias is the one sent by End X (relay with two CT inputs; P544 - P546).

1.1.7 Stub bus protection

The P54x relays include a facility to provide stub bus protection. When the line isolator is open, an auxiliary contact from the isolator can energize an input on the relay to enable this protection. When enabled, all current values transmitted to the remote relays, and all those received from remote relays, are set to zero. The protection will now provide differential protection for the stub zone.

For an internal fault the relay will operate, tripping the two local circuit breakers. When in stub bus mode, the relay will not send a differential intertrip signal.

1.1.8 The minimum operating current

It should be noted that the minimum operating current is related, but not equal to, the Is1 setting.

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Consider a single end fed fault with no load but fault current, I:-

$|Idiff| = I$

$|Ibias| = ½I$

Assuming $|Ibias| < Is2$, then, using the equations from section 1.1, the relay will operate if:-

$|Idiff| > k1.|Ibias| + Is1$ or

$I > k1.½I + Is1$ or

$I > Is1 / (1 - 0.5 k1)$

The minimum operating current is therefore a function of the Is1 and k1 settings. With k1 set to 30% and Is1 set to 0.2 pu, the minimum operating current will be:

$I_{min} = 1.176\ Is1$

$I_{min} = 0.235$ pu

1.2 Disabling/enabling differential protection

The differential function can be globally enabled or disabled using the CONFIGURATION /Phase Diff/Enabled-Disabled setting.

If the differential function is disabled globally (i.e. CONFIGURATION column), no current differential message is transmitted and no current differential measurements (Measurements 3) and channel communication statistics (Measurements 4) are displayed. Therefore a remote connected relay, will display a signaling fail and C Diff failure alarm.

If the differential function is enabled globally (i.e. CONFIGURATION column) and disabled within a group (i.e. group x column), current differential message is exchanged, current differential measurements (Measurements 3) and channel communication statistics (Measurements 4) are displayed, local current differential protection cannot trip but relay can receive a differential inter-trip from the remote end.

1.3 Differential relay compatibility with previous versions

Current differential protection in P54x relays is as follows:

- P543 - P546 models suffix K are compatible with each other
- In non GPS mode P543 - P546 models suffix K are compatible with relay models P543 - P546 suffix B,G and J
- In GPS mode P543 - P546 models suffix K are compatible with relay models P545 - P546 suffix B,G and J
- P543 - P546 models suffix K are not compatible with suffix A models

If a relay suffix K is communicating with a relay suffix B,G or J, a monitor bit labeled "H/W B to J model" in Measurement 4/Channel status will become "1"

Differential current transformer supervision (Differential CTS) in P543 - P546 models suffix K are only compatible with P543 - P546 models suffix K.

1.4 Differential relay without voltage connections

Differential protection does not need phase or neutral voltage connections as this protection relies entirely on the currents measured at each end of the line.

If there are no voltage connections to the P54x relay, the "VTs Connected Yes/No" setting under “CT AND VT RATIOS” should be set to "No". Once set to "No", this will cause the relay VTS logic to set the VTS Slow Block and VTS Fast Block DDBs, but it will not raise any alarms. It will also override the “VTS enabled” setting should the user set it. The purpose of this is to stop the pole dead logic working incorrectly in the absence of voltage and current inputs.

1.5 Line parameters settings

1.5.1 Phase rotation

A setting is used to select whether the 3 phase voltage set is rotating in the standard ABC sequence, or whether the rotation is in reverse ACB order. The appropriate selection is required to ensure that all sequence components and faulted phase flagging/targeting is correct.

1.5.2 Trip mode - selection of single or three phase tripping

This selects whether instantaneous trips are permitted as Single pole, or will always be 3 pole. Protection elements considered as “instantaneous” are those normally set to trip with no intentional time delay, i.e.: Differential, directional earth/ground DEF aided scheme and if fitted, Zone 1 distance and distance channel aided scheme. The selection “1 and 3 pole” allows single pole tripping for single phase to ground faults. The selection “3 pole” converts all trip outputs to close Trip A, Trip B and Trip C contacts simultaneously, for three pole tripping applications.

Logic is provided to convert any double phase fault, or any evolving fault during a single pole auto-reclose cycle into a three phase trip. Two phase tripping is never permitted. This functionality is shown in Figure 11 below, and supplemented by the Pole Dead Logic in the next section.

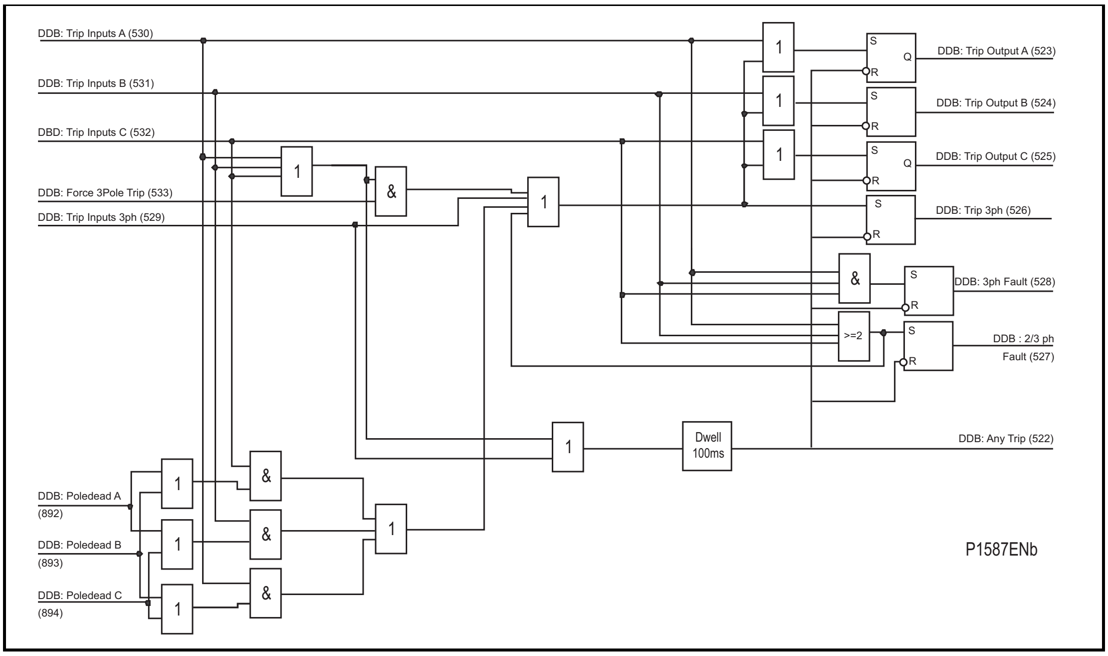

Figure 11: Trip conversion scheme logic

1.5.3 Pole dead logic

Pole dead logic is used by the relay to determine when the circuit breaker poles are open ("pole dead"). This indication may be forced, by means of status indication from CB auxiliary contacts (52a or 52b), or internally determined by the relay. When no auxiliary contacts are available, the relay uses lack of phase current (Setting: CB FAIL & I</UNDER CURRENT/I< Current Set), and an undervoltage level detector (pick up fixed at 38.1V - drop off fixed at 43.8V to declare a "pole dead". Note that if the VT is connected at the busbar side, auxiliary contacts (52a or 52b) must be connected to the relay for a correct pole dead indication. The logic diagrams, Figures 12 & 13 below show the details:

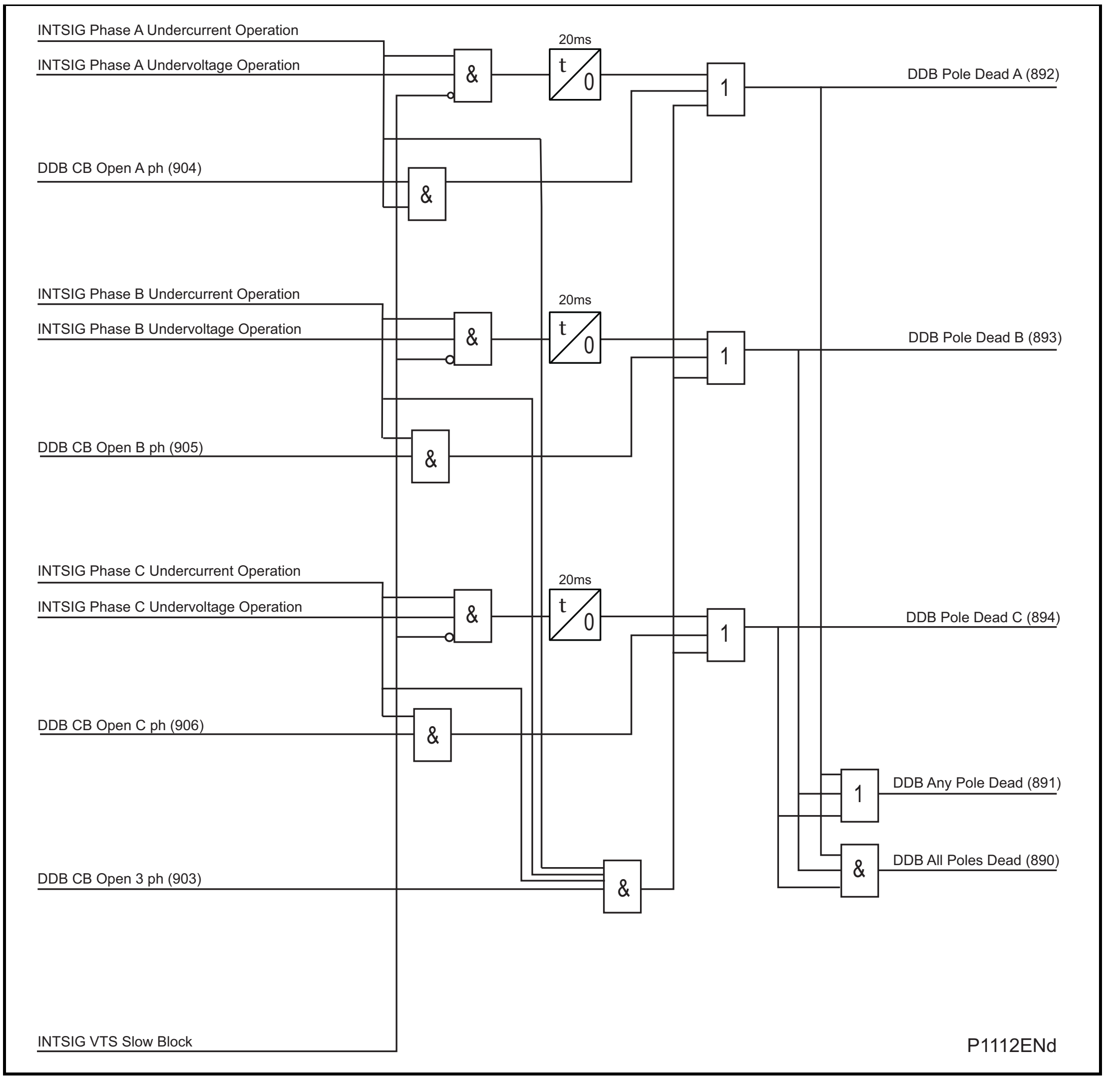

Figure 12: Pole dead logic for P543/P545

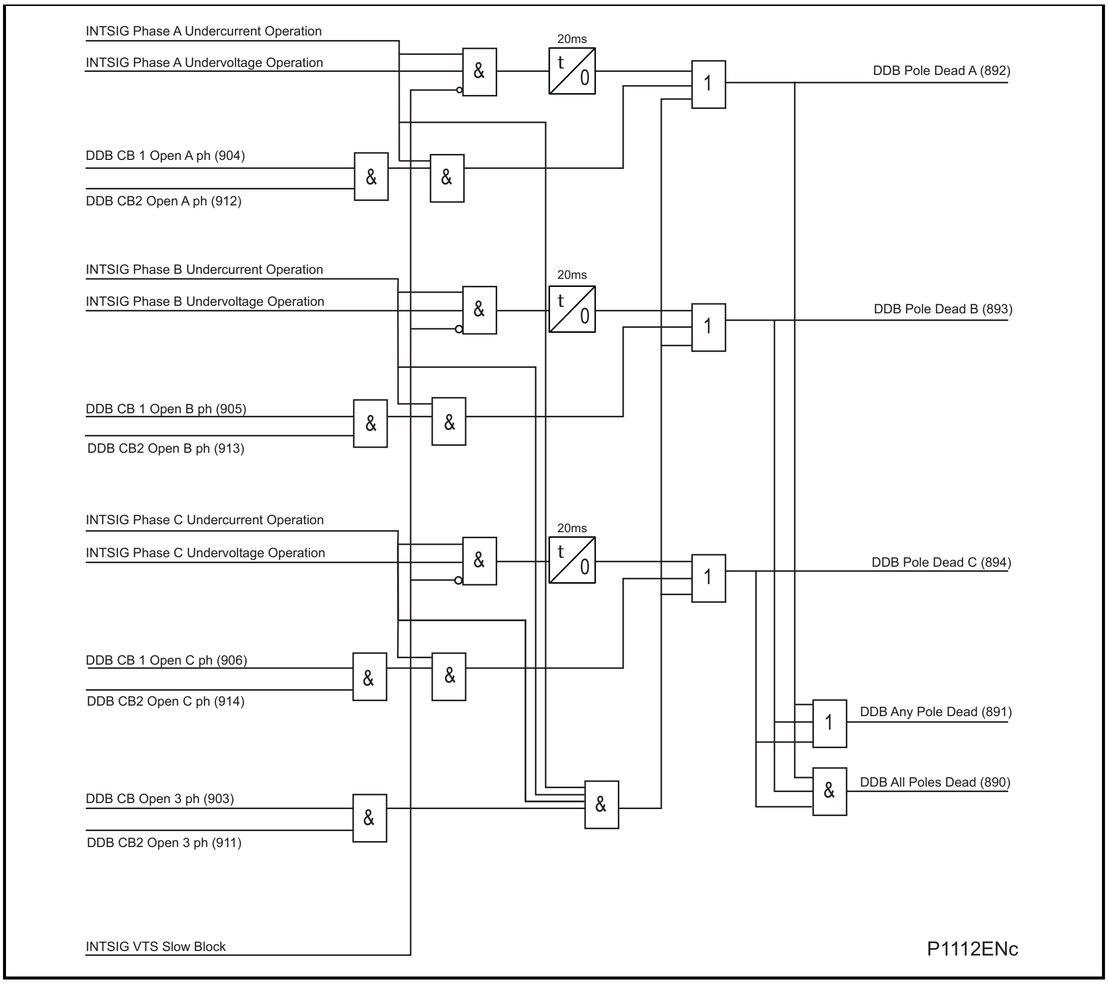

Figure 13: Pole dead logic for P544/P546

Residual compensation for earth/ground faults

For earth faults, residual current (derived as the vector sum of phase current inputs (Ia + Ib + Ic) is assumed to flow in the residual path of the earth loop circuit. Thus, the earth loop reach of any zone must generally be extended by a multiplication factor of (1 + kZN) compared to the positive sequence reach for the corresponding phase fault element.

Caution: The kZN Angle is different than previous LFZP, SHNB, and LFZR relays: When importing settings from these older products, subtract angle ∠ Z1.

1.5.4 Mutual compensation for parallel lines

When applied to parallel circuits mutual flux coupling can alter the impedance seen by the fault locator, and distance zones. The effect on the ground distance elements and on the fault locator of the zero sequence mutual coupling can be eliminated by using the mutual compensation feature provided. This requires that the residual current on the parallel line is measured, as shown in the connection diagram. It is extremely important that the polarity of connection for the mutual CT input is correct.

The major disadvantage of standard mutual compensation is that faults on a parallel line can cause misoperation of the healthy line protection. The P54x uses fast dynamic control of the mutual compensation, which prevents such misoperations of the healthy line protection, while providing correct mutual compensation for faults inside the protected section. The dynamic control is achieved by effectively eliminating the mutual compensation above a set level of parallel line residual current (I MUTUAL) compared to the protected line residual current (IN).

- If the ratio: I MUTUAL/IN is less than the *'Mutual Cutoff'* setting, then full mutual compensation is applied to all distance zones, and the fault locator.
- If the ratio: I MUTUAL/IN is greater than the *'Mutual Cutoff'* setting, then no mutual compensation is applied.

1.6 Phase fault distance protection (optional)

The MiCOM P54x has 5 zones of phase fault protection. It is possible to set all zones either with quadrilateral (polygon) characteristics, or with mho circles. Each zone can be set independently to be permanently disabled, permanently enabled or enabled in case of protection communication channel fail. The impedance plot Figure 14 shows the characteristic when set for mho operation. The characteristic drawn for illustration is based on the default distance settings without dynamic expansion.

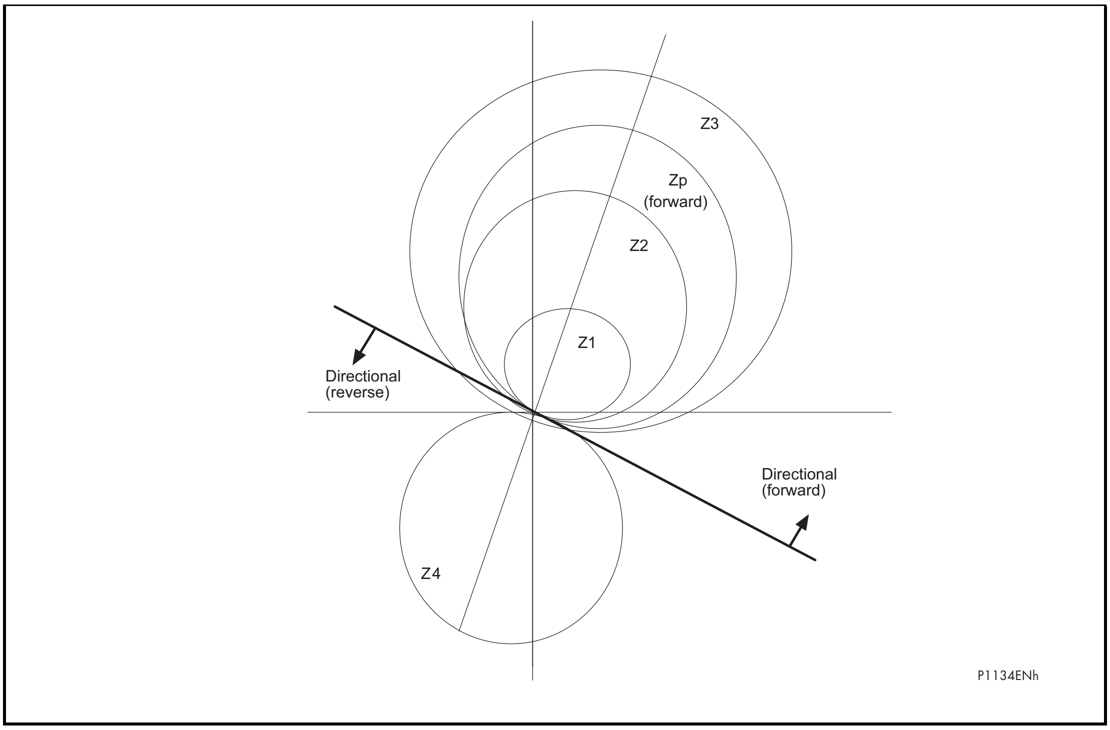

Figure 14: Phase fault Mho characteristics

– The protection elements are directionalized as follows:

– Zones 1, 2 and 3 - Directional forward zones, as used in conventional three zone distance schemes. Note that Zone 1 can be extended to Zone 1X when required in zone 1 extension schemes.

– Zone P - Programmable directionality. Selectable as a directional forward or reverse zone.

– Zone 4 - Directional reverse zone.

1.7 Earth fault distance protection (optional)

The MiCOM P54x has 5 zones of earth (ground) fault protection. It is also possible to set all zones either with quadrilateral characteristics, or with mho circles. The choice of mho or quadrilateral is independent of the general characteristic selection for the phase fault elements. Each zone can be set independently to be permanently disabled, permanently enabled or enabled in case of protection communication channel fail.

All earth fault distance elements are directionalized as per the phase fault elements, and use residual compensation of the corresponding phase fault reach. The impedance plot Figure 15 adds the characteristics when set for quadrilateral operation.

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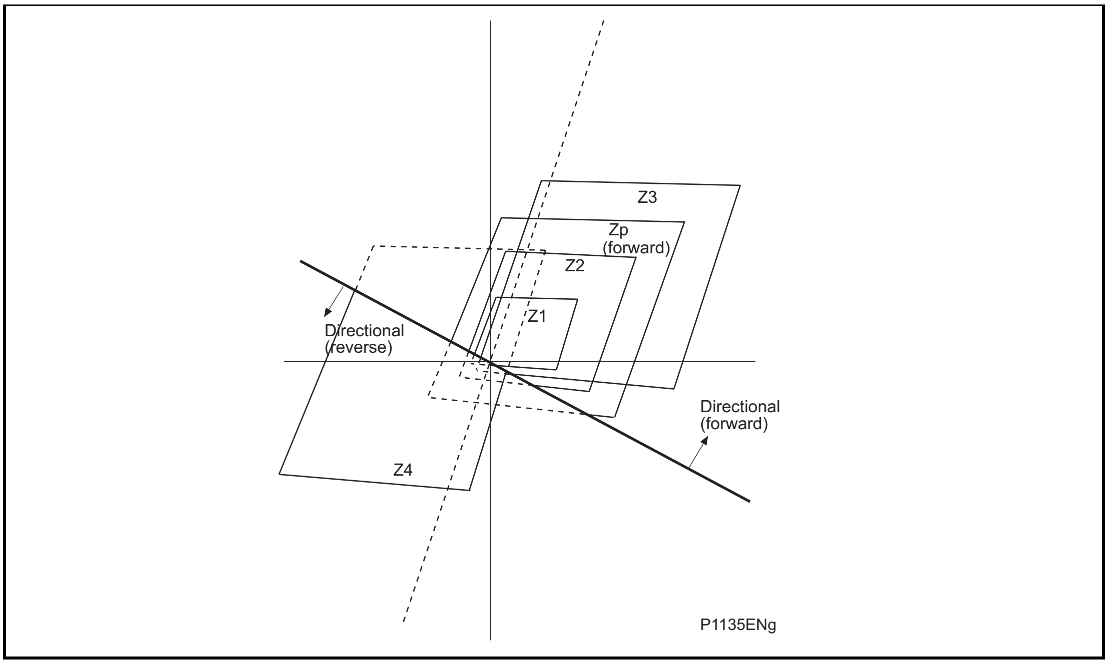

Figure 15: Earth fault quadrilateral characteristics

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1.8 Distance protection tripping decision

For the MiCOM P54x, five conditions would generally need to be satisfied in order for a correct relay trip to result. These are:

- The phase selector needs to identify the faulted phases, and ensure that only the correct distance measuring zones may proceed to issue a trip. Possible phase selections are AN, BN, CN, AB, BC, CA, ABC. For double phase to ground faults, the selection is AB, BC or CA, with N (neutral) just for indication only.
- The loop current for the selected phase-ground or phase-phase loop must exceed the minimum sensitivity for the tripping zone. By default, this sensitivity is 5%In for ground faults, and both of the faulted phases must exceed 5%In for phase-phase faults. The user may raise this minimum sensitivity if required, but this is not normally done.
- The faulted phase impedance must appear within a tripping (measuring) zone, corresponding to the phase selection. Five independent zones of protection are provided. The tripping zones are mho circles or quadrilateral, and selected independently for phase, and ground faults. The ground fault distance elements require compensation for the return impedance, this residual compensation modifies the replica impedance for each zone. Under conditions were a parallel line is present the relay can compensate for the mutual coupling between the lines; this adjusts the replica impedance in the same way as the residual compensated based on the current in the parallel line. The reach setting Z for ground fault mho and quadrilateral elements is determined as follows:

$Z = Z_1 + [(I_{res} / I_P) \times Z_{res}] + [(I_{mut} / I_P) \times Z_{mut}]$

Where:

Z_1 is the positive sequence reach setting

I_P is the current in the faulted phase

I_{res} is the residual current (= $I_a + I_b + I_c$)

Z_{res} is the residual impedance (= $(Z_0 - Z_1)/3$) = $K_{res} \times Z_1$

I_{mut} is the residual current in the parallel line

Z_{mut} is the mutual compensating impedance

- For directional zones within the relay (Zone 1, P, 2, 4 and Z3 if set directional), the delta directional line must be in agreement with the tripping zone. For example, zone 1 is a forward directional zone, and must not trip for reverse faults behind the relay location. A zone 1 trip will only be permitted if the directional line issues a “forward” decision. The converse will be true for zone 4, which is reverse-looking and this needs a reverse decision by the directional line. If the delta directional cannot make a decision then conventional direction lines are used.
- The set time delay for the measuring zone must expire, with the fault impedance measured inside the zone characteristic for the duration. In general, Zone 1 has no time delay (“instantaneous”), all other zones have time delays. Where channel-aided distance schemes are used, the time delay tZ2 for overreaching Zone 2 may be bypassed under certain conditions.

In order to achieve fast, sub-cycle operation, the phase selection, measuring zones and directional line algorithms run in parallel, with their outputs gated in an AND configuration. This avoids sequential measurement which would slow the operation of the relay.

1.9 Phase selection

Phase selection is the means by which the relay is able to identify exactly which phase are involved in the fault and allow the correct measuring zones to trip.

Operation of the distance elements, is controlled by the Superimposed Current Phase Selector. Only elements associated with the fault type selected by the phase selector are allowed to operate during a period of two cycles following the phase selection. If no such element operates, all elements are enabled for the following 5 cycles, before the phase selector returns to its quiescent state.

Operation of an enabled distance element, during the two cycle or 5 cycle period, causes the phase selector state to be maintained until the element resets. The one exception to this is when the phase selector decision changes while an element is operated. In this case, the selected elements are reset and the two cycle period re-starts with the new selection. Note that any existing trip decision is not reset under this condition. After the first cycle following a selection, the phase selector is only permitted to change to a selection involving additional phases.

On double phase to ground faults, only the appropriate phase-phase elements are enabled. The indication of the involvement of ground is by operation of a biased neutral current level detector.

1.9.1 Theory of operation

Selection of the faulted phase(s) is performed by comparing the magnitudes of the three phase-to-phase superimposed currents. A single phase-to-ground fault produces the same superimposed current on two of these signals and zero on the third. A phase-to-phase or double phase-to-ground fault produces one signal which is larger than the other two. A three phase fault produces three superimposed currents which are the same size. Reference is made to Figure 16 to show how the change in current can be used to select the faulted phases for a CN fault.

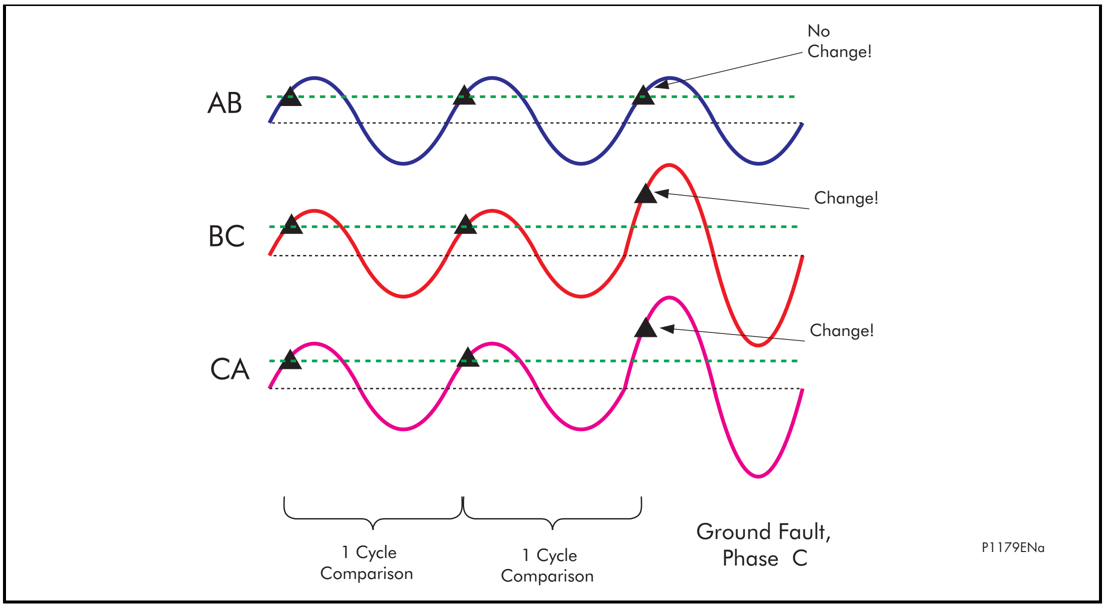

Figure 16: Phase to phase currents showing change for CN fault

A superimposed current is deemed to be large enough to be included in the selection if it is greater than 80% of the largest superimposed current.

A controlled decay of the superimposed threshold ensures that the phase selector resets correctly on fault clearance.

Phase selection can only be made when any superimposed current exceeds 4% of nominal current (In) as a default value.

Under normal power system conditions, the superimposed currents are made by subtracting the phase-phase current sample taken 96 samples (2 cycles) earlier from the present sample.

When a fault is detected, resulting in a phase selection being made, the “previous” memorized sample used in the superimposed current calculation is taken from a re-cycled buffer of “previous” samples. This ensures that, if the fault develops to include other phases, the original selection is not lost. The re-cycling of the prefault buffers is continued until the phase selector resets, either because the fault is cleared or when the 5 cycle period has expired and no element has operated.

Under conditions on load with high levels of sub-synchronous frequencies, it is necessary to increase the ΔI phase selector threshold from its default (4% In) to prevent sporadic operation. This is automatically performed by the relay, which will self-adjust the threshold to prevent operation upon the noise signals, whilst still maintaining a high sensitivity to faults.

In order to facilitate testing of the Distance elements using test sets which do not provide a dynamic model to generate true fault delta conditions, a Static Test Mode setting is provided. This setting is found in the COMMISSIONING TESTS menu column. When set, this disables phase selector control and forces the relay to use a conventional (non-delta) directional line.

1.10 Mho element polarization and expansion

To ensure coverage for close-up faults, distance protection always includes a proportion of voltage memory. Thus, when each zone characteristic is determined, the phase comparator used in the zone decision will use a mix of vectors “V” (the directly measured phase/line voltage), “IZ” (a voltage constructed from the fault current and zone impedance reach setting) and “Vpol” (a polarizing voltage). The MiCOM P54x allows the user to specify the composition of Vpol, deciding on how to mix the proportion of two voltage selections:

The amount of directly measured (“self”) polarizing in the mix;

The amount of clean memory stored from before the fault inception.

One of the additional benefits in adding memory into the polarizing mix is that mho characteristics will offer dynamic expansion in the event of a forward fault. This phenomenon is shown in Figure 17 for the default setting Vpol=1, where a Zone 1 characteristic with reach Z will grow to cover 50% of Zs to cover more fault arc resistance.

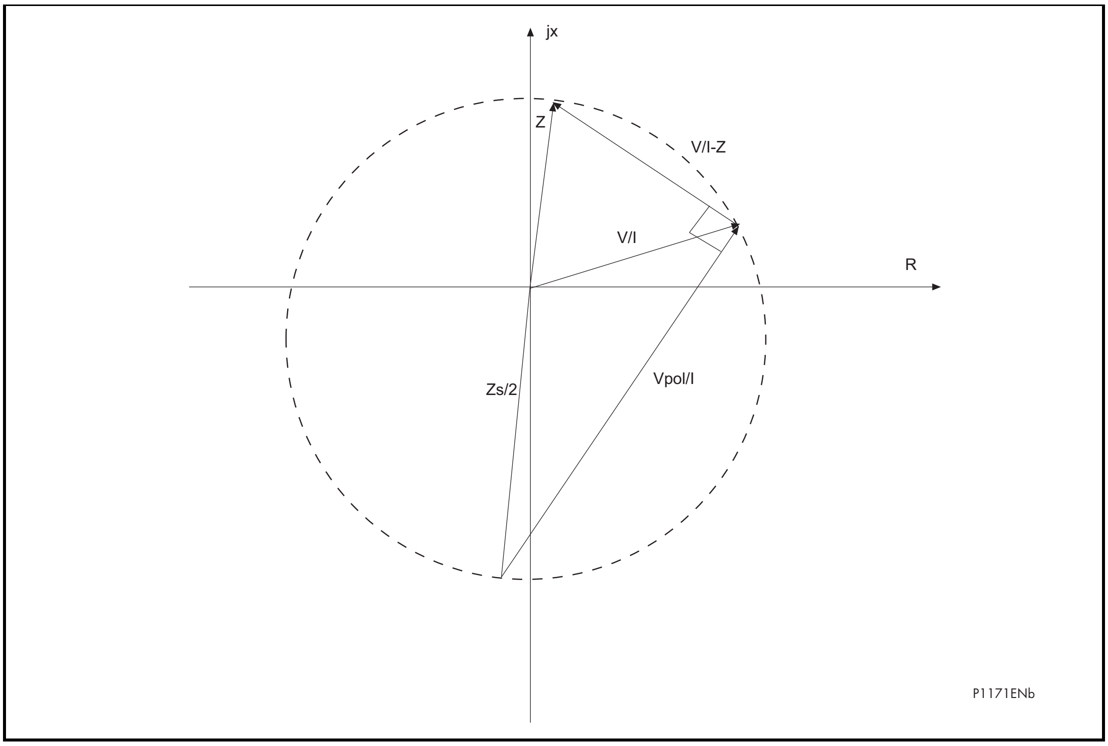

Figure 17: Expansion of zone 1 for the default polarizing setting Vpol=1

Key: Zs = Source impedance behind the relay location

The MiCOM P54x does not allow the polarizing to be selected as entirely self polarized, or entirely memory polarized. Vpol always contains the directly measured self-polarized voltage, onto which a percentage of the pre-fault memory voltage can be added. The percentage memory addition is settable within the range 0.2 (20%) to 5 (500%).

Setting 20% means that the majority of the polarizing will be self-polarizing, with minimal mho circle expansion, and just enough memory to counteract any CVT transients. Setting 500% means that in the overall polarizing mix the ratio would be 1 part self polarizing to 5 parts memory. Such a high memory content would offer large dynamic expansion, covering 83% of the source impedance (Zs) behind the relay.

– Mho expansion = [(Polarizing Setting)/(Setting + 1)] . Zs

This characteristic is used for Zones 1, P (optionally reversed), 2, 4 and Zone 3 if the offset is disabled.

The characteristic is generated by a phase comparison between V/I-Z and the polarizing signal Vpol

Where:

V is the fault voltage

Vpol is a user selected mix of the fault voltage and prefault memory

I is the fault current

Z is the zone reach setting (including residual compensation for ground fault elements)

Zs is the source impedance (included in Figure 17 to show the position of the Vpol phasor)

The polarizing signal Vpol is a combination of the fault voltage and the stored vector taken from 2 cycles before the fault, which is a representation of the volts at the source.

$$Vpol = IZs + V$$

or

$$Vpol/I = Zs + V/I$$

Operation occurs when the angle between the signals is greater than 90°, which is for faults inside the circle.

The validity of the voltage memory in MiCOM P54x extends to 16 cycles after loss of the VT input voltage. If no memory is available, the polarizing signal is substituted by cross polarizing from the unfaulted phase(s). For example if Vamem is unavailable, the voltages measured on phases B and C now are used, phase-shifted as necessary.

To produce the reversed zones (Zone 4 and, optionally, Zone P), the impedance Z is automatically set to a negative value.

1.10.1 Switch on to fault action for zone 1

Operation of the distance elements is generally prevented if the polarizing signal magnitude is insufficient (less than 1V). The exception is for Zone 1, which following breaker closure is allowed to operate with a small (10%) reverse offset. This is to ensure operation when closing on to a close-up three phase fault (Scenario: earthing/ground clamps inadvertently left in position).

In addition Z4 reverse operation is held if it operates in memory.

Other zones may have their zone time delays bypassed for SOTF/TOR, as detailed in the application notes.

1.10.2 Offset Mho

If the Zone 3 offset is enabled then it uses no memory polarizing and has a fixed reverse offset from the origin of a distance polar diagram. Characteristic angle and residual compensation as per the forward settings.

1.11 Quadrilateral elements

The quadrilateral elements are made from combinations of reactance lines, directional lines and load blinders.

A counter, similar to that used for the mho element, is incremented when all the relevant phase comparisons indicate operation. A fast up-count of 6 is issued when the fault is within 80% of the reach of the zone, and well within the resistive reach boundary. Elsewhere, the increment is always 1 but a fast decrement (6) is used when the faulted phase current is less than half the minimum operating current setting. Thus, an area of fast operation for faults near the characteristic angle is always available, whether mho or quadrilateral characteristics are applied.

1.11.1 Directional quadrilateral

This characteristic is used for Zones 1, P (optionally reversed), 2 and 4 (reversed).

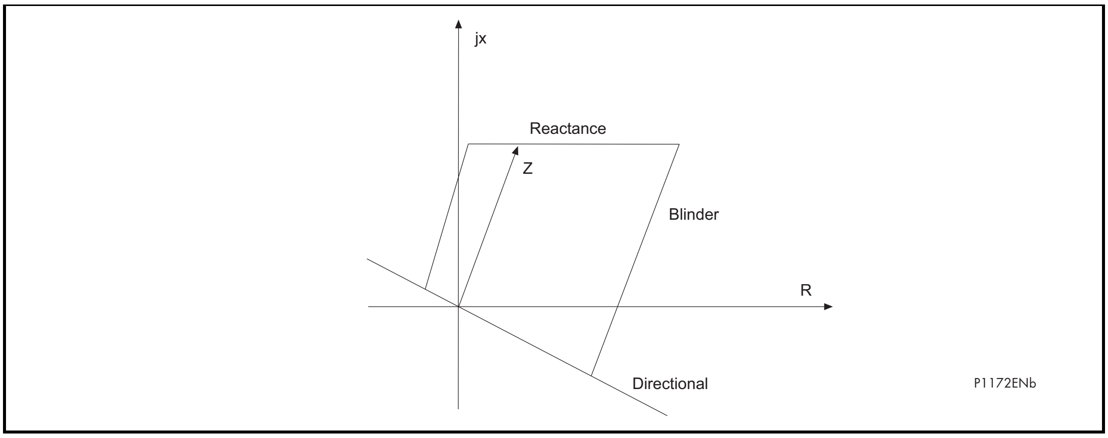

Figure 18: Quadrilateral characteristics (directional line shown simplified)

It is formed from two parallel reactance lines, two parallel resistive reach blinders and controlled by the delta or conventional directional line. The bottom reactance line (not shown on Figure 18) and the left hand reach blinder are automatically set to 25% of the reactance reach and the right hand blinder, respectively. The reactance line is arranged to operate for faults below the line, the blinders for faults within the resistive reach limits, and the delta directional line for forward faults. The counter increments when all of these conditions are satisfied.

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1.11.2 Offset quadrilateral

This characteristic is used for Zone 3 when the offset is enabled.

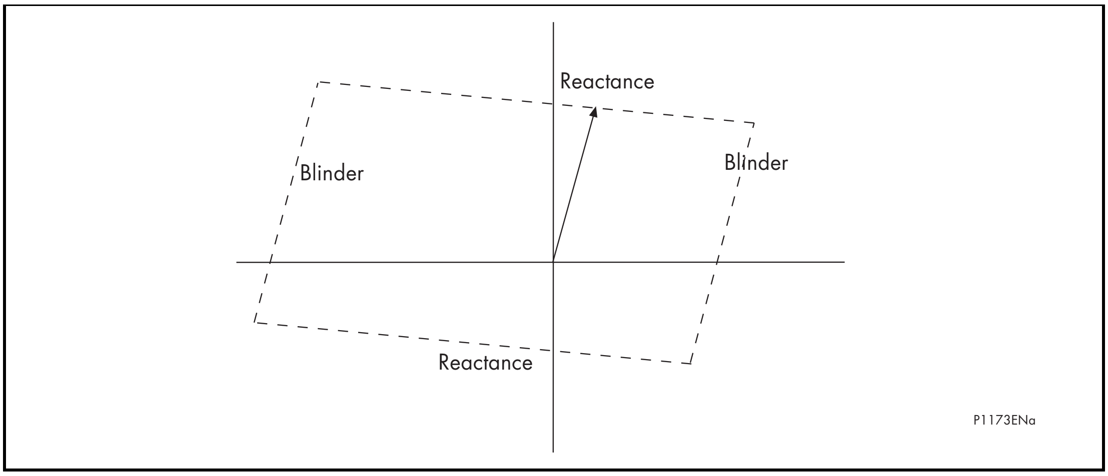

Figure 19: Offset quadrilateral for zone 3

It is formed from two reactance lines and two resistive reach blinders. The upper reactance line is arranged to operate for faults below it and the lower for fault above it. The right hand blinder is arranged to operate for faults to its left and the left hand blinder for faults to its right. The counter increments when all these conditions are satisfied.

It should be noted that when Zone 3 is set offset in simple setting mode, the left hand blinder and lower reactance line equal the offset percentage setting of the line impedance and fault resistance respectively. In the advanced setting mode, both lines can be set independently.

1.11.3 Reactance line - top line of quadrilateral

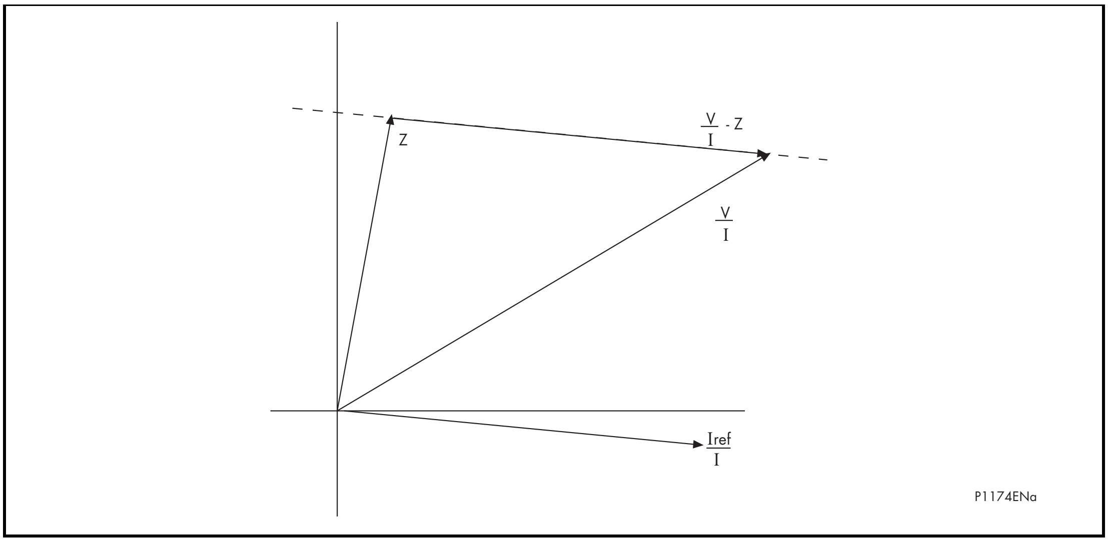

Figure 20: Reactance line - top line of quadrilateral

A reactance line is formed by the phase comparison between an operating signal V/I - Z, which is the same as that used for the equivalent mho element, and a polarizing signal Iref/I.

Where:

V is the fault voltage

I is the fault current

Z is the zone reach setting, including residual compensation

Iref is the negative sequence current, with a -3° phase shift for ground distance

Iref is the fault current with a user settable tilt angle applied, for phase distance

Operation occurs when the operating signal lags the polarizing signal.

Negative sequence current is used for ground fault Iref since it provides a better estimate of the current in the fault than either the faulted phase current or zero sequence current. As a result the reactance line follows the fault resistance impedance and tilts up or down (depending on the load direction) to avoid underreach or overreach.

The -3° phase shift is introduced to reduce the possibility of overreach caused by any small differences between the negative sequence source impedances, and general CT/VT angle tolerances.

The following additional constraints also exist to ensure that the top line does not tilt too far:-

- The Zone 1 reactance (top) line can only stay at -3° droop compared to the resistive axis, or can tilt down. The top line may never tilt up, to ensure that Zone 1 does not overreach. This maintains grading/selectivity with downstream protection.
- The Zone 2 reactance (top) line can only ever stay at -3° droop compared to the resistive axis, or can tilt up. The top line may never tilt down, to ensure that Zone 2 does not underreach. This is particularly important when Zone 2 is used to key channel-aided distance schemes.
- The maximum permissible tilt is +/- 45° either side of the nominal -3° degree fixed droop.

When one circuit breaker pole is open, during a single pole reclose sequence, the polarizing signal is replaced by the fault current with a -7° phase shift, allowing the protection of the remaining phases, even though the negative sequence current is not available. The additional phase shift is provided to reduce the possibility of overreach caused by the faulted phase as the reference.

1.11.4 Right hand resistive reach line

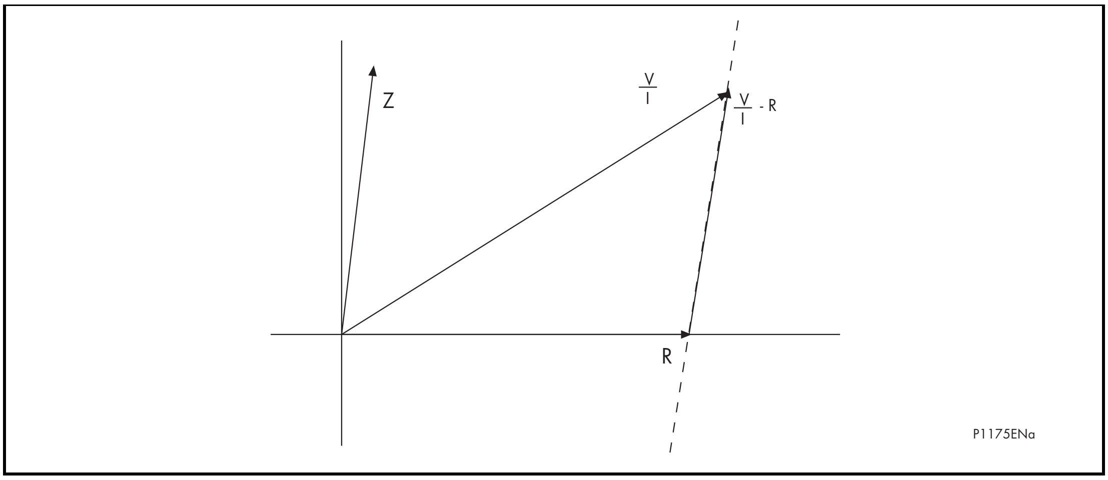

Figure 21: Resistive reach line (load blinder)

A load blinder is formed by the phase comparison between an operating signal V/I - R and a polarizing signal Z

Where:

V is the fault voltage

I is the fault current

R is the resistive reach of the blinder

Z zone reach setting (including neutral compensation for ground distance)

Operation occurs when the operating signal leads the polarizing signal.

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1.12 Quadrilateral phase resistive reaches

The resistive reach setting is used to select the resistive intercept of the quadrilaterals – the right-hand side of the zone. Note that the RPh setting applied defines the fault arc resistance that can be detected for a phase-phase fault. For such a fault, half of the fault resistance appears in the positive sequence network, and half in the negative sequence network. Thus, as most injection test sets will plot impedance characteristics in positive sequence terms, the right-hand intercept will be found at half the setting applied (= Rph/2).

1.13 Quadrilateral ground resistive reaches

The resistive reach setting is used to select the resistive intercept of the quadrilaterals – the right-hand side of the zone. Note that the RG setting applied defines the fault arc resistance that can be detected for a single phase-ground fault. For such a fault, the fault resistance appears in the out and return total fault loop, in which the line impedance is Z1 x (1 + kZN). Thus, as most injection test sets will plot impedance characteristics in positive sequence terms, the right-hand intercept will be found at less than setting applied (= RG/[1+kZN]).

1.14 Distance directional principle and setup

The characteristic angle set in this section is used by the DISTANCE PROTECTION. Distance zones are directionalized by the delta decision.

Delta directional looks at the relative phase angle of the superimposed current ΔI compared to the superimposed voltage ΔV, at the instant of fault inception. The delta is only present when a fault occurs and a step change from the prefault steady-state load is generated by the fault itself.

Under healthy network conditions, the system voltage will be close to Vn nominal, and load current will be flowing. Under such steady-state conditions, if the voltage measured on each phase now is compared with a stored memory from exactly two power system cycles previously (equal to 96 samples), the difference between them will be zero. Zero change equals zero "delta" ($\Delta V = 0$). The same will be generally true for the current ($\Delta I = 0$), except when there are changes in load current etc.

When a fault occurs on the system, the delta changes measured will be:

ΔV = fault voltage (time "t") - prefault healthy voltage (t-96 samples)

ΔI = fault current (time "t") - prefault load current (t-96 samples)

The delta measurements are a vector difference, resulting in a delta magnitude and angle. Under healthy system conditions, the prefault values will be those measured 2 cycles earlier, but when a fault is detected, the prefault values will be retained for the duration of the fault.

The changes in magnitude are used to detect the presence of the fault, and the angles are used to determine whether the fault is in the Forward or Reverse direction.

Consider a single phase to ground fault as shown in Figure 22 below.

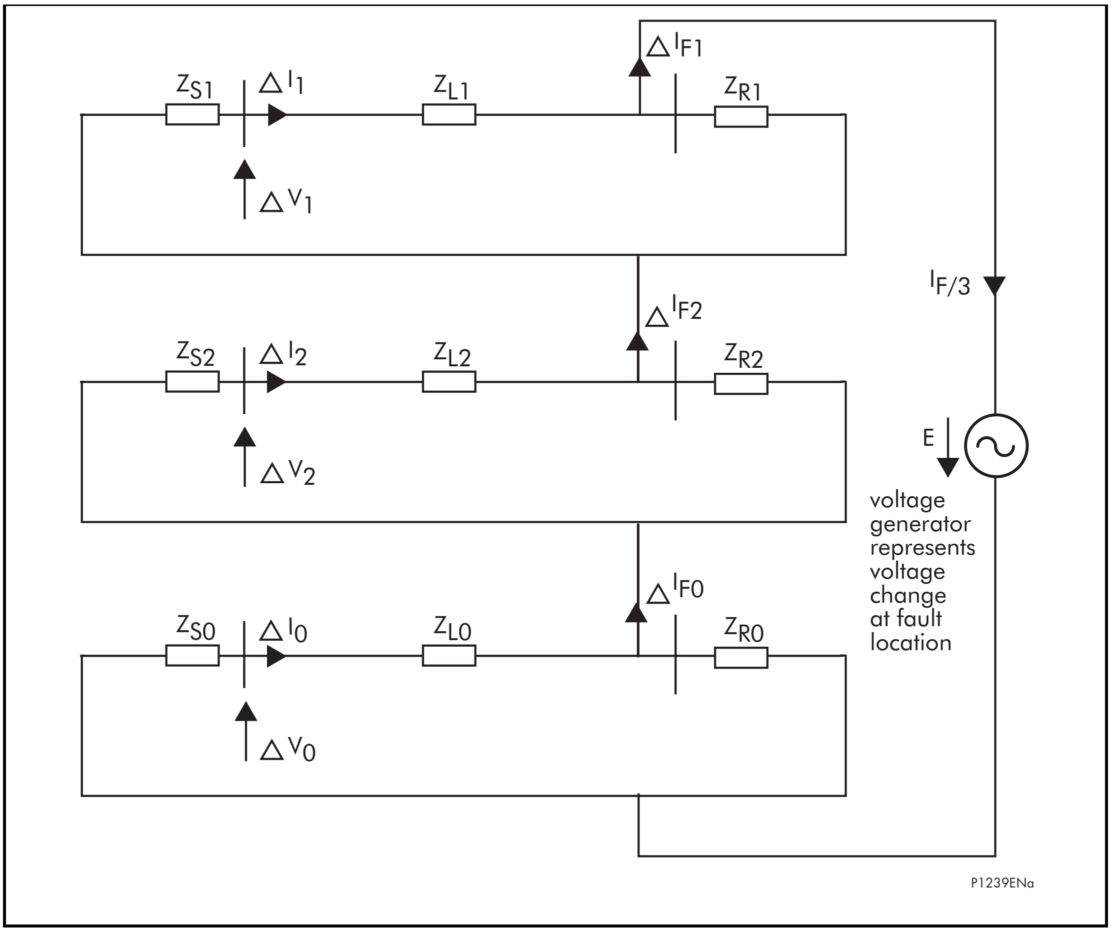

Figure 22: Sequence networks connection for an internal A-N fault

The fault is shown near to the busbar at end R of the line, and results in a connection of the positive, negative, and zero sequence networks in series. Drawing the delta diagram, it is seen that any fault is effectively a generator of Δ, connected at the location of fault inception. The characteristics are:

1. The ΔI generated by the fault is equal to the total fault arc current
2. The ΔI will split into parallel paths, with part contribution from source "S", and part from remote end "R" of the line. Therefore, each relay will measure a lower proportion of delta I

3. The ΔV generated by the fault is equal to the fault arc voltage minus the prefault voltage (and so will be in antiphase with the prefault voltage)

The ΔV will generally be smaller as measured at the relay location, due to the voltage collapse being smaller near to the source than at the fault itself. The delta V measured by a relay is effectively the voltage drop across the source impedance behind the relay location.

If a fault were to occur at any point on the protected line, the resulting ΔI and ΔV as measured at the relay location must be greater than the “Delta I Fwd” and “Delta V Fwd” thresholds, in order that the fault can be detected. Scenarios (2) and (4) above must be verified for all fault types: Ph-G, Ph-Ph, Ph-Ph-G, and 3-phase)

1.14.1 Delta directional decision

On fault inception, delta quantities are generated, and it is then simple for the relay to determine the direction of the fault:

Forward fault - Delta V is a decrease in voltage, and so is in the negative sense; whereas delta I is a forward current flow and so is in the positive sense. Where delta I and delta V are approximately in antiphase, the fault is forward. The exact angle relationship for the forward fault is:

$\Delta V/\Delta I$ = - (source impedance, Zs)

Reverse fault - Delta V is a decrease in voltage, and so is in the negative sense; delta I is an outfeed flowing in the reverse direction, so that too is in the negative sense. Where delta I and delta V are approximately in phase, the fault is reverse. The exact angle relationship for the reverse fault is:

$\Delta V/\Delta I$ = - (remote source impedance Zs’ + ZL)

Where ZL is protected line impedance and Zs’ source impedance behind the relay.

An RCA angle setting in the relay allows the user to set the center of the directional characteristic, according to the amount the current will nominally lag the reference delta voltage. The characteristic boundary will then be ± 90 degrees either side of the set center.

ΔV=0.5V and ΔI=4%In. If the fault ΔV is below the setting of 0.5V, a conventional distance line ensures correct forward/reverse polarizing.

The directional criteria for delta directional decisions are given below:

Directional forward

-90o < (angle(ΔI) - angle(ΔV+180^{o}) - RCA) < 90^{o}

Directional reverse

-90^{o} > (angle(ΔI) - angle(ΔV+180^{o}) - RCA) > 90^{o}

In order to facilitate testing of the Distance elements using test sets which do not provide a dynamic model to generate true fault delta conditions, a Static Test Mode setting is provided. This setting is found in the COMMISSIONING TESTS menu column. When set, this disables phase selector control and forces the relay to use a conventional (non-delta) directional line.

1.15 Advanced distance elements zone settings

For most applications the user will configure the relay in “Simple” setting mode, whereby all zone reaches are based on the protected line impedance, scaled by a reach percentage. In such a case there is then no need to set the individual zone ohmic reaches and compensation factors, because the automatic calculation will already have determined these settings. Thus with Simple settings, the menu column “GROUP x DISTANCE ELEMENTS” will merely be a list of what settings have been automatically calculated and applied. This list is useful as a reference when commissioning and periodic injection testing.

Using the “Advanced” setting mode, the user has decided to set all the zones him/herself, and must complete all the reach and residual/mutual compensation settings on a per zone basis.

Note that distance zones are directionalized (where applicable) by a delta directional decision. The characteristic angle for this decision is set along with the Delta Directional configuration, in the “GROUP x DIRECTIONAL FN” menu column. The default setting is 60°.

1.15.1 Phase fault zone settings

It can be noted that each zone has two additional settings that are not accessible in the Simple set mode. These settings are:

– A tilt angle on the top line of any quadrilateral set for phase faults;

– A minimum current sensitivity setting.

By factory defaults, the Top Line of quadrilateral characteristics is not fixed as a horizontal reactance line. To account for phase angle tolerances in the line CT, VT and relay itself, the line is tilted downwards, at a “droop” of -3°. This tilt down helps to prevent zone 1 overreach.

The current *Sensitivity* setting for each zone is used to set the minimum current that must be flowing in each of the faulted phases before a trip can occur. If for example a phase A-B line fault is present, the relay must measure both currents Ia and Ib above the minimum set sensitivity. The default setting is 7.5% In for Zones 1 and 2, 5% In for other zones, ensuring that distance element operation is not constrained, right through to an SIR ratio of 60.

1.15.2 Ground fault zone settings

It should be noted that the Ground reach settings (Reach and Angle) are set according to the **positive sequence line impedance**, and so will generally be identical to the Phase reach settings.

The Top Line of ground quadrilateral characteristics is not fixed as a horizontal reactance line. To account for phase angle tolerances in the line CT, VT and relay itself, the line is tilted downwards, at a “droop” of -3°. This tilt down helps to prevent zone 1 overreach. However, to further improve performance this line incorporates an additional dynamic tilt, which will change according to the phase angle between the faulted phase current and the negative sequence current:

– Zone 1 is allowed to tilt down to avoid overreaching for prefault power export;

– Zones 2 and 3 are allowed to tilt up to avoid underreaching for prefault power import.

As the tilt is dynamic, this is why ground fault elements do not have a setting for the angle.

The current *Sensitivity* setting for each zone is used to set the minimum current that must be flowing in the faulted phase and the neutral before a trip can occur. If for example an A-ground fault is present, the relay must measure both currents Ia and Iresidual above the minimum set sensitivity. The default setting is 5% In, ensuring that distance element operation is not constrained, right through to an SIR ratio of 60.

1.16 Conventional voltage transformer and capacitor VT applications

The MiCOM P54x achieves fast trip times due an optimized counting strategy. For faults on angle and up to 80% of the set reach of the zone, a counter increments quickly to reach the level at which a trip is issued. Near the characteristic boundary, the count increments slower to avoid transient overreach, and to ensure boundary accuracy. This strategy is entirely sufficient where conventional wound voltage transformers are used. Thus, where capacitor-coupled voltage transformers (CVT) are not employed, the setting “CVT Filters” can be set to Disabled.

Where capacitor-coupled voltage transformers are employed, then for a close-up fault the transient component can be very large in relation to the fundamental component of fault voltage. The relay has setting options available to allow additional filtering to be switched-in when required, and the filter options to use depend on the likely severity of the CVT transient. The two filtering methods are explained below.

1.16.1 CVTs with passive suppression of ferroresonance

Passive suppression employs an anti-resonance design, and the resulting transient/distortion is fairly small. Sometimes such suppression is classed as a “type 2” CVT. In passive CVT applications, the affect on characteristic accuracy is generally negligible for source to line impedance ratios of less than 30 (SIR < 30). However, at high SIRs it is advisable to use the slower count strategy. This is achieved by setting “*CVT Filters*” to “Passive”.

It is important to note that by enabling this filter, the relay will not be slowed unless the SIR is above that set. If the line terminal has an SIR below the setting, the relay can still trip subcycle. It is only if the SIR is estimated higher than the setting that the instantaneous operating time will be increased by about a quarter of a power frequency cycle. The relay estimates the SIR as the ratio of nominal rated voltage Vn to the size of the comparator vector IZ (in volts):

SIR = Vn/IZ

Where:

Vn = Nominal phase to neutral voltage

I = Fault current

Z = Reach setting for the zone concerned

Thus for slower counting “I” would need to be low, as restricted by a relatively weak infeed, and “Z” would need to be small as per a short line.

1.16.2 CVTs with active suppression of ferroresonance

Active suppression employs a tuned L-C circuit within the CVT. The damping of transients is not as efficient as for the passive designs, and such suppression is often termed as being a “type 1” CVT. In active CVT applications, to ensure reach point accuracy the setting “CVT *Filters*” is set to “Active”. The relay then varies the count strategy according to the calculated SIR (= Vn / IZ). Subcycle tripping is maintained for lower SIRs, up to a ratio of 2, with the instantaneous operating time increasing by about a quarter of a power frequency cycle at higher SIRs.

Transients caused by voltage dips, however severe, will not have an impact on the relay’s directional measurement as the MiCOM P54x uses voltage memory.

1.17 Load blinding (load avoidance)

Load blinders are provided for both phase and ground fault distance elements, to prevent misoperation (mal-tripping) for heavy load flow. The purpose is to configure a blinder envelope which surrounds the expected worst case load limits, and to block tripping for any impedance measured within the blinded region. Only a fault impedance which is outside of the load area will be allowed to cause a trip. The blinder characteristics are shown in Figure 23.

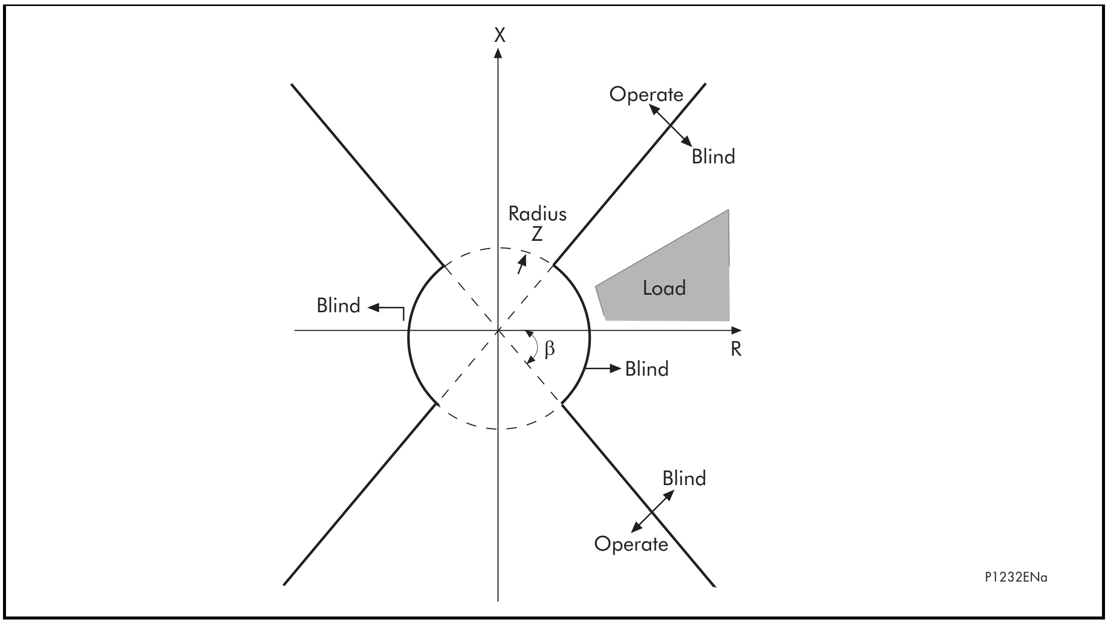

Figure 23: Load blinder characteristics

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In Figure 23:

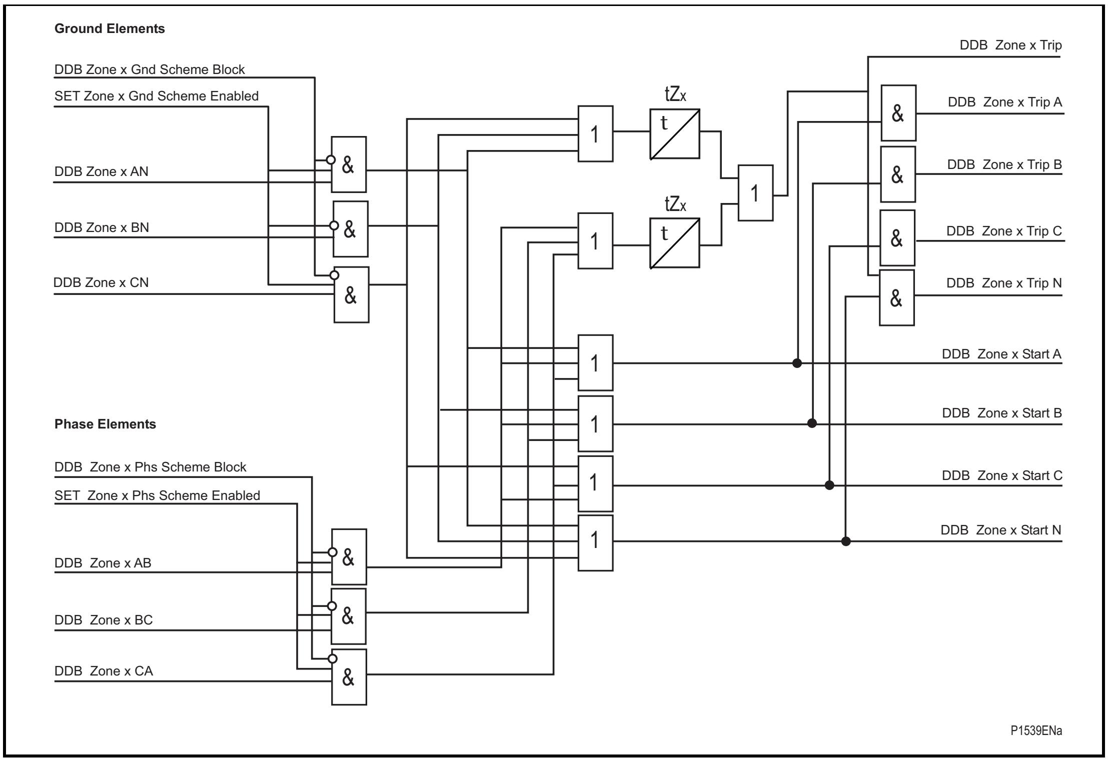
– Z denotes the Load/B Impedance setting. This sets the radius of the underimpedance circle.

– β denotes the Load/B Angle setting. This sets the angle of the two blinder boundary lines - the gradient of the rise or fall with respect to the resistive axis.

The MiCOM P54x has a facility to allow the load blinder to be bypassed any time the measured voltage for the phase in question falls below an undervoltage V< setting. Under such circumstances, the low voltage could not be explained by normal voltage excursion tolerances on-load. A fault is definitely present on the phase in question, and it is acceptable to override the blinder action and allow the distance zones to trip according to the entire zone shape. The benefit is that the resistive coverage for faults near to the relay location can be higher.

1.18 Distance elements basic scheme setting

Configuration of which zones will trip, and the zone time delays is set in the menu column “GROUP x SCHEME LOGIC” (where “x” is the setting group). Phase and ground elements may have different time delays if required. Operation of distance zones according to their set time delays is termed the “Basic Scheme”, and is shown in Logic Diagram Figure 24 which follows. The basic scheme always runs, regardless of any channel-aided acceleration schemes which may be enabled (see later).



Signal	Zone 1	Zone 2	Zone 3	Zone P	Zone 4
Zone x Ground Block	384	386	388	390	392
Zone x Phase Block	385	387	389	391	393
Zone x AN	960	966	972	978	984
Zone x BN	961	967	973	979	985
Zone x CN	962	968	974	980	986
Zone x AB	963	969	975	981	987
Zone x BC	964	970	976	982	988
Zone x CA	965	971	977	983	989
Zone x Trip	608	613	618	623	628
Zone x Trip A	609	614	619	624	629
Zone x Trip B	610	615	620	625	630
Zone x Trip C	611	616	621	626	631
Zone x Trip N	612	617	622	627	632
Zone x Start A	741	745	749	753	757
Zone x Start B	742	746	750	754	758
Zone x Start C	743	747	751	755	759
Zone x Start N	744	748	752	756	760

Figure 24: Basic scheme delayed trip

Note: The numbers in the table represent the DDB signals available in the PSL.

1.19 Power swing detection, alarming and blocking

1.19.1 Detection of power swings

A power swing may cause the impedance presented to a distance relay to move away from the normal load area and into one or more of its tripping characteristics. In the case of a stable power swing it is important that the relay should not trip. The relay should also not trip during loss of stability since there may be a utility strategy for controlled system break up during such an event.

The power swing detection in the MiCOM P54x is an advanced technique that does not require any start-up impedance characteristics to be set. The detection technique uses superimposed current (ΔI) detector similar to the phase selection principle described above. However for the power swing detector the current is always compared to that 2 cycles previous. For a fault condition this power swing detector (PSD) will reset after 2 cycles as no superimposed current is detected.

For a power swing, PSD will measure superimposed current for longer than 2 cycles, and it is the length of time for which the superimposed current persists that is used to distinguish between a fault and a power swing. A power swing is deemed to be in progress if a three phase selection, or a phase to phase selection when one pole is open, produced in this way is retained for more than 3 cycles, as shown in Figure 25. At this point the required distance zones can be blocked, to avoid tripping should the swing impedances cross into a tripping zone.

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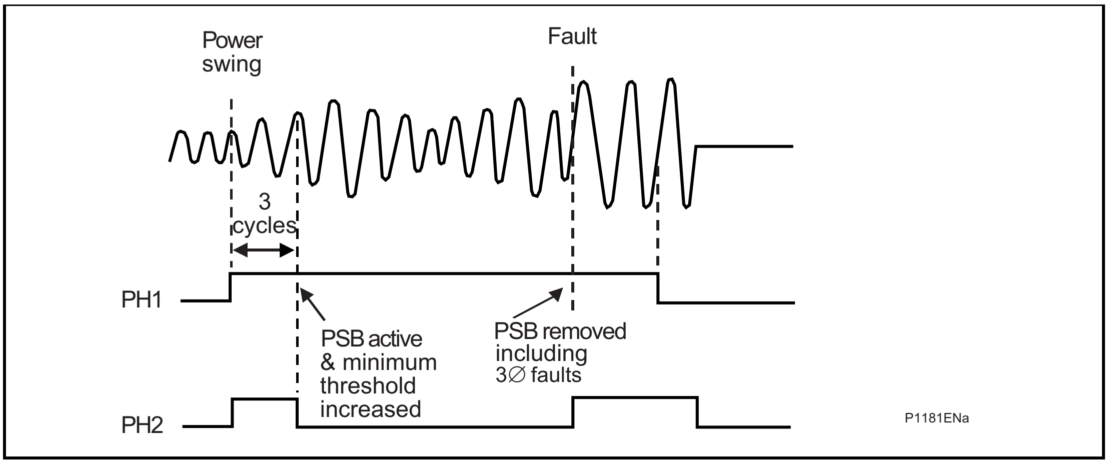

Figure 25: Power swing detected for 3 cycles continuous ΔI

In order to detect slow power swings, when the superimposed current remains below the minimum threshold (5%In), a second method of detection is also used. This method requires the distance load blinders to be enabled. If the fault impedance remains within a band based on the load blinder characteristic for more than 3 cycles then a power swing is deemed to have occurred.

1.19.2 Actions upon power swing detection

Once a power swing is detected the following actions occur:

- Distance elements are blocked on selected zones providing blocking is enabled
- All zones are switched to self polarized mho characteristics for maximum stability during the swing
- A power swing block alarm is issued when the swing impedance enters a distance zone. The condition of entering an impedance zone avoids alarming for low current momentary swings that settle quickly
- When a power swing is in progress, the minimum threshold used by the phase selector is increased to twice the maximum superimposed current prevailing in the swing

Therefore, the phase selector resets once a power swing is detected. It can then be used to detect a fault during a power swing.

1.19.3 Detection of a fault during a power swing

A fault is detected during a swing when the phase selector operates, based on its increased threshold. Thus, any operation of the phase selector will cause PSB unblocking, and allow a trip. Example scenarios are:

- A fault causes the delta current measured to increase above twice that stored during the swing (a step change in delta I rather than the expected gradual transition in a power swing).

1.19.4 Actions upon detection of a fault during a power swing

- The block signal is only removed from zones that start within 2 cycles of a fault being detected. This improves stability for external faults during power swings. Any measuring zone that was detecting an impedance within its characteristic before The phase selector detected the fault will remain blocked. This minimizes the risk of tripping for a swing impedance that may naturally be passing through Zone 1, and could otherwise cause a spurious trip if all zones were unblocked on fault inception. Any measuring zone that picks up beyond the two cycle window will remain blocked. This minimizes the risk of tripping for a continued swing that may pass through Zone 1, and could otherwise cause a spurious trip if all zones were allowed to unblock together.

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1.19.5 Power swing settings

The power swing detection is setting free and does not require any system study. The only setting available to a user is to decide whether a zone should be blocked or allowed to trip after a power swing is detected. Zone by zone, it is possible to select one mode from the following:

– "<u>Allow Trip</u>" - should a power swing locus remain within a trip zone characteristic for a duration equal to the zone time delay, the trip will be allowed to happen;

– "<u>Blocking</u>" - to keep stability for that zone, even if a power swing locus should enter it;

– "<u>Delayed Unblock</u>" - maintains the block for a set duration. If the swing is still present after the "PSB Timeout Set" window has expired, tripping is allowed as normal.

Other setting possibilities are:

– Selection of PSB as "Indication" only will raise an alarm, without blocking any zones.

– The *PSB Unblock Dly* function allows for any power swing block to be removed after a set period of time. For a persistent swing that does not stabilize, any blocked zones will be made free to trip once the timer has elapsed. In setting which relays will unblock, the user should consider which relay locations are natural split points for islanding the power system.

– The *PSB Reset Delay* is a time delay on drop-off timer, which maintains the PSB detection even after the swing has apparently stabilized. It is used to ensure that where the swing current passes through a natural minimum and delta I detection might reset, that the detection does not drop out/chatter. It can thus be used to ensure a continual Power Swing indication when pole slipping (an unstable out of step condition) is in progress.

A simplified logic diagram showing operation of the power swing blocking is attached as Figure 26 which follows.

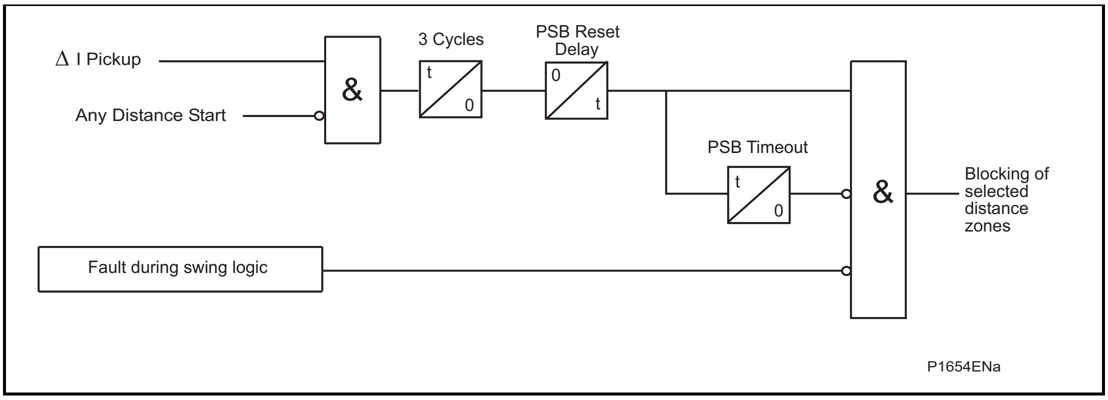

Figure 26: Power swing blocking

1.20 Out of step detection and tripping

Out of Step protection is used to split the power system into possibly stable areas of generation and load balance during unstable power oscillations. The points at which the system should be split are determined by detailed system stability studies.

The P54x Out of Step function has 4 different setting options:

1. Disabled
2. Predictive OST
3. OST
4. Predictive OST or OST

When set 'Disabled', Out of Step function is not operational. The P54x also provides an option to split the system in advance by selecting the 'Predictive OST' (sometimes called an early OST) in order to minimize the angle shift between two ends and aid stability in the split areas. The third setting option is to split the system on detection of the out of step condition i.e. when a pole slip occurs. The fourth option is a combination of the two.

1.20.1 Out of step detection

The Out of Step detection is based on the well proven $\Delta Z/\Delta t$ principle associated with two concentric polygon characteristic, as presented in Figure 27.

1.20.1.1 Characteristic

Both polygon characteristics are independent and have independent settings for their respective reactance and resistive reaches.

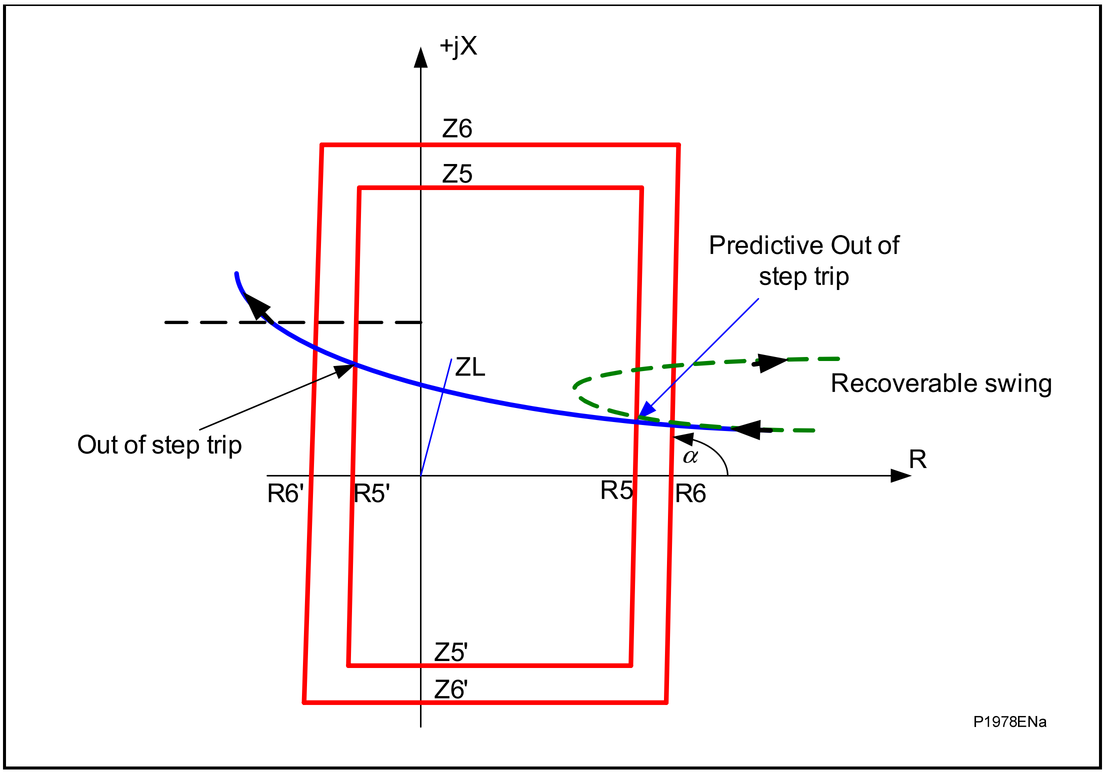

Figure 27: Out of step detection characteristic

Note that both the inner (Zone 5) and outer (Zone 6) characteristics, as shown above, are settable in positive sequence impedance terms to ensure correct Out of Step detection during open pole swing conditions. Hence, there is only one Z5 and Z6 positive sequence impedance polygon characteristic instead of 6 characteristics for each measured loop. The measured positive sequence impedance is calculated as:

Z1 = V1/I1

Where V1 and I1 are positive sequence voltage and current derived from the measured phase quantities. Note that during symmetrical power oscillations, there is no difference between phase impedance loops and positive sequence impedance loop, whilst for the open pole oscillations the phase and positive sequence impedances are different. This fact must be taken into account during testing/commissioning.

All four resistive blinders are parallel, using the common angle setting 'α' that corresponds to the angle of the total system impedance ZT (= ZS + ZL + ZR), where ZS and ZR are equivalent positive sequence impedances at the sending and receiving ends and ZL positive sequence line impedance. Tilting of the reactance line and residual compensation is not implemented.

In Figure 27, the solid impedance trajectory represents the locus for the non-recoverable power oscillation, also known as pole slip or out of step condition. The dotted impedance trajectory on the other hand represents a recoverable power oscillation, usually called swings.

1.20.1.2 Operating principle

The Out of Step detection algorithm is based on measuring the speed of positive sequence impedance passing through the set ΔZ region. As soon as measured positive sequence impedance touches the outer polygon, a timer is started.

If the disturbance takes less than 25ms from entering zone 6 to entering zone 5, the relay will consider this to be a power system fault and not an out of step trip condition. The timer of 25ms is a fixed timer in the logic and not user accessible. During a power system fault, the speed of impedance change from a load to a fault is fast, but the relay may operate slower for marginal faults close to a zone boundary, particularly for high resistive faults inside the zone operating characteristic and close to the Z5 boundary. Therefore, the fixed time of

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25ms is implemented to provide sufficient time for a distance element to operate and therefore to distinguish between a fault and an extremely fast power system oscillation.

If the disturbance takes more than 25ms but less than DeltaT set time from entering Zone 6 to entering Zone 5, this will be seen as a very fast oscillation. Therefore, the relay will trip if setting option 2 or 4 was selected. The minimum DeltaT setting is 30ms, allowing 5ms margin to the fixed 25ms timer.

If the disturbance takes longer than the DeltaT setting time to enter Zone 5 after entering Zone 6 then it is considered as a slow power oscillation. Upon entering Z5, the relay will record the polarity of the resistive part of the positive sequence impedance. Two scenarios are possible:

1. If the resistive part of the positive sequence impedance leaves Z5 with the same polarity as previously recorded on entering Zone 5, it is deemed a recoverable swing. No tripping will be issued.

2. If the resistive part of the positive sequence impedance has the opposite polarity when exiting Zone 5 to that of the recorded polarity on Zone 5 entering, an Out of Step condition is recognized, followed by the tripping if setting option 3 or 4 was selected. It should be noted that in the case when the DeltaT timer did not expire and setting option 3 is selected, the Out of Step condition will also be detected, followed by OST operation.

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As the tripping mode for the detected Out of Step condition is always 3 ph trip, the 'Predictive OST' and OST DDB signals are mapped to the 3ph tripping in the default PSL. Also, Out of Step operation will block auto-reclose function. The Out of Step tripping time delay TOST is also available to delay the OST tripping command until the angle between internal voltages between two ends are at 240 deg closing towards 360 deg. This is to limit the voltage stress across the circuit breaker. In the case of a fault occurring during the swing condition, the out of step tripping function will be blocked.

The Out of Step algorithm is completely independent from the distance elements and setting free power swing detection function. The load blinder does not have any effect on the OST characteristics. For the Out of Step operation, the minimum positive sequence current of 5%In must be present.

The Out of Step algorithm is given in Figure 28.

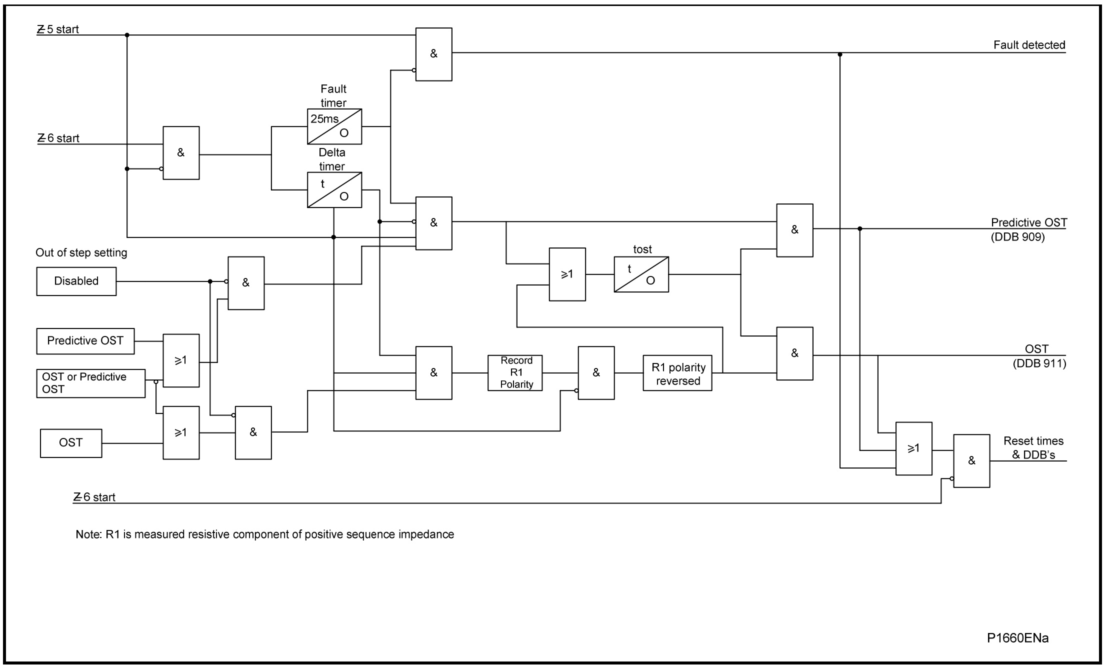

Figure 28: Out of step algorithm

1.21 Switch on to fault (SOTF) and trip on reclose (TOR)

The settings for SOTF and TOR are included in the menu column “TRIP ON CLOSE” (TOC) within the MiCOM P54x relay. The settings are designed to deal with two different scenarios.

– SOTF is designed to provide instantaneous operation of selected elements for a fault present on manual closure of the circuit breaker;

– TOR is designed to provide instantaneous operation of selected elements for a persistent fault present on auto-reclosing of the circuit breaker.

The SOTF and TOR functions are communally termed “Trip on Close” logic. The operation of these features is shown in Figure 29 which follows.

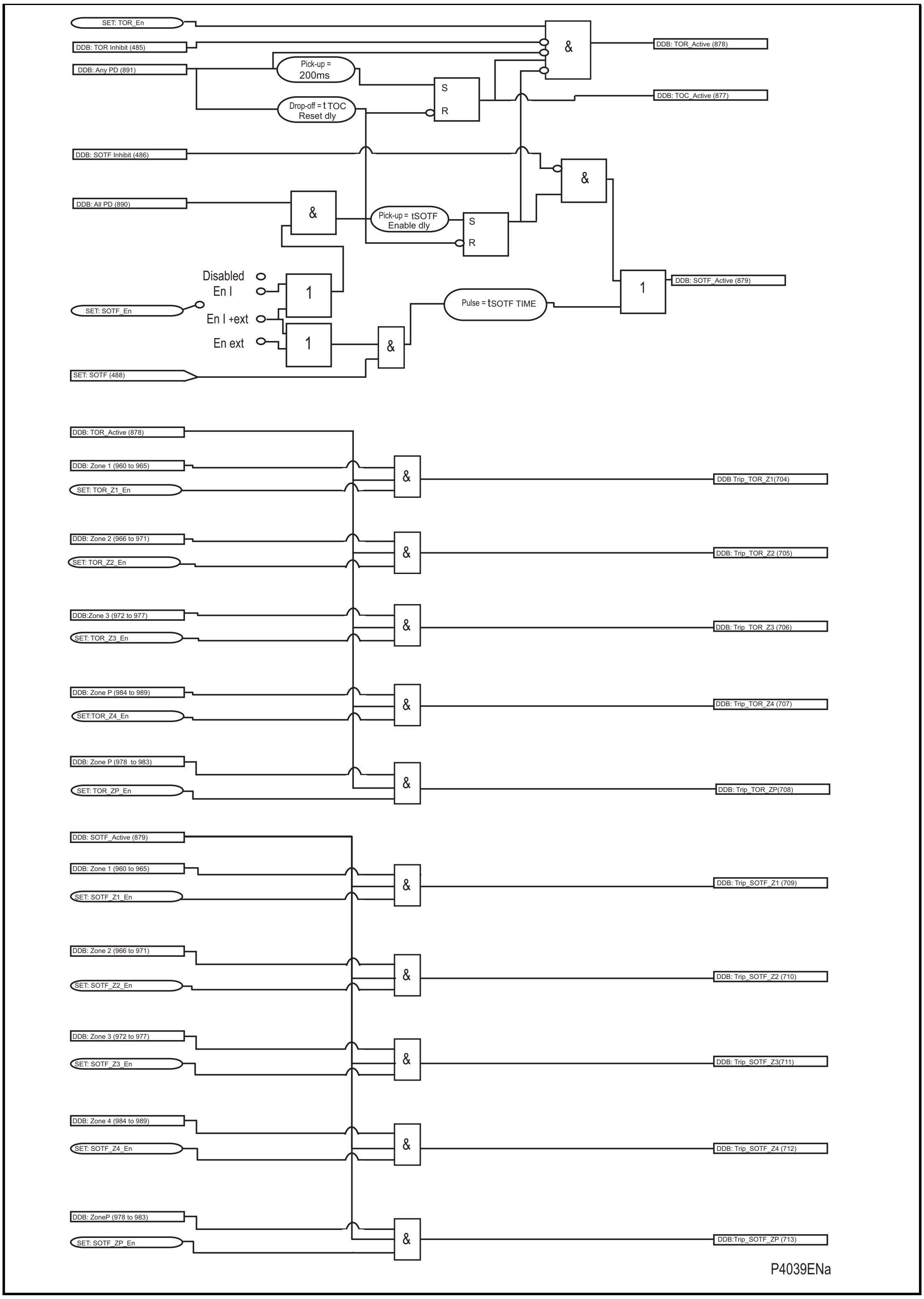

Figure 29: Trip on close

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1.21.1 Switch onto fault mode

The settings applied are as follows:

SOTF Status - SOTF can be activated in three different manners:

1. Enabled by using pole dead logic detection logic. A 'SOTF Delay' timer starts if "all pole dead" condition is detected. Once this timer expires, SOTF becomes enabled and remains active during the period set on "TOC Reset Delay" setting.

2. Enabled by an external pulse. SOTF becomes enabled after an external pulse (as a circuit breaker close command for example) linked to DDB "Set SOTF" (DDB 488) is ON. The function remains active for the duration of the "SOTF Pulse" setting.

3. Enabled by using the two previous methods.

With this feature *Enabled*, the relay operates in Switch on to Fault mode. Three pole instantaneous tripping (and auto-reclose blocking) occurs for any fault detected by the selected zones when in Switch on to Fault mode. Whether this feature is enabled or disabled, the normal time delayed elements or aided channel scheme continues to function and can operate to trip the circuit.

TOC Reset Delay - The SOTF (when enabled by pole dead detection logic) and TOR features remain in-service for the duration of the TOC reset delay once the circuit is energized.

SOTF Tripping Link - While the Switch on to Fault Mode is active, the MiCOM P54x will trip instantaneously for pick up of any zone selected in these links. To operate for faults on the entire circuit length it is recommended that at least Zone 1 and Zone 2 are selected. If no elements are selected then the normal time delayed elements and aided scheme provide the protection.

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1.21.2 Trip on reclose mode

The settings applied are as follows:

TOR Status - With this feature Enabled, for a period following circuit breaker closure, the relay operates in Trip on Reclose mode. Three pole instantaneous tripping occurs for any fault detected by the selected zones. Whether this feature is enabled or disabled, the normal time delayed elements or aided channel scheme continue to function and can operate to trip the circuit.

TOC Reset Delay - The SOTF and TOR features remain in-service for the duration of the TOC reset delay once the circuit is energized.

TOR Tripping Links - While the Trip on Reclose Mode is active, the MiCOM P54x will trip instantaneously for pick up of any zone selected in these links. To operate for faults on the entire circuit length it is recommended that at least Zone 1 and Zone 2 are selected. If no elements are selected then the normal time delayed elements and aided scheme provide the protection.

1.21.3 Polarization during circuit energization

While the Switch on to Fault and Trip on Reclose modes are active, the directionalized distance elements are partially cross polarized from other phases. The same proportion of healthy phase to faulted phase voltage as given by the Distance Polarizing setting in the DISTANCE SETUP menu is used.

Partial cross polarization is thus used in substitute for the normal memory polarizing, for the duration of the TOC window. If insufficient polarizing voltage is available, a slight reverse offset (10% of the forward reach) is included in the zone 1 characteristic to enable fast clearance of close up three phase faults.

1.22 Setup of DEF

The MiCOM P54x with distance option installed has one additional aided channel ("pilot") scheme that can be used to supplement differential and distance protection. Directional earth (ground) fault protection (DEF) and can configured as unit protection, with a communication channel connected between the remote line ends.

In order to make use of this scheme, base setting data must be made in the "GROUP x DIRECTIONAL FN" menu column, to determine the sensitivity of level detectors.

1.22.1 DEF zero sequence polarization with "virtual current polarizing"

With earth fault protection, the polarizing (directional reference) signal requires to be representative of the earth fault condition. As residual voltage is generated during earth fault conditions, this quantity is commonly used to polarize the directional decision of DEF elements. The relay internally derives this voltage from the 3 phase voltage input which must be supplied from either a 5-limb or three single phase VTs. These types of VT design allow the passage of residual flux and consequently permit the relay to derive the required residual voltage. In addition, the primary star point of the VT must be earthed. A three-limb VT has no path for residual flux and, is therefore unsuitable to supply the relay.

It is possible that small levels of residual voltage will be present under normal system conditions due to system imbalances, VT inaccuracies, relay tolerances etc. Hence, the relay includes a user settable threshold (DEF VNPol Set) which must be exceeded in order for the DEF function to be operational. Note that residual voltage is nominally 180° out of phase with residual current. Consequently, the DEF relays are polarized from the '-Vres' quantity. This 180° phase shift is automatically introduced within the relay.

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A distinct advantage of the MiCOM P54x is that the relay can trip by this method of polarizing, even if VNpol is less than the set threshold. Provided that the superimposed current phase selector has identified the faulted phase (suppose phase A), it will remove that phase from the residual calculation Va + Vb + Vc, leaving only Vb + Vc. The resultant polarizing voltage will have a large magnitude, and will be in the same direction as –Vres. This allows the relay to be applied even where very solid earthing behind the relay prevents residual voltage from being developed.

This technique of subtracting the faulted phase is given the description "virtual current polarizing" as it removes the need to use current polarizing from a CT in a transformer star (wye)-ground connection behind the relay. This would have been necessary with traditional relays.

The directional criteria with zero sequence (virtual current) polarization are given below:

Directional forward

$-90° < (\text{angle}(IN) - \text{angle}(VNpol+180°) - RCA) < 90°$

Directional reverse

$-90° > (\text{angle}(IN) - \text{angle}(VNpol+180°) - RCA) > 90°$

Where VNpol is as per the table below:

Phase Selector Pickup	VNpol
A Phase Fault	VB + VC
B Phase Fault	VA + VC
C Phase Fault	VA + VB
No Selection	VN = VA + VB + VC

1.22.2 DEF negative sequence polarization

In certain applications, the use of residual voltage polarization of DEF may either be not possible to achieve, or problematic. An example of the former case would be where a suitable type of VT was unavailable, for example if only a three-limb VT was fitted. An example of the latter case would be an HV/EHV parallel line application where problems with zero sequence mutual coupling may exist.

In either of these situations, the problem may be solved by the use of negative phase sequence (nps) quantities for polarization. This method determines the fault direction by comparison of nps voltage with nps current. The operate quantity, however, is still residual current. It requires a suitable voltage and current threshold to be set in cells *'DEF V2pol Set'* and *'DEF I2pol Set'*, respectively.

The directional criteria with negative sequence polarization are given below:

Directional forward

$-90^{o} < (\text{angle}(I2) - \text{angle}(V2+180^{o}) - \text{RCA}) < 90^{o}$

Directional reverse

$-90^{o} > (\text{angle}(I2) - \text{angle}(V2+180^{o}) - \text{RCA}) > 90^{o}$

1.23 Channel aided schemes

The MiCOM P54x offers two sets of aided channel (“pilot”) schemes, which may be operated in parallel.

Aided Scheme 1 - May be keyed by distance and/or DEF;

Aided Scheme 2 - May be keyed by distance and/or DEF;

The provision of two discrete channel selections would allow the following to be implemented, as an example:

– Distance POR with DEF POR scheme operating over a common shared channel… Select both in AIDED SCHEME 1 only, with AIDED SCHEME 2 “Disabled”.

– Distance PUR with DEF BLOCKING operating over separate channels due to the dissimilar scheme types… Assign Distance to AIDED SCHEME 1, and DEF to AIDED SCHEME 2.

Note: Where schemes share a common channel, the signal send and signal receive logic operates in a logical “OR” mode.

Aided Scheme 1 and Aided Scheme 2 are two instances of the same logic. Each of these schemes provides the same options and can be independently applied. The scheme logic is split into three sections defined in the following diagram: send logic, receive logic, and aided tripping logic, as shown in Figure 30. Detailed scheme descriptions follow later. As there are two instances of the aided scheme, any internal logic signals which are specific to the instance of the scheme are shown in the diagrams with two DDB numbers relating to the first and second instance, respectively.

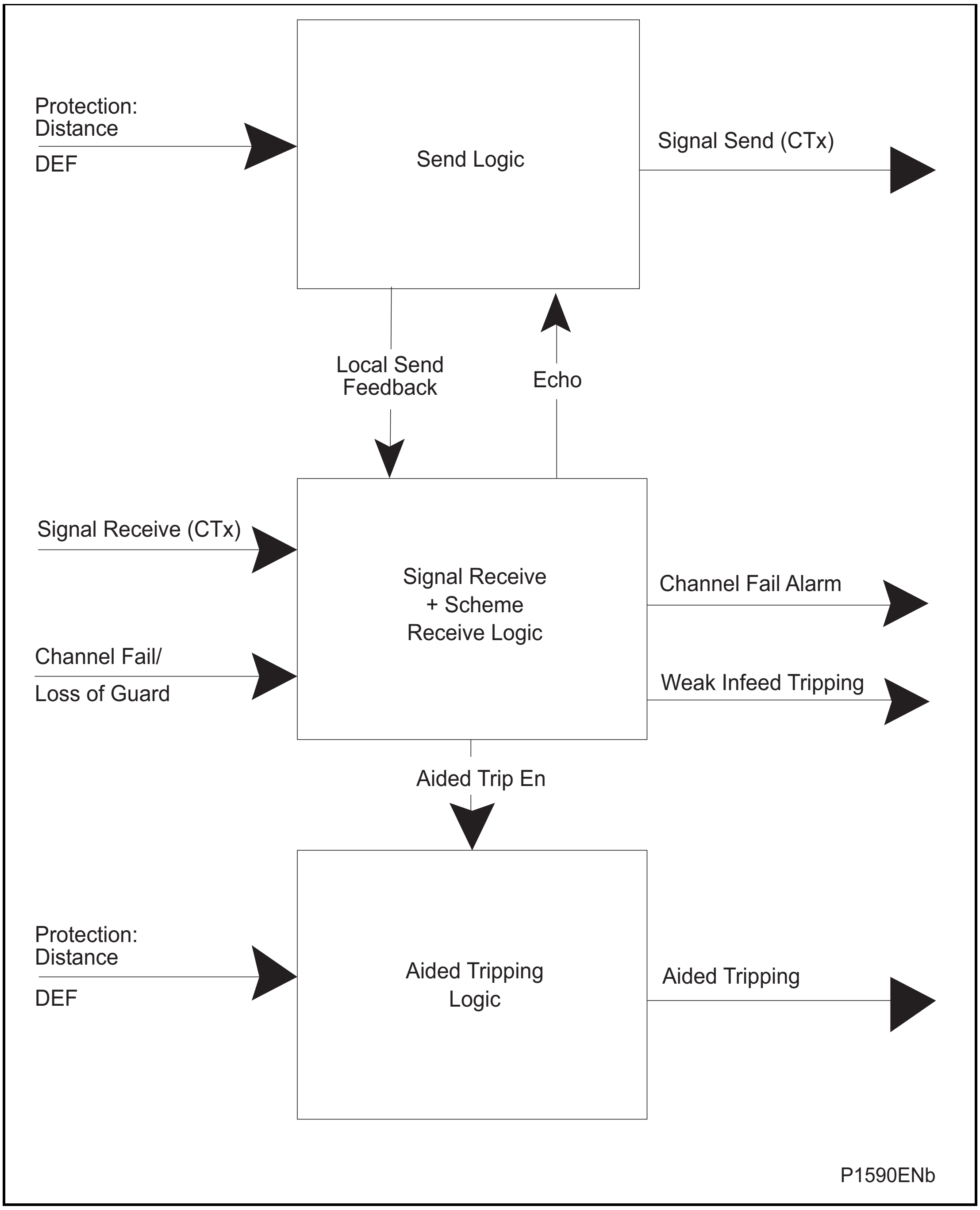

Figure 30: Aided scheme logic overview

The full Logic Diagrams of the Send, Receive and Aided Trip Logic are now attached here, for reference. It is not necessary to understand the entire logic in order to apply any scheme, as in later sections abbreviated scheme diagrams are available.

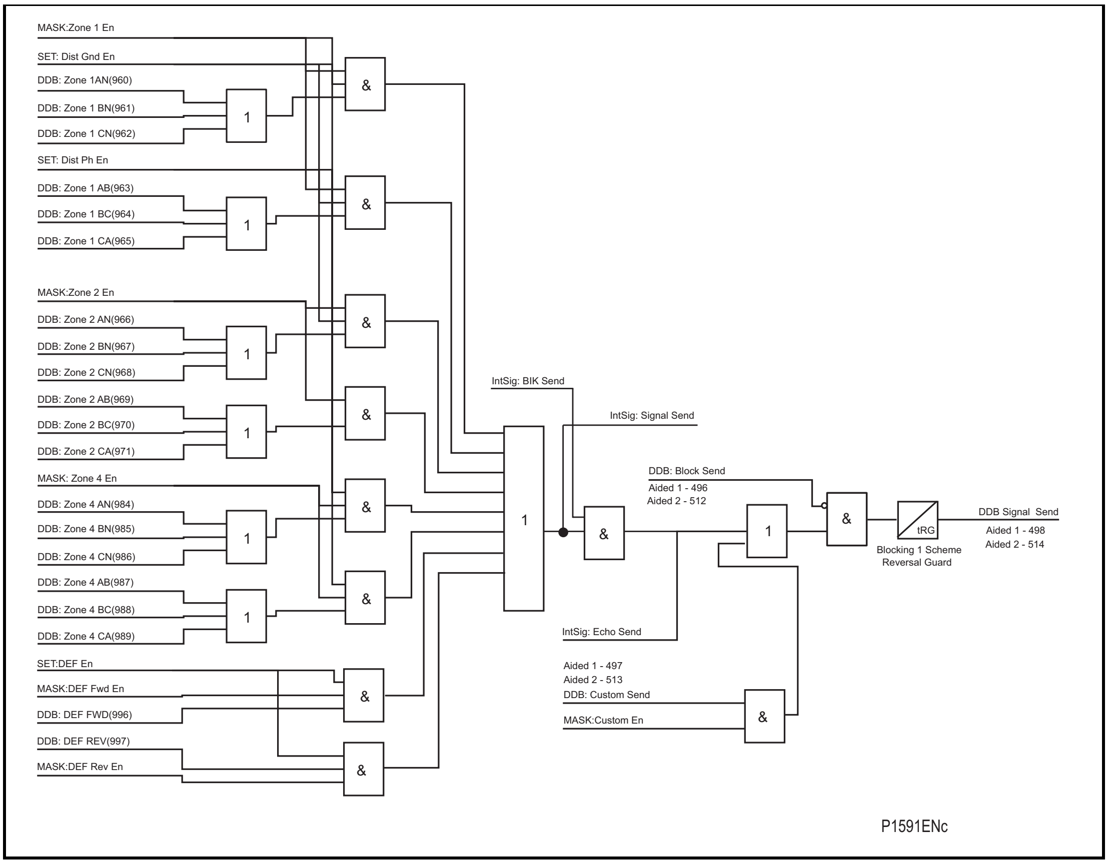

Figure 31: Send logic

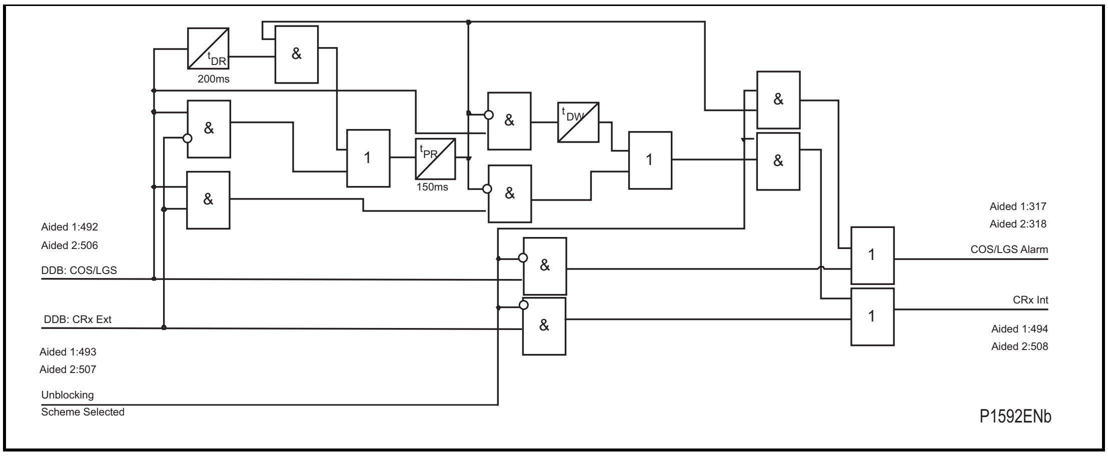

Figure 32: Receive logic

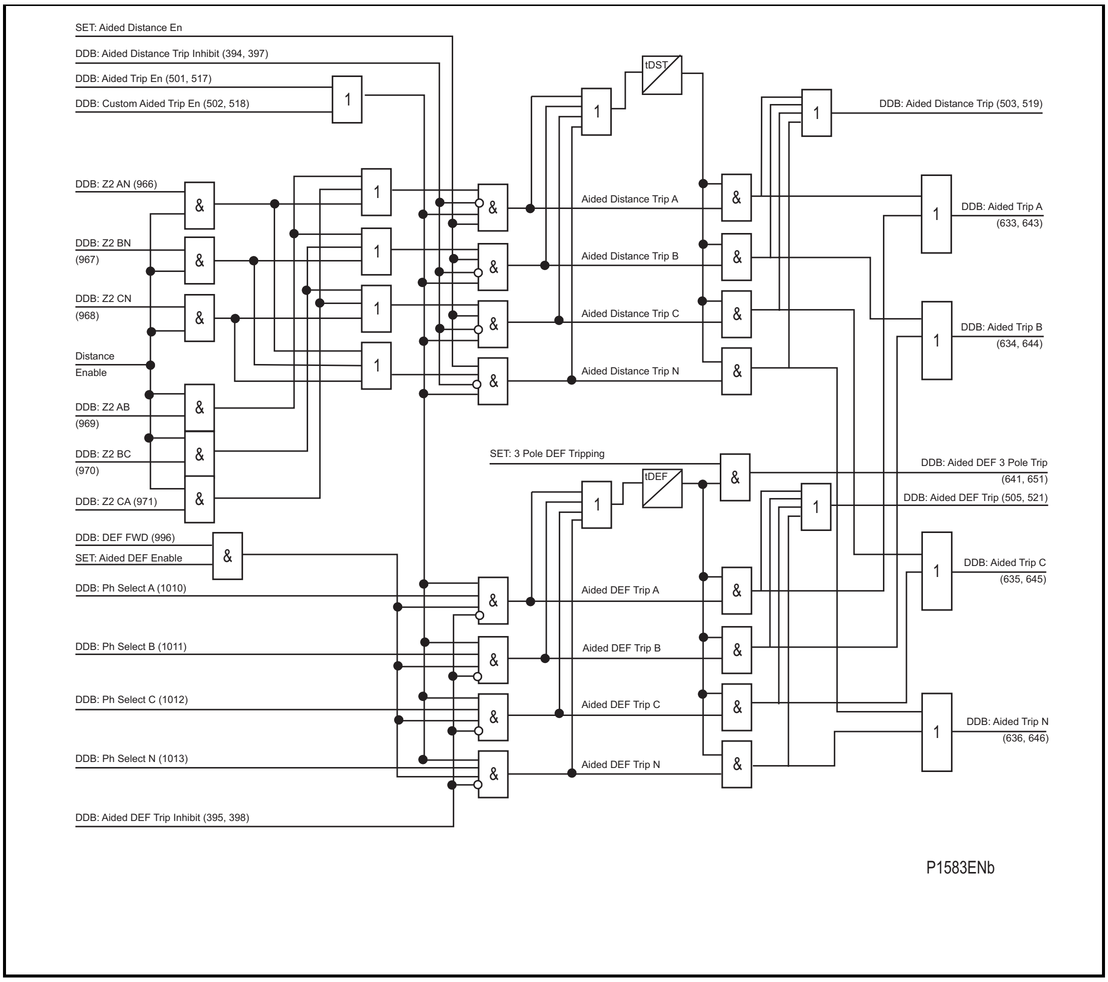

Figure 33: Aided tripping logic

1.23.1 Distance scheme PUR - permissive underreach transfer trip

To provide fast fault clearance for all faults, both transient and permanent, along the length of the protected circuit, it is necessary to use a signal aided tripping scheme. The simplest of these is the permissive underreach protection scheme (PUR). The channel for a PUR scheme is keyed by operation of the underreaching zone 1 elements of the relay. If the remote relay has detected a forward fault upon receipt of this signal, the relay will operate with no additional delay. Faults in the last 20% (Note 1) of the protected line are therefore cleared with no intentional time delay.

Note 1: Assuming a 20% typical "end-zone" when Zone 1 is set to 80% of the protected line.

Listed below are some of the main features/requirements for a permissive underreaching scheme:

– Only a simplex signaling channel is required

– The scheme has a high degree of security since the signaling channel is only keyed for faults within the protected line

– If the remote terminal of a line is open then faults in the remote 20% of the line will be cleared via the zone 2 time delay of the local relay

– If there is a weak or zero infeed from the remote line end, (i.e. current below the relay sensitivity), then faults in the remote 20% of the line will be cleared via the zone 2 time delay of the local relay

– If the signaling channel fails, Basic distance scheme tripping will be available

OP

Figure 34 shows the simplified scheme logic.

Send logic: Zone 1

Permissive trip logic: Zone 2 plus Channel Received

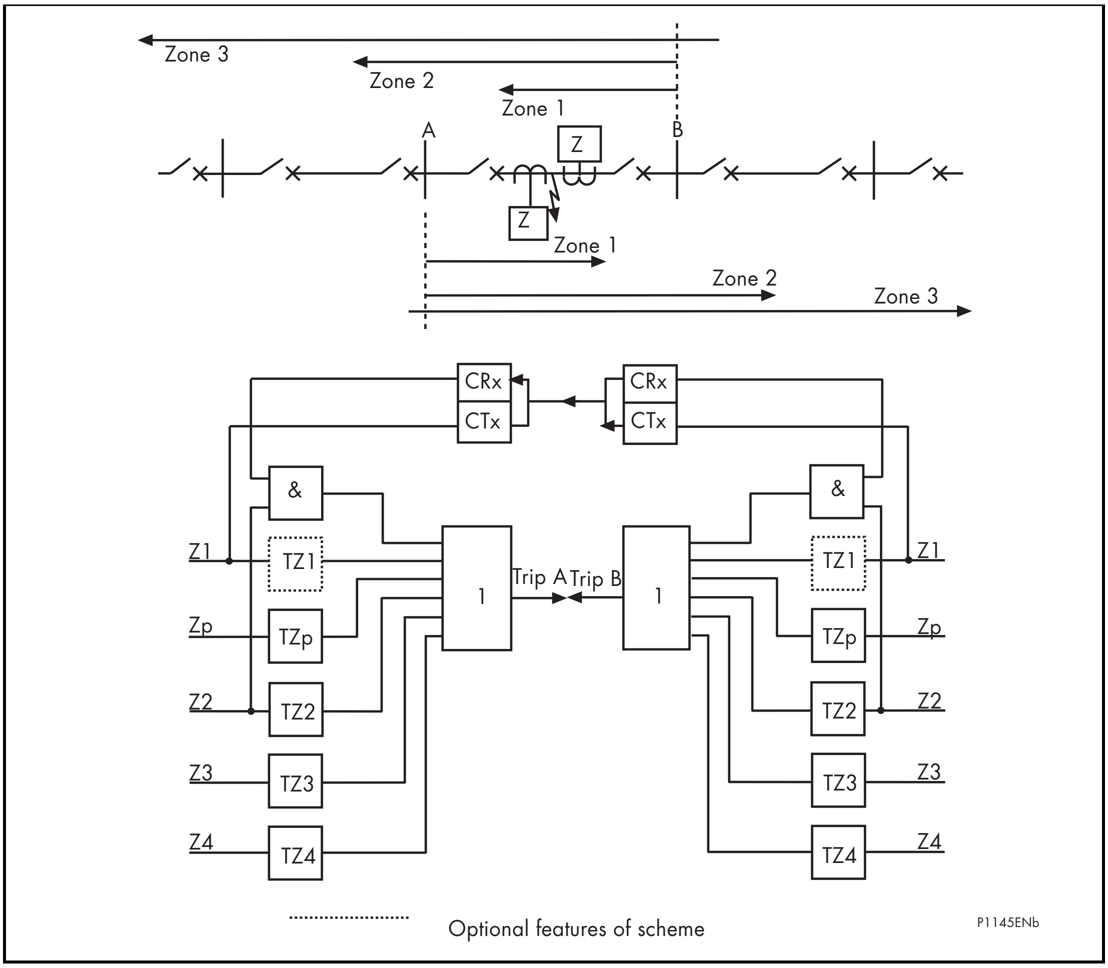

Figure 34: Permissive underreach transfer trip scheme (PUR)

Detailed logic is shown in Figure 35, as follows:

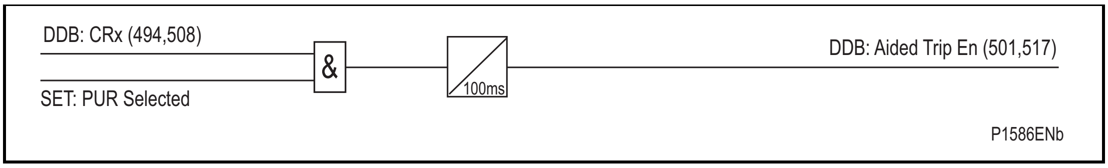

Figure 35: PUR

1.23.2 Distance scheme POR - permissive overreach transfer trip

The channel for a POR scheme is keyed by operation of the overreaching zone 2 elements of the relay. If the remote relay has detected a forward fault upon receipt of this signal, the relay will operate with no additional delay. Faults in the last 20% (Note 1) of the protected line are therefore cleared with no intentional time delay.

Note 1: Assuming a 20% typical "end-zone" when Zone 1 is set to 80% of the protected line.

OP

Listed below are some of the main features/requirements for a permissive overreaching scheme:

- The scheme requires a duplex signaling channel to prevent possible relay maloperation due to spurious keying of the signaling equipment. This is necessary due to the fact that the signaling channel is keyed for faults external to the protected line.
- The POR scheme may be more advantageous than permissive underreach schemes for the protection of short transmission lines, since the resistive coverage of the Zone 2 elements may be greater than that of the Zone 1 elements.
- Current reversal guard logic is used to prevent healthy line protection maloperation for the high speed current reversals experienced in double circuit lines, caused by sequential opening of circuit breakers.
- If the signaling channel fails, Basic distance scheme tripping will be available.

Note that the POR scheme also uses the reverse looking zone 4 of the relay as a reverse fault detector. This is used in the current reversal logic and in the optional weak infeed echo feature, shown dotted in Figure 36.

Send logic: Zone 2

Permissive trip logic: Zone 2 plus Channel Received

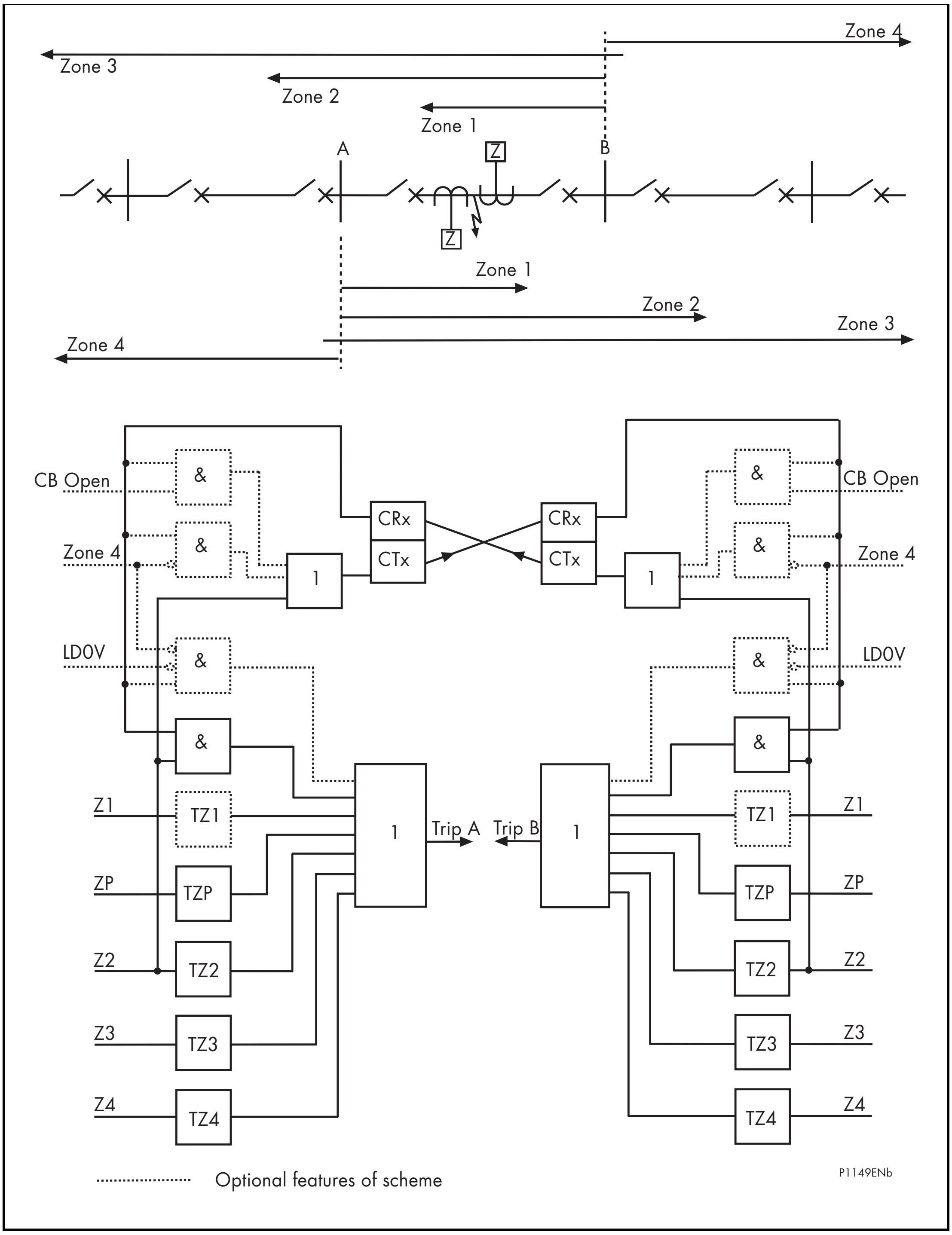

Figure 36: Permissive overreach transfer trip scheme (POR)

Detailed logic is shown in Figure 37, as follows:

OP

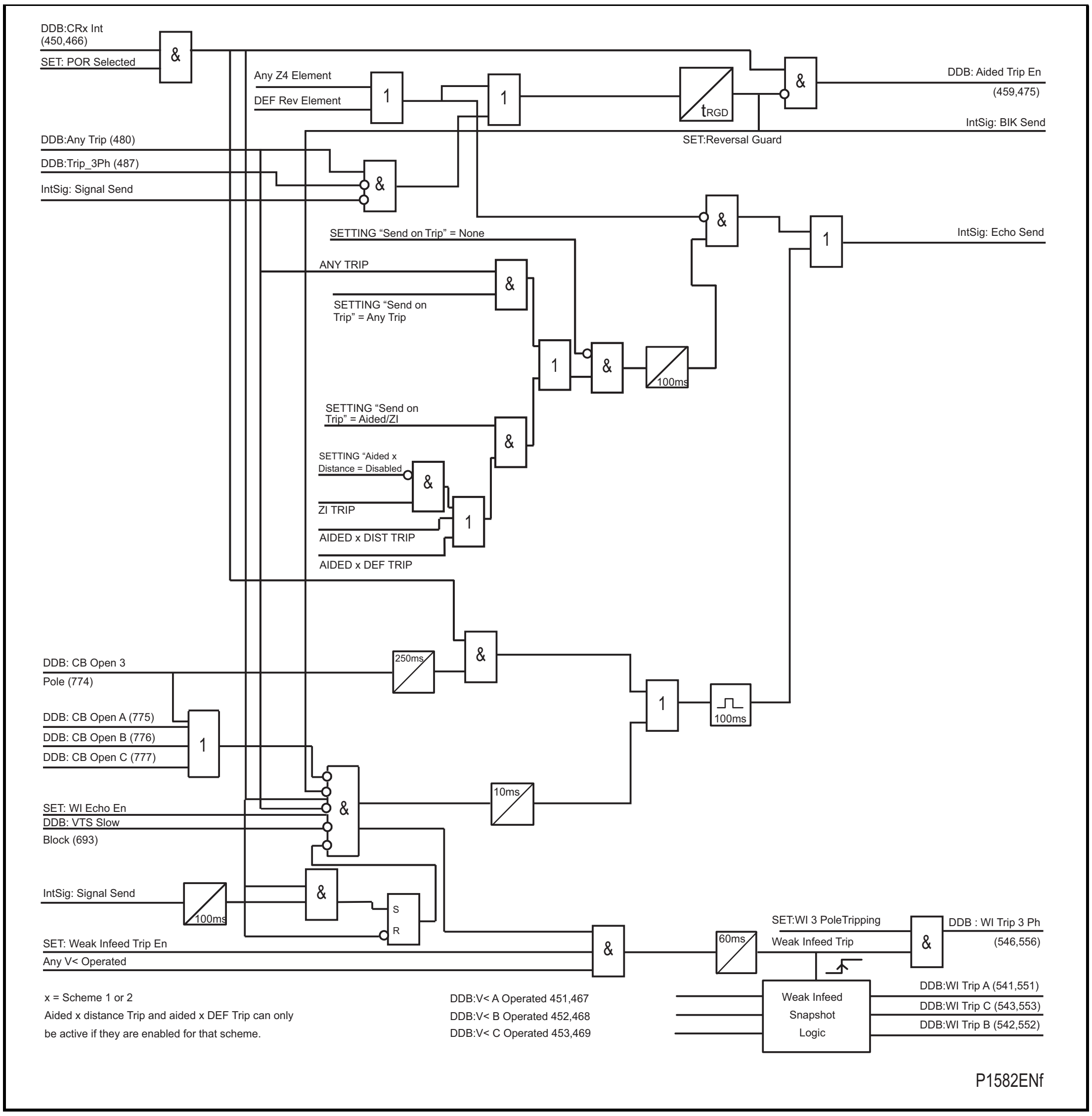

Figure 37: POR

1.23.3 Permissive overreach scheme weak infeed features

Weak infeed logic can be enabled to run in parallel with the POR schemes. Two options are available: WI Echo, and WI Tripping.

(Note: Special stub-end transformer Weak Infeed is covered in section 1.37)

Weak Infeed Echo - For permissive schemes, a signal would only be sent if the required signal send zone were to detect a fault. However, the fault current infeed at one line end may be so low as to be insufficient to operate any distance zones, and risks a failure to send the signal. Also, if one circuit breaker had already been left open, the current infeed would be zero. These are termed weak infeed conditions, and may result in slow fault clearance at the strong infeed line end (tripping after time tZ2). To avoid this slow tripping, the weak infeed relay can be set to "echo" back any channel received to the strong infeed relay (i.e. to immediately send a signal once a signal has been received). This allows the strong infeed relay to trip instantaneously in its permissive trip zone.

The additional signal send logic is:

Echo Send - No Distance Zone Operation, plus Channel Received.

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<u>Weak Infeed Tripping</u> - Weak infeed echo logic ensures an aided trip at the strong infeed terminal but not at the weak infeed. The MiCOM P54x also has a setting option to allow tripping of the weak infeed circuit breaker of a faulted line. Three undervoltage elements, Va<, Vb< and Vc< are used to detect the line fault at the weak infeed terminal. This voltage check prevents tripping during spurious operations of the channel or during channel testing.

The additional weak infeed trip logic is:

<u>Weak Infeed Trip</u> - No Distance Zone Operation, plus V<, plus Channel Received.

Weak infeed tripping is time delayed according to the "WI Trip Delay" value. Due to the use of phase segregated undervoltage elements, single pole tripping can be enabled for WI trips if required. If single pole tripping is disabled a three pole trip will result after the time delay.

1.23.4 Permissive scheme unblocking logic - loss of guard

This mode is designed for use with frequency shift keyed (FSK) power line carrier communications. When the protected line is healthy a guard frequency is sent between line ends, to verify that the channel is in service. However, when a line fault occurs and a permissive trip signal must be sent over the line, the power line carrier frequency is shifted to a new (trip) frequency. Thus, distance relays should receive either the guard, or trip frequency, but not both together. With any permissive scheme, the PLC communications are transmitted over the power line which may contain a fault. So, for certain fault types the line fault can attenuate the PLC signals, so that the permissive signal is lost and not received at the other line end. To overcome this problem, when the guard is lost and no "trip" frequency is received, the relay opens a window of time during which the permissive scheme logic acts as though a "trip" signal had been received. Two opto inputs to the relay need to be assigned, one is the Channel Receive opto, the second is designated Loss of Guard (the inverse function to guard received). The function logic is summarized in the table below.

System Condition	Permissive Channel Received	Loss of Guard	Permissive Trip Allowed	Alarm Generated
Healthy Line	No	No	No	No
Internal Line Fault	Yes	Yes	Yes	No
Unblock	No	Yes	Yes, during a 150ms window	Yes, delayed on pickup by 150ms
Signaling Anomaly	Yes	No	No	Yes, delayed on pickup by 150ms

The window of time during which the unblocking logic is enabled starts 10ms after the guard signal is lost, and continues for 150ms. The 10ms delay gives time for the signaling equipment to change frequency as in normal operation. For the duration of any alarm condition, zone 1 extension logic will be invoked if the option *Z1 Ext on Chan. Fail* has been Enabled.

1.23.5 Distance scheme BLOCKING

The signaling channel is keyed from operation of the reverse zone 4 elements of the relay. If the remote relay has picked up in zone 2, then it will operate after the trip delay if no block is received. Listed below are some of the main features/requirements for a BLOCKING scheme:

– BLOCKING schemes require only a simplex signaling channel

– Reverse looking Zone 4 is used to send a blocking signal to the remote end to prevent unwanted tripping

OP

– When a simplex channel is used, a BLOCKING scheme can easily be applied to a multi-terminal line provided that outfeed does not occur for any internal faults

– The blocking signal is transmitted over a healthy line, and so there are no problems associated with power line carrier signaling equipment

– BLOCKING schemes provides similar resistive coverage to the permissive overreach schemes

– Fast tripping will occur at a strong source line end, for faults along the protected line section, even if there is weak or zero infeed at the other end of the protected line

– If a line terminal is open, fast tripping will still occur for faults along the whole of the protected line length

– If the signaling channel fails to send a blocking signal during a fault, fast tripping will occur for faults along the whole of the protected line, but also for some faults within the next line section

– If the signaling channel is taken out of service, the relay will operate in the conventional basic mode

– A current reversal guard timer is included in the signal send logic to prevent unwanted trips of the relay on the healthy circuit, during current reversal situations on a parallel circuit

Figure 38 shows the simplified scheme logic.

Send logic: Reverse Zone 4

Trip logic: Zone 2, plus Channel **NOT** Received, delayed by Tp

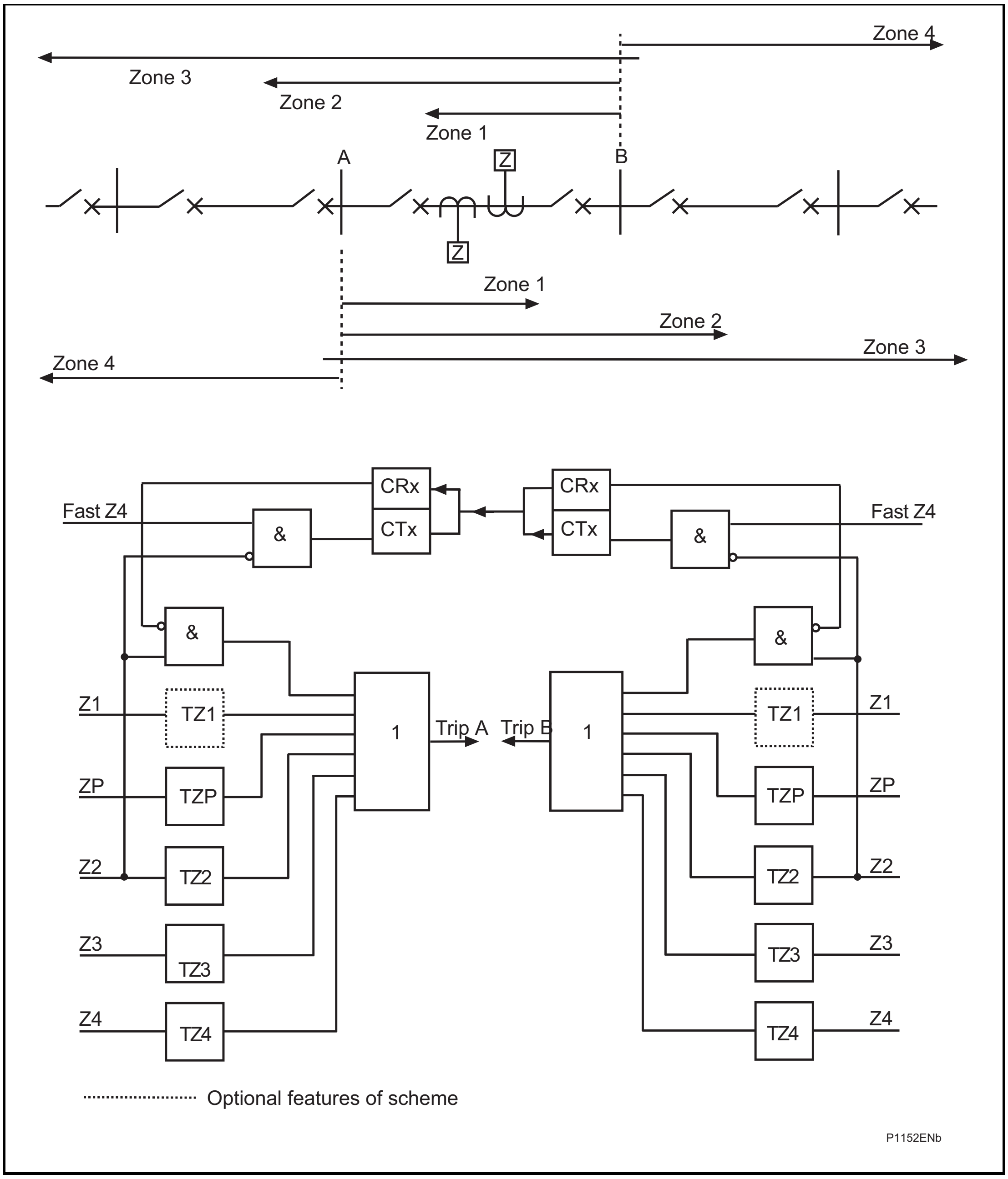

Figure 38: Distance blocking scheme (BOP)

1.23.6 Distance schemes current reversal guard logic

For double circuit lines, the fault current direction can change in one circuit when circuit breakers open sequentially to clear the fault on the parallel circuit. The change in current direction causes the overreaching distance elements to see the fault in the opposite direction to the direction in which the fault was initially detected (settings of these elements exceed 150% of the line impedance at each terminal). The race between operation and resetting of the overreaching distance elements at each line terminal can cause the Permissive Overreach, and Blocking schemes to trip the healthy line. A system configuration that could result in current reversals is shown in Figure 39. For a fault on line L1 close to circuit breaker B, as circuit breaker B trips it causes the direction of current flow in line L2 to reverse.

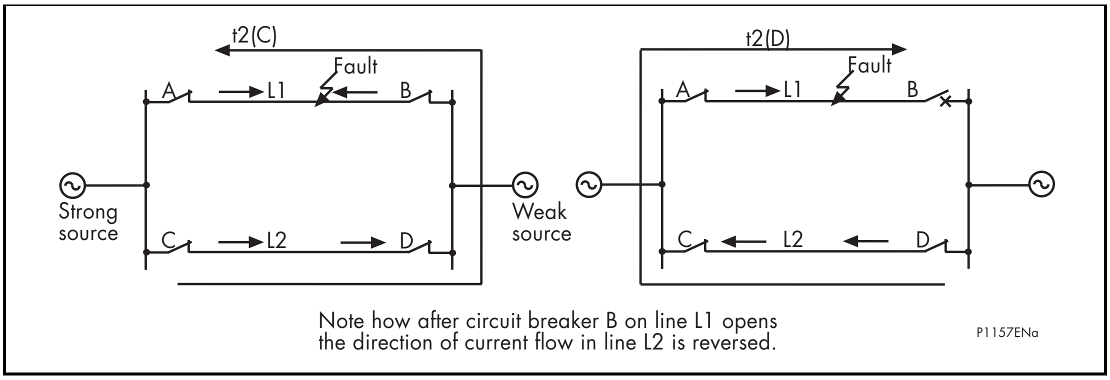

Figure 39: Example of fault current reverse of direction

1.23.7 Permissive overreach schemes current reversal guard

The current reversal guard incorporated in the POR scheme logic is initiated when the reverse looking Zone 4 elements operate on a healthy line. Once the reverse looking Zone 4 elements have operated, the relay's permissive trip logic and signal send logic are inhibited at substation D. The reset of the current reversal guard timer is initiated when the reverse looking Zone 4 resets. A time delay tREVERSAL GUARD is required in case the overreaching trip element at end D operates before the signal send from the relay at end C has reset. Otherwise this would cause the relay at D to over trip. Permissive tripping for the relays at D and C substations is enabled again, once the faulted line is isolated and the current reversal guard time has expired.

OP

1.23.8 Blocking scheme 1 and 2 current reversal guard

The current reversal guard incorporated in the BLOCKING scheme logic is initiated when a blocking element picks-up to inhibit the channel-aided trip. When the current reverses and the reverse looking Zone 4 elements reset, the blocking signal is maintained by the timer tREVERSAL GUARD. Thus, the relays in the healthy line are prevented from over tripping due to the sequential opening of the circuit breakers in the faulted line. After the faulted line is isolated, the reverse-looking Zone 4 elements at substation C and the forward looking elements at substation D will reset.

Two variants of Blocking scheme exist, BLOCKING 1, and BLOCKING 2. The only difference in functionality is:

- BLOCKING 1 - The Reversal Guard is applied to the Signal Send
- BLOCKING 2 - The Reversal Guard is applied to the Signal Receive

The difference in the receive logic is shown in Logic Diagrams, Figures 40 and 41 below:

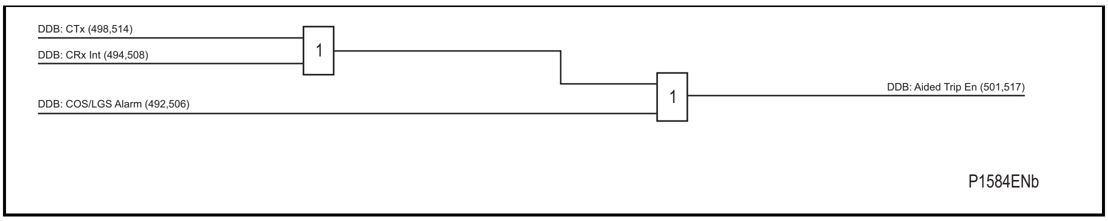

Figure 40: Blocking 1

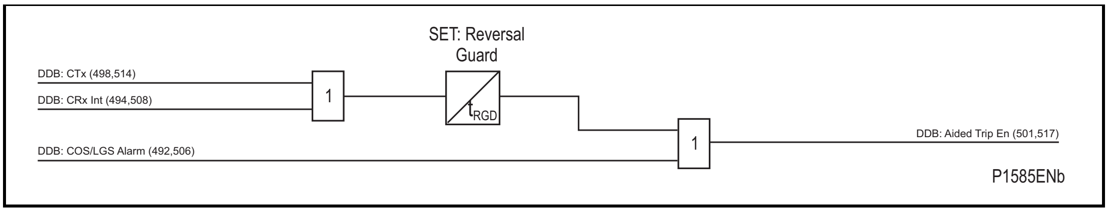

Figure 41: Blocking 2

The relative merits of Blocking 1 and Blocking 2 are discussed in the Application Notes.

1.23.9 Aided DEF ground fault scheme - permissive overreach

Figure 42 shows the element reaches, and Figure 43 the simplified scheme logic. The signaling channel is keyed from operation of the forward IN> DEF element of the relay. If the remote relay has also detected a forward fault, then it will operate with no additional delay upon receipt of this signal.

Send logic: IN> Forward pickup

Permissive trip logic: IN> Forward plus Channel Received

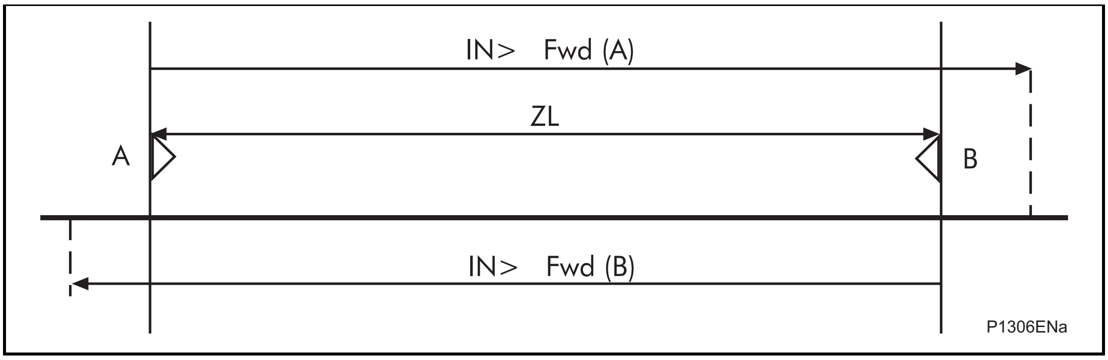

Figure 42: The DEF permissive scheme

The scheme has the same features/requirements as the corresponding distance scheme and provides sensitive protection for high resistance earth faults.

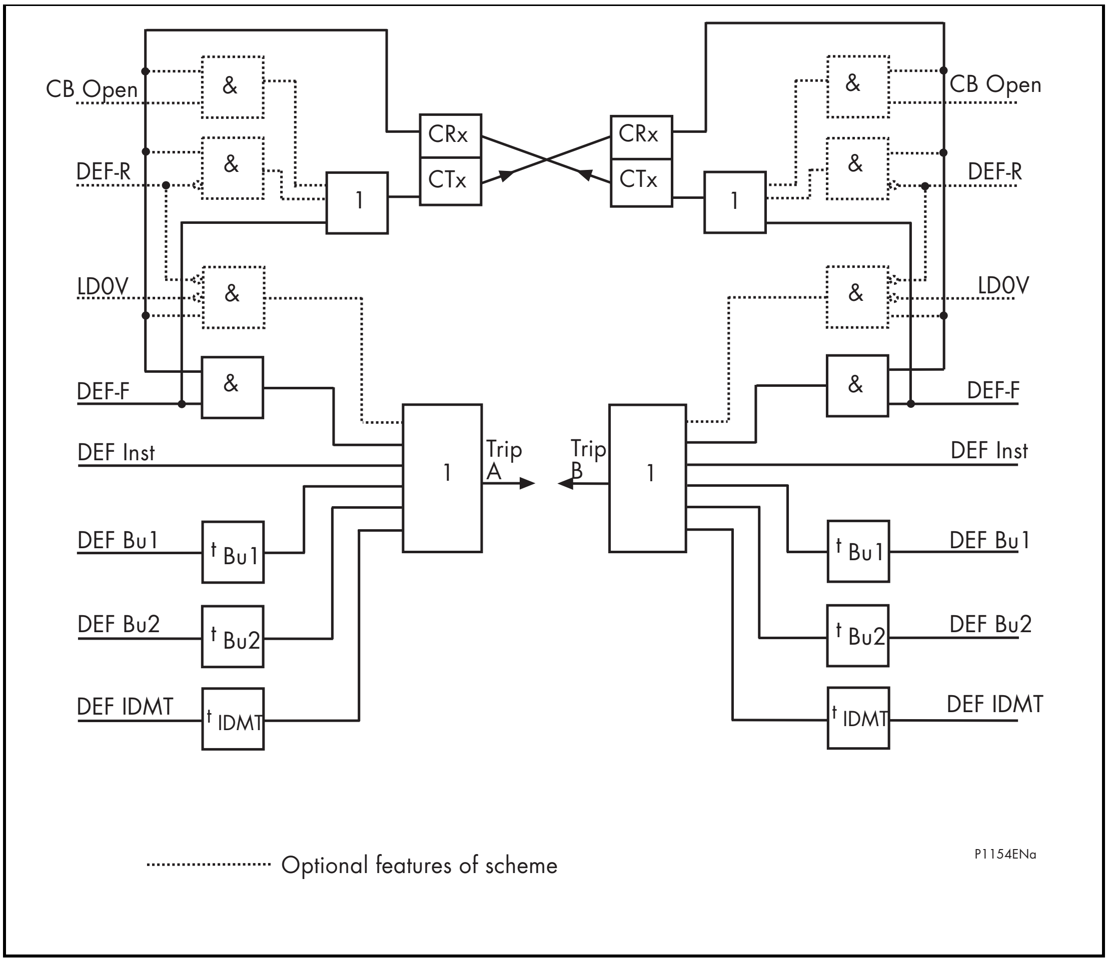

Figure 43: Aided DEF (ground) permissive scheme logic

1.23.10 Aided DEF ground fault scheme - blocking

Figure 44 shows the element reaches, and Figure 45 the simplified scheme logic. The signaling channel is keyed from operation of the reverse DEF element of the relay. If the remote relay forward IN> element has picked up, then it will operate after the set Time Delay if no block is received.

Send logic: DEF Reverse

Trip logic: IN> Forward, plus Channel NOT Received, with small set delay

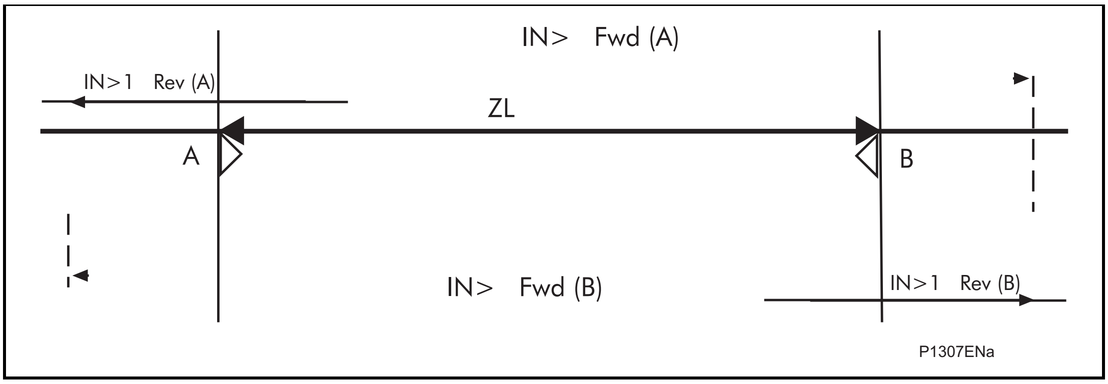

Figure 44: The DEF blocking scheme

The scheme has the same features/requirements as the corresponding distance scheme and provides sensitive protection for high resistance earth faults.

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Where "t" is shown in the diagram this signifies the time delay associated with an element. To allow time for a blocking signal to arrive, a short time delay on aided tripping must be used.

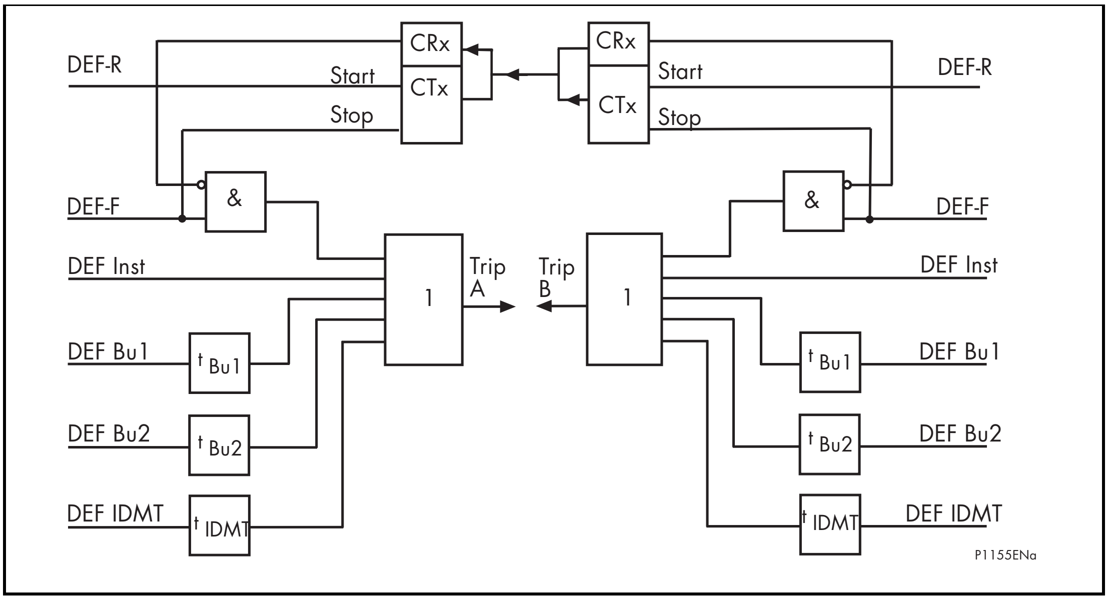

Figure 45: Aided DEF (ground) blocking scheme logic

1.24 Zone 1 extension and loss of load schemes

The MiCOM P54x offers additional non-channel distance schemes, notably Zone 1 extension, and loss of load.

1.24.1 Zone 1 extension scheme

Auto-reclosure is widely used on radial overhead line circuits to re-establish supply following a transient fault. A Zone 1 extension scheme may therefore be applied to a radial overhead feeder to provide high speed protection for transient faults along the whole of the protected line. Figure 46 shows the alternative reach selections for zone 1: Z1 or the extended reach Z1X.

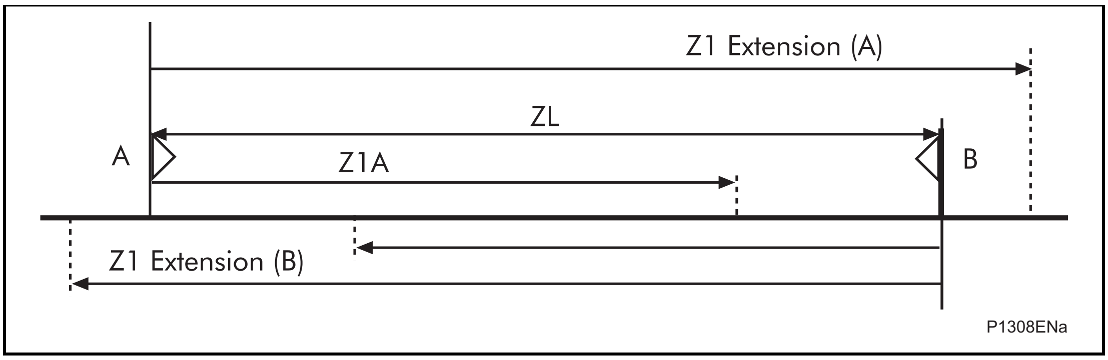

Figure 46: Zone 1 extension scheme

In this scheme, Zone 1X is enabled and set to overreach the protected line. A fault on the line, including one in the end 20% not covered by zone 1, will now result in instantaneous tripping followed by auto-reclosure. Zone 1X has resistive reaches and residual compensation similar to Zone 1. The auto-recloser in the relay is used to inhibit tripping from zone 1X such that upon reclosure the relay will operate with Basic scheme logic only, to co-ordinate with downstream protection for permanent faults. Thus, transient faults on the line will be cleared instantaneously, which will reduce the probability of a transient fault becoming

OP

permanent. The scheme can, however, operate for some faults on an adjacent line, although this will be followed by auto-reclosure with correct protection discrimination. Increased circuit breaker operations would occur, together with transient loss of supply to a substation.

The time delays associated with extended zone Z1X are shown in the table below:

Scenario	Z1X Time Delay
First fault trip	= tZ1
Fault trip for persistent fault on auto-reclose	= tZ2

The Zone 1X reach is set as a percentage of the Zone 1 reach, i.e. as a reach multiplier.

Note that the Zone 1 extension scheme can be “Disabled”, permanently “Enabled” or just brought into service when the distance communication channel fails and the aided scheme would be inoperative. A selection of which out of the two channels available in the MiCOM P54x is monitored, is provided, with selections from Channel 1 and Channel 2 in any combination. The Logic Diagram is attached as Figure 47 below:

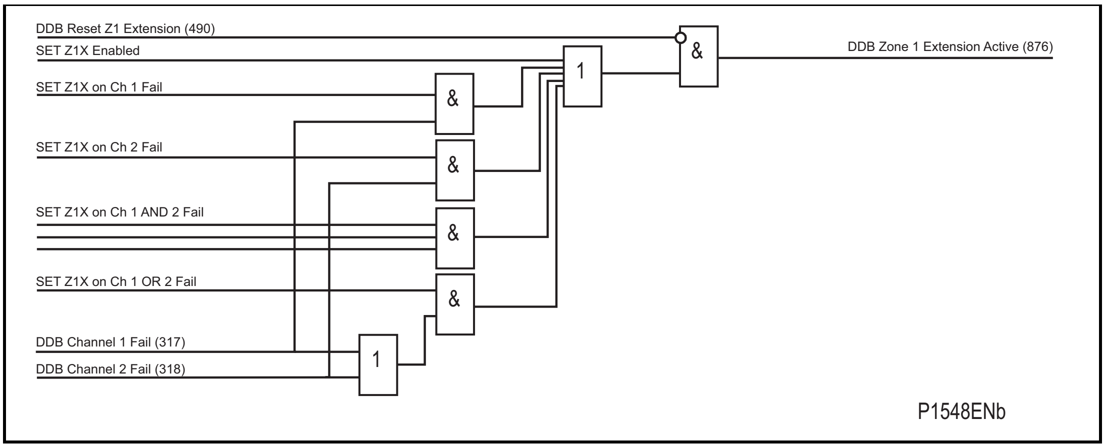

Figure 47: Zone 1 extension

1.24.2 Loss of load accelerated tripping (LoL)

The loss of load accelerated trip logic is shown in abbreviated form in Figure 48. The loss of load logic provides fast fault clearance for faults over the whole of a double end fed protected circuit for all types of fault, except three phase. The scheme has the advantage of not requiring a signaling channel. Alternatively, the logic can be chosen to be enabled when the channel associated with an aided scheme has failed. This failure is detected by permissive scheme unblocking logic, or a Channel Out of Service (COS) opto input. A selection of which out of the two channels available in the MiCOM P54x is monitored, is provided, with selections from Channel 1 and Channel 2 in any combination.

Any fault located within the reach of Zone 1 will result in fast tripping of the local circuit breaker. For an end zone fault with remote infeed, the remote breaker will be tripped in Zone 1 by the remote relay and the local relay can recognize this by detecting the loss of load current in the healthy phases. This, coupled with operation of a Zone 2 comparator causes tripping of the local circuit breaker.

Before an accelerated trip can occur, load current must have been detected prior to the fault. The loss of load current opens a window during which time a trip will occur if a Zone 2 comparator operates. A typical setting for this window is 40ms as shown in Figure 48, although this can be altered in the menu “LoL Window” cell. The accelerated trip is delayed by 18ms to prevent initiation of a loss of load trip due to circuit breaker pole discrepancy occurring for clearance of an external fault. The local fault clearance time can be deduced as follows:

t = Z1d + 2CB + LDr + 18ms

Where:

Z1d = Maximum downstream zone 1 trip time

CB = Breaker operating time

LDr = Upstream level detector (LoL: I<) reset time

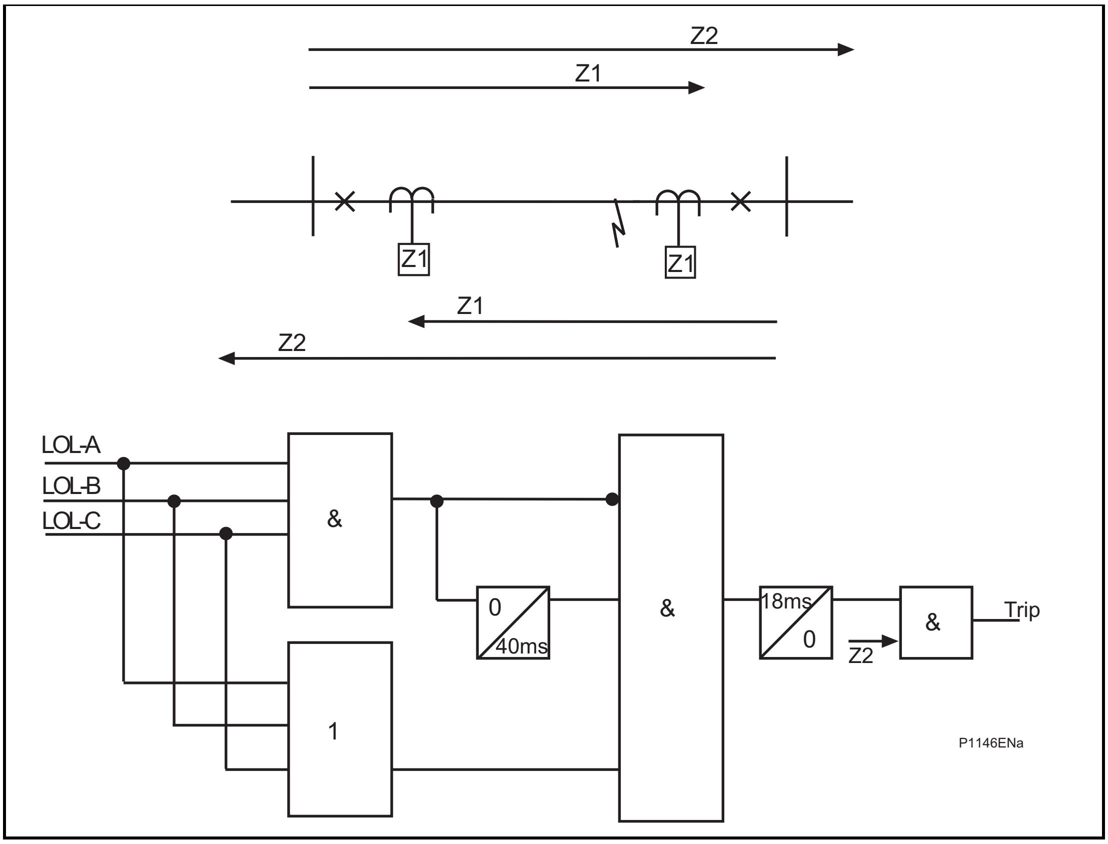

Figure 48: Loss of load accelerated trip scheme

For circuits with load tapped off the protected line, care must be taken in setting the loss of load feature to ensure that the I< level detector setting is above the tapped load current. When selected, the loss of load feature operates in conjunction with the main distance scheme that is selected. In this way it provides high speed clearance for end zone faults when the Basic scheme is selected or, with permissive signal aided tripping schemes, it provides high speed back-up clearance for end zone faults if the channel fails.

Note that loss of load tripping is only available where 3 pole tripping is used. The detailed Logic Diagram follows in Figure 49.

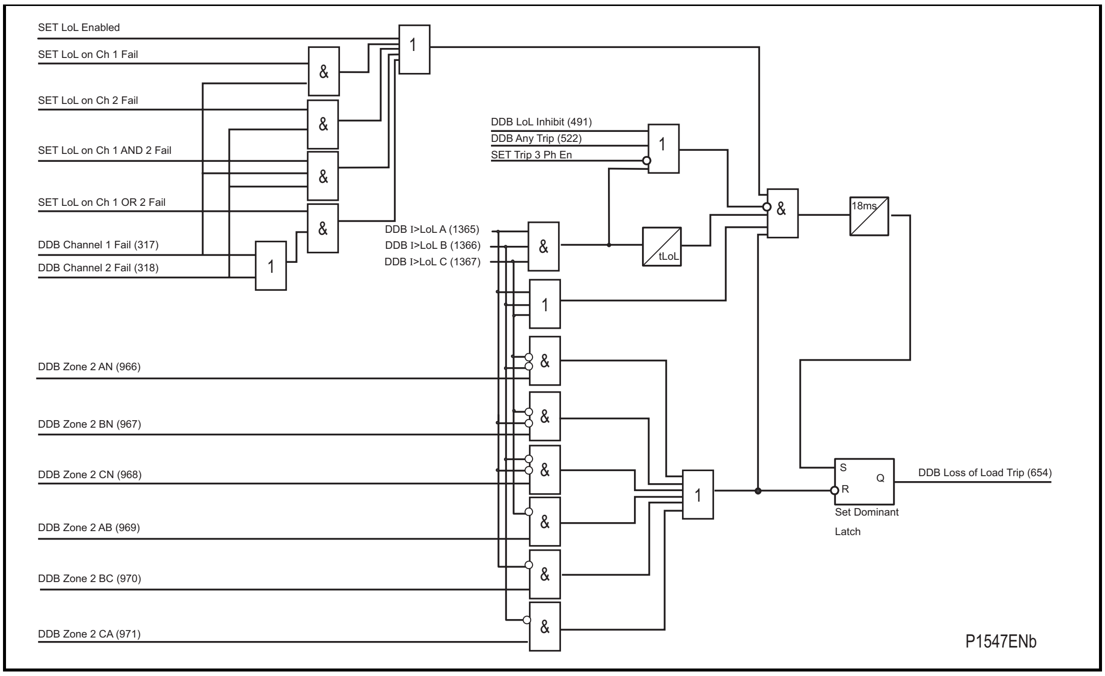

Figure 49: Loss of load

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1.25 Phase fault overcurrent protection

Phase fault overcurrent protection is provided as a form of back-up protection that could be:

- Permanently disabled
- Permanently enabled
- Enabled only in case of VT fuse/MCB failure
- Enabled only in case of protection communication channel failure
- Enabled if VT fuse/MCB or protection communication channel fail
- Enabled if VT fuse/MCB and protection communication channel fail

In addition, each stage may be disabled by a DDB (463,464,465 or 466) “Inhibit I > x“ (x = 1, 2, 3 or 4)

It should be noted that phase overcurrent protection is phase segregated, but the operation of any phase is mapped to 3 phase tripping in the default PSL.

The VTS element of the relay can be selected to either block the directional element or simply remove the directional control.

The first two stages can be set either inverse time or definite time only. The third and fourth stages have a DT characteristic only. Each stage can be configured to be directional forward, directional reverse or non-directional.

For the IDMT characteristics the following options are available.

The IEC/UK IDMT curves conform to the following formula:

$$t = T \times \left(\frac{\beta}{(I/Is)^{\alpha} - 1} + L \right)$$

The IEEE/US IDMT curves conform to the following formula:

$$t = TD \times \left(\frac{\beta}{(I/Is)^{\alpha} - 1} + L \right)$$

t = Operation time

β = Constant

I = Measured current

Is = Current threshold setting

α = Constant

L = ANSI/IEEE constant (zero for IEC curves)

T = Time multiplier setting for IEC/UK curves

TD = Time multiplier setting for IEEE/US curves

IDMT Curve Description	Standard	β Constant	α Constant	L Constant
Standard Inverse	IEC	0.14	0.02	0
Very Inverse	IEC	13.5	1	0
Extremely Inverse	IEC	80	2	0
Long Time Inverse	UK	120	1	0
Moderately Inverse	IEEE	0.0515	0.02	0.114
Very Inverse	IEEE	19.61	2	0.491
Extremely Inverse	IEEE	28.2	2	0.1217
Inverse	US-C08	5.95	2	0.18
Short Time Inverse	US	0.16758	0.02	0.11858

Note: That the IEEE and US curves are set differently to the IEC/UK curves, with regard to the time setting. A time multiplier setting (TMS) is used to adjust the operating time of the IEC curves, whereas a time dial setting is employed for the IEEE/US curves. The menu is arranged such that if an IEC/UK curve is selected, the ‘I> Time Dial’ cell is not visible and vice versa for the TMS setting.

1.25.1 Reset characteristics for overcurrent elements

Note that the IEC/UK inverse characteristics can be used with a definite time reset characteristic, however, the IEEE/US curves may have an inverse or definite time reset characteristic. The following equation can used to calculate the inverse reset time for IEEE/US curves:

$$tRESET = \frac{TD \times S}{(1 - M^2)} \text{ in seconds}$$

Where:

TD = Time dial setting for IEEE curves

S = Constant

M = I/Is

Curve Description	Standard	S Constant
Moderately Inverse	IEEE	4.85
Very Inverse	IEEE	21.6
Extremely Inverse	IEEE	29.1
Inverse	US	5.95
Short Time Inverse	US	2.261

1.25.2 Directional overcurrent protection

The phase fault elements of the MiCOM P54x relays are internally polarized by the quadrature phase-phase voltages, as shown in the table below:

Phase of Protection	Operate Current	Polarizing Voltage
A Phase	IA	VBC
B Phase	IB	VCA
C Phase	IC	VAB

Under system fault conditions, the fault current vector will lag its nominal phase voltage by an angle dependent upon the system X/R ratio. It is therefore a requirement that the relay operates with maximum sensitivity for currents lying in this region. This is achieved by means of the relay characteristic angle (RCA) setting; this defines the angle by which the current applied to the relay must be displaced from the voltage applied to the relay to obtain maximum relay sensitivity. This is set in cell "I>Char Angle" in the overcurrent menu. On the MiCOM P54x relays, it is possible to set characteristic angles anywhere in the range –95° to +95°.

The functional logic block diagram for directional overcurrent is shown overleaf.

The overcurrent block is a level detector that detects that the current magnitude is above the threshold and together with the respective polarizing voltage, a directional check is performed based on the following criteria:

Directional forward

-90° < (angle(I) - angle(V) - RCA) < 90°

Directional reverse

-90° > (angle(I) - angle(V) - RCA) > 90°

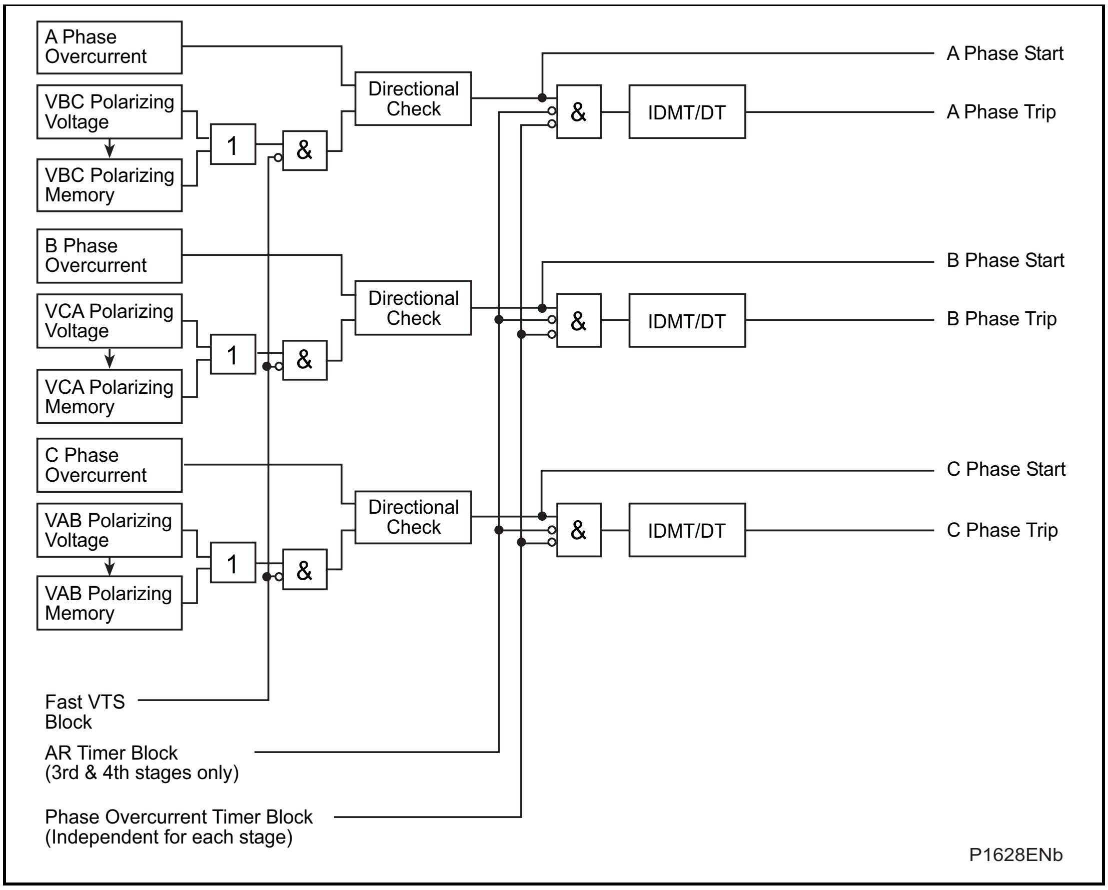

Figure 50: Directional overcurrent logic

Any of the four overcurrent stages may be configured to be directional noting that IDMT characteristics are only selectable on the first two stages. When the element is selected as directional, a VTS Block option is available. When the relevant bit is set to 1, operation of the Voltage Transformer Supervision (VTS), will block the stage if directionalized. When set to 0, the stage will revert to non-directional upon operation of the VTS.

1.26 Synchronous polarization

For a close up three-phase fault, all three voltages will collapse to zero and no healthy phase voltages will be present. For this reason, the MiCOM P54x relays include a synchronous polarization feature that stores the pre-fault voltage information and continues to apply it to the directional overcurrent elements for a time period of 3.2 seconds. This ensures that either instantaneous or time delayed directional overcurrent elements will be allowed to operate, even with a three-phase voltage collapse.

1.27 Thermal overload protection

The relay incorporates a current based thermal replica, using rms load current to model heating and cooling of the protected plant. The element can be set with both alarm and trip stages.

The heat generated within an item of plant, such as a cable or a transformer, is the resistive loss (I2R x t). Thus, heating is directly proportional to current squared. The thermal time characteristic used in the relay is therefore based on current squared, integrated over time. The relay automatically uses the largest phase current for input to the thermal model.

Equipment is designed to operate continuously at a temperature corresponding to its full load rating, where heat generated is balanced with heat dissipated by radiation etc.
Over-temperature conditions therefore occur when currents in excess of rating are allowed to flow for a period of time. It can be shown that temperatures during heating follow exponential time constants and a similar exponential decrease of temperature occurs during cooling.

OP

The relay provides two characteristics that may be selected according to the application.

Thermal overload protection may be disabled by DDB 478 “Inhibit Thermal > “.

1.27.1 Single time constant characteristic

This characteristic is used to protect cables, dry type transformers (e.g. type AN), and capacitor banks.

The thermal time characteristic is given by:

$$t \quad = \quad - \tau \log_e \left(\frac{I^2 - (K.I_{FLC})^2}{(I^2 - Ip^2)} \right)$$

Where:

t = Time to trip, following application of the overload current, I;

τ = Heating and cooling time constant of the protected plant;

I = Largest phase current;

IFLC = Full load current rating (relay setting ‘Thermal Trip’);

k = 1.05 constant, allows continuous operation up to <1.05 IFLC;

IP = Steady state pre-loading before application of the overload.

The time to trip varies depending on the load current carried before application of the overload, i.e. whether the overload was applied from 'hot” or “cold”.

The thermal time constant characteristic may be rewritten as:

$$e^{(-t/\tau)} = \left(\frac{\theta - \theta_p}{\theta - 1} \right)$$

Where:

θ = I2/k2 IFLC2

and

θp = Ip2/k2 IFLC2

Where θ is the thermal state and is θp the pre-fault thermal state.

> Note: A current of 105%Is (kIFLC) has to be applied for several time constants to cause a thermal state measurement of 100%.

1.27.2 Dual time constant characteristic (typically not applied for MiCOM P54x)

This characteristic is used to protect oil-filled transformers with natural air cooling (e.g. type ONAN). The thermal model is similar to that with the single time constant, except that two timer constants must be set.

For marginal overloading, heat will flow from the windings into the bulk of the insulating oil. Thus, at low current, the replica curve is dominated by the long time constant for the oil. This provides protection against a general rise in oil temperature.

For severe overloading, heat accumulates in the transformer windings, with little opportunity for dissipation into the surrounding insulating oil. Thus, at high current, the replica curve is dominated by the short time constant for the windings. This provides protection against hot spots developing within the transformer windings.

Overall, the dual time constant characteristic provided within the relay serves to protect the winding insulation from ageing, and to minimize gas production by overheated oil. Note, however, that the thermal model does not compensate for the effects of ambient temperature change.

The thermal curve is defined as:

$$0.4e^{(-t/\tau)} + 0.6e^{(-t/\tau)} = \frac{I^2 - (k.IFLC)^2}{I^2 - Ip^2}$$

Where:

$\tau 1$ = Heating and cooling time constant of the transformer windings;

$\tau 2$ = Heating and cooling time constant for the insulating oil.

In practice, it is difficult to solve this equation to give the operating time (t), therefore a graphical solution, using a spreadsheet package, is recommended. The spreadsheet can be arranged to calculate the current that will give a chosen operating time. The equation to calculate the current is defined as:

$$I = \sqrt{\frac{0.4Ip^2.e^{(-t/\tau 1)} + 0.6Ip^2.e^{(-t/\tau 2)} - k^2.I_{FLC}{}^2}{0.4\ e^{(-t/\tau 1)} + 0.6\ e^{(-t/\tau 2)} - 1}} \qquad \text{…….. Equation 1}$$

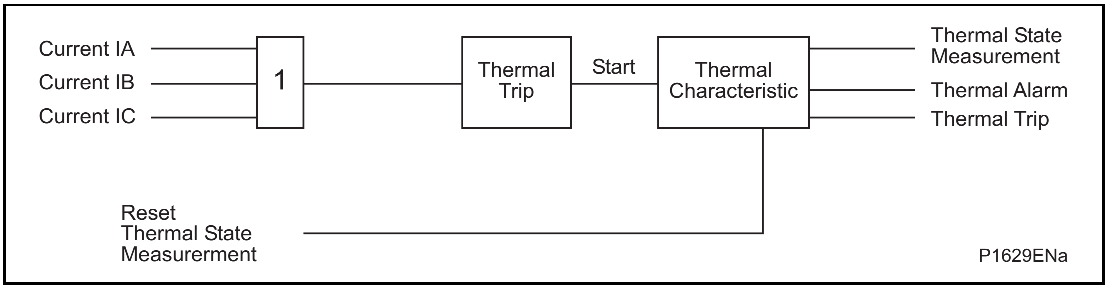

Figure 51: Thermal overload protection logic diagram

The functional block diagram for the thermal overload protection is shown in Figure 51.

The magnitudes of the three phase input currents are compared and the largest magnitude taken as the input to the thermal overload function. If this current exceeds the thermal trip threshold setting a start condition is asserted.

1.28 Earth fault (ground overcurrent) and sensitive earth fault (SEF) protection

The P54x relays include backup earth fault protection. Two elements are available; a derived earth fault element (where the residual current to operate the element is derived from the addition of the three line CT currents) and a sensitive earth fault element where low current settings are required. The sensitive earth fault element has a separate CT input and would normally be connected to a core balance CT. The derived and sensitive earth fault elements both have four stages of protection. The first two stages can be set either inverse time or definite time only. Each stage can be configured to be directional forward, directional reverse or non-directional.

A feature also exists whereby the protection can be enabled upon failure of the differential protection communication channel (not applicable to sensitive earth fault). Earth fault Overcurrent IN> can be set to:

– Permanently disabled

– Permanently enabled

– Enabled only in case of VT fuse/MCB failure

– Enabled only in case of protection communication channel failure

– Enabled if VT fuse/MCB or protection communication channel fail

– Enabled if VT fuse/MCB and protection communication channel fail

In addition, each stage (not for SEF) may be disabled by a DDB (467,468,469 and 470) “Inhibit IN > x“ (x = 1, 2, 3 or 4).

The VTS element of the relay can be selected to either block the directional element or simply remove the directional control.

The IN> and ISEF> Function Links settings have the following effect:

VTS Block - When the relevant is set to 1, operation of the Voltage Transformer Supervision (VTS) will block the stage if it directionalized. When set to 0 the stage will revert to non-directional upon operation of the VTS.

The inverse time characteristics available for the earth fault protection are the same as those for the phase overcurrent elements.

A/R Block - The auto-reclose logic can be set to block instantaneous earthfault elements after a prescribed number of shots. This is set in the auto-reclose column. When a block instantaneous signal is generated then only those earthfault stages selected to a '1' in the IN> or ISEF Function Link will be blocked.

1.29 Directional earth fault protection

As stated in the previous sections, each of the four stages of earth fault protection may be set to directional if required. Consequently, as with the application of directional overcurrent protection, a suitable voltage supply is required by the relay to provide the necessary polarization. Two options are available for polarization; Residual Voltage or Negative Sequence.

1.30 Residual voltage polarization

With earth fault protection, the polarizing signal requires to be representative of the earth fault condition. As residual voltage is generated during earth fault conditions, this quantity is commonly used to polarize DEF elements. The relay internally derives this voltage from the 3 phase voltage input which must be supplied from either a 5-limb or three single phase VTs. These types of VT design allow the passage of residual flux and consequently permit the relay to derive the required residual voltage. In addition, the primary star point of the VT must be earthed. A three-limb VT has no path for residual flux and is therefore unsuitable to supply the relay.

Note that residual voltage is nominally 180° out of phase with residual current. Consequently, the DEF relays are polarized from the '-Vres' quantity. This 180° phase shift is automatically introduced within the relay.

The directional criteria with zero sequence (residual voltage) polarization are given below:

Directional forward

$-90^{o} < (\text{angle(IN)} - \text{angle(VN}+180^{o}) - \text{RCA}) < 90^{o}$

Directional reverse

$-90^{o} > (\text{angle(IN)} - \text{angle(VN}+180^{o}) - \text{RCA}) > 90^{o}$

The *virtual current polarizing* feature is not available for use with the backup earth fault elements - that is used exclusively in DEF aided schemes only.

The logic diagram for directional earth fault overcurrent with neutral voltage polarization is shown overleaf.

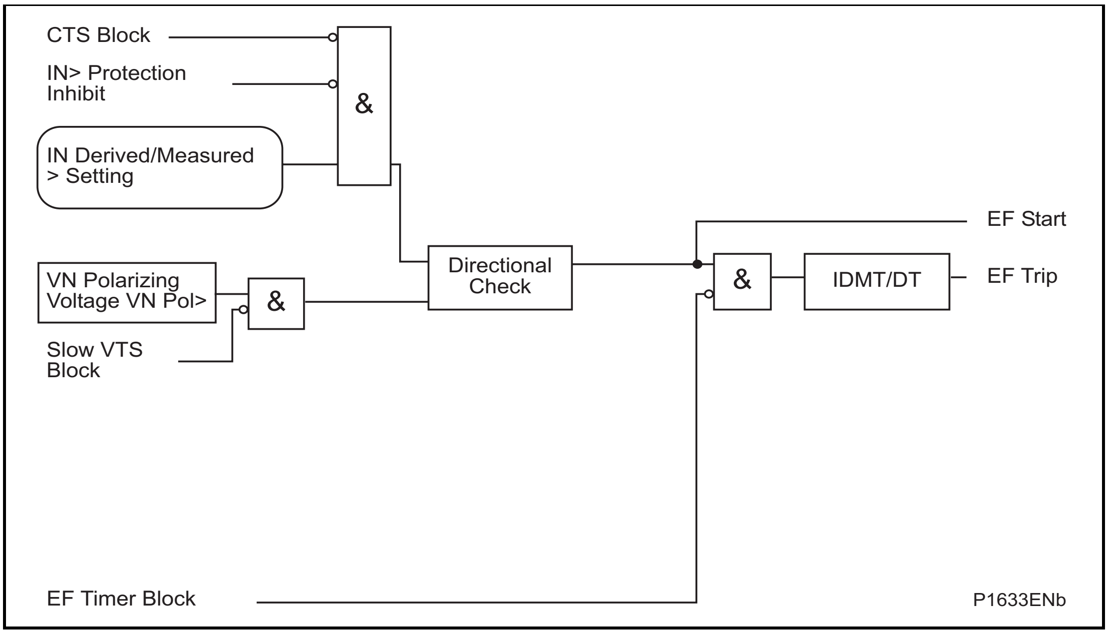

Figure 52: Directional EF with neutral voltage polarization (single stage)

1.30.1 Negative sequence polarization (Not for SEF)

In certain applications, the use of residual voltage polarization of DEF may either be not possible to achieve, or problematic. An example of the former case would be where a suitable type of VT was unavailable, for example if only a three limb VT was fitted. An example of the latter case would be an HV/EHV parallel line application where problems with zero sequence mutual coupling may exist.

In either of these situations, the problem may be solved by the use of negative phase sequence (nps) quantities for polarization. This method determines the fault direction by comparison of nps voltage with nps current. The operate quantity, however, is still residual current.

It requires a suitable voltage and current threshold to be set in cells "IN>V2pol set" and "IN>I2pol set", respectively.

Negative sequence polarizing is not recommended for impedance earthed systems regardless of the type of VT feeding the relay. This is due to the reduced earth fault current limiting the voltage drop across the negative sequence source impedance (V2pol) to negligible levels. If this voltage is less than 0.5 volts the relay will cease to provide DEF.

The logic diagram for directional earth fault overcurrent with negative sequence polarization is shown overleaf.

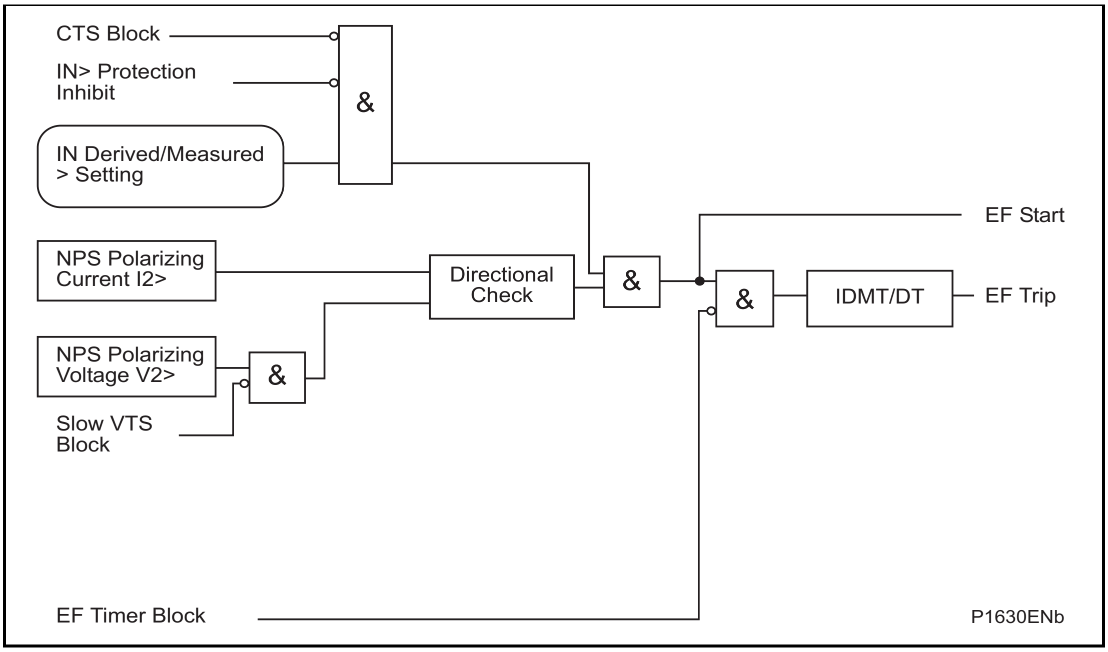

Figure 53: Directional EF with negative sequence polarization (single stage)

The directional criteria with negative sequence polarization is given below:

Directional forward

-90° < (angle(I2) - angle(V2 + 180°) - RCA) < 90°

Directional reverse

-90° > (angle(I2) - angle(V2 + 180°) - RCA) > 90°

1.31 Negative sequence overcurrent protection (NPS)

The negative phase sequence overcurrent element has a current pick up setting "I2> Current Set", and is time delayed in operation by the adjustable timer "I2> Time Delay". The user may choose to directionalize operation of the element, for either forward or reverse fault protection for which a suitable relay characteristic angle may be set. Alternatively, the element may be set as non-directional.

When the element is selected as directional, a VTS Block option is available. When the relevant bit is set to 1, operation of the Voltage Transformer Supervision (VTS), will block the stage if directionalized. When set to 0, the stage will revert to non-directional upon operation of the VTS.

I2> may be disabled by DDB 477 “Inhibit I2 >

1.31.1 Directionalizing the negative phase sequence overcurrent element

Directionality is achieved by comparison of the angle between the negative phase sequence voltage and the negative phase sequence current and the element may be selected to operate in either the forward or reverse direction. A suitable relay characteristic angle setting (I2> Char Angle) is chosen to provide optimum performance. This setting should be set equal to the phase angle of the negative sequence current with respect to the inverted negative sequence voltage (– V2), in order to be at the center of the directional characteristic.

For the negative phase sequence directional elements to operate, the relay must detect a polarizing voltage above a minimum threshold, "I2> V2pol Set". The logic diagram for negative sequence overcurrent protection (shown with directional operation) is attached as Figure 54 below.

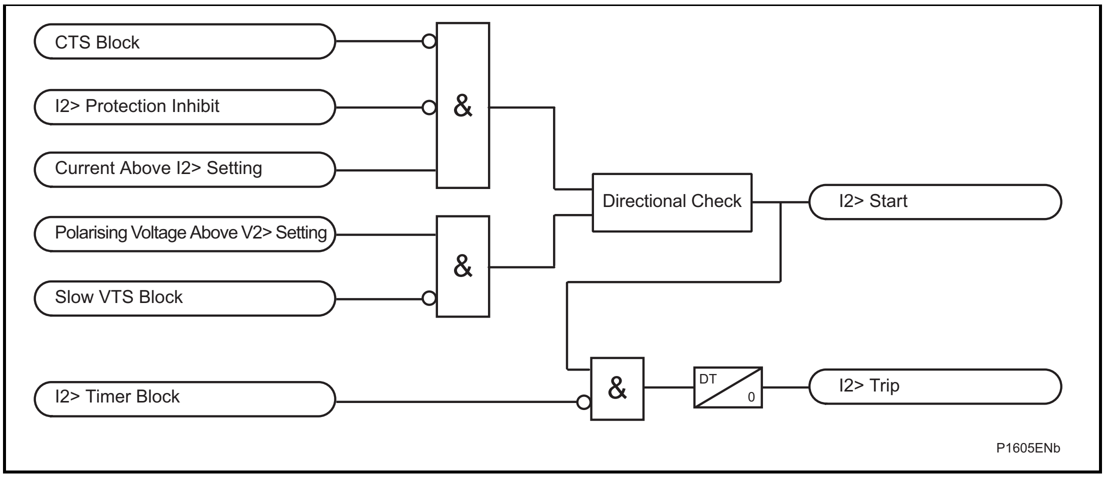

Figure 54: Directionalizing the negative phase sequence overcurrent element

1.32 Undervoltage protection

Both the under and overvoltage protection functions can be found in the relay menu "Volt Protection". The undervoltage protection included within consists of two independent stages. These are configurable as either phase to phase or phase to neutral measuring within the "V<Measur't mode" cell.

Stage 1 may be selected as either IDMT, DT or Disabled, within the "V<1 function" cell. Stage 2 is DT only and is enabled/disabled in the "V<2 status" cell.

Two stages are included to provide both alarm and trip stages, where required. Alternatively, different time settings may be required depending upon the severity of the voltage dip.

Outputs are available for single or three phase conditions via the "V<Operate Mode" cell.

When the protected feeder is de-energized, or the circuit breaker is opened, an undervoltage condition would be detected. Therefore, the "V<Polehead Inh" cell is included for each of the two stages to block the undervoltage protection from operating for this condition. If the cell is enabled, the relevant stage will become inhibited by the inbuilt pole dead logic within the relay. This logic produces an output when it detects either an open circuit breaker via auxiliary contacts feeding the relay opto inputs or it detects a combination of both undercurrent and undervoltage on any one phase.

The IDMT characteristic available on the first stage is defined by the following formula:

$t = K/(1 - M)$

Where:

K = Time multiplier setting

t = Operating time in seconds

M = Measured voltage / relay setting voltage (V< Voltage Set)

The logic diagram for the first stage undervoltage function is shown in Figure 55.

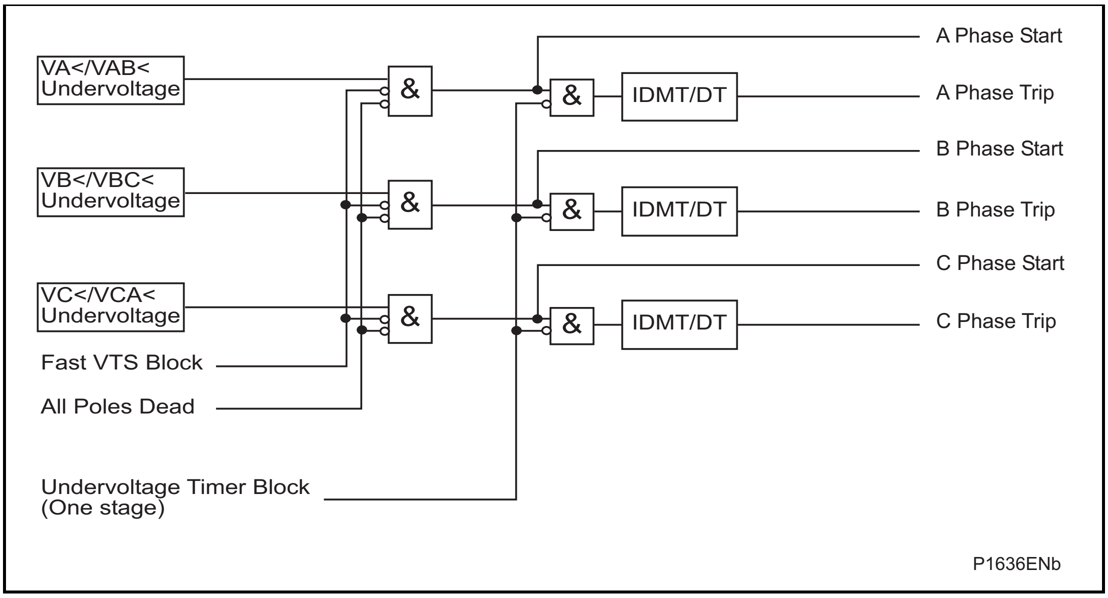

Figure 55: Undervoltage - single and three phase tripping mode (single stage)

It should be noted that undervoltage protection is phase segregated, but the operation of any phase is mapped to 3 phase tripping in the default PSL.

Each stage of Undervoltage protection may be disabled by a DDB (471 or 472) “Inhibit Vx<“.

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1.33 Overvoltage protection

Both the over and undervoltage protection functions can be found in the relay menu "Volt Protection".

The IDMT characteristic available on the first stage is defined by the following formula:

t = K/(M - 1)

Where:

K = Time multiplier setting

t = Operating time in seconds

M = Measured voltage/relay setting voltage (V> Voltage Set)

The logic diagram for the first stage overvoltage function is shown in Figure 56.

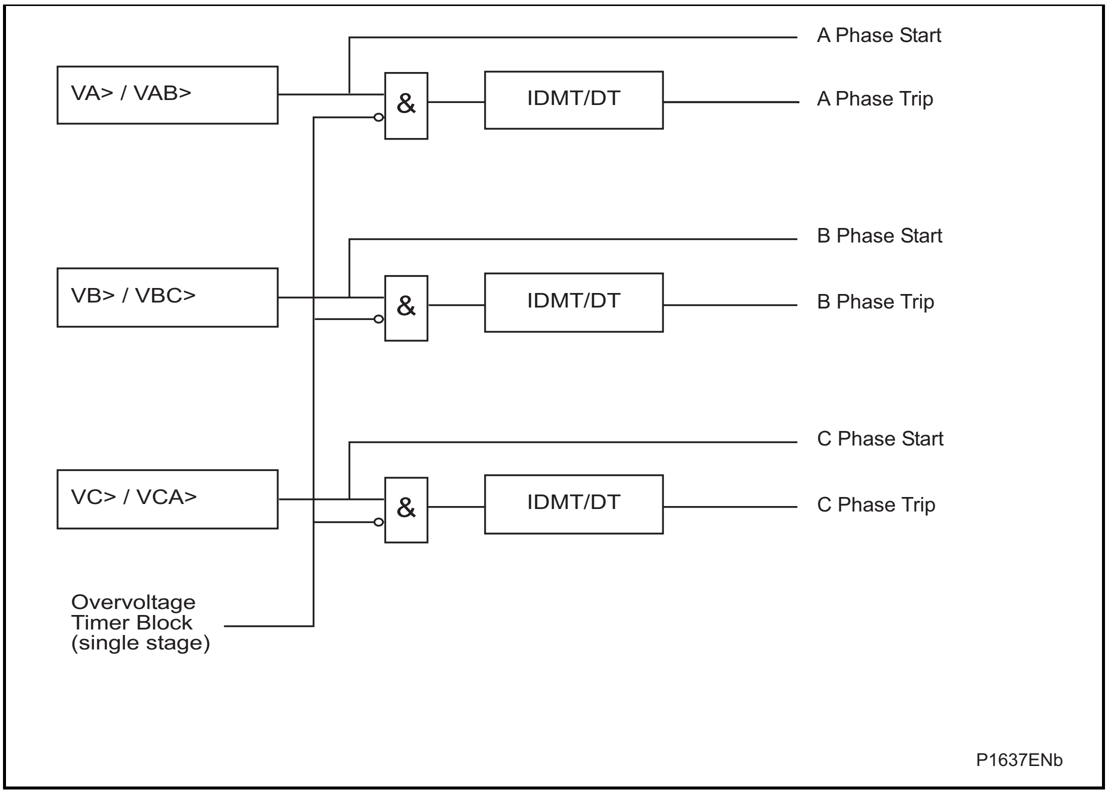

Figure 56: Overvoltage - single and three phase tripping mode (single stage)

It should be noted that phase overvoltage protection is phase segregated, but the operation of any phase is mapped to 3 phase tripping in the default PSL.

Each stage of Overvoltage protection may be disabled by a DDB (473 or 474) “Inhibit Vx>“ (x = 1, 2).

1.34 Residual overvoltage (neutral displacement) protection

The NVD element within the MiCOM P54x is of two stage design, each stage having separate voltage and time delay settings. Stage 1 may be set to operate on either an IDMT or DT characteristic, whilst stage 2 may be set to DT only. Two stages are included for the NVD protection to account for applications which require both alarm and trip stages.

The relay internally derives the NVD voltage from the 3 input phases which must be supplied from either a 5-limb or three single phase VT’s. These types of VT design allow the passage of residual flux and consequently permit the relay to derive the required residual voltage. In addition, the primary star point of the VT must be earthed. A three limb VT has no path for residual flux and is therefore unsuitable to supply the relay.

The IDMT characteristic available on the first stage is defined by the following formula:

$t = K/(M - 1)$

Where:

K = Time multiplier setting

t = Operating time in seconds

M = Derived residual voltage/relay setting voltage (VN> Voltage Set)

The functional block diagram of the first stage residual overvoltage is shown below:

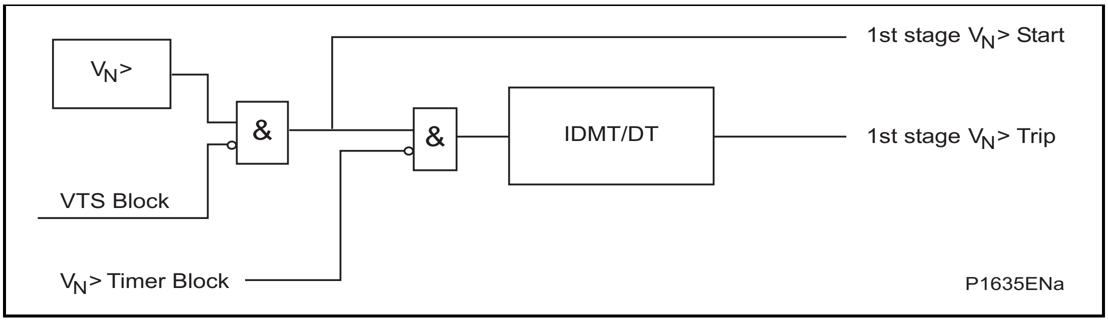

Figure 57: Residual overvoltage logic (single stage)

Each stage of Residual Overvoltage protection may be disabled by a DDB (475 or 476) “Inhibit VN>x“ (x = 1, 2).

1.35 Circuit breaker fail protection (CBF)

The circuit breaker failure protection incorporates two timers, ‘CB Fail 1 Timer’ and ‘CB Fail 2 Timer’, allowing configuration for the following scenarios:

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– Simple CBF, where only ‘CB Fail 1 Timer’ is enabled. For any protection trip, the ‘CB Fail 1 Timer’ is started, and normally reset when the circuit breaker opens to isolate the fault. If breaker opening is not detected, ‘CB Fail 1 Timer’ times out and closes an output contact assigned to breaker fail (using the programmable scheme logic). This contact is used to backtrip upstream switchgear, generally tripping all infeeds connected to the same busbar section.

– A re-tripping scheme, plus delayed backtripping. Here, ‘CB Fail 1 Timer’ is used to route a trip to a second trip circuit of the same circuit breaker. This requires duplicated circuit breaker trip coils, and is known as re-tripping. Should re-tripping fail to open the circuit breaker, a backtrip may be issued following an additional time delay. The backtrip uses ‘CB Fail 2 Timer’, which is also started at the instant of the initial protection element trip.

CBF elements ‘CB Fail 1 Timer’ and ‘CB Fail 2 Timer’ can be configured to operate for trips triggered by protection elements within the relay or via an external protection trip. The latter is achieved by allocating one of the relay opto-isolated inputs to ‘External Trip’ using the programmable scheme logic.

1.35.1 Reset mechanisms for breaker fail timers

It is common practice to use low set undercurrent elements in protection relays to indicate that circuit breaker poles have interrupted the fault or load current, as required. This covers the following situations:

– Where circuit breaker auxiliary contacts are defective, or cannot be relied upon to definitely indicate that the breaker has tripped.

– Where a circuit breaker has started to open but has become jammed. This may result in continued arcing at the primary contacts, with an additional arcing resistance in the fault current path. Should this resistance severely limit fault current, the initiating protection element may reset. Thus, reset of the element may not give a reliable indication that the circuit breaker has opened fully.

For any protection function requiring current to operate, the relay uses operation of undercurrent elements (I<) to detect that the necessary circuit breaker poles have tripped and reset the CB fail timers. However, the undercurrent elements may not be reliable methods of resetting circuit breaker fail in all applications. For example:

– Where non-current operated protection, such as under/overvoltage derives measurements from a line connected voltage transformer. Here, I< only gives a reliable reset method if the protected circuit would always have load current flowing. Detecting drop-off of the initiating protection element might be a more reliable method.

– Similarly, where the distance scheme includes Weak Infeed ("WI") trip logic, the reset of the WI trip condition should be used in addition to the undercurrent check. Set: *'WI Prot Reset'* = Enabled.

– Where non-current operated protection, such as under/overvoltage derives measurements from a busbar connected voltage transformer. Again using I< would rely upon the feeder normally being loaded. Also, tripping the circuit breaker may not remove the initiating condition from the busbar, and hence drop-off of the protection element may not occur. In such cases, the position of the circuit breaker auxiliary contacts may give the best reset method.

Resetting of the CBF is possible from a breaker open indication (from the relay's pole dead logic) or from a protection reset. In these cases resetting is only allowed provided the undercurrent elements have also reset. The resetting options are summarized in the following table.

Initiation (Menu Selectable)	**CB Fail Timer Reset Mechanism**
Current based protection (e.g. 50/51/46/21/67)	The resetting mechanism is fixed [IA< operates] & [IB< operates] & [IC< operates] & [IN< operates]
Non-current based protection (e.g. 27/59)	Three options are available. The user can Select from the following options: [All I< and IN< elements operate] [Protection element reset] AND [All I< and N< elements operate] CB open (all 3 poles) AND [All I< and IN< elements operate]
External protection	Three options are available: The user can select any or all of the options. [All I< and IN< elements operate] [External trip reset] AND [All I< and IN< elements operate] CB open (all 3 poles) AND [All I< and IN< elements operate]

The complete breaker fail logic is illustrated in Figure 58 and 59.

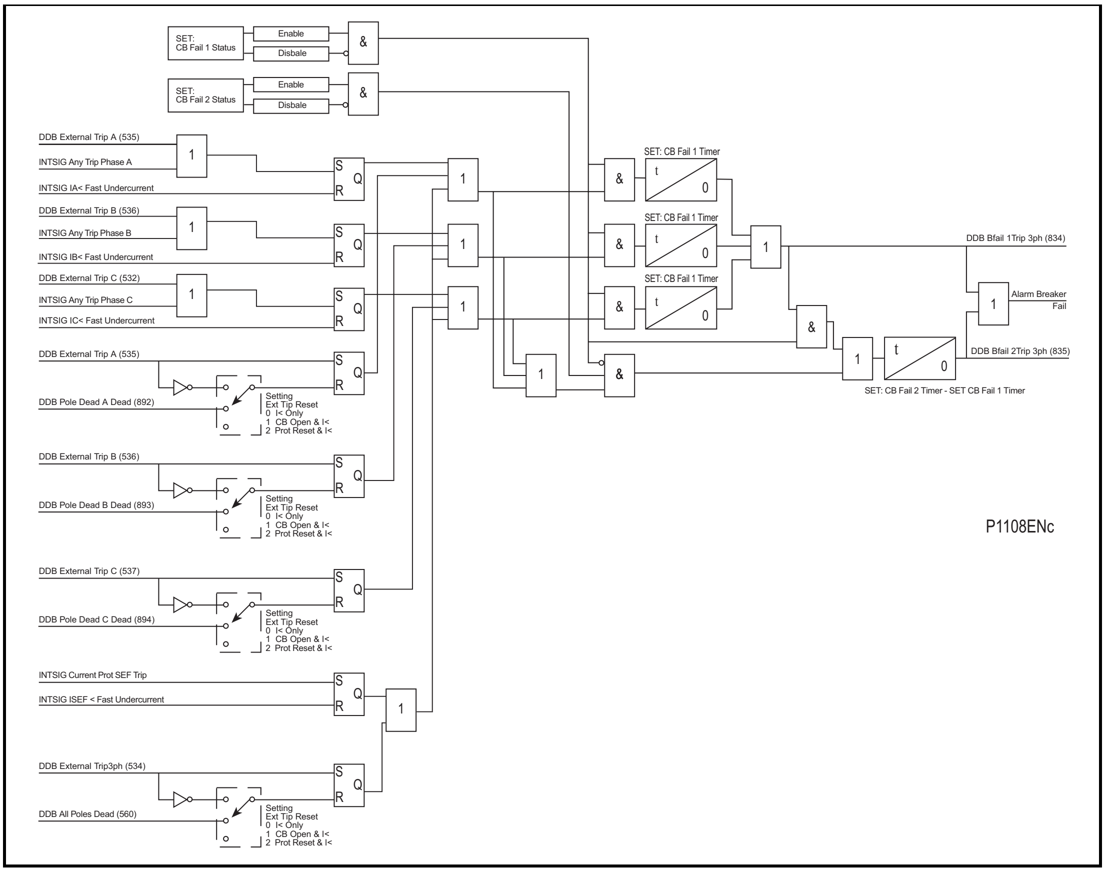

Figure 58: CB failure for P543 and P545 models

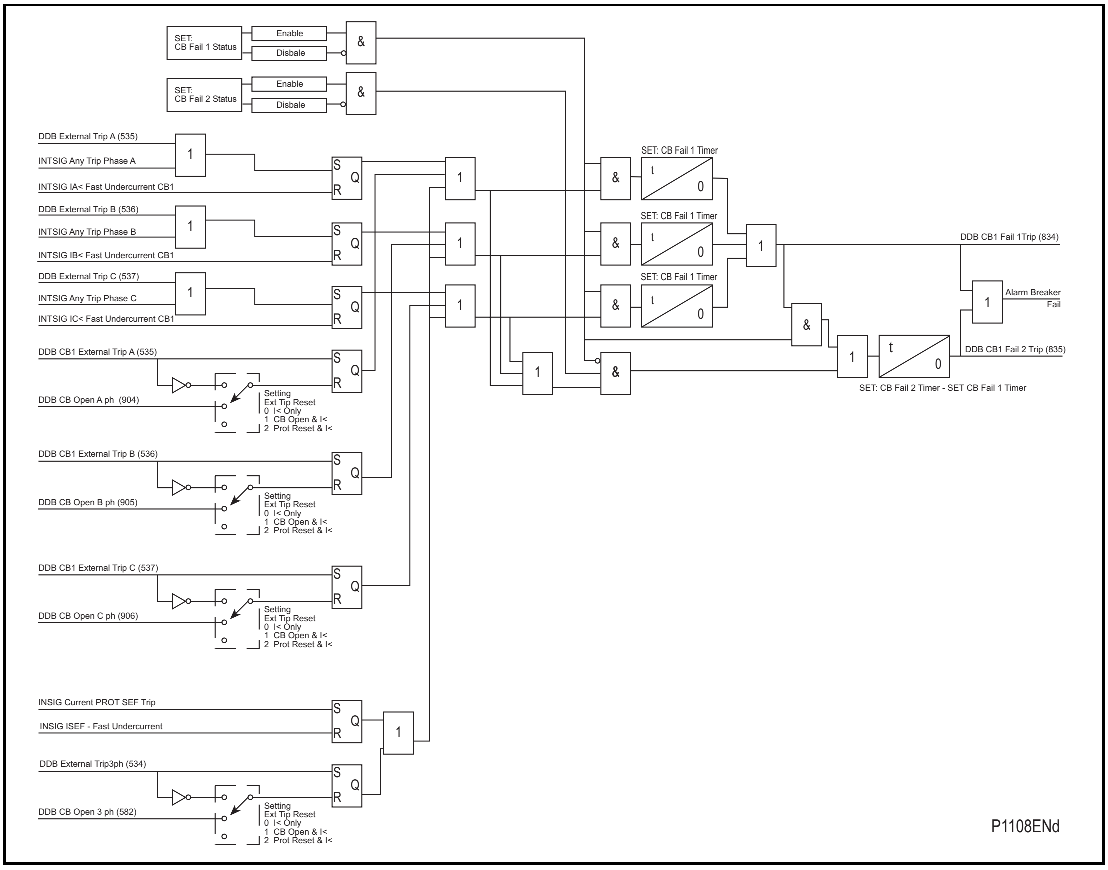

Figure 59: CB failure for P544 and P546 models (repeated for each CB)

1.36 Broken conductor detection

The relay incorporates an element which measures the ratio of negative to positive phase sequence current ($I2/I1$). This will be affected to a lesser extent than the measurement of negative sequence current alone, since the ratio is approximately constant with variations in load current. Hence, a more sensitive setting may be achieved.

The logic diagram is as shown below. The ratio of $I2/I1$ is calculated and is compared with the threshold and if the threshold is exceeded then the delay timer is initiated. The CTS block signal is used to block the operation of the delay timer.

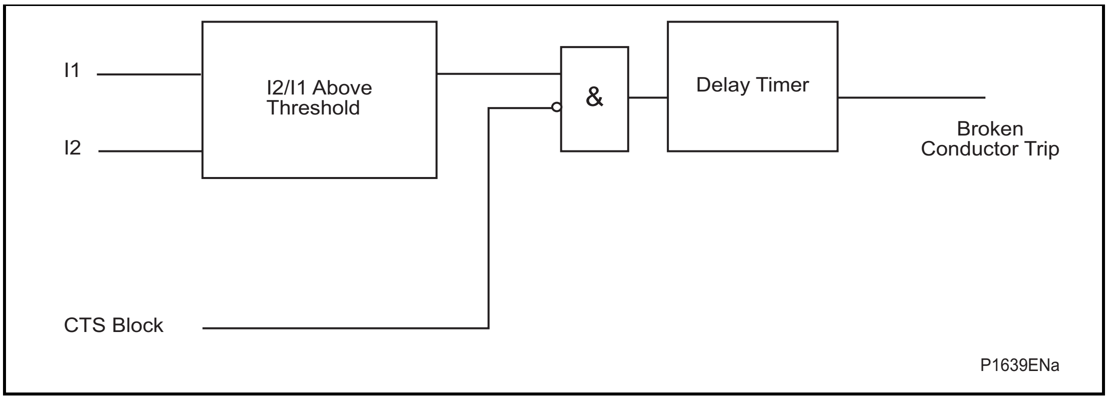

Figure 60: Broken conductor logic

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1.37 Special weak infeed logic for stub end transformer terminals

The true weak infeed condition is when no current based protection element is sensitive enough to operate. This is the case when zero or minimal generation is connected at that terminal, and the prospective level of fault current flowing through the CT is insufficient for any forward/reverse protection operation. In such cases, the fault will be cleared using either POR or Blocking schemes and enabling WI Echo + Trip.

However, there could be a specific configuration as presented in Figure 61 that may not be detected by relay as a weak infeed condition, even if there is no generation at that end (left side - relay R2).

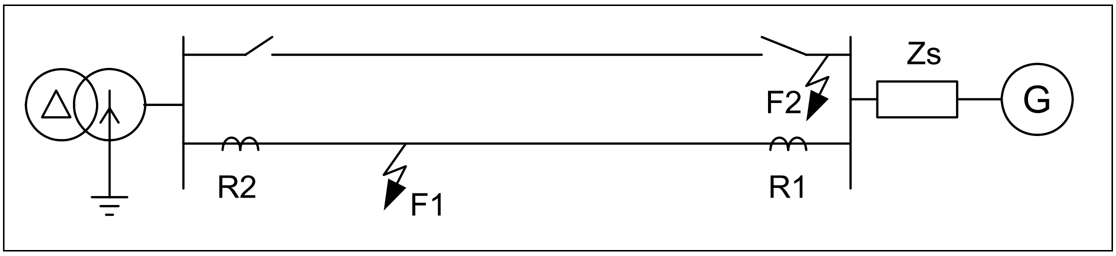

Figure 61: Weak infeed configuration on stub-fed radial circuit (parallel line is out of service)

The reason is a star earthed transformer which, in case of phase to ground and double phase to ground faults, imposes a very low zero sequence impedance and almost infinite positive and negative sequence impedance, i.e. behaving as a source of zero sequence current only. In such a case, the zero sequence current Io will dominate over I_1 and I_2 at the weak end, where all three phase currents will approximately equal Io (all in phase and equal in magnitude). This is true for F1 earth faults at R2, and for F2 earth faults at R1 and R2. The phase currents will be sufficient to pickup current level detectors in the MiCOM P54x, and a true weak infeed condition will not be seen as such by the relay.

In such a stub-end feeding case, relay R2 may experience some overreach in the case of double-phase to ground faults. This is caused by the unusual current distribution making the MiCOM P54x detect a single phase fault condition (and potential single pole tripping only in single pole tripping applications).

For this unusual feeding arrangement, the MiCOM P54x makes available a Zero sequence stabilizing feature, that measures the dominance of zero sequence current over negative sequence current (I_o/I_2). It promotes stability by forcing the relay to recognize the above configuration as a WI condition. It then blocks all distance elements, once the measured I_o/I_2 ratio exceeds the setting.

2. OPERATION OF NON PROTECTION FUNCTIONS

2.1 Single and three phase auto-reclosing

Note: Auto-reclose is only offered in the P543 and P545.

2.1.1 Time delayed and high speed auto-reclosing

The MiCOM P54x will initiate auto-reclosure following any current differential, Zone 1, or distance-aided scheme trips which occur. In addition, the user can selectively decide to auto-reclose for trips from time-delayed distance zones, overcurrent and earth (ground) elements, and DEF aided schemes.

The auto-reclose function offers multi-shot auto-reclose control, selectable to perform up to a four shot cycle. Dead times (Note 1) for all shots (Note 2) are independently adjustable. Should the CB close successfully at the end of the dead time, a "Reclaim Time" starts. If the circuit breaker does not trip again, the auto-reclose function resets at the end of the reclaim time. If the protection trips again during the reclaim time the relay advances to the next shot in the programmed cycle, or, if all programmed reclose attempts have been made, goes to lockout.

Note 1 - "Dead Time" denotes the open (dead) interval delay of the CB.

Note 2 - A "Shot" is a reclosure attempt

Logic diagrams to explain the operation of the auto-reclose feature are grouped together at the end of this section.

2.1.2 Auto-reclose logic inputs

The auto-reclose function uses inputs in the logic, which can be assigned and activated from any of the opto-isolated inputs on the relay via the programmable scheme logic (PSL). Contacts from external equipment may be used to influence the auto-recloser via the optos, noting that the CB Status (open/closed) must also be available via auxiliary contact inputs to the relay.

These logic inputs can also be assigned and activated from other sources. The function of these inputs is described below, identified by their DDB signal text. The inputs can be selected to accept either a normally open or a normally closed contact, programmable via the PSL editor.

2.1.2.1 CB healthy

The majority of circuit breakers are only capable of providing one trip-close-trip cycle. Following this, it is necessary to re-establish sufficient energy in the circuit breaker before the CB can be reclosed. The CB Healthy input is used to ensure that there is sufficient energy available to close and trip the CB before initiating a CB close command. If on completion of the dead time, sufficient energy is not detected by the relay from the CB Healthy input for a period given by the CB Healthy time timer, lockout will result and the CB will remain open.

2.1.2.2 BAR

The "BAR" input will block auto-reclose and cause a lockout if auto-reclose is in progress. It can be used when protection operation without auto-reclose is required.

2.1.2.3 Reset lockout

The "Reset Lockout" input can be used to reset the auto-reclose function following lockout and reset any auto-reclose alarms, provided that the signals which initiated the lockout have been removed.

2.1.2.4 Pole discrepancy

CBs with independent mechanisms for each pole normally incorporate a ‘phases not together’ or ‘pole discrepancy’ protection device which automatically trips all three phases if they are not all in the same position i.e. all open or all closed.

During single pole auto-reclosing a pole discrepancy condition is deliberately introduced and the pole discrepancy device must not operate for this condition. This may be achieved by using a delayed action pole discrepancy device with a delay longer than the single pole auto-reclose dead time, ‘1 Pole Dead Time’. Alternatively, a signal can be given from the relay during the single pole auto-reclose dead time, “AR 1 Pole In Progress”, to inhibit the pole discrepancy device.

The “Pole Discrepancy” input is activated by a signal from an external device indicating that all three poles of the CB are not in the same position. The “Pole Discrepancy” input forces a 3 pole trip which will cancel any single pole auto-reclose in progress and start three pole auto-reclose in progress.

2.1.2.5 Enable 1 pole AR

The “En 1 Pole Reclose” input is used to select the single phase auto-reclose operating mode.

2.1.2.6 Enable 3 pole AR

OP

The “En 3 Pole Reclose” input is used to select the three phase auto-reclose operating mode.

2.1.2.7 External trip

The “External Trip 3Ph” input and the “External Trip A”, “External Trip B” and “External Trip C” inputs can be used to initiate three or single phase auto-reclose. Note, these signals are not used to trip the CB but do initiate auto-reclose. To trip the CB directly they could be assigned to the trip contacts of the relay in the PSL.

2.1.3 Internal signals

2.1.3.1 Trip initiate signals

The “Trip Inputs A”, “Trip Inputs B” and “Trip Inputs C” signals are used to initiate signals or three phase auto-reclose. Note, for single phase auto-reclose these signals must be mapped in the PSL as shown in the default.

2.1.3.2 Circuit breaker status

The “CB Open 3 ph”, “CB Open A ph”, “CB Open B ph” and “CB Open C ph”, signals are used to indicate if a CB is open three or single phase. These are driven from the internal pole dead logic and the CB auxiliary inputs.

The “CB Closed 3 ph”, “CB Closed A ph”, “CB Closed B ph” and “CB Closed C ph”, signals are used to indicate if a CB is closed three or single phase. These are driven from the internal pole dead logic and the CB auxiliary inputs.

2.1.3.3 Check synch ok and system check ok

Internal signals generated from the internal system check function and external system check equipment are used by the internal auto-reclose logic to permit auto-reclosure.

2.1.4 Auto-reclose logic outputs

The following DDB signals can be masked to a relay contact in the PSL or assigned to a Monitor Bit in “Commissioning Tests”, to provide information about the status of the auto-reclose cycle. These are described below, identified by their DDB signal text.

2.1.4.1 AR 1 pole in progress

The “AR 1 Pole in Progress” output indicates that single pole auto-reclose is in progress. The output is on from protection initiation to the end of the single pole dead time, “1 Pole Dead Time”.

2.1.4.2 AR 3 pole in progress

The “AR 3 Pole in Progress” output indicates that three pole auto-reclose is in progress. The output is on from protection initiation to the end of the three pole dead time, ‘Dead Time 1, 2, 3, 4’.

2.1.4.3 Successful close

The “AR Successful Reclose” output indicates that an auto-reclose cycle has been successfully completed. A successful auto-reclose signal is given after the CB has tripped from the protection and reclosed whereupon the fault has been cleared and the reclaim time has expired resetting the auto-reclose cycle. The successful auto-reclose output is reset at the next CB trip or from one of the reset lockout methods; see section 2.1.7.5 ’Reset from lockout’.

2.1.4.4 AR status

The “A/R In Status 1P” output indicates that the relay is in the single phase auto-reclose mode. The “A/R In Status 3P” output indicates that the relay is in the three phase auto-reclose mode.

2.1.4.5 Auto close

The “Auto Close” output indicates that the auto-reclose logic has issued a close signal to the CB. This output feeds a signal to the control close pulse timer and remains on until the CB has closed. This signal may be useful during relay commissioning to check the operation of the auto-reclose cycle. This signal is combined with the manual close signal to produce the signal “Control Close” which should be mapped to an output contact.

2.1.5 Auto-reclose alarms

The following DDB signals will produce a relay alarm. These are described below, identified by their DDB signal text.

2.1.5.1 AR No checksync (latched)

The “AR No Checksync” alarm indicates that the system voltages were not in synchronism at the end of the “Check Sync Time”, leading to a lockout condition. This alarm can be reset using one of the reset lockout methods; see section 2.1.7.5 ’Reset from lockout’.

2.1.5.2 AR CB unhealthy (latched)

The “AR CB Unhealthy” alarm indicates that the “CB Healthy” input was not energized at the end of the “CB Healthy Time”, leading to a lockout condition. The “CB Healthy” input is used to indicate that there is sufficient energy in the CB operating mechanism to close and trip the CB at the end of the dead time. This alarm can be reset using one of the reset lockout methods; see section 2.1.7.5 ’Reset from lockout’.

2.1.5.3 AR lockout (self reset)

The “AR Lockout” alarm indicates that the relay is in a lockout state and that further reclose attempts will not be made; see section 2.1.7.4 ‘AR Lockout’ for more details. This alarm can be reset using one of the reset lockout methods; see section 2.1.7.5 ’Reset from lockout’.

2.1.6 Auto-reclose logic operating sequence

An auto-reclose cycle can be internally initiated by operation of a protection element, provided the circuit breaker is closed until the instant of protection operation. The user can, via a setting, determine if the auto-reclose shall be initiated on the rising edge of the protection trip (Protection Op) or on the falling edge (Protection Reset).

If single pole auto-reclose [A/R Status 1P] only is enabled then if the first fault is a single phase fault the single pole dead time ("1 Pole Dead Time") and single pole auto-reclose in progress [AR 1pole in prog] starts on the rising or falling edge (according to the setting) of the single phase trip. If the relay has been set to allow more than one single pole reclose [Single Pole Shot >1] then any subsequent single phase faults will be converted to 3 pole trips. The three pole dead times ("Dead Time 2, Dead Time 3, Dead Time 4") [Dead Time 2, 3, 4] and three pole auto-reclose in progress [AR 3pole in prog] will start on the rising or falling edge (according to the setting) of the three pole trip for the 2nd, 3rd and 4th trips [shots]. For a multi-phase fault the relay will lockout on the rising or falling edge (according to the setting) of the three phase trip.

If three pole auto-reclose [A/R Status 3P] only is enabled then for any fault the three pole dead time ("Dead Time 1, Dead Time 2, Dead Time 3, Dead Time 4") [Dead Time 1, 2, 3, 4] and three pole auto-reclose in progress [AR 3pole in prog] starts on the rising or falling edge (according to the setting) of the three phase trip. The logic forces a 3 pole trip [Force 3 pole AR] for any single phase fault if three pole auto-reclose [A/R Status 3P] only is enabled.

OP

If single [A/R Status 1P] and three phase auto-reclose [A/R Status 3P] are enabled then if the first fault is a single phase fault the single pole dead time ("1 Pole Dead Time") [1 Pole Dead Time] and single pole auto-reclose in progress [AR 1pole in prog] starts on the rising or falling edge (according to the setting) of the single phase trip. If the first fault is a multi-phase fault the three pole dead time ("Dead Time 1") and three pole auto-reclose in progress [AR 3pole in prog] starts on the rising or falling edge (according to the setting) of the three phase trip. If the relay has been set to allow more than one reclose [Three Pole Shot >1] then any subsequent faults will be converted to 3 pole trips [Force 3 pole AR]. The three pole dead times ("Dead Time 2, Dead Time 3, Dead Time 4") [Dead Time 2, 3, 4] and three pole auto-reclose in progress [AR 3pole in prog] will start on the rising or falling edge (according to the setting) of the three pole trip for the 2nd, 3rd and 4th trips [shots]. If a single phase fault evolves to a multi-phase fault during the single pole dead time [1 Pole Dead Time] then single pole auto-reclose in progress [AR 1pole in prog] is stopped and the three pole dead time [Dead Time 1] and three pole auto-reclose in progress [AR 3pole in prog] is started.

At the end of the relevant dead time, the auto-reclose single phase or three phase in progress signal is reset and a CB close signal is given, provided system conditions are suitable. The system conditions to be met for closing are that the system voltages are in synchronism or dead line/live bus or live line/dead bus conditions exist, indicated by the internal check synchronizing element and that the circuit breaker closing spring, or other energy source, is fully charged indicated from the “CB Healthy” input. The CB close signal is cut-off when the circuit breaker closes. For single pole auto-reclose no voltage or synchronism check is required as synchronizing power is flowing in the two healthy phases. Check synchronizing for the first three phase cycle is controlled by a setting.

When the CB has closed the reclaim time (“Reclaim Time”) starts. If the circuit breaker does not trip again, the auto-reclose function resets at the end of the reclaim time. If the protection operates during the reclaim time the relay either advances to the next shot in the programmed auto-reclose cycle, or, if all programmed reclose attempts have been made, goes to lockout.

Every time the relay trips the sequence counter is incremented by 1. The relay compares the “Single Pole Shots” and “Three Pole Shots” counter values to the sequence count. If the fault is single phase and the sequence count is greater than the “Single Pole Shots” setting then the relay will lockout. If the fault is multi-phase phase and the sequence count is greater than the “Three Pole Shots” setting then the relay will also lockout.

For example, if “Single Pole Shots” = 2 and “Three Pole Shots” = 1, after two phase-phase faults the relay will lockout because the sequence count = 2 which is greater than the “Three Pole Shots” target of 1 and the second fault was a multi-phase fault. If there was a permanent earth fault the relay would trip and reclose twice and on the third application of earth fault current it would lockout. This is because on the third application of fault current the sequence count would be greater than the “Single Pole Shots” target of 2 and the third fault was an earth fault. There is no lockout at the second trip because the second trip was single phase and the sequence count is not greater than the “Single Pole Shots” target of 2. If there was a single phase fault which evolved to a phase-phase-ground fault then the relay would trip and reclose and on the second multi-phase fault would lockout. This is because on the second application of fault current the sequence count is greater than the “Three Pole Shots” target of 1 and the second fault was a multi-phase fault.

The total number of auto-reclosures is shown in the CB Control menu under “Total Reclosures”. This value can be reset to zero with the “Reset Total A/R” command.

The selection of which protection is used to initiate auto-reclose can be made using the settings “Initiate AR, No Action or Block AR” for the protection functions listed in the auto-reclose menu. See section 2.1.7.2 ‘Auto-reclose Initiation’ for more details.

For multi-phase faults the auto-reclose logic can be set to allow auto-reclose block for 2 and 3 phase faults or to block auto-reclose for 3 phase faults only using the setting “Multi Phase AR - Allow AR/BAR 2 & 3 Phase/BAR 3 Phase” in the Auto-reclose settings.

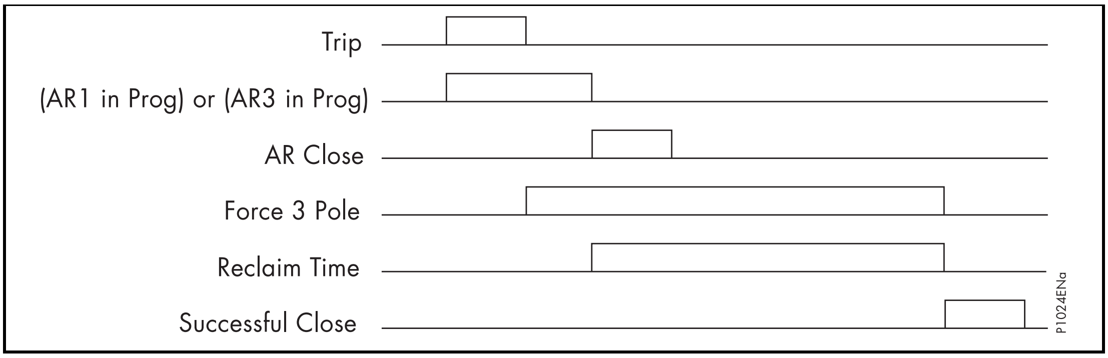

Figure 62: Auto-reclose timing diagram - single fault

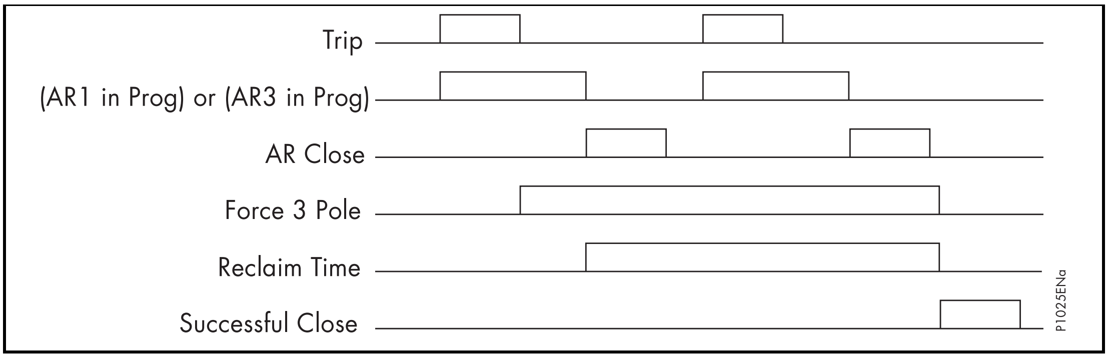

Figure 63: Auto-reclose timing diagram - repeated fault inception

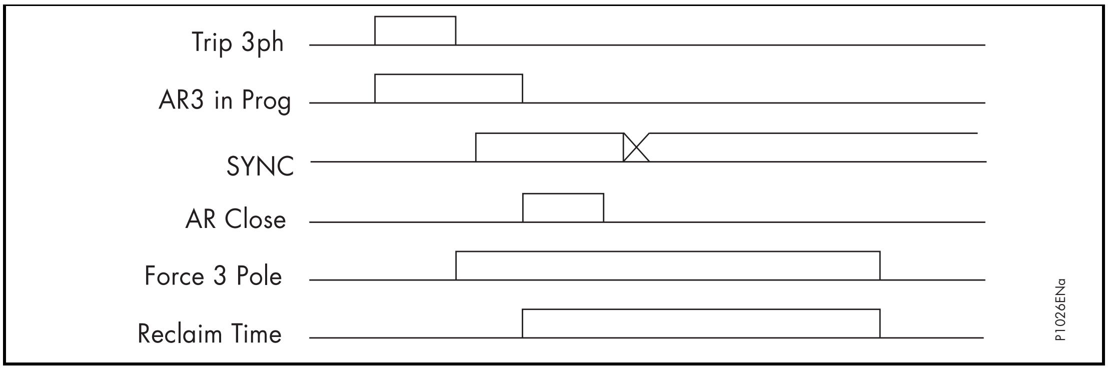

Figure 64: Auto-reclose timing diagram - fault with system synchronism

OP

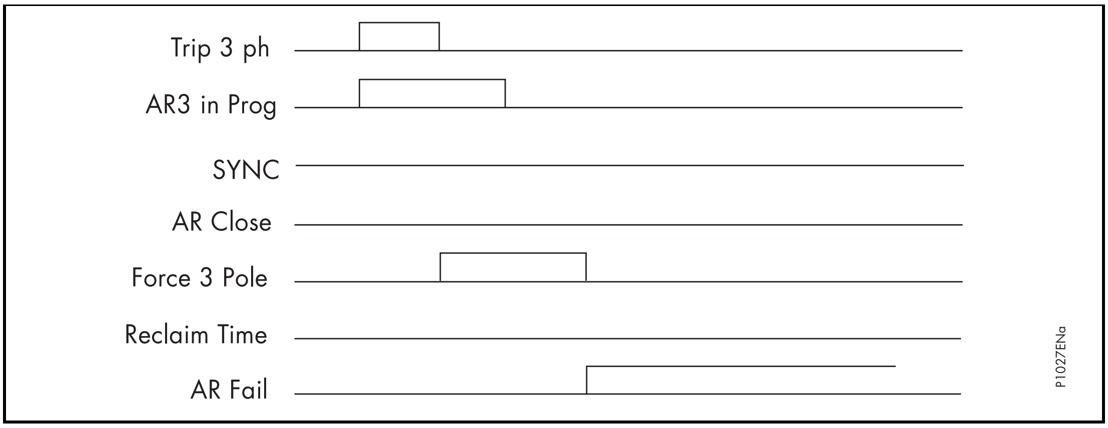

Figure 65: Auto-reclose timing diagram - lockout for no checksynch

2.1.7 Main operating features

2.1.7.1 Auto-reclose modes

The auto-reclose function has three operating modes:

OP

Single Pole Auto-reclose

Three Pole Auto-reclose

Single/Three Pole Auto-reclose

Single pole and three pole auto-reclose modes can be selected from opto inputs assigned for "En 1 Pole Reclose" and "En 3 Pole Reclose" respectively. Energizing both opto inputs would select the single/three pole operating mode. Alternatively, the settings "Single Pole A/R - Enabled/Disabled" and "Three Pole A/R - Enabled/Disabled" in the CB Control menu can also be used to select the operating modes. How these operating modes affect the operating sequence is described above.

2.1.7.2 Auto-reclose initiation

Auto-reclose is initiated from the internal protection of the relay. The current differential distance zones, DEF aided, overcurrent and earth fault protection can be selected to "Initiate AR, No Action or Block AR" in the Auto-reclose settings.

– By default, all "instantaneous" schemes will initiate auto-reclose, thus current differential, Zone 1 distance, Aided Scheme 1, and Aided Scheme 2 will all initiate AR.

– For these instantaneous tripping elements, it is possible to override initiation for user set combinations of multi-phase faults if required, by use of the '*Multi Phase AR'* Block setting. This will prevent auto-reclose initiation, and drive the sequence to lockout.

2.1.7.3 Auto-reclose inhibit following manual close

The AR Inhibit Time setting can be used to prevent auto-reclose being initiated when the CB is manually closed onto a fault. Auto-reclose is disabled for the AR Inhibit Time following manual CB closure.

2.1.7.4 AR lockout

If protection operates during the reclaim time, following the final reclose attempt, the relay will be driven to lockout and the auto-reclose function will be disabled until the lockout condition is reset. This will produce an alarm, "AR Lockout".

The block auto-reclose logic in the relay will also cause an auto-reclose lockout if auto-reclose is in progress. The "BAR" input assigned to an opto input will block auto-reclose and cause a lockout if auto-reclose is in progress. The auto-reclose logic can also be set to block auto-reclose for 2 and 3 phase faults or to block auto-reclose for 3 phase faults only using the setting “Multi Phase AR - Allow AR/BAR 2&3 Phase/BAR 3 Phase” in the

Auto-reclose menu. Also, the protection functions can be individually selected to block auto-reclose using the settings, “Initiate AR, No Action or Block AR” in the Auto-reclose menu.

Auto-reclose lockout can also be caused by the CB failing to close because the CB springs are not charged/low gas pressure or there is no synchronism between the system voltages indicated by the “AR CB Unhealthy” and “AR No Checksync” alarms.

An auto-reclose lockout is also given if the CB is open at the end of the reclaim time.

Note: Lockout, can also be caused by the CB condition monitoring functions maintenance lockout, excessive fault frequency lockout, broken current lockout, CB failed to trip and CB failed to close and manual close - no check synchronism and CB unhealthy. These lockout alarms are mapped to a composite signal “CB Lockout Alarm”.

2.1.7.5 Reset from lockout

The “Reset Lockout” input assigned to an opto input can be used to reset the auto-reclose function following lockout and reset any auto-reclose alarms, provided that the signals which initiated the lockout have been removed. Lockout can also be reset from the clear key or the CB CONTROL command “Lockout Reset”.

The “Reset Lockout” by setting, “CB Close/ User interface” in CB CONTROL is used to enable/ disable reset of lockout automatically from a manual close after the manual close time “AR Inhibit Time”.

2.1.7.6 System check on shot 1

The “SysChk on Shot 1” setting is used to “Enable/Disable” system checks for the first reclose after a 3 pole trip in an auto-reclose cycle. When the “SysChk on Shot 1” is set to “Disabled” no system checks are required for the first reclose which may be preferred when high speed auto-reclose is applied to avoid the extra time for a system check. Subsequent reclose attempts in a multi-shot cycle will still require a system check.

2.1.7.7 Immediate auto-reclose with check synchronism

The CS AR Immediate setting allows immediate auto-reclosure without waiting for the expiry of the settable dead time, provided the check synchronism conditions are met and a fault is not detected. The intention is to allow the local end to reclose immediately if the remote end has already reclosed successfully and the synchronizing conditions are met.

This feature applies when the setting is enabled. It applies to all dead times, just for three pole auto-reclose and just for Live Line-Live Bus condition (plus other check synchronizing conditions of phase angle, frequency etc).

When set to disabled the relay will wait for the relevant dead time.

2.1.7.8 Discrimination timer setting

A single-phase fault can result in a single-phase trip and a single-pole auto-reclose cycle will be started, however the fault may evolve during the dead time to affect another phase. For an evolving fault, the protection issues a three-phase trip.

The discrimination timer starts simultaneously with the dead time timer, and is used to discriminate from which point in time an evolving fault is identified as no longer one continued evolution of the first fault, but is now a discrete second fault condition. If the evolving fault occurs before the expiry of the discrimination time, the protection will start a three-pole auto-reclose cycle if permitted. If however, the second phase fault occurs after the discrimination time, the automatic reclose function is blocked, and driven to AR Lockout.

2.1.8 Auto-reclose logic diagrams

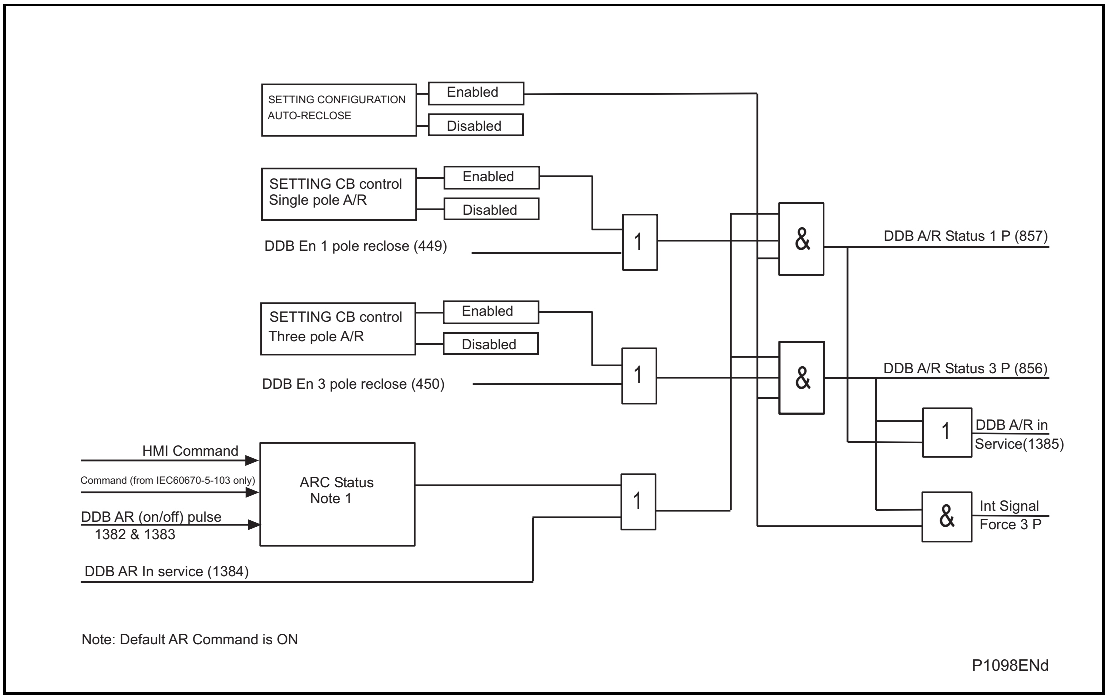

Figure 66: Auto-reclose enable logic

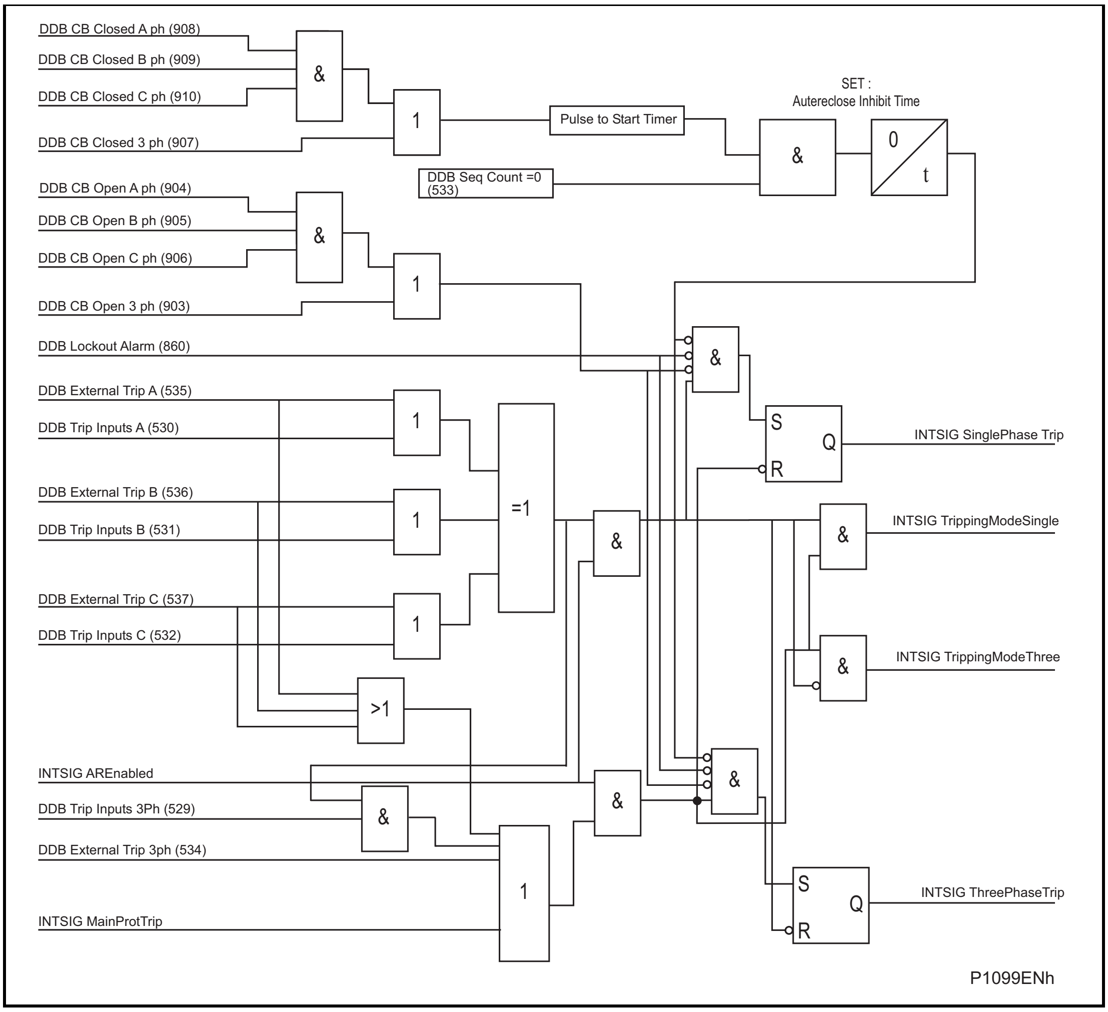

Figure 67: Auto-reclose single/three pole tripping

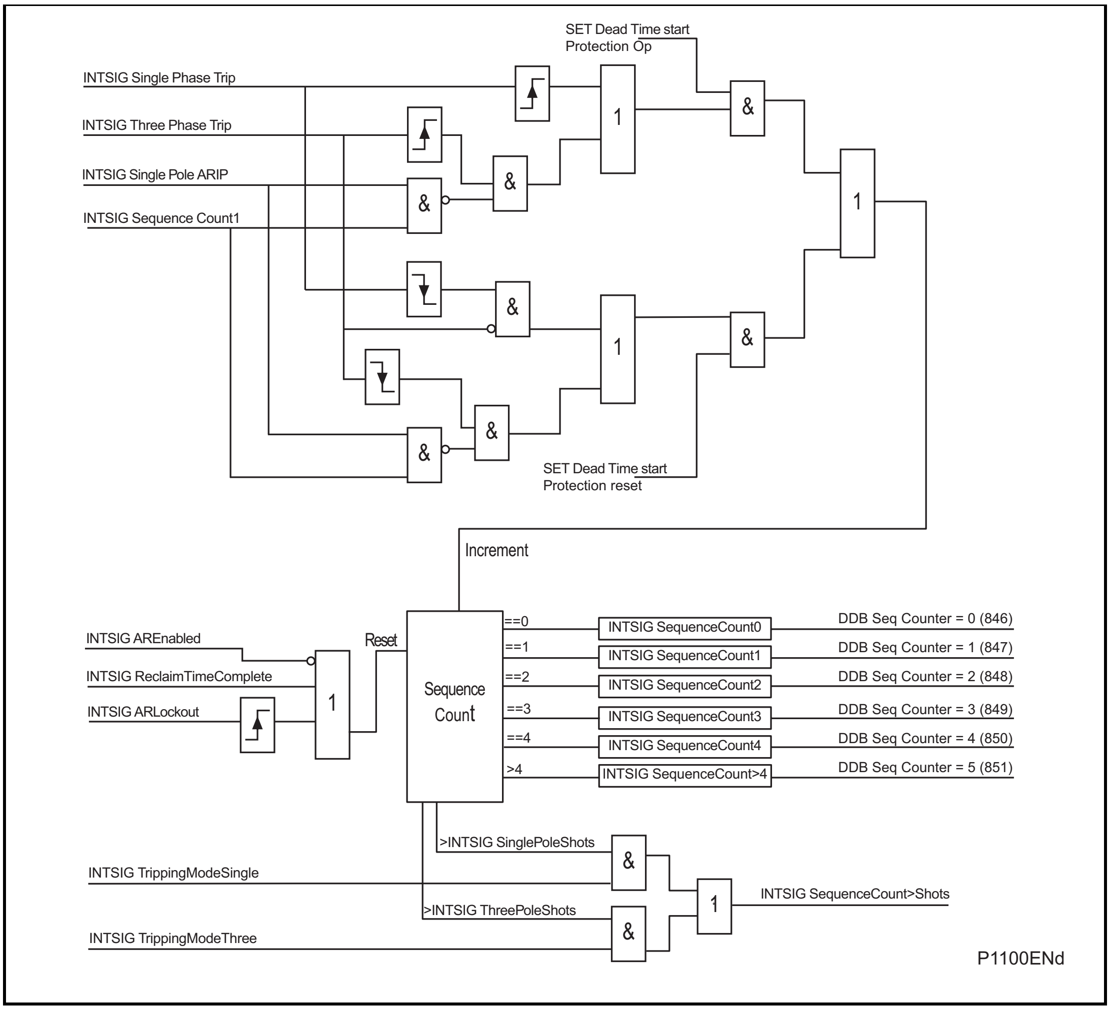

Figure 68: Auto-reclose inhibit sequence count

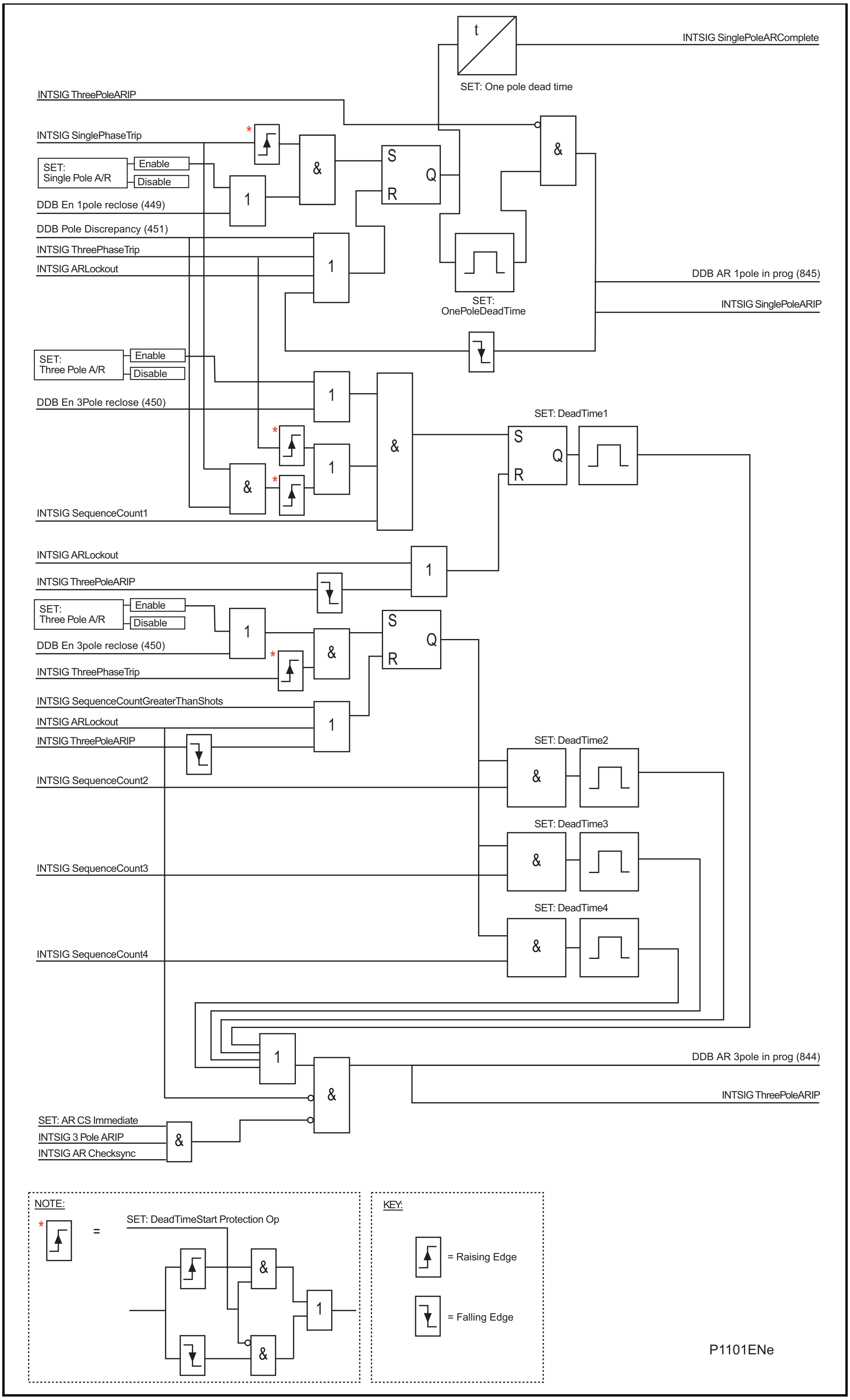

Figure 69: Auto-reclose cycles

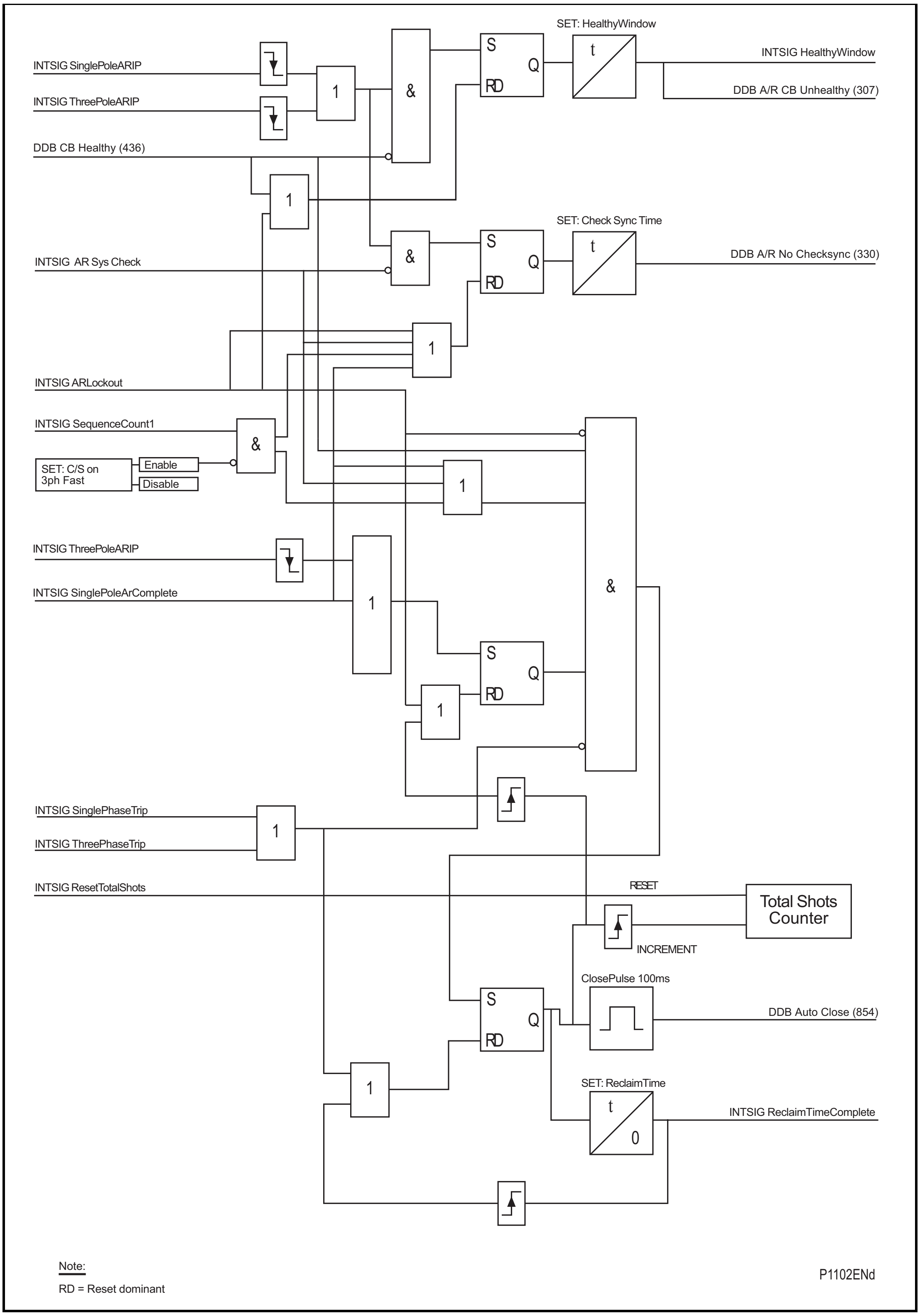

Figure 70: Auto-reclose close

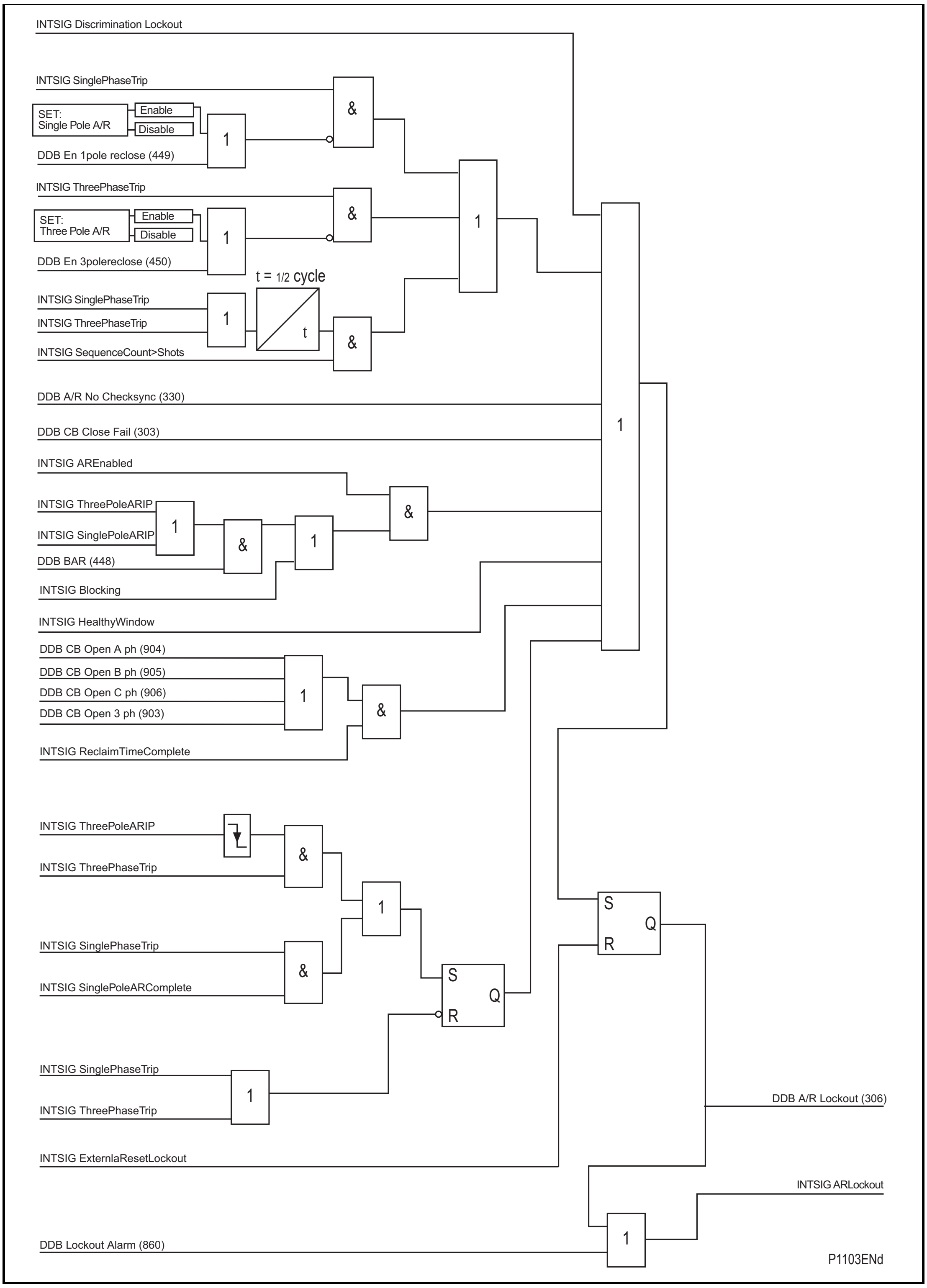

Figure 71: Auto-reclose lockout logic

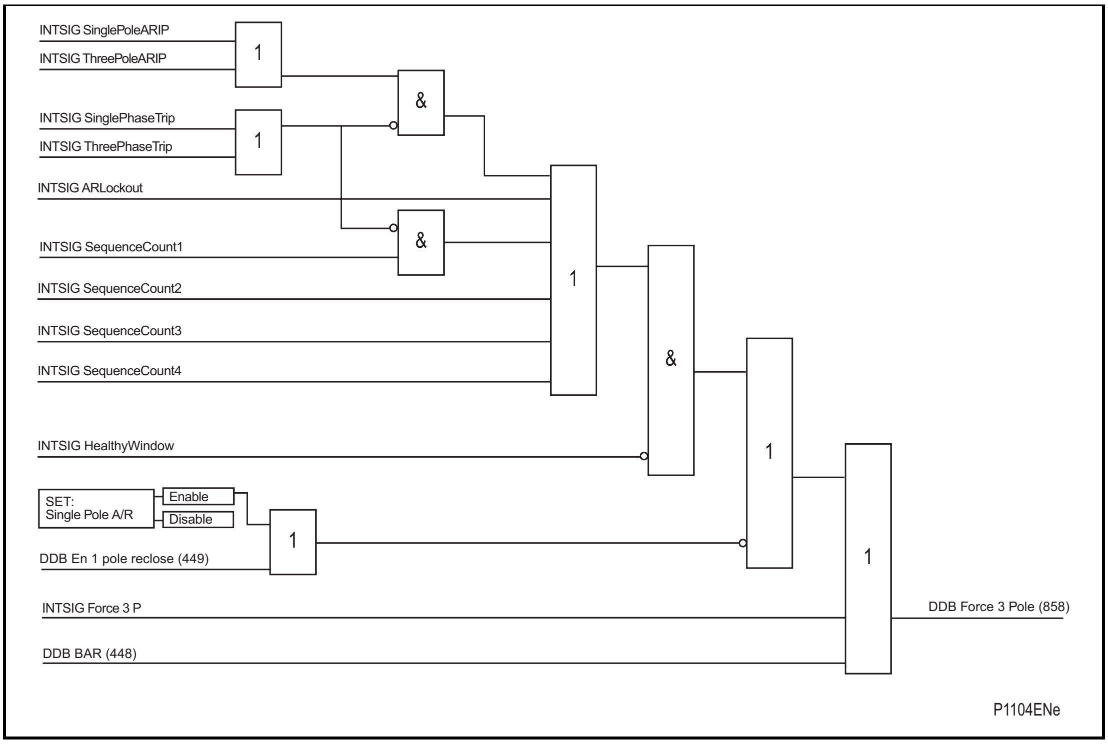

Figure 72: Auto-reclose force 3 pole trip

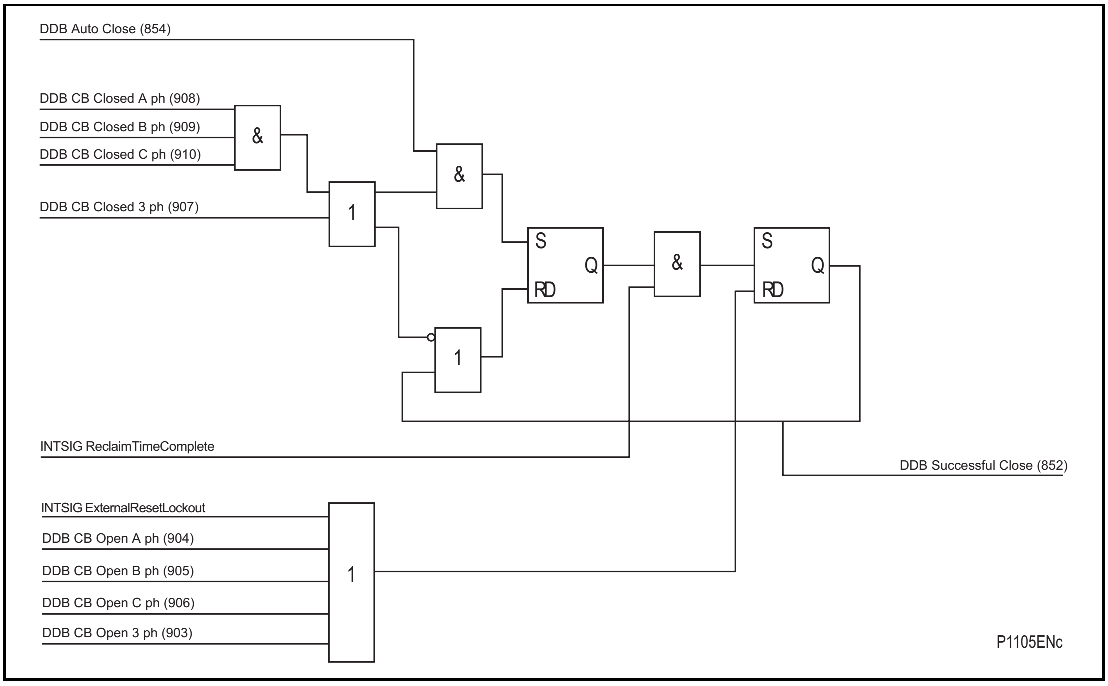

Figure 73: Auto-reclose close notify

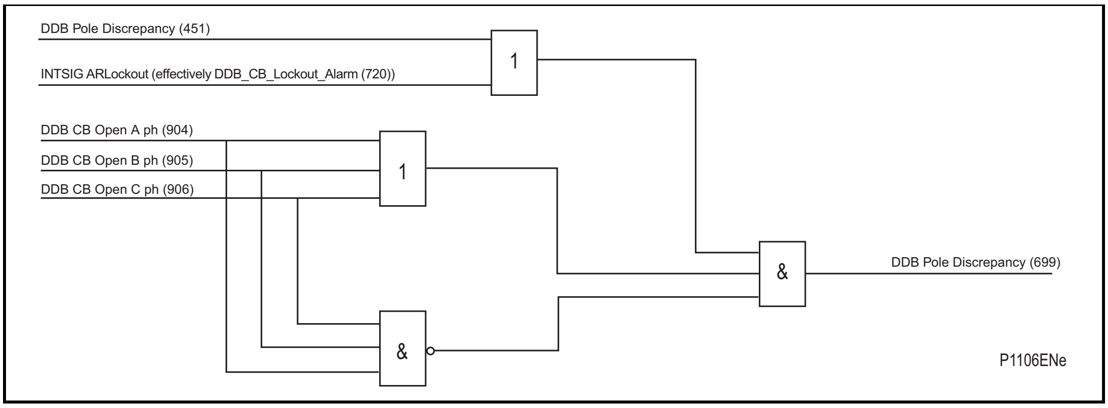

Figure 74: Ddb pole discrepancy trip

2.2 System checks (including check synchronizer)

Note: Systems checks is only offered in the P543 and P545.

2.2.1 Overview

OP

In some situations it is possible for both “bus” and “line” sides of a circuit breaker to be live when the circuit breaker is open, for example at the ends of a feeder which has a power source at each end. Therefore, when closing the circuit breaker, it is normally necessary to check that the network conditions on both sides are suitable, before giving a CB Close command. This applies to both manual circuit breaker closing and auto-reclosure. If a circuit breaker is closed when the line and bus voltages are both live, with a large phase angle, frequency or magnitude difference between them, the system could be subjected to an unacceptable shock, resulting in loss of stability, and possible damage to connected machines.

System checks involve monitoring the voltages on both sides of a circuit breaker, and, if both sides are live, performing a synchronism check to determine whether the phase angle, frequency and voltage magnitude differences between the voltage vectors, are within permitted limits.

The pre-closing system conditions for a given circuit breaker depend on the system configuration and, for auto-reclosing, on the selected auto-reclose program. For example, on a feeder with delayed auto-reclosing, the circuit breakers at the two line ends are normally arranged to close at different times. The first line end to close usually has a live bus and a dead line immediately before reclosing, and charges the line (dead line charge) when the circuit breaker closes. The second line end circuit breaker sees live bus and live line after the first circuit breaker has reclosed. If there is a parallel connection between the ends of the tripped feeder, they are unlikely to go out of synchronism, i.e. the frequencies will be the same, but the increased impedance could cause the phase angle between the two voltages to increase. Therefore the second circuit breaker to close might need a synchronism check, to ensure that the phase angle has not increased to a level which would cause unacceptable shock to the system when the circuit breaker closes.

If there are no parallel interconnections between the ends of the tripped feeder, the two systems could lose synchronism, and the frequency at one end could “slip” relative to the other end. In this situation, the second line end would require a synchronism check comprising both phase angle and slip frequency checks.

If the second line end busbar has no power source other than the feeder which has tripped, the circuit breaker will see a live line and dead bus assuming the first circuit breaker has reclosed. When the second line end circuit breaker closes the bus will charge from the live line (dead bus charge).

2.2.2 VT selection

The MiCOM P54x has a three phase "Main VT" input and a single phase "Check Sync VT" input. Depending on the primary system arrangement, the main three phase VT for the relay may be located on either the busbar side or the line side of the circuit breaker, with the check sync VT being located on the other side. Hence, the relay has to be programmed with the location of the main VT. This is done via the "Main VT Location" setting in the CT & VT RATIOS menu.

The Check Sync VT may be connected to either a phase to phase or phase to neutral voltage, and for correct synchronism check operation, the relay has to be programmed with the required connection. The "C/S Input" setting in the CT & VT RATIOS menu should be set to A-N, B-N, C-N, A-B, B-C or C-A as appropriate.

2.2.3 Basic functionality

System check logic is collectively enabled or disabled as required, by setting "System Checks" in the CONFIGURATION menu. The associated settings are available in SYSTEM CHECKS, sub-menus VOLTAGE MONITORS, CHECK SYNC and SYSTEM SPLIT. If "System Checks" is selected to Disabled, the associated SYSTEM CHECKS menu becomes invisible, and a *Sys checks Inactive* DDB signal is set.

In most situations where synchronism check is required, the Check Sync 1 function alone will provide the necessary functionality, and the Check Sync 2 and System Split signals can be ignored.

2.2.4 System check logic outputs

When enabled, the MiCOM P54x system check logic sets signals as listed below, according to the status of the monitored voltages.

Line Live	– If the Line voltage magnitude is not less than VOLTAGE MONITORS - Live Voltage setting
Line Dead	– If the Line voltage magnitude is less than VOLTAGE MONITORS - Dead Voltage setting
Bus Live	– If the Bus voltage magnitude is not less than VOLTAGE MONITORS - Live Voltage setting
Bus Dead	– If the Bus voltage magnitude is less than VOLTAGE MONITORS - Dead Voltage setting
Check Sync 1 OK	– If Check Sync 1 Status is Enabled, the Line and Bus voltages are both live, and the parameters meet the CHECK SYNC - Check Sync 1 ---- settings
Check Sync 2 OK	– If Check Sync 2 Status is Enabled, the Line and Bus voltages are both live, and the parameters meet the CHECK SYNC - Check Sync 2 ---- settings
System Split	– If SS Status is Enabled, the Line and Bus voltages are both live, and the measured phase angle between the voltage vectors is greater than SYSTEM SPLIT - SS Phase Angle setting

All the above signals are available as DDB signals for mapping in Programmable Scheme Logic (PSL). In addition, the Checksync 1 & 2 signals are "hard coded" into the auto-reclose logic.

2.2.5 Check sync 2 and system split

Check Sync 2 and System Split functions are included for situations where the maximum permitted slip frequency and phase angle for synchro check can change according to actual system conditions. A typical application is on a closely interconnected system, where synchronism is normally retained when a given feeder is tripped, but under some circumstances, with parallel interconnections out of service, the feeder ends can drift out of synchronism when the feeder is tripped. Depending on the system and machine characteristics, the conditions for safe circuit breaker closing could be, for example:

Condition 1: for synchronized systems, with zero or very small slip:

slip ≦50 mHz; phase angle <30°

Condition 2: for unsynchronized systems, with significant slip:

slip ≦250 mHz; phase angle <10° and decreasing

By enabling both Check Sync 1, set for condition 1, and Check Sync 2, set for condition 2, the relay can be configured to allow CB closure if either of the two conditions is detected.

For manual circuit breaker closing with synchro check, some utilities might prefer to arrange the logic to check initially for condition 1 only. However, if a System Split is detected before the condition 1 parameters are satisfied, the relay will switch to checking for condition 2 parameters instead, based upon the assumption that a significant degree of slip must be present when system split conditions are detected. This can be arranged by suitable PSL logic, using the system check DDB signals.

2.2.6 Synchronism check

Check Sync 1 and Check Sync 2 are two synchro check logic modules with similar functionality, but independent settings.

OP

For either module to function:

The System Checks setting must be Enabled

AND

The individual Check Sync 1(2) Status setting must be Enabled

AND

The module must be individually “enabled”, by activation of DDB signal Check Sync 1(2) Enabled, mapped in PSL

When enabled, each logic module sets its output signal when:

Line volts and bus volts are both live (Line Live and Bus Live signals both set)

AND

Measured phase angle is < Check Sync 1(2) Phase Angle setting

AND

(For Check Sync 2 only), the phase angle magnitude is decreasing (Check Sync 1 can operate with increasing or decreasing phase angle provided other conditions are satisfied)

AND

If Check Sync 1(2) Slip Control is set to Frequency or Frequency + Timer, the measured slip frequency is < Check Sync 1(2) Slip Freq setting

AND

If Check Sync Voltage Blocking is set to OV, UV + OV, OV + DiffV or UV + OV + DiffV, both line volts and bus volts magnitudes are < Check Sync Overvoltage setting

AND

If Check Sync Voltage Blocking is set to UV, UV + OV, UV + DiffV or UV + OV + DiffV, both line volts and bus volts magnitudes are > Check Sync Undervoltage setting

AND

If Check Sync Voltage Blocking is set to DiffV, UV + DiffV, OV + DiffV or UV + OV + DiffV, the voltage magnitude difference between line volts and bus volts is < Check Sync Diff Voltage setting

AND

If Check Sync 1(2) Slip Control is set to Timer or Frequency + Timer, the above conditions have been true for a time > or = Check Sync 1(2) Slip Timer setting

Note: Live Line/Dead Bus and Dead Bus/Line functionality is provided as part of the default PSL (see Figure 76).

2.2.7 Slip control by timer

If Slip Control by Timer or Frequency + Timer is selected, the combination of Phase Angle and Timer settings determines an effective maximum slip frequency, calculated as:

$$\frac{2 \text{ x A}}{\text{T x 360}} \text{ Hz. for Check Sync 1}$$

or

$$\frac{\text{A}}{\text{T x 360}} \text{ Hz. for Check Sync 2}$$

Where:

A = Phase Angle setting (°)

T = Slip Timer setting (seconds)

For example, with Check Sync 1 Phase Angle setting 30° and Timer setting 3.3 sec, the “slipping” vector has to remain within ±30° of the reference vector for at least 3.3 seconds. Therefore a synchro check output will not be given if the slip is greater than 2 x 30° in 3.3 seconds. Using the formula: 2 x 30 ÷ (3.3 x 360) = 0.0505 Hz (50.5 mHz).

For Check Sync 2, with Phase Angle setting 10° and Timer setting 0.1 sec, the slipping vector has to remain within 10° of the reference vector, with the angle decreasing, for 0.1 sec. When the angle passes through zero and starts to increase, the synchro check output is blocked. Therefore an output will not be given if slip is greater than 10° in 0.1 second. Using the formula: 10 ÷ (0.1 x 360) = 0.278 Hz (278 mHz).

Slip control by Timer is not practical for “large slip / small phase angle” applications, because the timer settings required are very small, sometimes < 0.1s. For these situations, slip control by frequency is recommended.

If Slip Control by Frequency + Timer is selected, for an output to be given, the slip frequency must be less than BOTH the set Slip Freq value and the value determined by the Phase Angle and Timer settings.

2.2.8 System split

For the System Split module to function:

The System Checks setting must be Enabled.

AND

The SS Status setting must be Enabled.

AND

The module must be individually “enabled”, by activation of DDB signal System Split Enabled, mapped in PSL.

When enabled, the System Split module sets its output signal when:

Line volts and bus volts are both live (Line Live and Bus Live signals both set).

AND

Measured phase angle is > SS Phase Angle setting.

AND

If SS Volt Blocking is set to Undervoltage, both line volts and bus volts magnitudes are > SS Undervoltage setting.

The System Split output remains set for as long as the above conditions are true, or for a minimum period equal to the SS Timer setting, whichever is longer.

The “Check Synch” and “System Synch” functionality is illustrated in Figure 75, and the logic block diagram is shown in Figure 76.

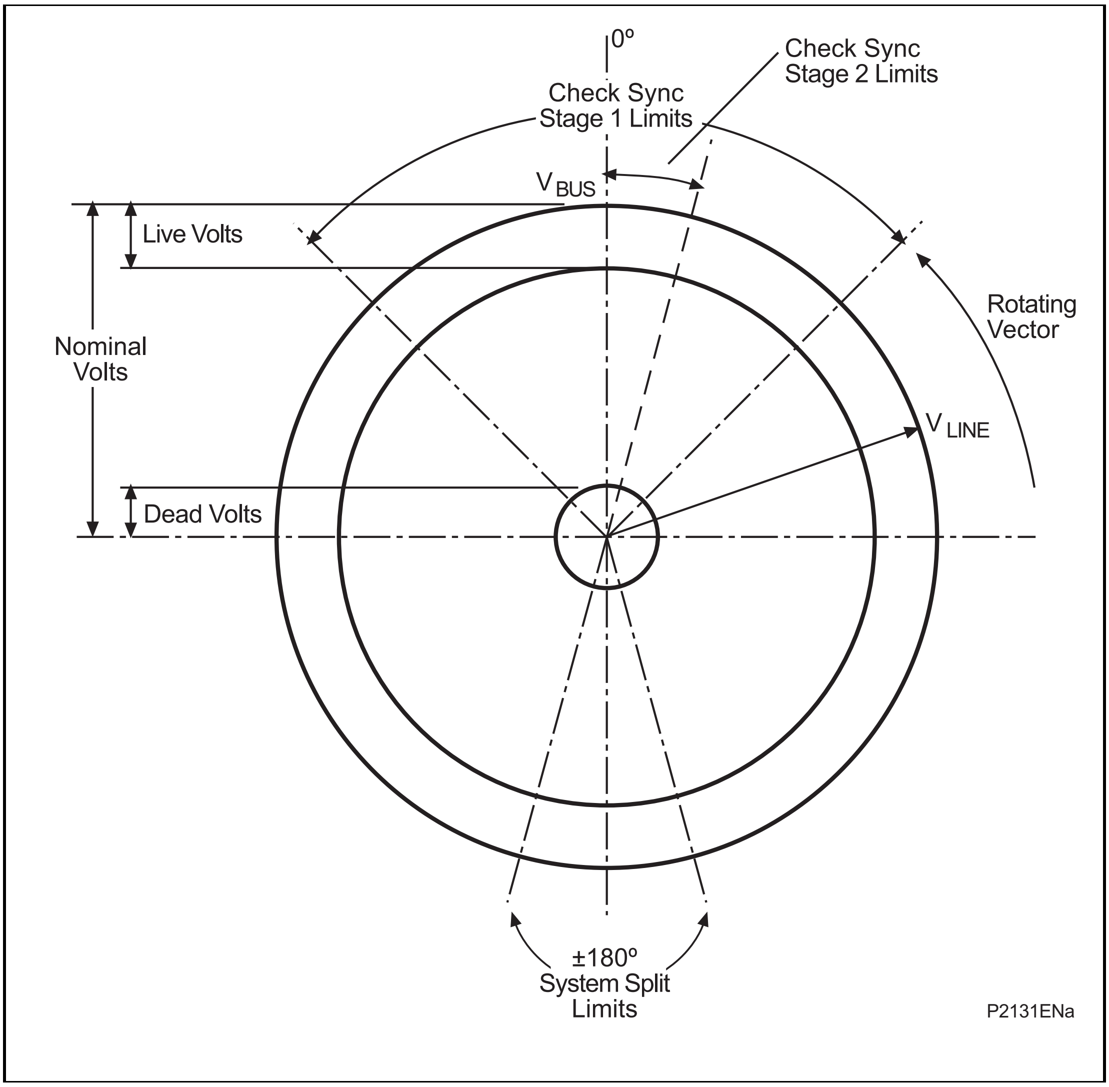

Figure 75: Synchro check and synchro split functionality

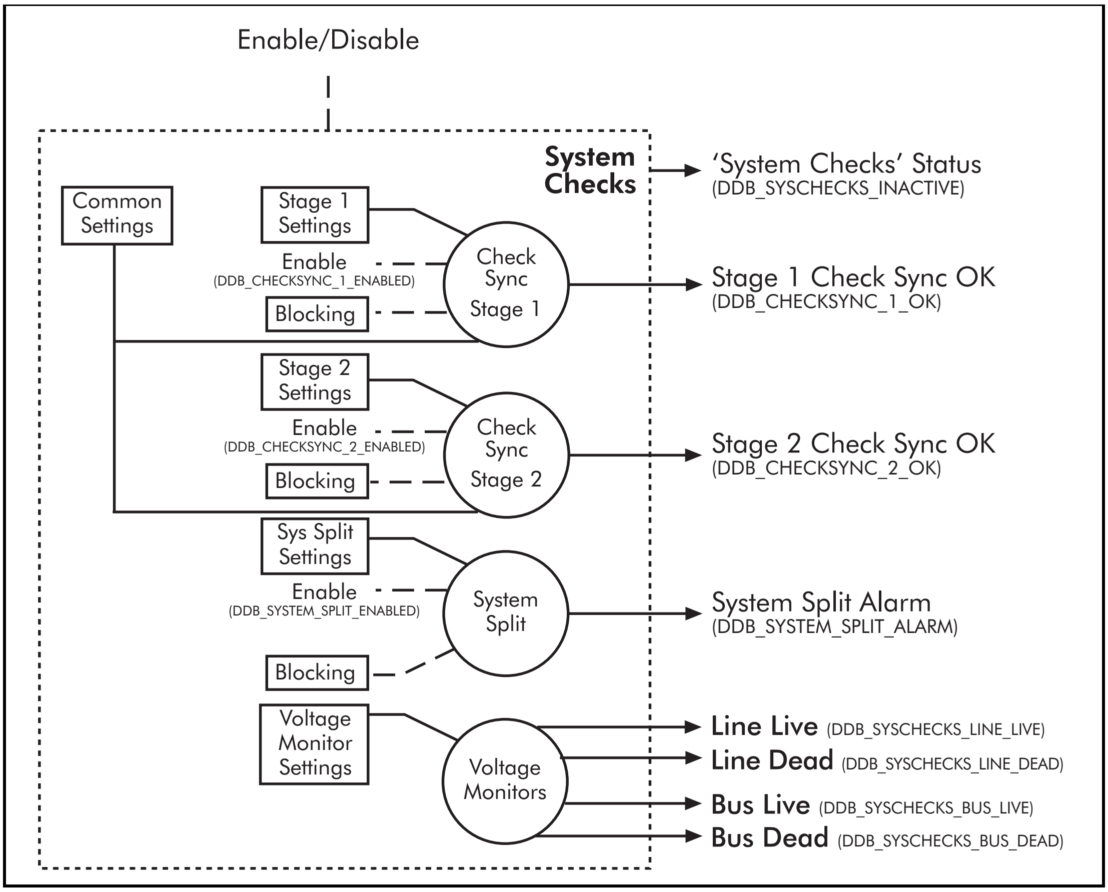

Figure 76: Check sync

2.3 Auto-reclose/check synchronization interface

Output signals from the internal system check function and signals from an external system check device are combined and made available as two internal inputs to the auto-reclose function. One internal input permits auto-reclose based on system check conditions being met. The other internal input permits immediate auto-reclose based on check synchronism conditions being met, if this feature is enabled (CS AR Immediate).

Figure 77 shows the logic diagram for the interaction between the auto-reclose and system checks.

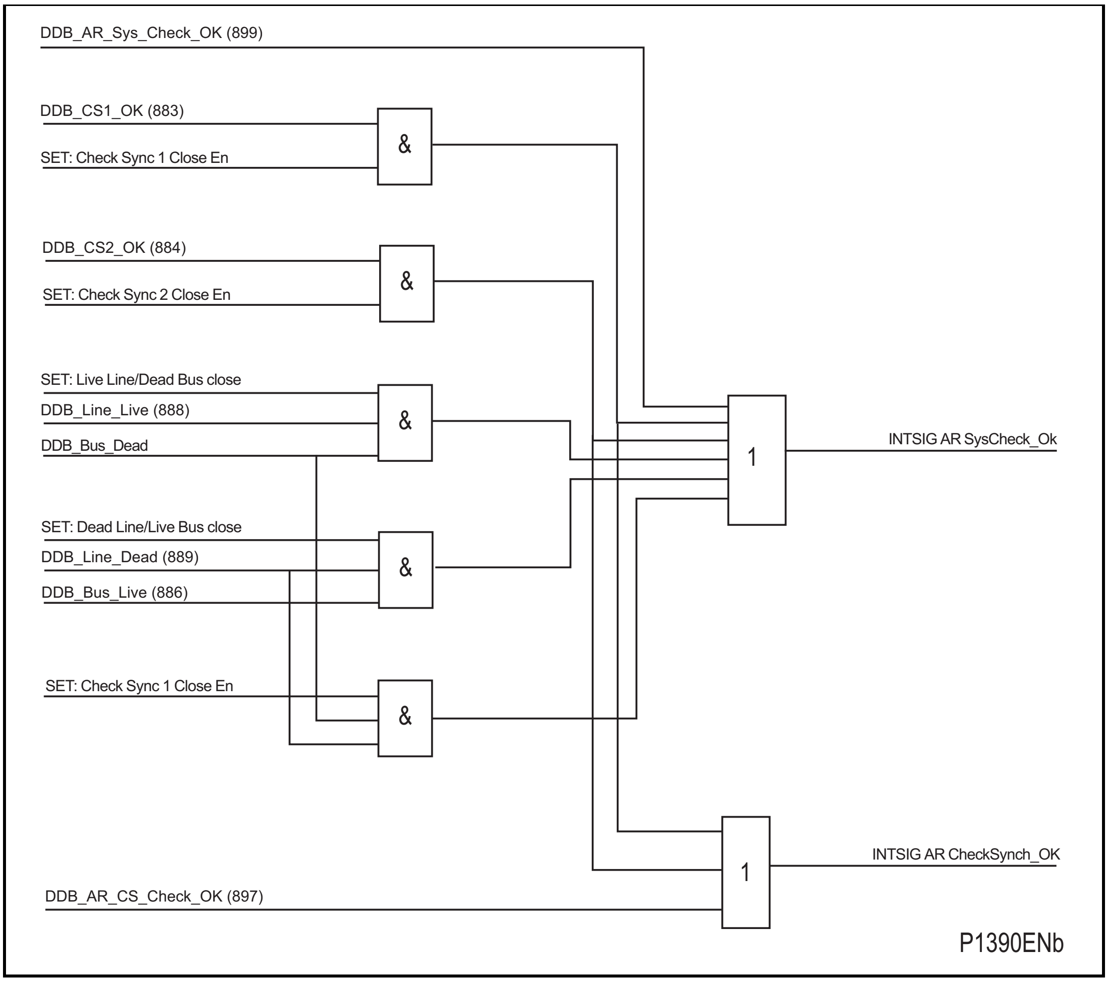

Figure 77: Auto-reclose/check sync interface

If an external system check device is to be used with the internal auto-reclose function then logic inputs are available for the purpose and can be assigned to opto-isolated inputs using the PSL. These logic inputs are.

AR Check Synch OK

AR System Check OK/SYNC

2.4 Voltage transformer supervision - fuse fail

The voltage transformer supervision (VTS) feature is used to detect failure of the ac voltage inputs to the relay. This may be caused by internal voltage transformer faults, overloading, or faults on the interconnecting wiring to relays. This usually results in one or more VT fuses blowing. Following a failure of the ac voltage input there would be a misrepresentation of the phase voltages on the power system, as measured by the relay, which may result in maloperation.

The VTS logic in the relay is designed to detect the voltage failure, and automatically adjust the configuration of protection elements whose stability would otherwise be compromised. A time-delayed alarm output is also available.

A setting "VTs Connected" Yes/No (Voltage transformers connected to the relay) under CT AND VT RATIOS will:

When set to yes this setting will have no effect.

When set to No it causes the VTS logic to set the VTS Slow Block and VTS Fast Block DDBs, but not raise any alarms. It will also override the VTS enabled setting should the user set it. The effect of this is to stop the pole dead logic working incorrectly with the presence of no voltage and no current but not the CB open part of the logic and also block the distance, under voltage and other voltage dependant functions.

VTS can be declared by a mini circuit breaker (MCB) status input, by an internal logic using relay measurement or both. A setting “VTS Mode” (Measured + MCB /Measured Only/MCB Only) is available to select the method to declare VT failure.

For the measured method, there are three main aspects to consider regarding the failure of the VT supply. These are defined below:

1. Loss of one or two phase voltages

2. Loss of all three phase voltages under load conditions

3. Absence of three phase voltages upon line energization

2.4.1 Loss of one or two phase voltages

The VTS feature within the relay operates on detection of negative phase sequence (nps) voltage without the presence of negative phase sequence current. This gives operation for the loss of one or two phase voltages. Stability of the VTS function is assured during system fault conditions, by the presence of nps current. The use of negative sequence quantities ensures correct operation even where three-limb or ‘V’ connected VT’s are used.

Negative Sequence VTS Element:

The negative sequence thresholds used by the element are V2 = 10V and I2 = 0.05 to 0.5In settable (defaulted to 0.05In).

2.4.2 Loss of all three phase voltages under load conditions

Under the loss of all three phase voltages to the relay, there will be no negative phase sequence quantities present to operate the VTS function. However, under such circumstances, a collapse of the three phase voltages will occur. If this is detected without a corresponding change in any of the phase current signals (which would be indicative of a fault), then a VTS condition will be raised. In practice, the relay detects the presence of superimposed current signals, which are changes in the current applied to the relay. These signals are generated by comparison of the present value of the current with that exactly one cycle previously. Under normal load conditions, the value of superimposed current should therefore be zero. Under a fault condition a superimposed current signal will be generated which will prevent operation of the VTS.

The phase voltage level detectors are fixed and will drop off at 10V and pickup at 30V.

The sensitivity of the superimposed current elements is fixed at 0.1In.

2.4.3 Absence of three phase voltages upon line energization

If a VT were inadvertently left isolated prior to line energization, incorrect operation of voltage dependent elements could result. The previous VTS element detected three phase VT failure by absence of all 3 phase voltages with no corresponding change in current. On line energization there will, however, be a change in current (as a result of load or line charging current for example). An alternative method of detecting 3 phase VT failure is therefore required on line energization.

The absence of measured voltage on all 3 phases on line energization can be as a result of 2 conditions. The first is a 3 phase VT failure and the second is a close up three phase fault. The first condition would require blocking of the voltage dependent function and the second would require tripping. To differentiate between these 2 conditions an overcurrent level detector (VTS I> Inhibit) is used which will prevent a VTS block from being issued if it operates. This element should be set in excess of any non-fault based currents on line energization (load, line charging current, transformer inrush current if applicable) but below the level of current produced by a close up 3 phase fault. If the line is now closed where a 3 phase VT failure is present the overcurrent detector will not operate and a VTS block will be applied. Closing onto a three phase fault will result in operation of the overcurrent detector and prevent a VTS block being applied.

This logic will only be enabled during a live line condition (as indicated by the relays pole dead logic) to prevent operation under dead system conditions i.e. where no voltage will be present and the VTS I> Inhibit overcurrent element will not be picked up.

The relay may respond as follows, on operation of any VTS element:

– VTS set to provide alarm indication only;

– Optional blocking of voltage dependent protection elements;

– Optional conversion of directional overcurrent elements to non-directional protection (available when set to Blocking mode only). These settings are found in the Function Links cell of the relevant protection element columns in the menu.

The VTS I> Inhibit or VTS I2> Inhibit elements are used to override a VTS block in event of a fault occurring on the system which could trigger the VTS logic. Once the VTS block has been established, however, then it would be undesirable for subsequent system faults to override the block. The VTS block will therefore be latched after a user settable time delay ‘VTS Time Delay’. Once the signal has latched then two methods of resetting are available. The first is manually via the front panel interface (or remote communications) provided the VTS condition has been removed and secondly, when in ‘Auto’ mode, by the restoration of the 3 phase voltages above the phase level detector settings mentioned previously.

A VTS indication will be given after the VTS Time Delay has expired. In the case where the VTS is set to indicate only the relay may potentially maloperate, depending on which protection elements are enabled. In this case the VTS indication will be given prior to the VTS time delay expiring if a trip signal is given.

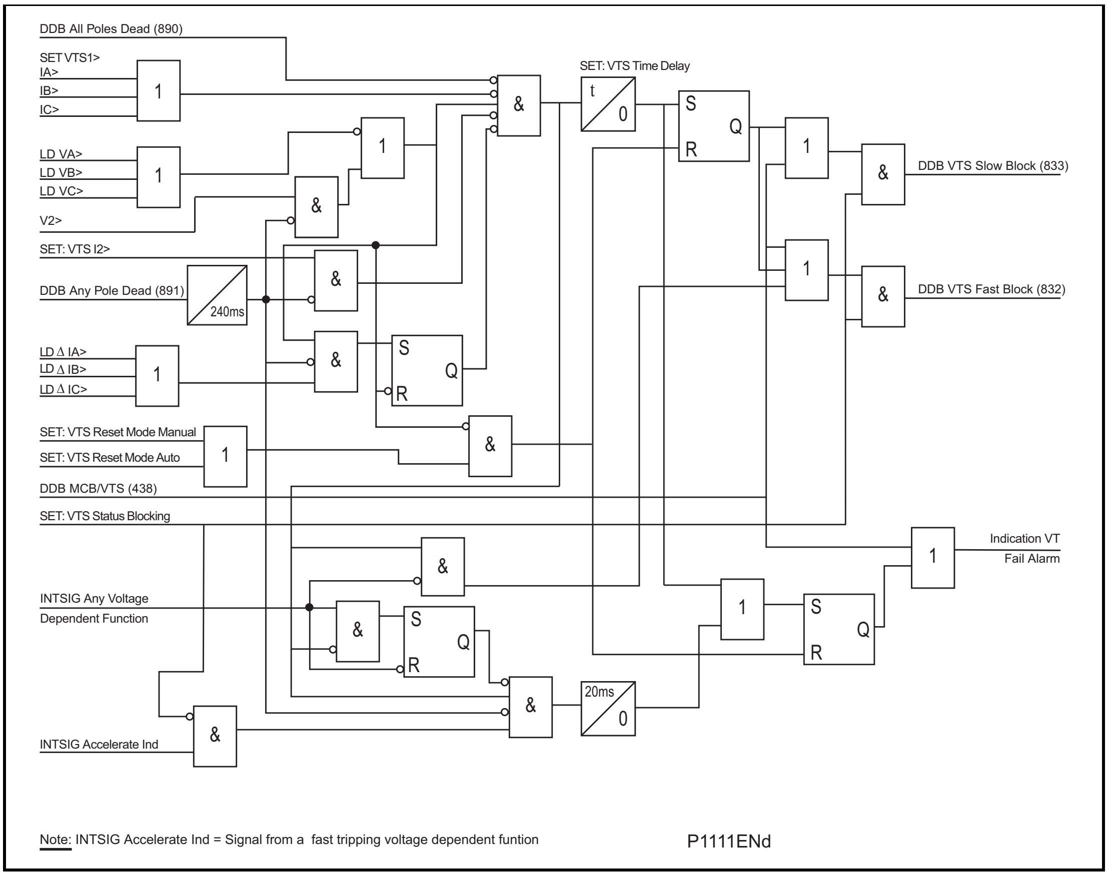

Figure 78: VTS logic

Where a miniature circuit breaker (MCB) is used to protect the voltage transformer ac output circuits, it is common to use MCB auxiliary contacts to indicate a three phase output disconnection. As previously described, it is possible for the VTS logic to operate correctly without this input. However, this facility has been provided for compatibility with various utilities current practices. Energizing an opto-isolated input assigned to "DDB: MCB/VTS" on the relay will therefore provide the necessary block.

2.5 Current transformer supervision

The current transformer supervision feature is used to detect failure of one or more of the ac phase current inputs to the relay. Failure of a phase CT or an open circuit of the interconnecting wiring can result in incorrect operation of any current operated element. Additionally, interruption in the ac current circuits risks dangerous CT secondary voltages being generated.

MiCOM P54x has two methods to achieve CT supervision feature (CTS). The first method called differential (I diff) method uses the ratio between positive and negative sequence currents to determine CT failure. Is non voltage dependant and relies on channel communications to declare a CTS condition. The second method called standard method relies on local measurements of zero sequence currents and voltages to declare CTS. The user should select what method to use according to the application.

The Differential CTS method should be used where differential protection is used. The Standard CTS is not fast enough to inhibit the differential protection at the remote end and so this should be used as a local supervision. The Standard CTS can be enabled by changing setting groups when the differential protection communication channel fails or is not in service to provide CTS for local back-up protection.

2.5.1 Differential CTS (no need of local voltage measurements to declare CTS)

Differential CT supervision scheme is based upon measurement of the ratio of I2 to I1 at all line ends. When this ratio is small (theoretically zero), one of four conditions is present:

- The system is unloaded - both I2 and I1 are zero
- The system is loaded but balanced - I2 is zero
- The system has a three phase fault present - I2 is zero
- There is a genuine 3 phase CT problem - unlikely, would probably develop from a single or two phase condition

If the ratio is non-zero, we can assume one of two conditions are present:

- The system has an asymmetric fault - both I2 and I1 are non-zero
- There is a 1 or 2 phase CT problem - both I2 and I1 are non-zero

Any measurement at a single end doesn't provide any more information than this, but if the ratio is calculated at all ends and compared, the MiCOM P54x assumes:

1. If the ratio is non-zero at more than two ends, it is almost certainly a genuine fault condition and so the CT supervision is prevented from operating.
2. If the ratio is non-zero at one end, there is a chance of either a CT problem or a single-end fed fault condition.

A second criteria looks to see whether the differential system is loaded or not. For this purpose MiCOM P54x looks at the positive sequence current I1. If load current is detected at one-end only, MiCOM P54x assumes that this is an internal fault condition and prevents CTS operation, but if load current is detected at two or more ends, CTS operation is permitted.

There are two modes of operation, Indication and Restrain. In Indication mode, a CTS alarm is raised but no effect on tripping. In Restrain mode, the differential protection is blocked during 20 ms after CT failure detection and then the setting for the Current Differential is raised to above load current. The CTS covers 2 sets of CTs in P544 and P546 as well as one set of CTs on P543 and P545.

In order to achieve correct operation of the scheme, it is necessary that differential CTS is enabled at each end of the protected zone.

Differential current transformer supervision (Differential CTS) in P543 - P546 models suffix K are only compatible with P543 - P546 models suffix K.

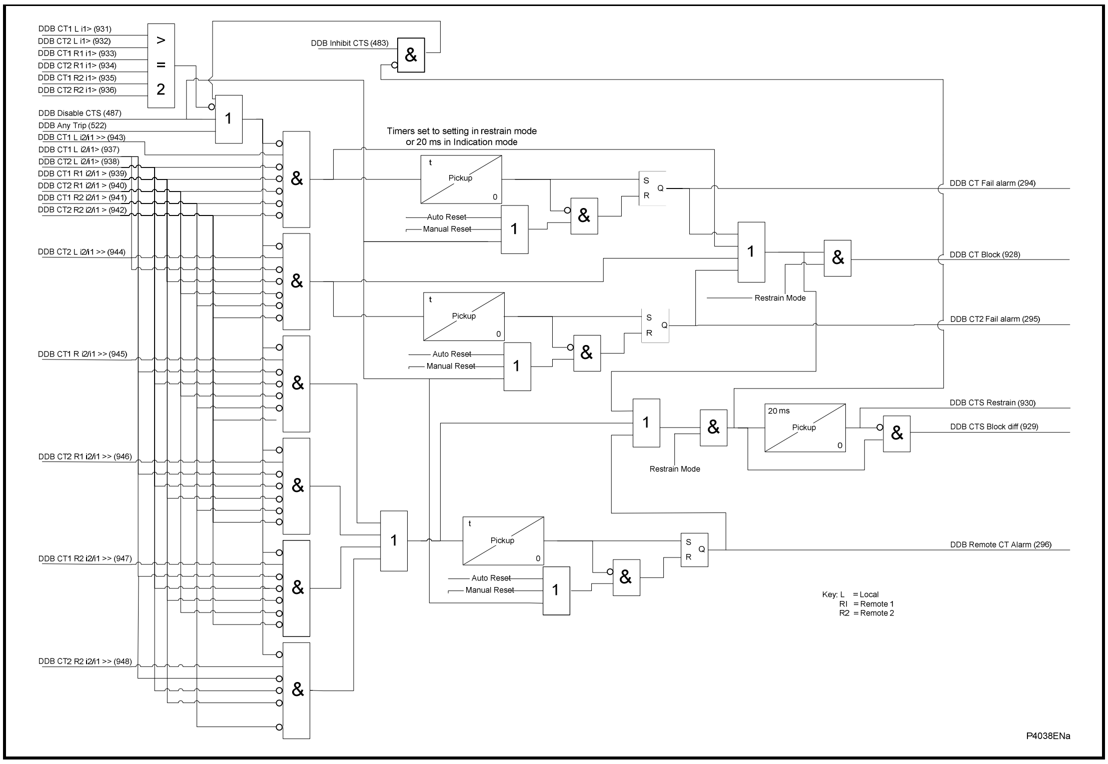

Figure 79: Differential CTS

2.5.2 Standard CTS (voltage dependant CTS no need of communications to declare CTS)

The standard CT supervision feature (CTS) operates on detection of derived zero sequence current, in the absence of a corresponding derived zero sequence voltage that would normally accompany it. The voltage transformer connection used must be able to refer zero sequence voltages from the primary to the secondary side. Thus, this element should only be enabled where the VT is of five limb construction, or comprises three single phase units, and has the primary star point earthed.

Operation of the element will produce a time-delayed alarm visible on the LCD, an event record and a DDB 294: CT Fail Alarm, with an instantaneous block (DDB 928: CTS Block) for inhibition of protection elements.

2.5.3 CTS blocking

The standard and differential methods will always block protection elements operating from derived quantities: Broken Conductor, Earth Fault and Neg Seq O/C. The differential method will also restrain the differential protection. Other protection functions such as DEF can be selectively blocked by customizing the PSL, gating DDB 928: CTS Block (originated by either method) or DDB 929 CTS Block Diff with the protection function logic. There is no need to block distance protection as the protection elements will not operate if there is no current.

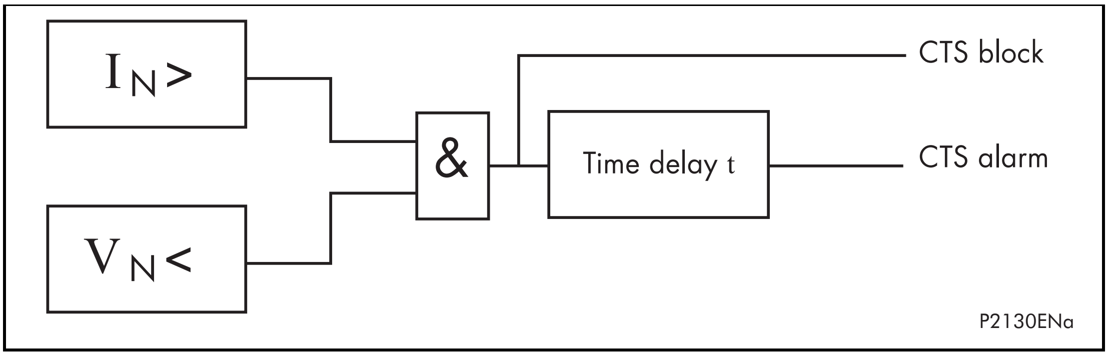

Figure 80: Voltage dependant CTS

2.6 Transformer magnetizing inrush detector

In section 1.1.4.1 “Transformer magnetizing inrush and High set differential setting” it is described how inrush is taking into account by the differential protection. As this inrush restrain technique is only valid for differential protection, there is a need of a separate inrush detector in order to prevent operation of other functions if needed.

The MiCOM P54x distance protection has been designed as a fast protection relay. It is therefore not desirable that distance zones should be slowed by forcing them to wait for a detection/no detection of transformer inrush current (in general applications). For this reason, the relay has no second harmonic blocking of the distance elements in the standard protection algorithms.

However should a user wish to employ, for example, a long Zone 1 reach through a transformer, it is possible to implement harmonic blocking for magnetizing inrush current. Provided that the Inrush Detection is “Enabled”, the user can then pick up the output of the I(2)/I(1) detectors in the Programmable Scheme Logic. The user can then assign blocking functions in the PSL as necessary, because as stated above this detector does not directly route into the relay’s fixed logic.

2.7 Function keys

The P54x relays offers users 10 function keys for programming any operator control functionality such as auto-reclose ON/OFF, earth fault1 ON/OFF etc. via PSL. Each function key has an associated programmable tri-color LED that can be programmed to give the desired indication on function key activation.

These function keys can be used to trigger any function that they are connected to as part of the PSL. The function key commands can be found in the ‘Function Keys’ menu (see Settings section, P54x/EN ST). In the ‘Fn. Key Status’ menu cell there is a 10 bit word which represent the 10 function key commands and their status can be read from this 10 bit word.

In the programmable scheme logic editor 10 function key signals, DDB 1096 - 1105, which can be set to a logic 1 or On state, as described above, are available to perform control functions defined by the user.

The “Function Keys” column has ‘Fn. Key n Mode’ cell which allows the user to configure the function key as either ‘Toggled’ or ‘Normal’. In the ‘Toggle’ mode the function key DDB signal output will remain in the set state until a reset command is given, by activating the function key on the next key press. In the ‘Normal’ mode, the function key DDB signal will remain energized for as long as the function key is pressed and will then reset automatically. A minimum pulse duration can be programmed for a function key by adding a minimum pulse timer to the function key DDB output signal.

The “Fn. Key n Status” cell is used to enable/unlock or disable the function key signals in PSL. The ‘Lock’ setting has been specifically provided to allow the locking of a function key thus preventing further activation of the key on consequent key presses. This allows function keys that are set to ‘Toggled’ mode and their DDB signal active ‘high’, to be locked in their active state thus preventing any further key presses from deactivating the associated function. Locking a function key that is set to the “Normal” mode causes the associated DDB

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signals to be permanently off. This safety feature prevents any inadvertent function key presses from activating or deactivating critical relay functions.

The “Fn. Key Labels” cell makes it possible to change the text associated with each individual function key. This text will be displayed when a function key is accessed in the function key menu, or it can be displayed in the PSL.

The status of the function keys is stored in battery backed memory. In the event that the auxiliary supply is interrupted the status of all the function keys will be recorded. Following the restoration of the auxiliary supply the status of the function keys, prior to supply failure, will be reinstated. If the battery is missing or flat the function key DDB signals will set to logic 0 once the auxiliary supply is restored. Please also note the relay will only recognize a single function key press at a time and that a minimum key press duration of approximately 200msec. is required before the key press is recognized in PSL. This deglitching feature avoids accidental double presses.

2.8 Circuit breaker state monitoring

The relay incorporates circuit breaker state monitoring, giving an indication of the position of the circuit breaker, or, if the state is unknown, an alarm is raised.

2.8.1 Circuit breaker state monitoring features

MiCOM relays can be set to monitor normally open (52a) and normally closed (52b) auxiliary contacts of the circuit breaker. Under healthy conditions, these contacts will be in opposite states. Should both sets of contacts be open, this would indicate one of the following conditions:

– Auxiliary contacts/wiring defective

– Circuit Breaker (CB) is defective

– CB is in isolated position

Should both sets of contacts be closed, only one of the following two conditions would apply:

– Auxiliary contacts/wiring defective

– Circuit Breaker (CB) is defective

If any of the above conditions exist, an alarm will be issued after a 5s time delay. A normally open / normally closed output contact can be assigned to this function via the programmable scheme logic (PSL). The time delay is set to avoid unwanted operation during normal switching duties.

In the CB CONTROL column of the relay menu there is a setting called ‘CB Status Input’. This cell can be set at one of the following seven options:

None	
52°	3 pole
52B	3 pole
52A & 52B	3 pole
52A	1 pole
52B	1 pole
52A & 52B	1 pole

Where ‘None’ is selected no CB status will be available. This will directly affect any function within the relay that requires this signal, for example CB control, auto-reclose, etc. Where only 52A is used on its own then the relay will assume a 52B signal from the absence of the 52A signal. Circuit breaker status information will be available in this case but no discrepancy alarm will be available. The above is also true where only a 52B is used. If both 52A and 52B are used then status information will be available and in addition a discrepancy alarm will be possible, according to the following table. 52A and 52B inputs are assigned to relay opto-isolated inputs via the PSL.

Auxiliary Contact Position		**CB State Detected**	**Action**
52A	52B		
Open	Closed	Breaker Open	Circuit breaker healthy
Closed	Open	Breaker Closed	Circuit breaker healthy
Closed	Closed	CB Failure	Alarm raised if the condition persists for greater than 5s
Open	Open	State Unknown	Alarm raised if the condition persists for greater than 5s

Where single pole tripping is used then an open breaker condition will only be given if all three phases indicate and open condition. Similarly for a closed breaker condition indication that all three phases are closed must be given. For single pole tripping applications 52A-a, 52A-b and 52A-c and/or 52B-a, 52B-b and 52B-c inputs should be used. The CB State Monitoring Logic is shown in Figure 81.

In the case of the P544 and P546 two circuit breakers are monitored. If inputs relevant to each of the circuit breaker's (CB1 and CB2) are available to the relay via the opto isolated inputs it will be able to determine the state of each circuit breaker.

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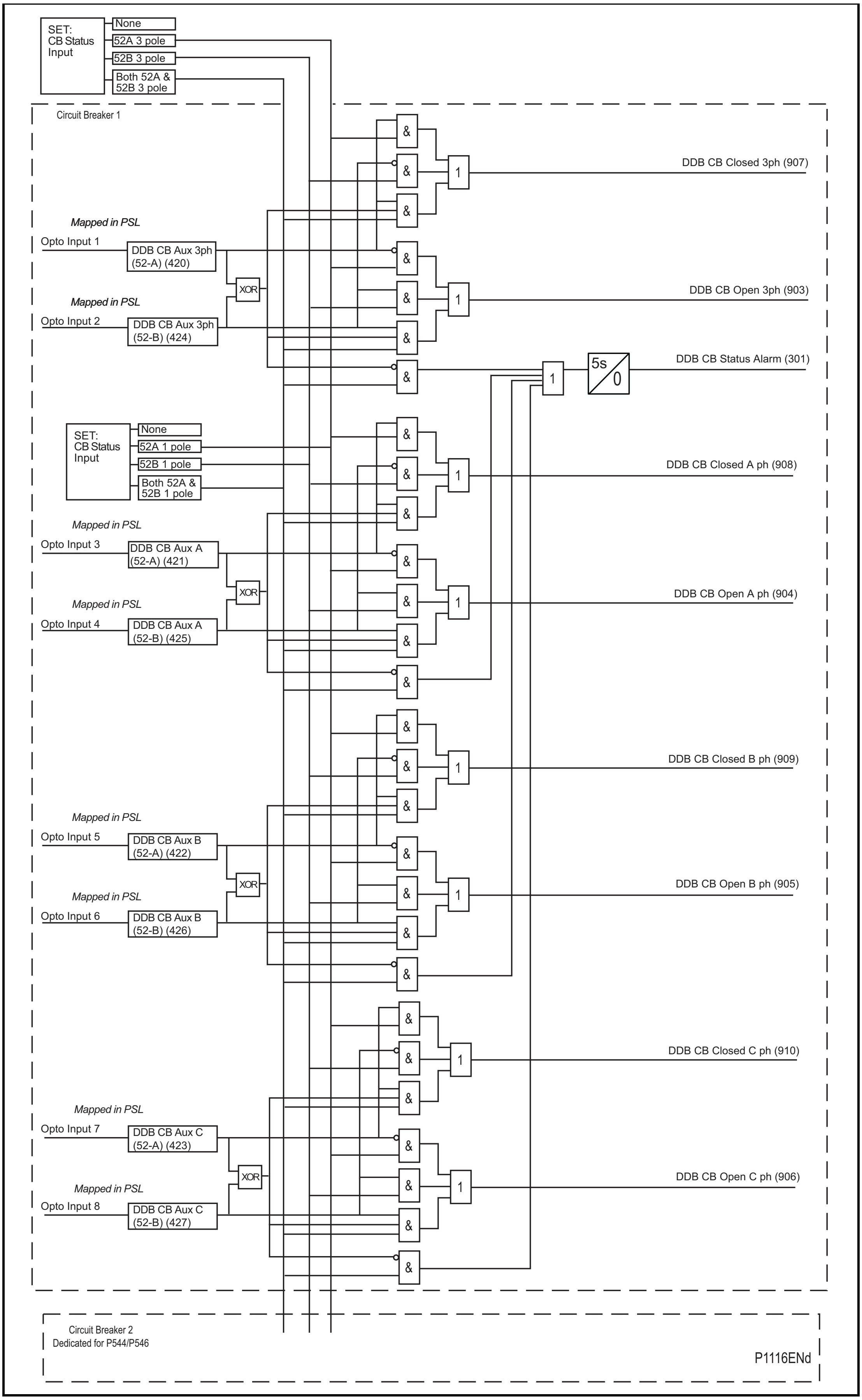

Figure 81: Circuit breaker state monitor

2.9 Circuit breaker condition monitoring (only for P543 and P545)

Periodic maintenance of circuit breakers is necessary to ensure that the trip circuit and mechanism operate correctly, and also that the interrupting capability has not been compromised due to previous fault interruptions. Generally, such maintenance is based on a fixed time interval, or a fixed number of fault current interruptions. These methods of monitoring circuit breaker condition give a rough guide only and can lead to excessive maintenance.

2.9.1 Circuit breaker condition monitoring features

For each circuit breaker trip operation the relay records statistics as shown in the following table taken from the relay menu. The menu cells shown are counter values only. The Min./Max. values in this case show the range of the counter values. These cells can not be set.

Menu Text	Default	Setting		Step Size
		Min.	Max.	
CB Operations {3 pole tripping}	0	0	10000	1
Displays the total number of 3 pole trips issued by the relay.				
Total IA Broken	0	0	25000In^	1
Displays the total fault current interrupted by the relay for the A phase.				
Total IB Broken	0	0	25000In^	1
Displays the total fault current interrupted by the relay for the A phase.				
Total IC Broken	0	0	25000In^	1In^
Displays the total fault current interrupted by the relay for the A phase.				
CB Operate Time	0	0	0.5s	0.001
Displays the calculated CB operating time.				
Reset CB Data	No		Yes, No	
Reset the CB condition counters.				

The above counters may be reset to zero, for example, following a maintenance inspection and overhaul. The circuit breaker condition monitoring counters will be updated every time the relay issues a trip command. In cases where the breaker is tripped by an external protection device it is also possible to update the CB condition monitoring. This is achieved by allocating one of the relays opto-isolated inputs (via the programmable scheme logic) to accept a trigger from an external device. The signal that is mapped to the opto is called ‘External Trip’.

Note that when in Commissioning test mode the CB condition monitoring counters will not be updated.

The measurement of circuit breaker operating time, broken current and the overall CB Monitoring logic diagram, now follow as Figures 82, 83 and 84.

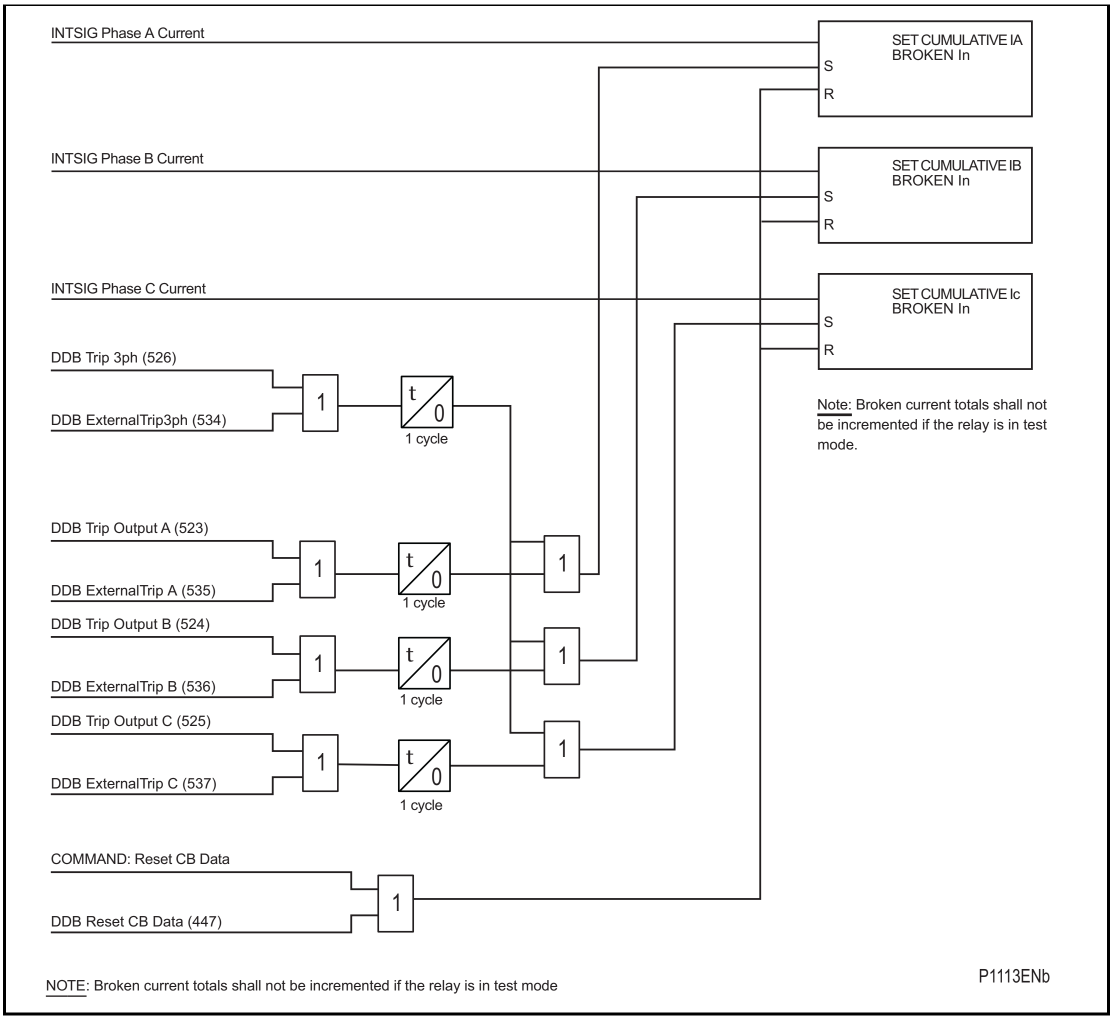

Figure 82: Circuit breaker condition monitoring - broken current (only models P543 and P545)

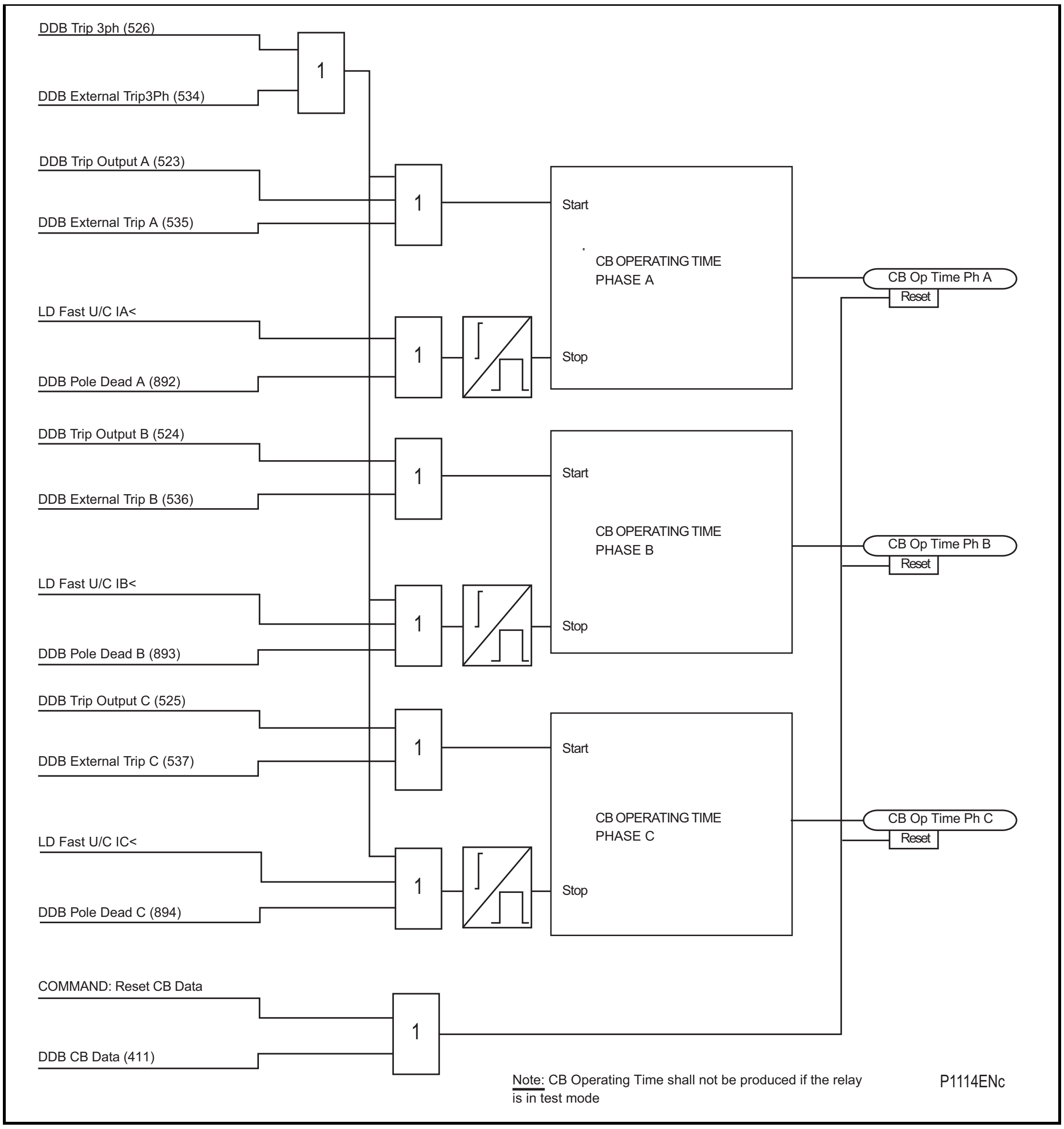

Figure 83: Circuit breaker condition monitoring - operation time (only models P543 and P545)

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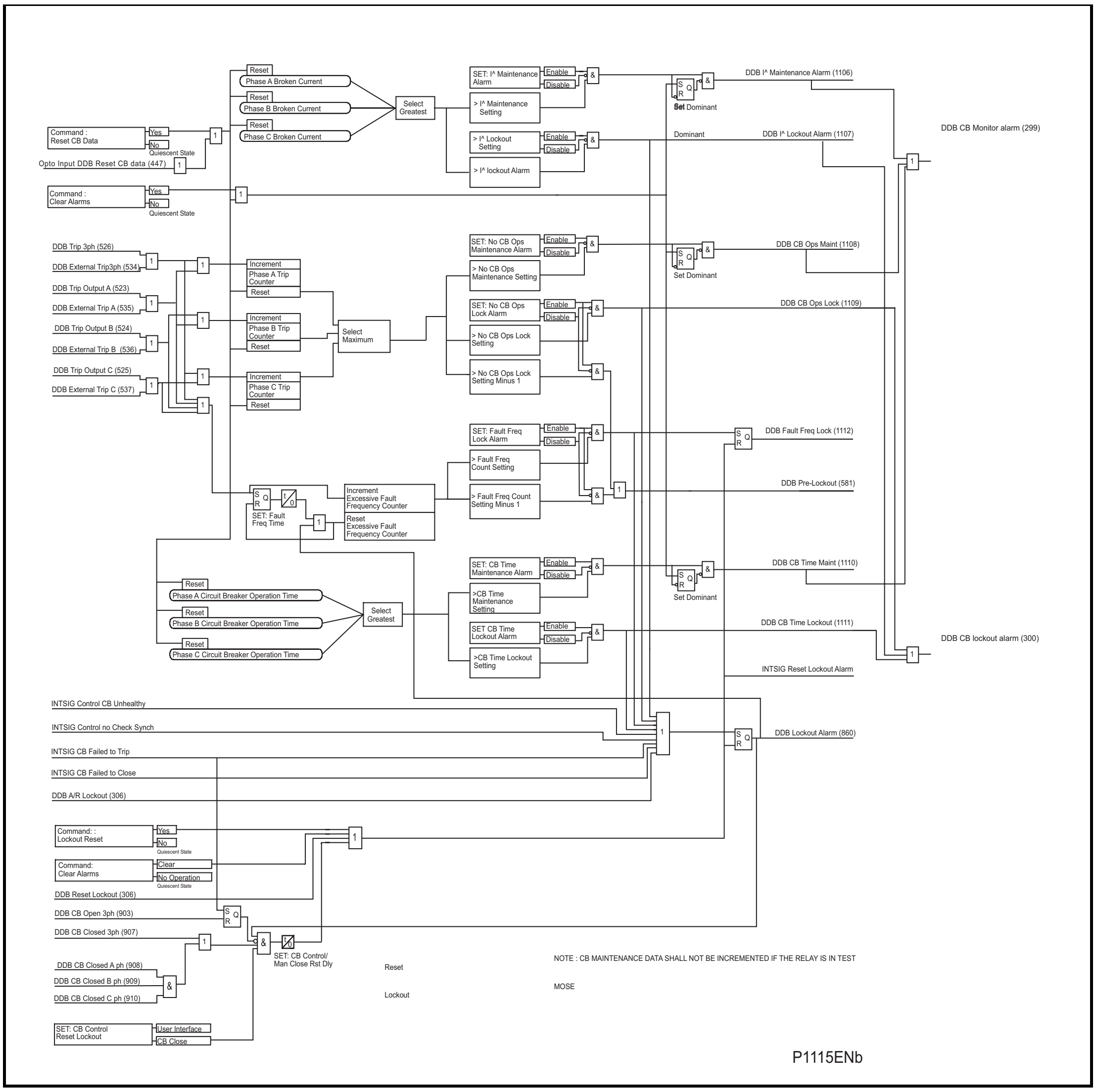

Figure 84: CB monitoring (only for models P543 and P545)

2.10 Circuit breaker control

The relay includes the following options for control of a single circuit breaker:

– Local tripping and closing, via the relay menu or *Hotkeys*

– Local tripping and closing, via relay opto-isolated inputs

– Remote tripping and closing, using the relay communications

It is recommended that separate relay output contacts are allocated for remote circuit breaker control and protection tripping. This enables the control outputs to be selected via a local/remote selector switch as shown in Figure 85. Where this feature is not required the same output contact(s) can be used for both protection and remote tripping.

In the case of the P544 and P546 two circuit breakers may be selectively controlled both locally and remotely if relay contacts are assigned to allow a separate control trip contact and a separate control close for each circuit breaker i.e. four output relay contacts.

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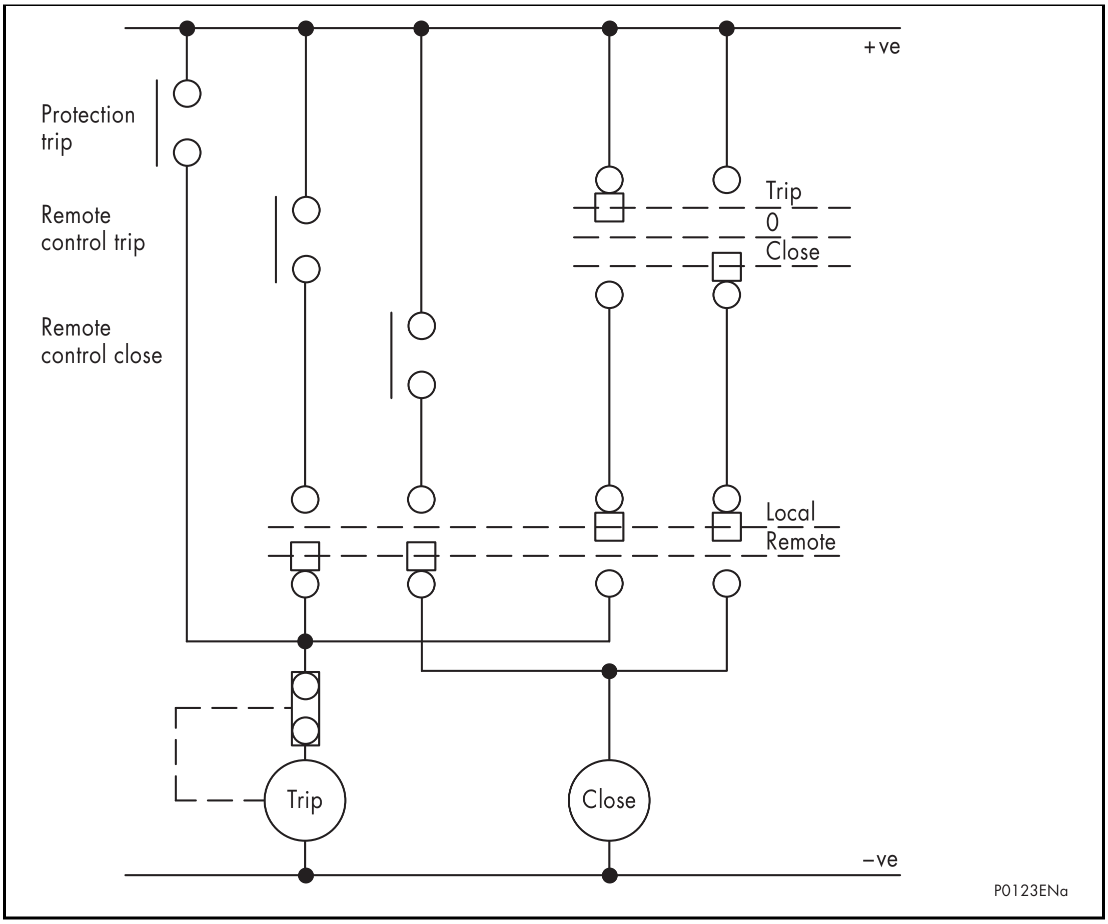

Figure 85: Remote control of circuit breaker

A manual trip will be permitted provided that the circuit breaker is initially closed. Likewise, a close command can only be issued if the CB is initially open. To confirm these states it will be necessary to use the breaker 52A and/or 52B contacts (the different selection options are given from the ‘CB Status Input’ cell above). If no CB auxiliary contacts are available then this cell should be set to None. Under these circumstances no CB control (manual or auto) will be possible.

Once a CB Close command is initiated the output contact can be set to operate following a user defined time delay (‘Man Close Delay’). This would give personnel time to move away from the circuit breaker following the close command. This time delay will apply to all manual CB Close commands.

The length of the trip or close control pulse can be set via the ‘Trip Pulse Time’ and ‘Close Pulse Time’ settings respectively. These should be set long enough to ensure the breaker has completed its open or close cycle before the pulse has elapsed.

Note that the manual trip and close commands are found in the SYSTEM DATA column and the hotkey menu.

If an attempt to close the breaker is being made, and a protection trip signal is generated, the protection trip command overrides the close command.

Where the check synchronism function is set, this can be enabled to supervise manual circuit breaker close commands. A circuit breaker close output will only be issued if the check synchronism criteria are satisfied. A user settable time delay is included (‘C/S Window’) for manual closure with check synchronizing. If the checksynch criteria are not satisfied in this time period following a close command the relay will lockout and alarm.

In addition to a synchronism check before manual reclosure there is also a CB Healthy check if required. This facility accepts an input to one of the relays opto-isolators to indicate that the breaker is capable of closing (circuit breaker energy for example). A user settable time delay is included (‘Healthy Window’) for manual closure with this check. If the CB does not indicate a healthy condition in this time period following a close command then the relay will lockout and alarm.

Where auto-reclose is used it may be desirable to block its operation when performing a manual close. In general, the majority of faults following a manual closure will be permanent faults and it will be undesirable to auto-reclose. The ‘Man Close RstDly’ timer setting is the time for which auto-reclose will be disabled following a manual closure of the breaker.

If the CB fails to respond to the control command (indicated by no change in the state of CB Status inputs) a ‘CB Failed to Trip’ or ‘CB Failed to Close’ alarm will be generated after the relevant trip or close pulses have expired. These alarms can be viewed on the relay LCD display, remotely via the relay communications, or can be assigned to operate output contacts for annunciation using the relays programmable scheme logic (PSL).

Note that the ‘Healthy Window’ timer and ‘C/S Window’ timer set under this menu section are applicable to manual circuit breaker operations only. These settings are duplicated in the Auto-reclose menu for Auto-reclose applications.

The ‘Lockout Reset’ and ‘Reset Lockout by’ setting cells in the menu are applicable to CB Lockouts **associated with manual circuit breaker closure, CB Condition monitoring (Number of circuit breaker operations,** for example) and auto-reclose lockouts.

The CB Control Logic is illustrated in Figures 86 and 87.

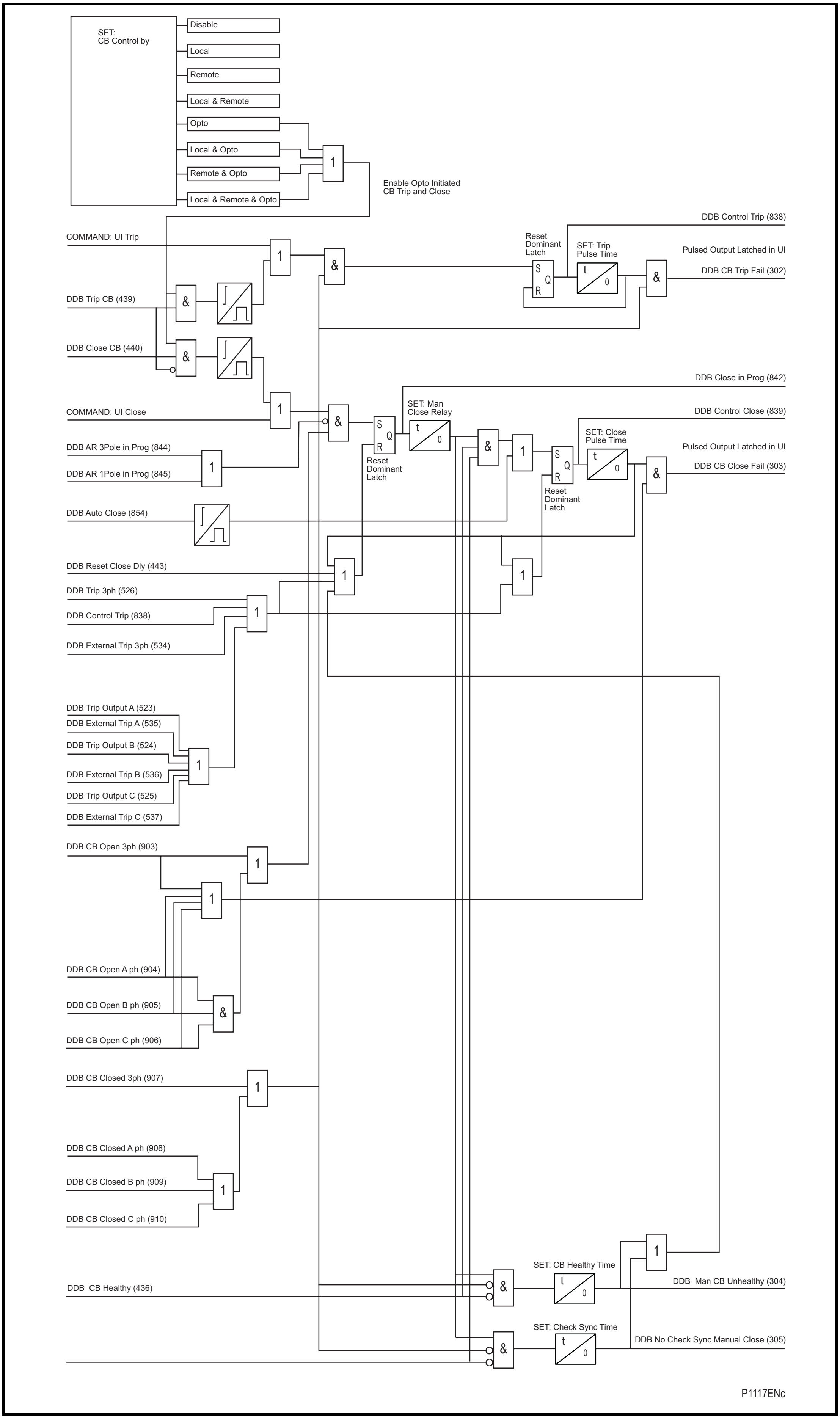

Figure 86: Circuit breaker control for P543 and P545

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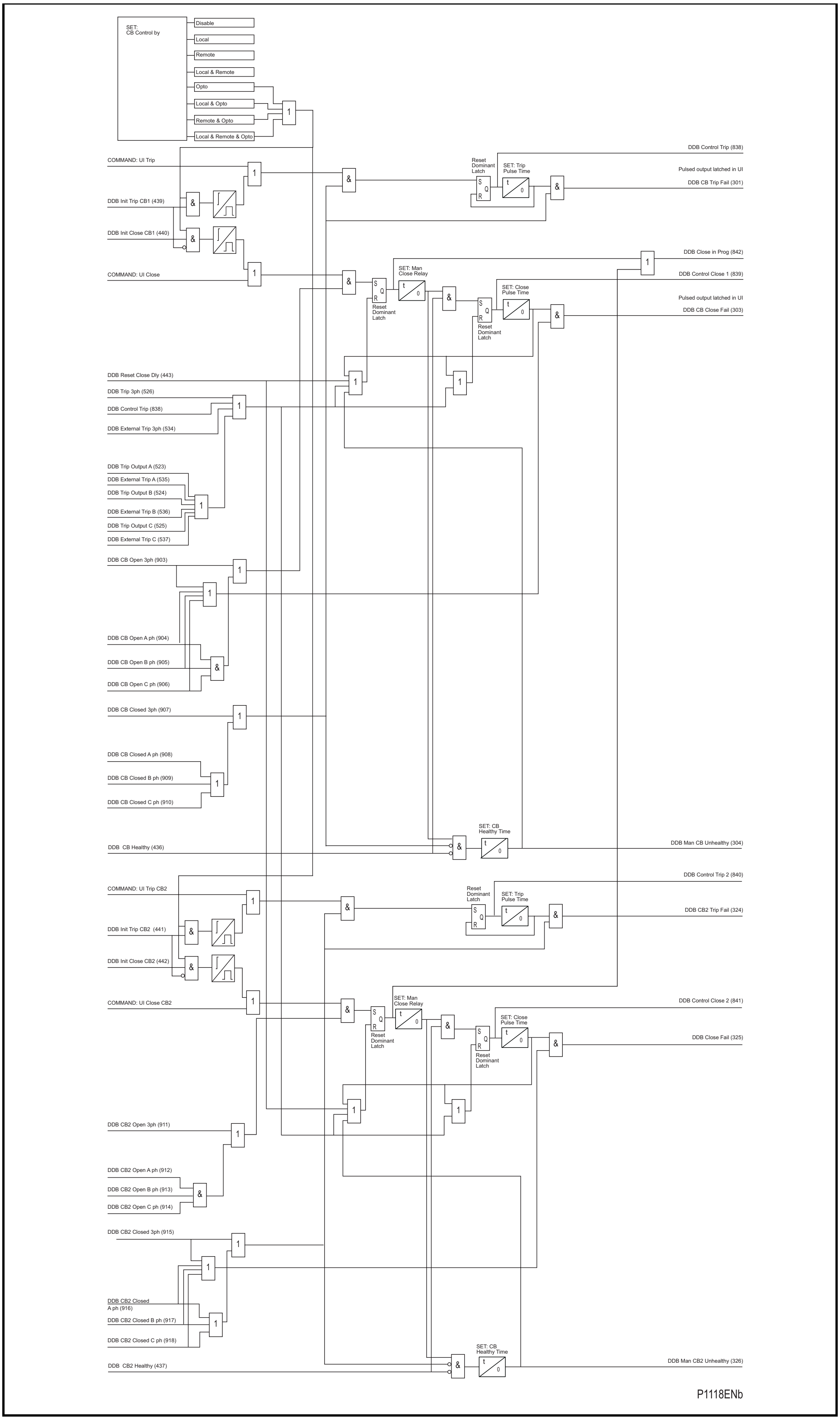


Figure 87: Circuit breaker control for P544 and P546

2.10.1 CB control using hotkeys

The hotkeys allow direct access to manual trip and close commands without the need to enter the SYSTEM DATA column. Red or green color coding can be applied when used in CB control applications.

IF <<TRIP>> or <<CLOSE>> is selected the user is prompted to confirm the execution of the relevant command. If a trip is executed a screen with the CB status will be displayed once the command has been completed. If a close is executed a screen with a timing bar will appear while the command is being executed. This screen has the option to cancel or restart the close procedure. The timer used is taken from the manual close delay timer setting in the CB Control menu. When the command has been executed, a screen confirming the present status of the circuit breaker is displayed. The user is then prompted to select the next appropriate command or exit - this will return to the default relay screen.

If no keys are pressed for a period of 25 seconds while waiting for the command confirmation, the relay will revert to showing the CB Status. If no key presses are made for a period of 25 seconds while displaying the CB status screen, the relay will revert to the default relay screen. Figure 88 shows the hotkey menu associated with CB control functionality.

To avoid accidental operation of the trip and close functionality, the hotkey CB control commands will be disabled for 10 seconds after exiting the hotkey menu.

OP

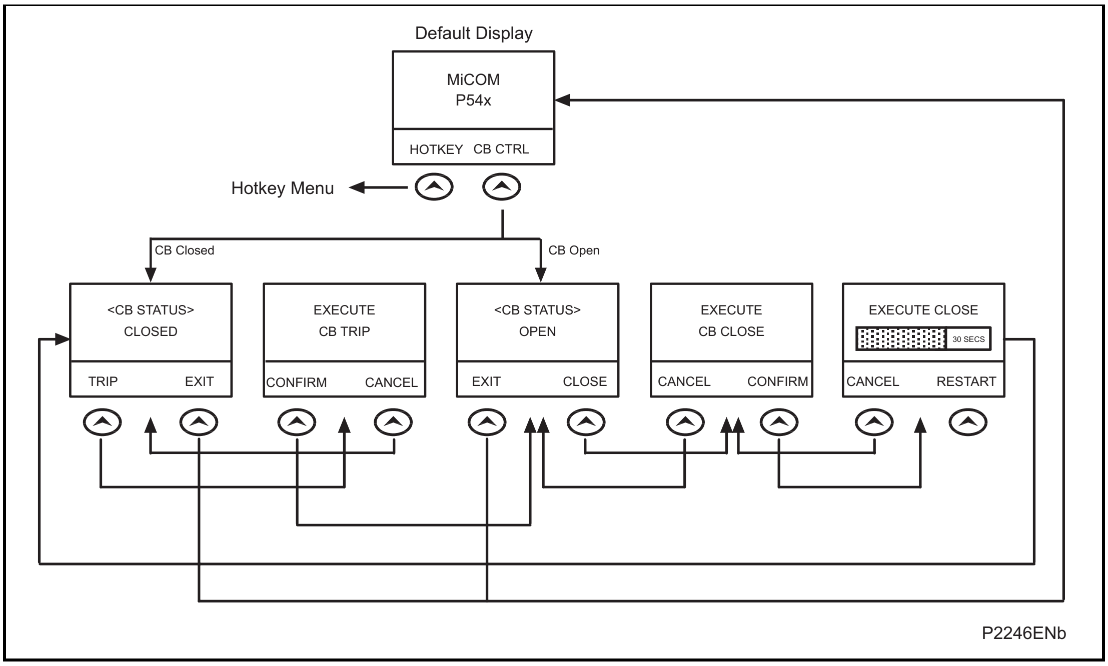


Figure 88: CB control hotkey menu

2.10.2 CB control using function keys

The function keys allow direct control of the circuit breaker if programmed to do this in PSL. local tripping and closing, via relay opto-isolated inputs must be set in the “CB Control” menu ‘CB control by’ cell to enable this functionality. All CB manual control settings and conditions will apply for manual tripping and closing via function keys.

The following default logic can be programmed to activate this feature:

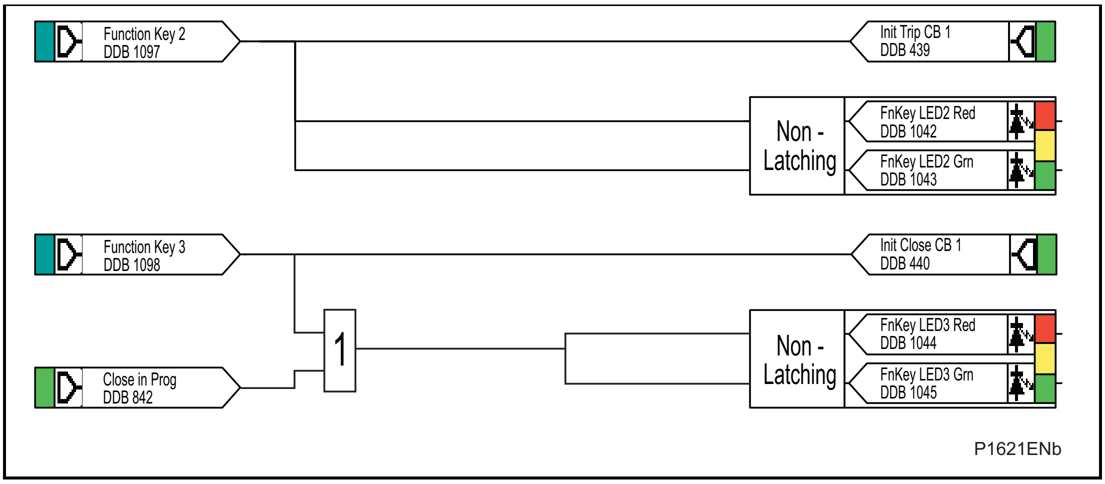


Figure 89: CB control via function keys default PSL

Function key 2 and function key 3 are both enabled and set to 'Normal' Mode and the associated DDB signals 'DDB 1097' and 'DDB 1098' will be active high '1' on key press.

OP

The following DDB signal must be mapped to the relevant function key:

Trip CB (DDB 439) - Initiate manual circuit breaker trip

Close CB (DDB 440) - Initiate manual circuit breaker close

The programmable function key LED's have been mapped such that the LED's will indicate yellow whilst the keys are activated.

2.11 Setting groups selection

The setting groups can be changed either via opto inputs, via a menu selection, via the hotkey menu or via function keys. In the Configuration column if 'Setting Group - select via optos' is selected then any opto input or function key can be programmed in PSL to select the setting group as shown in the table below. If 'Setting Group - select via menu' is selected then in the Configuration column the 'Active Settings - Group1/2/3/4' can be used to select the setting group.

The setting group can be changed via the hotkey menu providing 'Setting Group select via menu' is chosen.

Two DDB signals are available in PSL for selecting a setting group via an opto input or function key selection. The following table illustrates the setting group that is active on activation of the relevant DDB signals.

DDB 542 SG Select 1X	DDB 543 SG Select X1	Selected Setting Group
0	0	1
1	0	2
0	1	3
1	1	4

Note: Each setting group has its own PSL. Once a PSL has been designed it can be sent to any one of 4 setting groups within the relay. When downloading a PSL to the relay the user will be prompted to enter the desired setting group to which it will be sent. This is also the case when extracting a PSL from the relay.

2.12 Control inputs

The control inputs function as software switches that can be set or reset either locally or remotely. These inputs can be used to trigger any function that they are connected to as part of the PSL. There are three setting columns associated with the control inputs that are: “CONTROL INPUTS”, “CTRL. I/P CONFIG.” and “CTRL. I/P LABELS”. The function of these columns is described below:

Menu Text	Default Setting	Setting Range	Step Size
CONTROL INPUTS			
Ctrl I/P Status	00000000000000000000000000000000		
Control Input 1	No Operation	No Operation, Set, Reset	
Control Input 2 to 32	No Operation	No Operation, Set, Reset	

The Control Input commands can be found in the ‘Control Input’ menu. In the ‘Ctrl. I/P status’ menu cell there is a 32 bit word which represent the 32 control input commands. The status of the 32 control inputs can be read from this 32-bit word. The 32 control inputs can also be set and reset from this cell by setting a 1 to set or 0 to reset a particular control input. Alternatively, each of the 32 Control Inputs can be set and reset using the individual menu setting cells ‘Control Input 1, 2, 3’ etc. The Control Inputs are available through the relay menu as described above and also via the rear communications.

In the programmable scheme logic editor 32 Control Input signals, DDB 191 - 223, which can be set to a logic 1 or On state, as described above, are available to perform control functions defined by the user.

Menu Text	Default Setting	Setting Range	Step Size
CTRL. I/P CONFIG.			
Hotkey Enabled	11111111111111111111111111111111		
Control Input 1	Latched	Latched, Pulsed	
Ctrl Command 1	Set/Reset	Set/Reset, In/Out, Enabled/Disabled, On/Off	
Control Input 2 to 32	Latched	Latched, Pulsed	
Ctrl Command 2 to 32	Set/Reset	Set/Reset, In/Out, Enabled/Disabled, On/Off	

Menu Text	Default Setting	Setting Range	Step Size
CTRL. I/P LABELS			
Control Input 1	Control Input 1	16 character text	
Control Input 2 to 32	Control Input 2 to 32	16 character text	

The “CTRL. I/P CONFIG.” column has several functions one of which allows the user to configure the control inputs as either ‘latched’ or ‘pulsed’. A latched control input will remain in the set state until a reset command is given, either by the menu or the serial communications. A pulsed control input, however, will remain energized for 10ms after the set command is given and will then reset automatically (i.e. no reset command required).

In addition to the latched/pulsed option this column also allows the control inputs to be individually assigned to the “Hotkey” menu by setting ‘1’ in the appropriate bit in the “Hotkey Enabled” cell. The hotkey menu allows the control inputs to be set, reset or pulsed without the need to enter the “CONTROL INPUTS” column. The “Ctrl. Command” cell also allows the SET/RESET text, displayed in the hotkey menu, to be changed to something more suitable for the application of an individual control input, such as “ON/OFF”, “IN/OUT” etc.

The "CTRL. I/P LABELS" column makes it possible to change the text associated with each individual control input. This text will be displayed when a control input is accessed by the hotkey menu, or it can be displayed in the PSL.

Note: With the exception of pulsed operation, the status of the control inputs is stored in non volatile memory. In the event that the auxiliary supply is interrupted the status of all the inputs will be recorded. Following the restoration of the auxiliary supply the status of the control inputs, prior to supply failure, will be reinstated. If the battery is missing or flat the control inputs will set to logic 0 once the auxiliary supply is restored.

2.13 Real time clock synchronization via opto-inputs

In modern protective schemes it is often desirable to synchronize the relays real time clock so that events from different relays can be placed in chronological order. This can be done using the IRIG-B input, if fitted, or via the communication interface connected to the substation control system. In addition to these methods the MiCOM P54x range offers the facility to synchronize via an opto-input by routing it in PSL to DDB 400 (Time Sync.). Pulsing this input will result in the real time clock snapping to the nearest minute. The recommended pulse duration is 20ms to be repeated no more than once per minute. An example of the time sync. function is shown.

OP

Time of "Sync. Pulse"	Corrected Time
19:47:00 to 19:47:29	19:47:00
19:47:30 to 19:47:59	19:48:00

Note: The above assumes a time format of hh:mm:ss.

To avoid the event buffer from being filled with unnecessary time sync. events, it is possible to ignore any event that is generated by the time sync. opto input. This can be done by applying the following settings:

Menu Text	Value
RECORD CONTROL	
Opto Input Event	Enabled
Protection Event	Enabled
DDB 63 - 32 (Opto Inputs)	Set "Time Sync." associated opto to 0

To improve the recognition time of the time sync. opto input by approximately 10ms, the opto input filtering could be disabled. This is achieved by setting the appropriate bit to 0 in the "Opto Filter Cntl." cell (OPTO CONFIG. column). Disabling the filtering may make the opto input more susceptible to induced noise. Fortunately the effects of induced noise can be minimized by using the methods described in Firmware Design (P54x/EN FD) section.

2.14 Fault locator

The relay has an integral fault locator that uses information from the current and voltage inputs to provide a distance to fault location. The sampled data from the analog input circuits is written to a cyclic buffer until a fault condition is detected. The data in the input buffer is then held to allow the fault calculation to be made. When the fault calculation is complete the fault location information is available in the relay fault record.

When applied to parallel circuits mutual flux coupling can alter the impedance seen by the fault locator. The coupling will contain positive, negative and zero sequence components. In practice the positive and negative sequence coupling is insignificant. The effect on the fault locator of the zero sequence mutual coupling can be eliminated by using the mutual compensation feature provided.

2.14.1 Basic theory for ground faults

Figure 90 shows a two-machine equivalent circuit of a faulted power system.

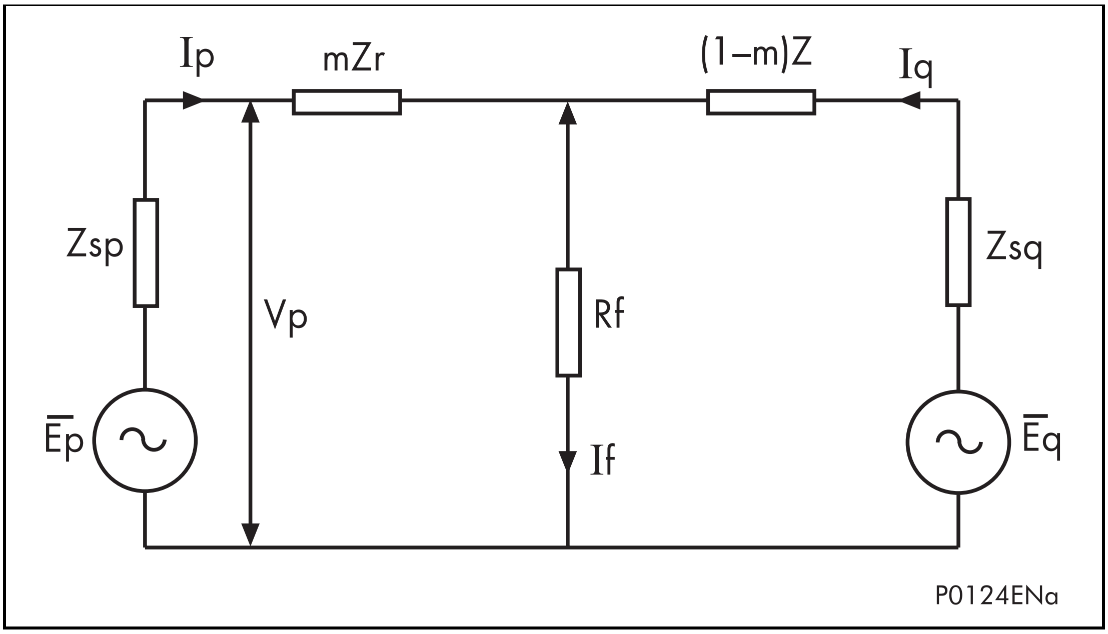


Figure 90: Two-machine equivalent circuit

From this diagram:

$Vp = mIpZr + IfRf$ …(equation 1)

The fault location, m, can be found if f can be estimated allowing equation 1 to be solved.

2.14.2 Data acquisition and buffer processing

The fault locator stores the sampled data within a 12 cycle cyclic buffer at a resolution of 48 samples per cycle. When the fault recorder is triggered the data in the buffer is frozen such that the buffer contains 6 cycles of pre-trigger data and 6 cycles of post-trigger data. Fault calculation commences shortly after this trigger point.

The trigger for the fault recorder is user selectable via the programmable scheme logic.

The fault locator can store data for up to four faults. This ensures that fault location can be calculated for all shots on a typical multiple reclose sequence.

2.14.3 Faulted phase selection

Phase selection is derived from the current differential protection or the superimposed current phase selector.

Phase selection and fault location calculations can only be made if the current change exceeds 5% In.

2.14.4 The fault location calculation

The fault location calculation works by:

a) First obtaining the vectors

b) Selecting the faulted phase(s)

c) Estimating the phase of the fault current If for the faulted phase(s)

d) Solving equation 1 for the fault location m at the instant of time where f = 0

OP

2.14.5 Obtaining the vectors

Different sets of vectors are chosen depending on the type of fault identified by the phase selection algorithm. The calculation using equation 1 is applied for either a phase to ground fault or a phase to phase fault.

thus for an A phase to ground fault:

IpZr=Ia(Zline/THETA line) + In (Zresidual/THETA residual) ...(equation 2)

and Vp=VA

and for a A phase to B phase fault:

IpZr=Ia(Zline/THETA line) - Ib (Zresidual / THETA residual) ...(equation 3)

and Vp = VA - VB

The calculation for a ground fault (equation 4) is modified when mutual compensation is used:

IpZr=Ia(Zline/THETA line) +In (residual/THETA residual)+

Im(mutual/THETA mutual) ...(equation 4)

2.14.6 Solving the equation for the fault location

As the sine wave of If passes through zero, the instantaneous values of the sine waves Vp and Ip can be used to solve equation (1) for the fault location m. (The term IfRf being zero).

This is determined by shifting the calculated vectors of Vp and IpZr by the angle (90° - angle of fault current) and then dividing the real component of Vp by the real component of IpZr. (See Figure 91).

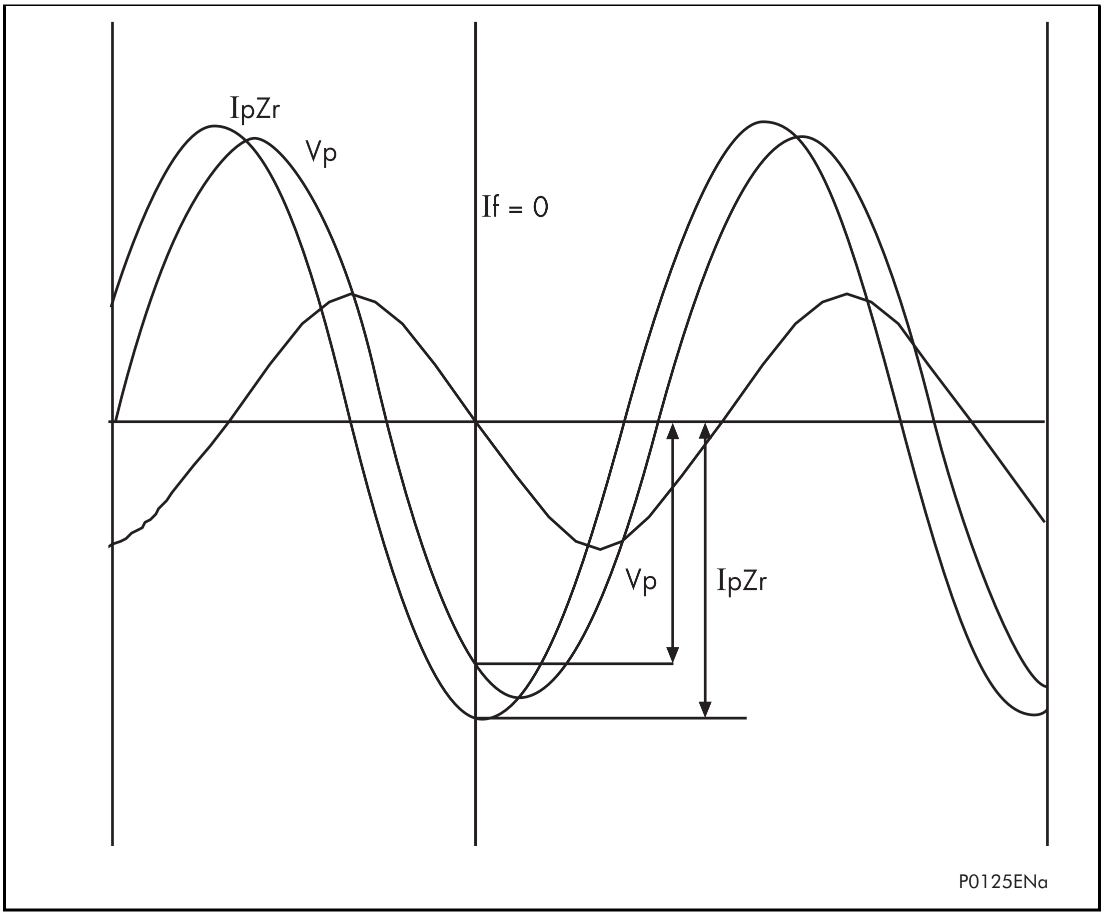


Figure 91: Fault locator selection of fault current zero

i.e.:

Phase advanced vector Vp

$= |Vp| [\cos(s) + j\sin(s)] * [\sin(d) + j\cos(d)]$

$= |Vp| [-\sin(s-d) + j\cos(s-d)]$

Phase advanced vector IpZr

$= |IpZr| [\cos(e) + j\sin(e)] * [\sin(d) + j\cos(d)]$

$= |IpZr| [-\sin(e-d) + j\cos(e-d)]$

Therefore, from equation 1:

$m = Vp \div (Ip * Zr)$ at $If = 0$

$= Vp \sin(s-d) / (IpZr * \sin(e-d))$

Where:

d	=	Angle of fault current If
s	=	Angle of Vp
e	=	Angle of IpZr

Thus the relay evaluates m which is the fault location as a percentage of the fault locator line impedance setting and then calculates the output fault location by multiplying this by the line length setting. When calculated the fault location can be found in the fault record under the VIEW RECORDS column in the Fault Location cells. Distance to fault is available in kilometers, miles, impedance or percentage of line length.

2.14.7 Mutual compensation

Analysis of a ground fault on one circuit of a parallel over-head line shows that a fault locator positioned at one end of the faulty line will tend to over-reach while that at the other end will tend to under-reach. In cases of long lines with high mutual inductance, mutual zero sequence compensation can be used to improve the fault locator accuracy. The compensation is achieved by taking an input to the relay from the residual circuit of the current transformers in the parallel line.

The MiCOM P54x provides mutual compensation for both the fault locator function, AND the distance protection zones.

3. COMMUNICATIONS BETWEEN RELAYS

3.1 Communications link options

A number of communications options are available, for the communication channels between P54x system ends. The various connection options are shown below. Choosing between each of these options will depend on the type of communications equipment that is available.

Where existing suitable multiplexer communication equipment is installed for other communication between substations, the 850nm option together with an appropriate ITU-T compatible electrical interface (P590 series unit) should be selected to match the existing multiplexer equipment. For further information on the P590 optical fiber to electrical interface units, refer to section 3.1.8.

Where an IEEE C37.94 compatible multiplexer is installed the 850nm option should be configured to interface directly to the multiplexer, refer to section 3.1.5.

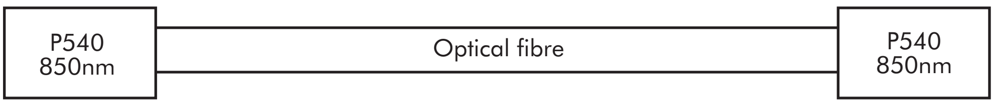
Where no multiplexer is installed, the direct optical fiber connection can be used, refer to sections 3.1.1 - 3.1.4. The type of fiber used (multi-mode or single-mode and wavelength) will be determined by the distance between the ends of the P54x relay system, refer to optical budgets in section P54x/EN/AP.

In any configuration, except the IEEE C37.94, the data rate may be selected as either 64kbit/sec or 56kbit/sec.

OP

3.1.1 Direct optical fiber link, 850nm multi-mode fiber

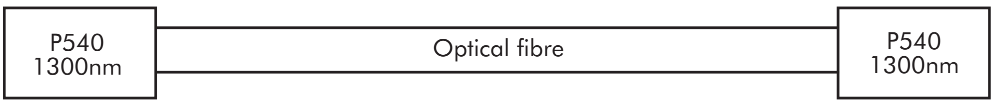
The relays are connected directly using two 850nm multi-mode optical fibers for each signaling channel. Multi-mode fiber type 50/125µm or 62.5/125µm is suitable. BFOC/2.5 type fiber optic connectors are used. These are commonly known as “ST” connectors (“ST” is a registered trademark of AT&T).



This is typically suitable for connection up to 1km.

3.1.2 Direct optical fiber link, 1300nm multi-mode fiber

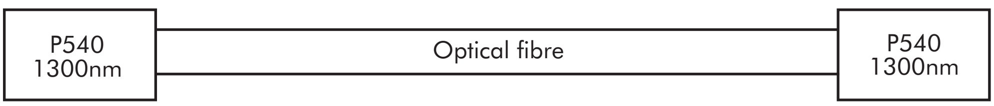
The relays are connected directly using two 1300nm multi-mode fibers for each signaling channel. Multi-mode fiber type 50/125µm or 62.5/125µm is suitable. BFOC/2.5 type fiber optic connectors are used.



This is typically suitable for connection up to 30km.

3.1.3 Direct optical fiber link, 1300nm single-mode fiber

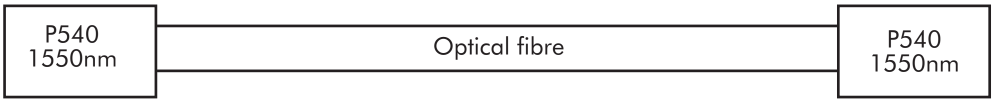
The relays are connected directly using two 1300nm single-mode fibers, type 9/125µm for each signaling channel. BFOC/2.5 type fiber optic connectors are used.



This is typically suitable for connection up to 65km.

3.1.4 Direct optical fiber link, 1550nm single-mode fiber

The relays are connected directly using two 1550nm single-mode fibers, type 9/125µm for each signaling channel. BFOC/2.5 type fiber optic connectors are used.



This is typically suitable for connection up to 90km.

The list of all available fiber channel options is:

820nm dual channel

1300 nm single-mode/single channel

1300 nm single-mode/dual channel

1300 nm multi-mode/single channel

1300 nm multi-mode/dual channel

1550 nm single-mode/single channel

1550 nm single-mode/dual channel

Ch 1 850nm multi-mode + Ch 2 1300nm single-mode

Ch 1 850nm multi-mode + Ch 2 1550nm single-mode

Ch 1 1300nm single-mode + Ch 2 850nm multi-mode

Ch 1 1300nm multi-mode + Ch 2 850nm multi-mode

Ch 1 1550nm single-mode + Ch 2 850nm multi-mode

3.1.5 IEEE C37.94 interface to multiplexer

A P54x relay with 850nm short haul optical interface is connected directly to the multiplexer by 850nm multi-mode optical fiber. Multi-mode fiber type 50/125µm or 62.5/125µm is suitable. BFOC/2.5 type fiber optic connectors are used.

The setting Comms Mode should be set to IEEE C37.94. Note the relay must be powered off and on before this setting change becomes effective.

The IEEE C37.94 standard defines an N*64kbits/s standard where N can be 1 – 12. N can be selected on the P54x or alternatively set to Auto in which case the relay will configure itself to match the multiplexer.

3.1.6 Switched communication networks

The P54x relays make use of digital communication signaling channels for the differential protection. For correct operation of this protection element, it is essential that the integrity of this link is continuously checked. For P54x relays, when GPS is not used it is also a requirement of this link that ‘go’ (tp1) and ‘return’ (tp2) times are similar (a difference of up to 1ms can be tolerated). Times greater than this can result in relay instability.

Where switched communications networks are used, it is possible that during switching, a transient time period may exist with different ‘go’ and ‘return’ times. All P54x relays include a facility to ensure protection stability during this transient period.

One of the checks performed on the communications link is a check on the calculated propagation delay for each data message. During normal operation the difference in calculated time should be minimal (possible delays being introduced by multiplexers or other intermediary communication equipment). If successive calculated propagation delay times exceed a user settable value (250 - 1000µs). The P54x raise a comm delay alarm and initiate a change in relay setting for a short time period (Char Mod Time setting) to overcome any switching delay. This change in setting is shown in Figure 93 whereby the relay bias setting, k1, is increased to 200%. This characteristic provides stability for all load conditions and will still allow tripping for most internal fault conditions.

Figure 92 shows a possible scenario for a switched network. Initially the P54x relays are communicating via path 1. The go and return times for this path are 2ms and hence the calculated propagation delay is (2 + 2)/2 = 2ms. When the channel is switched to path 2, a small time period exists where the P54x's could be sending messages via path 1 and returning via path 2.

The calculated propagation delay will now be (2 + 5)/2 = 3.5ms. The resultant 1.5ms error at each line end may cause the relay to maloperate due to incorrect time alignment of current vectors (see section 1.1.1.1). After a short delay, both 'go' and 'return' paths will follow route 2 and the calculated propagation delay will be (5 + 5)/2 = 5ms. The relay will now be stable, as correct current vector time alignment exists at each line end.

The Char Mod timer is started when a change in propagation delay is detected. Any subsequent change during this period will cause the timer to restart. In the above example the timer will start for the first change (2 to 3.5ms). The second change (3.5ms to 5ms) will cause the timer to restart, thus allowing for multiple switching between communication paths.

A change in propagation delay may result in a temporary failure of the protection communications channel. If this occurs, the propagation delay change may not be detected by the relay. To overcome this problem, the Char Mod Timer is re-started when the channel recovers from a protection communications channel failure if the Char Mod Timer was running when the channel failure occurred.

OP

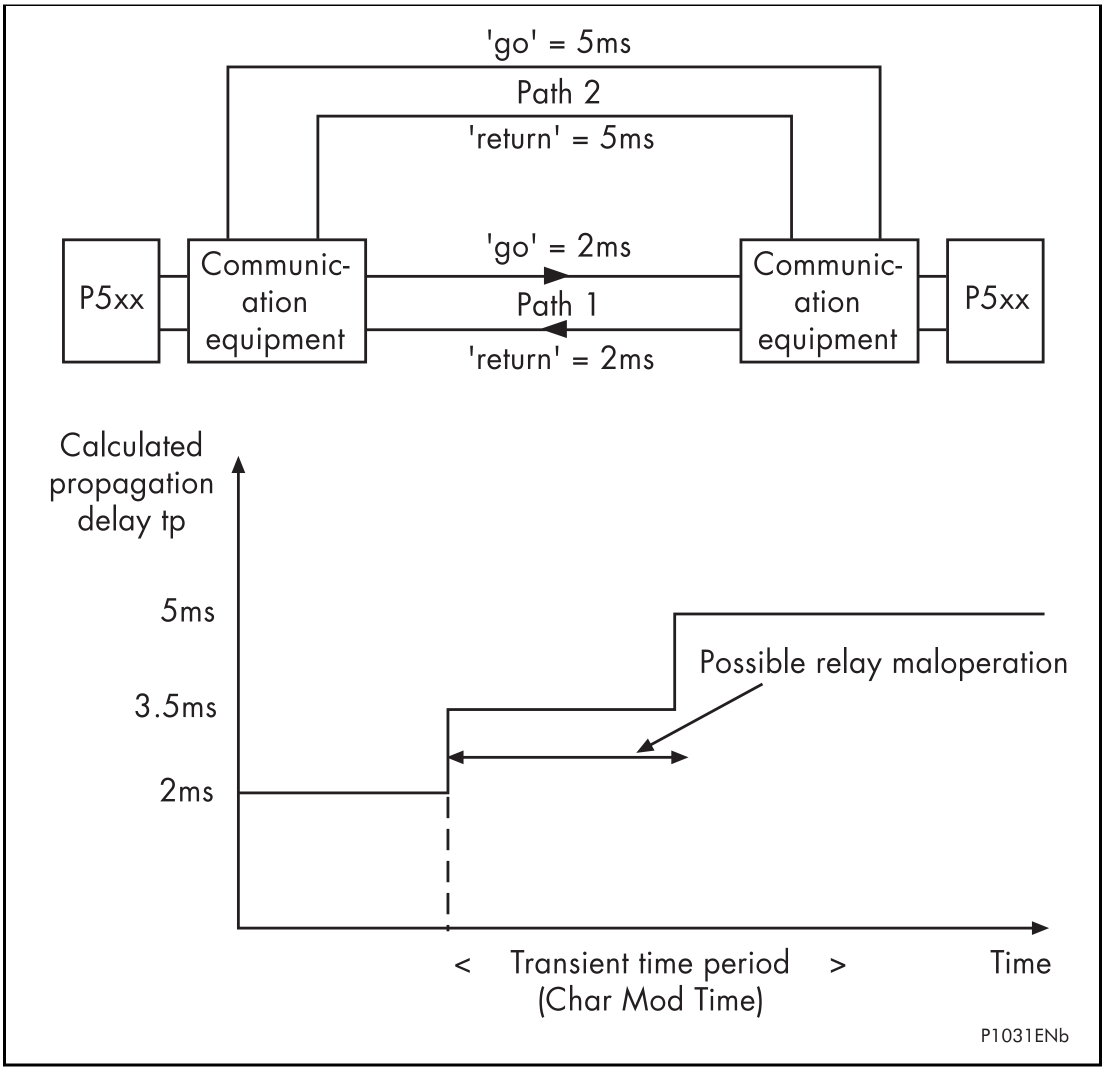


Figure 92: Switched communication network

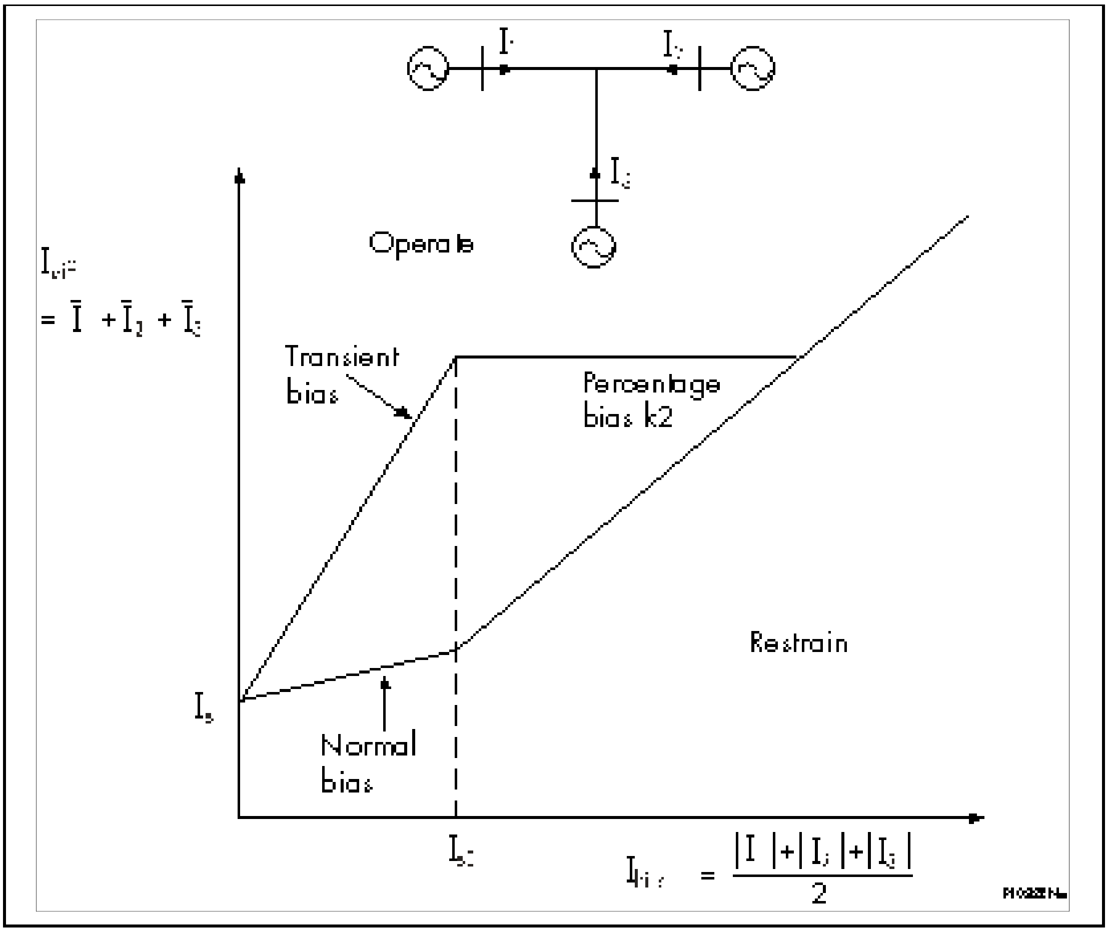


Figure 93: Transient bias characteristic

3.1.7 Switched communication networks with permanent or semi-permanent split routings

MiCOM P54x relays, utilizing timing information from the GPS system, are suitable for use on switched communication signaling channels for the differential protection. For correct operation of this protection element, it is essential that the integrity of this link is continuously checked. It is not, however, a requirement that ‘go’ (tp1) and ‘return’ (tp2) times are similar if the GPS synchronization feature is used.

3.1.8 P590 Series optical fiber to electrical interface units

In order to connect the P54x relays via a pulse code modulation (PCM) multiplexer network or digital communication channel, Type P590 type interface units are required. The following interface units are available:

– P591 interface to multiplexing equipment supporting ITU-T (formerly CCITT) Recommendation G.703 co-directional electrical interface

– P592 interface to multiplexing equipment supporting ITU-T Recommendation V.35 electrical interface

– P593 interface to multiplexing or ISDN equipment supporting ITU-T Recommendation X.21 electrical interface

The data rate for each unit can be 56kbit/sec or 64kbit/sec as required for the data communications link.

One P590 unit is required per relay data channel (i.e. for each transmit and receive signal pair). It provides optical to electrical and electrical to optical signal conversion between the P54x relay and the multiplexer. The interface unit should be located as close to the PCM multiplexer as possible, to minimize any effects on the data of electromagnetic noise or interference.

OP

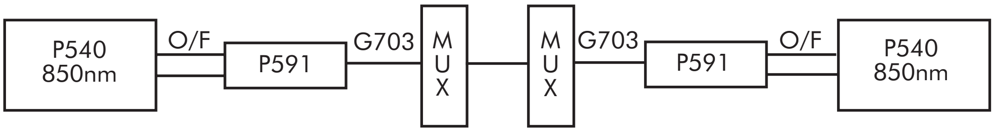
The units are housed in a 20TE MiCOM case.

Fiber optic connections to the unit are made through BFOC/2.5 type connectors, more commonly known as 'ST' connectors.

The optical characteristics are similar to the P54x 850nm multi-mode fiber optic interface (refer to optical budgets in section P54x/EN/AP).

3.1.9 Multiplexer link with G.703 electrical interface using auxiliary optical fibers and type P591 interface

A P54x relay with 850nm short haul optical interface is connected to a P591 unit by 850nm multi-mode optical fiber. Multi-mode fiber type 50/125µm or 62.5/125µm is suitable. BFOC/2.5 type fiber optic connectors are used. The P591 unit converts the data between optical fiber and ITU-T compatible G.703 co-directional electrical interface. The G.703 output must be connected to an ITU-T compatible G.703 co-directional channel on the multiplexer.



The P591 unit supports the ITU-T Recommendation G.703 co-directional interface.

OP

The G.703 signals are isolated by pulse transformers to 1kV.

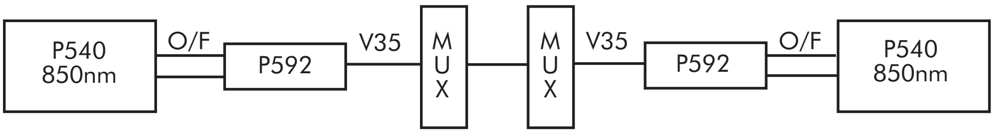
Since the G.703 signals are only of ±1V magnitude, the cable connecting the P591 unit and the multiplexer must be properly screened against electromagnetic noise and interference. The interface cable should consist of twisted pairs of 24AWG, overall shielded, and have a characteristic impedance of about 120Ω. It is generally recommended that the interface cable shield should be connected to the multiplexer frame ground only. The choice of grounding depends however on local codes and practices.

Electrical connections to the P591 unit are made via a standard 28-way Midos connector. Please refer to Installation chapter for the external connection diagram.

The P54x must be set with Clock Source as 'External', refer to section 3.3.3.

3.1.10 Multiplexer link with V.35 electrical interface using auxiliary optical fibers and type P592 interface

A P54x relay with 850nm short haul optical interface is connected to a P592 unit by 850nm multi-mode optical fiber. Multi-mode fiber type 50/125µm or 62.5/125µm is suitable. BFOC/2.5 type fiber optic connectors are used. The P592 unit converts the data between optical fiber and ITU-T compatible V.35 electrical interface. The V.35 output must be connected to an ITU-T compatible V.35 channel on the multiplexer.



The P592 unit supports the ITU-T Recommendation V.35 interface.

Connections of V.35 signals to the P592 unit are made via a standard female 34 pin 'M' block connector. Since the V.35 signals are either of ±0.55V or ±12V magnitude, the cable connecting the unit to the multiplexer must be properly screened against electromagnetic noise and interference. The interface cable should consist of twisted pairs of wires which are shielded, and have a characteristic impedance of about 100Ω. It is generally recommended that the interface cable shield is connected to the multiplexer frame ground. The choice of grounding depends however on local codes and practices.

The P592 front panel consists of five indicating LEDs and six DIL (dual in line) switches.

The switch labeled 'Clockswitch' is provided to invert the V.35 transmit timing clock signal if required.

The switch labeled 'Fiber-optic Loopback' is provided to allow a test loopback of the communication signal across the fiber optic terminals. When switched on, the red LED labeled 'Fiber-optic Loopback' is illuminated.

The switch labeled 'V.35 Loopback' is provided to allow a test loopback of the communication signal across the X.21 terminals. It loops the incoming V.35 'Rx' data lines internally back to the outgoing V.35 'Tx' data lines. When switched on, the red LED labeled 'V.35 Loopback' is illuminated.

The switch labeled 'DSR' is provided to select/ignore the DSR (Data Set Ready) handshaking control signal. The red LED labeled DSR Off is extinguished either when DSR is asserted or when overridden by setting the DSR switch On.

The switch labeled 'CTS' is provided to select/ignore the CTS (Clear To Send) handshaking control signal. The red LED labeled CTS Off is extinguished either when CTS is asserted or when overridden by setting the CTS switch On.

The switch labeled 'Data Rate' is provided to allow the selection of 56 or 64k bits/s data rate, as required by the PCM multiplexing equipment.

The LED labeled 'Supply Healthy' is green and provides indication that the unit is correctly powered.

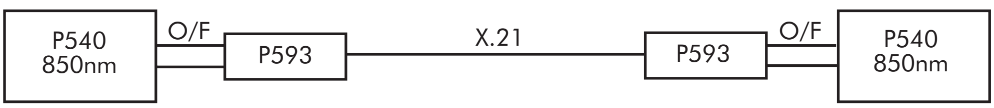
Please refer to Installation chapter for the external connection diagram.

The P54x may be set either with Clock Source as 'External' for a multiplexer network which is supplying a master clock signal, or with Clock Source as 'Internal' for a multiplexer network recovering signal timing from the equipment. Refer to Section 3.3.3.

3.1.11 Multiplexer link with X.21 electrical interface using auxiliary optical fibers and type P593 interface

The P593 unit supports the ITU-T Recommendation X.21 interface. It is approved as line interface equipment by the British Approvals Board for Telecommunications (BABT) for connection to the services described in this section; License Certificate Number NS/1423/1/T/605362.

A P54x relay with 850nm short haul optical interface is connected to a P593 unit by 850nm multi-mode optical fiber. Multi-mode fiber type 50/125µm or 62.5/125µm is suitable. BFOC/2.5 type fiber optic connectors are used. The P593 unit converts the data between optical fiber and ITU-T compatible X.21 electrical interface. The X.21 output must be connected to an ITU-T compatible X.21 channel on the multiplexer or ISDN digital data transmission link.



The P54x relays require a permanently open communications channel. Consequently, no communications handshaking is required, and it is not supported in the P593 unit. The signals supported are shown in the following Table.

ITU-T Recommendation X.21 is closely associated with EIA specifications RS422 and RS449. The P593 can be used with RS422 or RS449 communications channels which require only the signals shown overleaf.

ITU-T Designation	Description	Connector Pin	Direction
-	Case earth	1	-
G	Common return	8	-
T	Transmit data A	2	From P593
T	Transmit data B	9	From P593
R	Receive data A	4	To P593
R	Receive data B	11	To P593
S	Signal element timing A	6	To P593
S	Signal element timing B	13	To P593

X.21 circuits supported by P593 unit

Connections of X.21 signals to the P593 unit are made via a standard male 15 way D-type connector, wired as a DTE device. The interface cable should consist of twisted pairs of 24AWG, overall shielded, and have a characteristic impedance of about 100Ω. It is generally recommended that the interface cable shield is connected to the multiplexer frame ground. The choice of grounding depends however on local codes and practices.

Please refer to Installation chapter for the external connection diagram.

The P54x must be set with Clock Source as 'External', refer to section 3.3.3.

The P593 front panel consists of four indicating LEDs and two switches.

The LED labeled 'Supply healthy' is green and provides indication that the unit is correctly powered.

The LED labeled 'Clock' is green and provides indication that an appropriate X.21 signal element timing signal is presented to the unit.

One of the switches is labeled 'Fiber Optic Loopback'. This is provided to allow a test loopback of the communication signal across the fiber optic terminals. When switched on, the red LED labeled 'Fiber Optic Loopback' is illuminated.

The second switch is labeled 'X.21 Loopback'. This is provided to allow a test loopback of the communication signal across the X.21 terminals. It loops the incoming X.21 'Rx' data lines internally back to the outgoing X.21 'Tx' data lines, and also loops the incoming fiber optic 'Rx' data line (via the X.21 signal conversion circuitry) back to the outgoing fiber optic 'Tx' data line. When switched on, the red LED labeled 'X.21 Loopback' is illuminated.

3.1.12 Protection communications scheme set-up

The Scheme Set-up setting selects the connection between the system ends. A two ended system may have a single communication channel between the ends ("2 Terminal" option) or two independent communication channels to achieve dual redundancy ("Dual Redundant" option). A three ended system is selected by the option "3 Terminal".

3.1.13 Dual redundant ("hot standby")

If one of the channels has failed, the communication between the relays can still be maintained by the other healthy channel.

The dual redundant model provides redundancy for communication channels by transmitting and receiving messages over both channels. Each channel is monitored continuously by the relay. The messages from both channels are used to perform the relay functions. If only one channel is available, the messages from this healthy channel are used to perform the relay functions.

The messages are transmitted over the 2 channels alternately. Every message received is validated and processed, so that both channels are continuously monitored.

3.1.14 Protection communications address

The protection communication messages include an address field to ensure correct scheme connection.

There are twenty one options for groups of addresses. Each group is applied to one protection system, two ended or three ended, so there are two or three addresses within a group respectively.

All the address patterns are carefully chosen so as to provide optimum noise immunity against bit corruption. There is no preference as to which address group is better than the other.

The groups of addresses available when “2 Terminal” or “Dual Redundant” scheme is selected are as follows:

	Relay A	**Relay B**
Universal Address	0-0	0-0
Address Group 1	1-A	1-B
Address Group 2	2-A	2-B
Address Group 3	3-A	3-B
Address Group 4	4-A	4-B
Address Group 5	5-A	5-B
Address Group 6	6-A	6-B
Address Group 7	7-A	7-B
Address Group 8	8-A	8-B
Address Group 9	9-A	9-B
Address Group 10	10-A	10-B
Address Group 11	11-A	11-B
Address Group 12	12-A	12-B
Address Group 13	13-A	13-B
Address Group 14	14-A	14-B
Address Group 15	15-A	15-B
Address Group 16	16-A	16-B
Address Group 17	17-A	17-B
Address Group 18	18-A	18-B
Address Group 19	19-A	19-B
Address Group 20	20-A	20-B

For two relays to communicate with one another, their addresses have to be in the same address group. One relay should be assigned with address A and the other with address B. For example, if the group 1 address is used, the one relay should be given the address 1-A, and the other relay should be given the address 1-B.

The relay with address 1-A will only accept messages with the 1-A address and will send out messages carrying address 1-B. The relay assigned with address 1-B will only accept messages with address 1-B and will send out messages carrying address 1-A.

The groups of addresses available when “3 Terminal” scheme is selected are as follows:

	Relay A	**Relay B**	**Relay C**
Address Group 1	1-A	1-B	1-C
Address Group 2	2-A	2-B	2-C
Address Group 3	3-A	3-B	3-C
Address Group 4	4-A	4-B	4-C
Address Group 5	5-A	5-B	5-C
Address Group 6	6-A	6-B	6-C
Address Group 7	7-A	7-B	7-C
Address Group 8	8-A	8-B	8-C
Address Group 9	9-A	9-B	9-C
Address Group 10	10-A	10-B	10-C
Address Group 11	11-A	11-B	11-C
Address Group 12	12-A	12-B	12-C
Address Group 13	13-A	13-B	13-C
Address Group 14	14-A	14-B	14-C
Address Group 15	15-A	15-B	15-C
Address Group 16	16-A	16-B	16-C
Address Group 17	17-A	17-B	17-C
Address Group 18	18-A	18-B	18-C
Address Group 19	19-A	19-B	19-C
Address Group 20	20-A	20-B	20-C

For three relays to work together as a protection system, their addresses must be in the same group and they should be assigned separately with addresses A, B and C.

They must also have a fixed connection configuration, as shown in Figure 94, in which channel 1 of one relay is connected to channel 2 of another relay.

For example, if the group 1 address is used, addresses 1-A, 1-B and 1-C should be assigned to relays A, B and C respectively. Relay A will only accept messages with address 1-A and will send messages carrying addresses 1-B and 1-C to channel 1 and channel 2 respectively. Relay B will only accept messages with address 1-B and will send messages carrying addresses 1-C and 1-A to channel 1 and to channel 2 respectively. Similarly relay C will only accept messages with address 1-C and will send messages carrying addresses 1-A and 1-B to channel 1 and to channel 2 respectively.

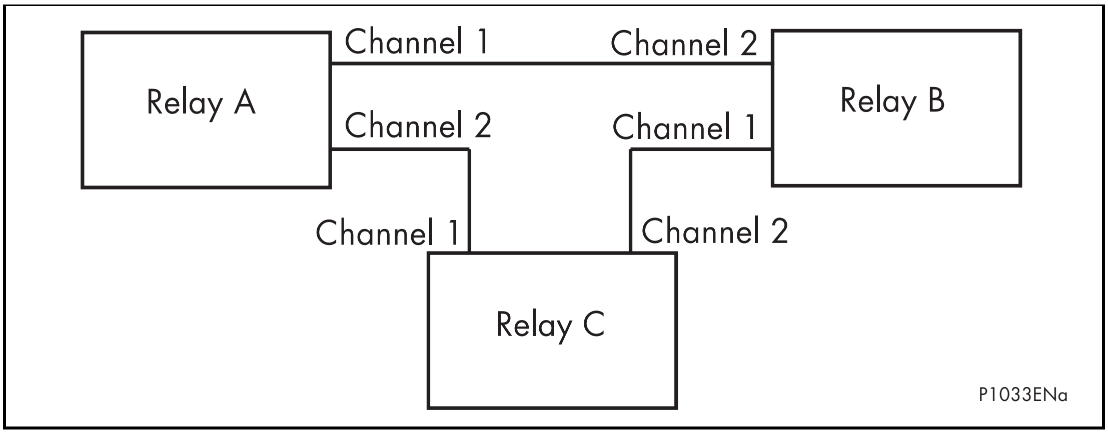


Figure 94: 3-terminal system connection

3.1.15 Reconfiguration of three-ended system

This function only applies to relays which are set-up for 3 Terminal operation. The operation depends on the status of the communication channels, the relays in the scheme and various time periods. There are two general areas of operation, these being the change in configuration by a user and that generated by an energization of a relay. The various considerations applying to each of these cases are given below.

Four settings are provided as follows:

– Three Ended

– Two Ended Local and Remote 1 (L & R1)

– Two Ended Local and Remote 2 (L & R2)

– Two Ended Remote 1 and Remote 2 (R1 & R2)

Remote 1 and Remote 2 relate to protection signaling channel 1 and 2 respectively.

The operation of the reconfiguration is described in 3.1.16 and 3.1.17.

3.1.16 User reconfiguration

This covers the normal set-up of the relays into a 2-ended or 3-ended scheme depending on the state of the protected line and the relays. The facilities provided allow the user to initially use two relays to protect a two ended line and later to upgrade the scheme to three ended using a further relay. It also allows one end of a three ended scheme to be isolated and the other two ends to operate as a two ended scheme. This allows tests to be performed on the end that has been isolated and also allows for that relay to be removed altogether.

The change in configuration is enabled by two external interlocks and by the current state of the relay and its communications. If the scheme is changed from 3-ended to 2-ended, it is considered to be a reconfigure command. If the scheme is changed from 2-ended to 3-ended, it is considered to be a restore command. The checks performed for a reconfiguration are slightly different to those for a restore.

The operation of the change configuration logic is as follows:

1. The configuration setting is changed

2. The relay detects the change in setting and attempts to implement the new setting

3. If the relay configuration is 2-ended and the new setting is also 2-ended then the relay will block the change and issue a configuration error alarm

If the relay configuration is 2-ended and the new setting is 3-ended then the relay will check that all the communications are healthy and send out the restore command to the other relays. It will then check that the scheme has stabilized at 3-ended after one second.

OP

If any of the communications in the scheme were failed or if the scheme has not stabilized at 3-ended then the relay will return to its original 2-ended setting and issue a configuration error alarm.

If the scheme did stabilize at 3-ended then the Re-configuration setting will be updated.

If the relay configuration is 3-ended and the new setting is 2-ended L & R1 then the relay will first check that the two interlock opto-inputs, “Inhibit Diff” and “Interlock” are energized (note that the “Inhibit Diff” opto-input will inhibit the differential tripping, but the backup protection can still operate the trip outputs). These inputs are allocated to opto-inputs L3 and L4 in the default programmable scheme logic. The relay then checks that the communication with Remote 1 relay is healthy and sends out the command to the remote relays. It will then check that the scheme has stabilized at 2-ended L & R1after one second.

If the interlocks are not energized or the communication with Remote 1 relay has failed or the scheme does not stabilize at 2-ended L & R1 then the relay will return to 3-ended and will issue a configuration error alarm.

If the scheme did stabilize at 2-ended L & R1 then the Re-configuration setting will be updated.

If the relay configuration is 3-ended and the new setting is 2-ended L & R2 then the relay reacts similarly to a 2-ended L & R1 reconfiguration.

If the relay configuration is 3-ended and the new setting is 2-ended R1 & R2 then the relay reacts similarly to a 2-ended L & R1 reconfiguration.

3.1.17 Energization reconfiguration

This type of configuration occurs when a relay is energized and the relay attempts to go into a configuration compatible with the other relays in the scheme. As far as possible the scheme will go to that which the user set up. There are, however, certain conditions which may prevent this from occurring.

The configuration that the relay takes up at power on is governed by the following factors:

a) the scheme currently configured on the remote relays

b) the status of the communication links

c) the configuration stored in non volatile memory before power down

Upon energization of a relay, the following events occur:

1. The relay checks whether any messages are arriving. If so then the configuration command in the first messages to arrive will be used as the relay configuration. This is subject to certain conditions. If the relay has a choice of 2-ended and 3-ended, it will assume the 2-ended scheme unless both incoming commands are 3-ended. If all three relays are 3-ended then they will remain so.

2. If no messages arrive from either end then after one second the relay will change to the configuration that was last selected, i.e. the configuration before power down. Once messages begin to arrive again, the relay will check them for validity against the current scheme. If one relay is 3-ended and the other is 2-ended then the configuration will change to 2-ended. If both are 3-ended or the same 2-ended scheme then that will become the configuration. If two relays have different 2-ended configurations then they are unable to determine which one to use and will each generate a configuration error alarm and each relay will remain in its current configuration. This condition can be cleared by restoring the relays or by removing the supply to the relay with the incorrect configuration.

3. If all the relays in a scheme are energized simultaneously then the configuration will revert to 3-ended if all the communication channels are healthy. This occurs because all the relays are waiting to be told their configuration and all default to 3-ended. This is a very unlikely event in normal use.

4. In cases where a communication channel has only half failed i.e. the receive channel has failed but not the transmit channel, then there may be configuration errors on power up due to the fact that the relays are not communicating correctly. If the status is available via the third relay and healthy communications via its two channels then the scheme will stabilize correctly.

3.2 InterMiCOM^{64} introduction

Eight digital signals from local relay to the remote relay can be sent by using Programmable InterMiCOM^{64} (IM64) teleprotection available in MiCOM P54x. This teleprotection uses the protection communication channel described in section 3.1.

In this scheme the signaling channel is used to convey simple ON/OFF data (from a local protection device) thereby providing some additional information to a remote device which can be used to accelerate in-zone fault clearance and/or prevent out-of-zone tripping.

3.2.1 Definition of teleprotection commands

The decision to send a command is made by a local protective relay operation, and three generic types of signal are available:

Intertripping

In intertripping (direct or transfer tripping applications), the command is not supervised at the receiving end by any protection relay and simply causes CB operation. Since no checking of the received signal by another protection device is performed, it is absolutely essential that any noise on the signaling channel isn't seen as being a valid signal. In other words, an intertripping channel must be very secure.

Permissive

In permissive applications, tripping is only permitted when the command coincides with a protection operation at the receiving end. Since this applies a second, independent check before tripping, the signaling channel for permissive schemes do not have to be as secure as for intertripping channels.

Blocking

In blocking applications, tripping is only permitted when no signal is received but a protection operation has occurred. In other words, when a command is transmitted, the receiving end device is blocked from operating even if a protection operation occurs. Since the signal is used to prevent tripping, it is imperative that a signal is received whenever possible and as quickly as possible. In other words, a blocking channel must be fast and dependable.

The requirements for the three channel types are represented pictorially in Figure 95.

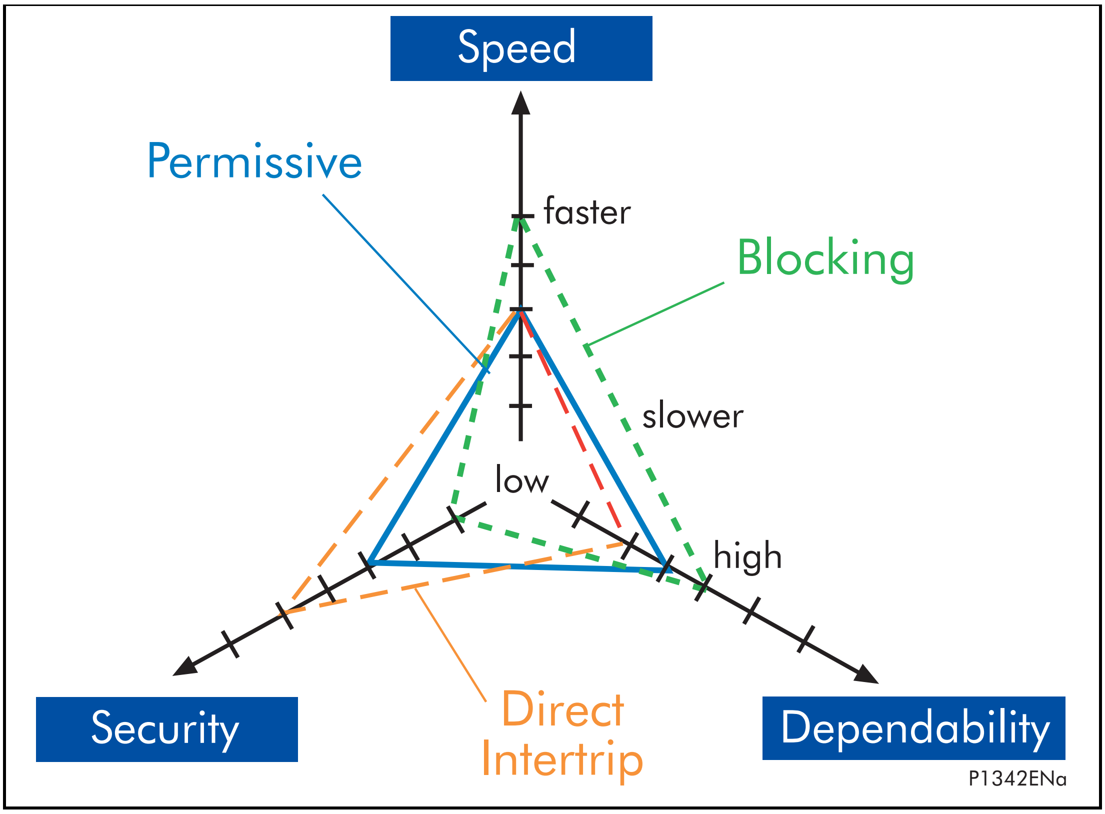


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Figure 95: Pictorial comparison of operating modes

This diagram shows that a blocking signal should be fast and dependable; a direct intertrip signal should be very secure and a permissive signal is an intermediate compromise of speed, security and dependability.

When InterMiCOM^{64} is used for teleprotection, only two modes are available: Direct trip and Permissive. Since the full and uncorrupted message has to be received by the relay over fiber, there would be no difference between received Blocking, Permissive and Direct commands in terms of speed, dependability or security, were just one message used. The only difference would be the need for extra security when Intertripping is required and for that reason a Direct trip command will be considered valid and executed only after 2 consecutive received commands (two consecutive messages in agreement instead of just one).

3.2.2 General features & implementation

InterMiCOM^{64} provides a direct fiber output from the relay's co-processor board that can be connected either directly to the protection at the opposite end(s) or through a MUX device as describe on section 3.1.

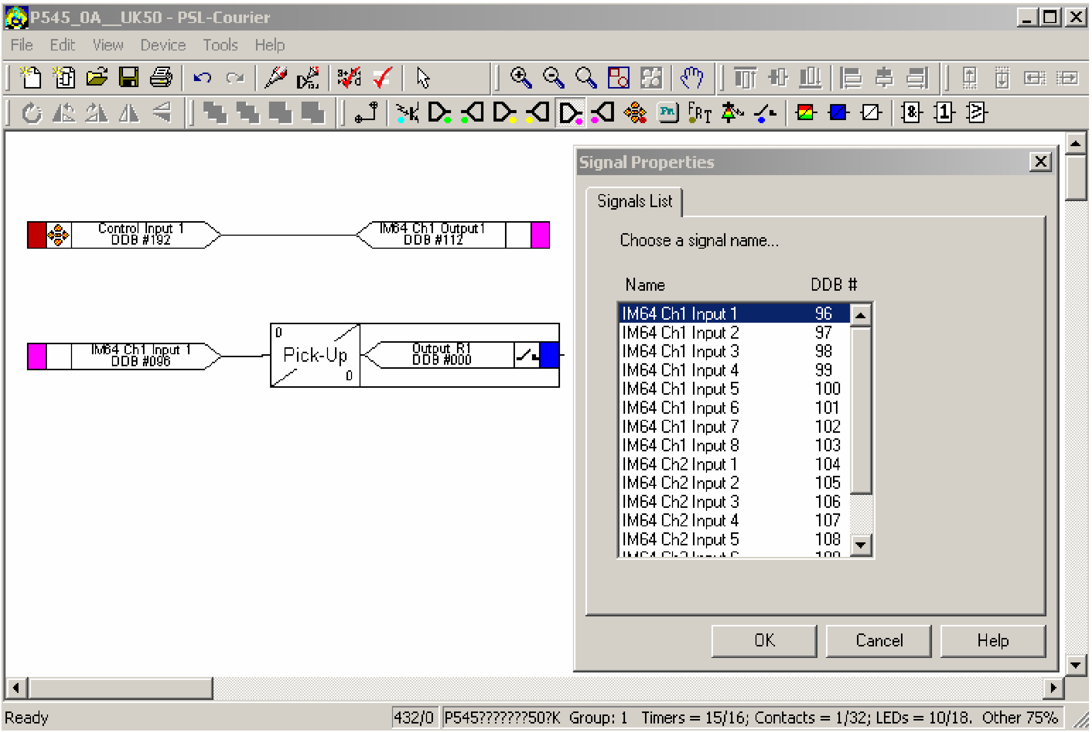
InterMiCOM^{64} can work:

- With Differential protection (In this case differential protection is enabled) or
- Standalone (In this case differential protection is disabled and InterMiCOM^{64} is enabled)

The number of available teleprotection commands is 8. In Dual redundant schemes 8 commands per channel are transmitted to and received from the remote end. In 3 ended configurations, 8 commands are transmitted bidirectional between each and every pair of relays. Unique relay addressing is available to prevent any spurious operation should a multiplexer inadvertently fall out of step and misroute messages.

3.2.3 Functional assignment

Even though settings are made on the relay to control the mode of the intertrip signals, it is necessary to assign InterMiCOM^{64} input and output signals in the relay Programmable Scheme Logic (PSL) if InterMiCOM^{64} is to be successfully implemented. Two icons are provided on the PSL editor of MiCOM S1 for “Integral tripping In” and “Integral tripping out” which can be used to assign the 8 intertripping commands. The example shown below in Figure 96 shows a “Control Input_1” connected to the “Intertrip O/P1” signal which would then be transmitted to the remote end. At the remote end, the “Intertrip I/P1” signal could then be assigned within the PSL. In this example, we can see that when intertrip signal 1 is received from the remote relay, the local end relay would operate an output contact, R1.



Example assignment of signals within the PSL

It should be noted that when an InterMiCOM^{64} signal is sent from the local relay, only the remote end relay will react to this command. The local end relay will only react to InterMiCOM^{64} commands initiated at the remote end. InterMiCOM^{64} is thus suitable for teleprotection schemes requiring Duplex signaling.

3.3 InterMiCOM^{64} statistics & diagnostics

It is possible to hide the channel diagnostics and statistics from view by setting the “Ch Statistics” and/or “Ch Diagnostics” cells to “Invisible”. All channel statistics are reset when the relay is powered up, or by user selection using the “Reset Statistics” cell.

3.3.1 InterMiCOM^{64} scheme setup - application

InterMiCOM^{64} can be applied to either 2 or 3 ended configurations. By simply mapping the Tx and Rx signals using the Programmable Scheme Logic (PSL). For mapping of the InterMiCOM^{64} commands in the PSL please refer to Section 3.2.3.

For security reasons, two MiCOM P54x relays may be connected in a Dual Redundant scheme, in which case both channels will be in use. This scheme is also known as a ‘Hot Standby’ scheme but it should be noted that Channel 1 has no priority over Channel 2 - the data that arrives first will be stored in the buffer and used in the PSL, whilst the same data received via the slower channel will simply be discarded.

The InterMiCOM^{64} connection for a three ended application is shown in Figure 96.

OP

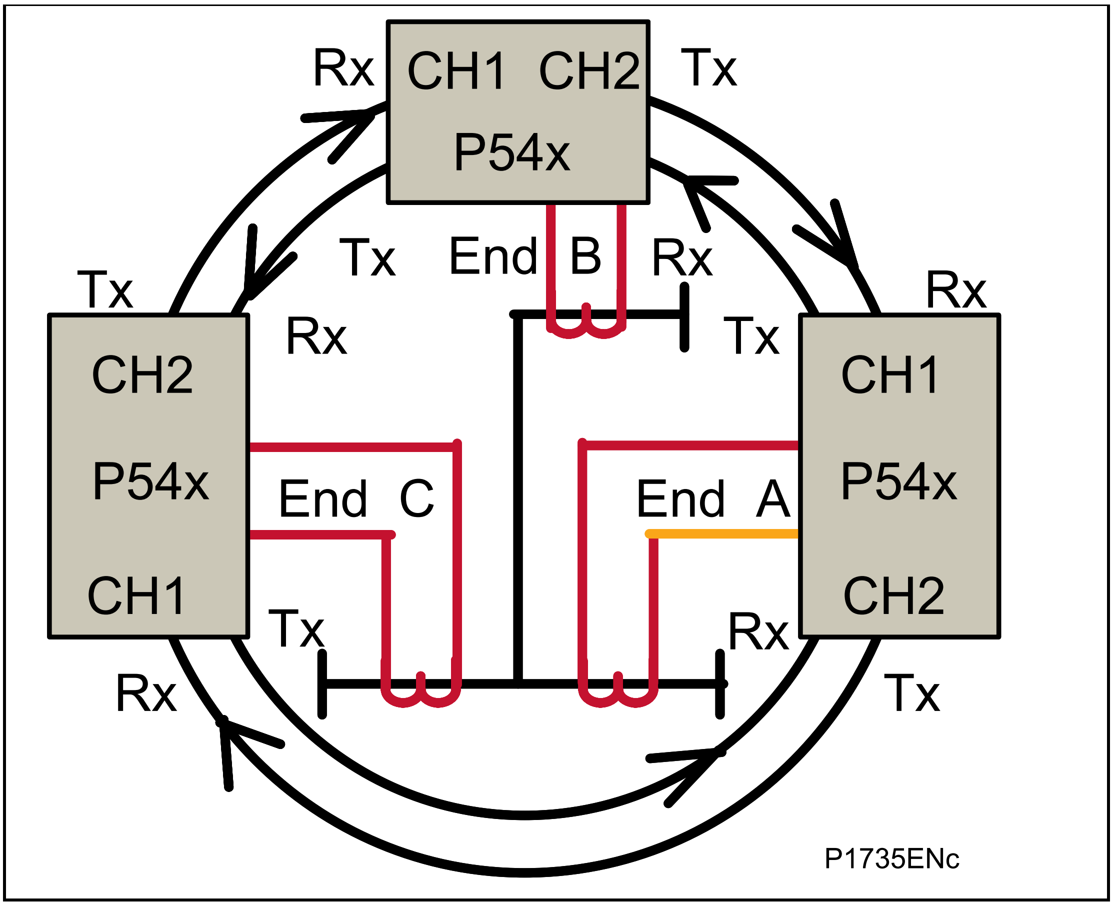


Figure 96: Triangulated InterMiCOM^{64} application

If InterMiCOM^{64} is working as standalone feature (i.e. Differential protection is disabled and InterMiCOM^{64} is enabled), a pass-through feature allows the scheme to remain in service in case of one channel outage. It should be noted that in the case when one leg of the communication triangle fails, i.e. channel A-C becomes unavailable, the InterMiCOM^{64} will continue to provide the full teleprotection scheme between all 3 ends. In this new 'Chain' topology, relays A and C will receive and transmit teleprotection commands via relay B, which means that the original 'Triangle' topology is not necessary. The retransmitting done by relay B (A-B-C and C-B-A) provides the self-healing for the lost links A-C and C-A).

Some users may apply Chain topology also as a means to save cost (two legs may be cheaper to install than full triangulation).

3.3.1.1 Teleprotection communications address

The protection communication messages include an address field to ensure correct scheme connection. There are twenty one options for groups of addresses. The description of them is exactly the same as per differential protection addresses described on section 3.1.14.

3.3.1.2 IMx fallback mode

In case the received message is corrupted due to ether channel failure or lost synchronization, the user can pre-define the status of each command individually as Latched or Default. The new status will take effect after the 'Channel Timeout' user settable time has elapsed. The "Default" mode allows a failsafe logic status to be applied.

3.3.1.3 InterMiCOM^{64} and differential communications

The Differential function can be globally enabled or disabled using the CONFIGURATION /Phase Diff/ Enabled-Disabled setting.

If the Differential function is enabled, communication messages between the relays will have the complete differential format including currents and additional bias. In addition, the GROUP X/PHASE DIFF/Enabled-Disabled setting will be displayed allowing the differential functionality to be enabled or disabled on a per group basis.

If the Differential function is disabled in Configuration column, a CONFIGURATION/InterMiCOM^{64}/Enabled-Disabled setting will be displayed. The InterMiCOM^{64} function could be enabled and the communication messages between the relays will have a different format compared with those of the differential function. The message format will include digital signals only and will be shorter and faster.

If differential protection in group is disabled, the InterMiCOM^{64} function can work with the differential message format or with an inherent stand-alone format where only digital signals are transmitted. The stand-alone message format has a pass though feature and is slightly faster than using the InterMiCOM^{64} function with the differential message format.

3.3.2 Permissive Intertrip

The P54x relays include a facility to send a permissive intertrip command over the protection communication channel, as shown in Figure 97.

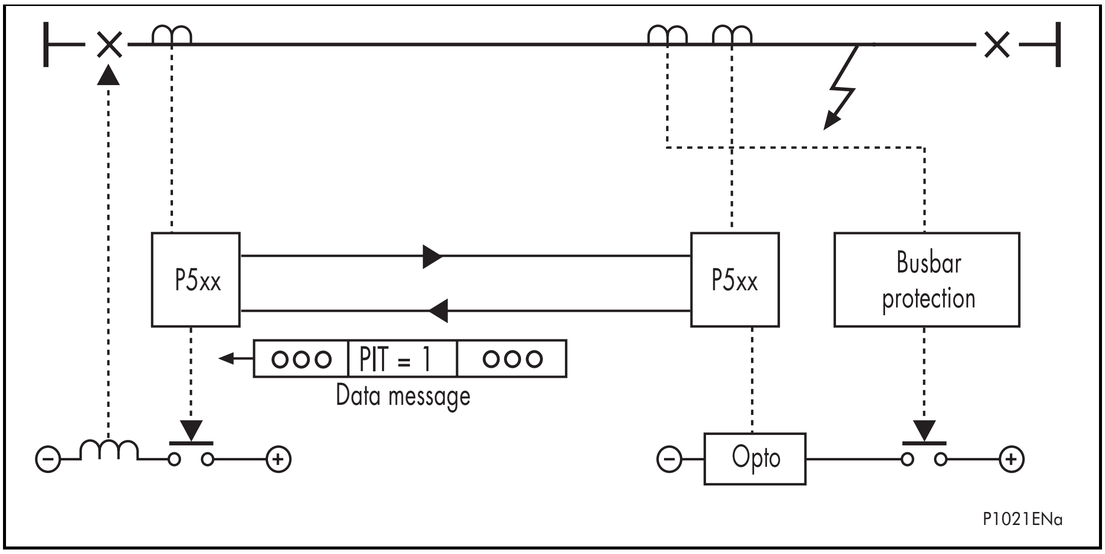


Figure 97: Permissive intertrip

An opto input can be assigned for this purpose. When energized, the PIT flag is set in the communication message. Upon receipt of this message the remote relay initiates a timer which, when the timer, providing that the current at this end is above its basic current threshold setting (Is1), times out, the relay closes it’s three phase differential trip contacts. The remote relay provides indication of the permissive intertrip.

The permissive intertrip timer is settable between 0 and 200ms. This time should be set to provide discrimination with other protection. For example, in Figure 97, the time delay should be set to allow the busbar protection to clear the fault in the event of a genuine busbar fault. A typical setting may be 100 - 150ms.

3.3.3 Clock source

A clock source is required to synchronize data transmissions between the system ends. This may be provided either by the P54x relays (internal) or may be a function of the telecommunications equipment (external). The P54x relays have a setting for each of Channel 1 and Channel 2 to set the Clock Source to either “Internal” or “External” according to the communications system configuration.

This setting is not applicable if IEEE C37.94 mode selected.

OP

3.3.4 Communication alarm

A communication alarm is raised by the relay if the message error rate exceeds the setting value under PROT COMMS/IM64/ Alarm Level (default = 25%) and persists over a defined period of time (refer to section 3.3.7 below). This is equivalent to a Bit Error Rate (BER) of 1.5×10^{-3}.

A communication alarm is also raised if the received message indicates failure of the signaling channel at the remote end.

3.3.5 Communication error statistics

To aid the bit error evaluation of the communication link, communication error statistics are kept by the relay. These give the number of Errored messages detected, the number of Lost Messages, and the number of Valid Messages received for each of the two channels. The number of errored messages detected complies with ITU-T G8.21 and is as follows:

Number of errored seconds	Number of seconds containing 1 or more errored or lost messages
Number of severely errored seconds	Number of seconds containing 31 or more errored or lost messages
Number of degraded minutes	Number of minutes containing 2 or more errored or lost messages
Note any severely errored seconds are ignored when working out the minute intervals	

OP

The number of lost messages recorded is intended as an indicator for noises under normal communication conditions and not for recording long communication breaks. The lost message count is accumulated by incrementing a counter when a message is rejected by the Error code check, message length check and the sequential time tag check.

The error statistics are automatically cleared on power-up. They can also be cleared using the Clear Statistics setting in Measurements column of the menu.

3.3.6 Communications delay timer

The communications delay timer is the maximum difference in the measured channel propagation delay time between consecutive messages that the relay will tolerate before switching the settings, as described in section 3.1.6.

This setting is factory set to 350µs. It should be increased to a suitable value if the propagation delay time is expected to vary considerably such as in the case of a microwave link with multiple repeaters.

3.3.7 Communications fail timer

The communication fail timer is the time during which communication errors must be continuously detected before the channel is declared failed. This governs the implementation of the communication alarm and the ‘Protection Scheme Inoperative’ alarm. The setting is normally set to the maximum of 10 seconds so that the two alarms will not be affected by short bursts of noises or interruptions. The communication fail time setting however may be set to a lower value of say 200 or 300ms if the alarm contacts are to be used for enabling standby protection, or to signal a change-over to reserve communication facilities should the communication link become noisy or fail completely.

3.3.8 Communications fail mode

The Communications Fail Mode is used to select the channel(s) responsible for raising the communication alarm when configured for dual redundant communications. Three options are available: ‘Ch 1 Failure’, ‘Ch 2 Failure’, Ch1 or Ch 2 Fail’ and Ch1 and Ch 2 Fail’ . If ‘Ch 1 Failure’ is selected, the communication alarm will only be raised if channel 1 has failed. If ‘Ch 2 Failure’ is selected, the communication alarm will only be raised if channel 2 has failed. If ‘Ch 1 or Ch 2 Fail’ is selected, the communication alarm will be raised if either channel has failed.

3.3.9 MiCOM P594 global positioning system (GPS) synchronizing module

MiCOM P54x Current Differential relays can use a satellite-derived one pulse per second synchronizing signal via a MiCOM P594 GPS Module. A simple diagram of the role of the GPS Timing Module within a two-ended scheme is shown in Figure 98 below.

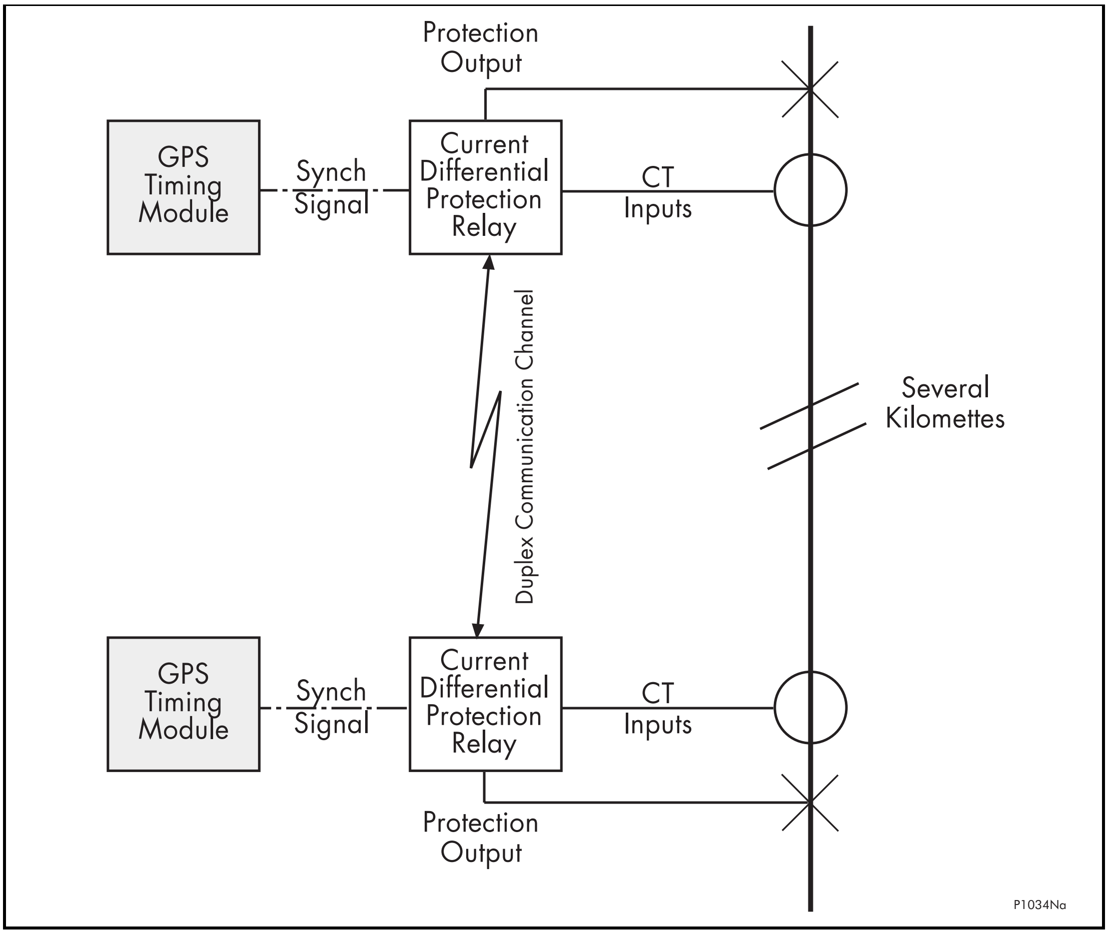


Figure 98: Network incorporating GPS synchronizing module

3.3.10 Synchronizing module output

The output to the relay from the synchronizing module is via a fiber-optic link, to reduce the risk of interference, and consists of one pulse per second, with each pulse having a width of 200ms, as shown in Figures 99 and 100. One synchronizing module provides outputs to synchronize up to 4 relays within a substation, using one 850nm multi mode fiber core per relay, with terminations as in section 3.1.1 and specification as shown in optical budgets in P54x/EN AP.

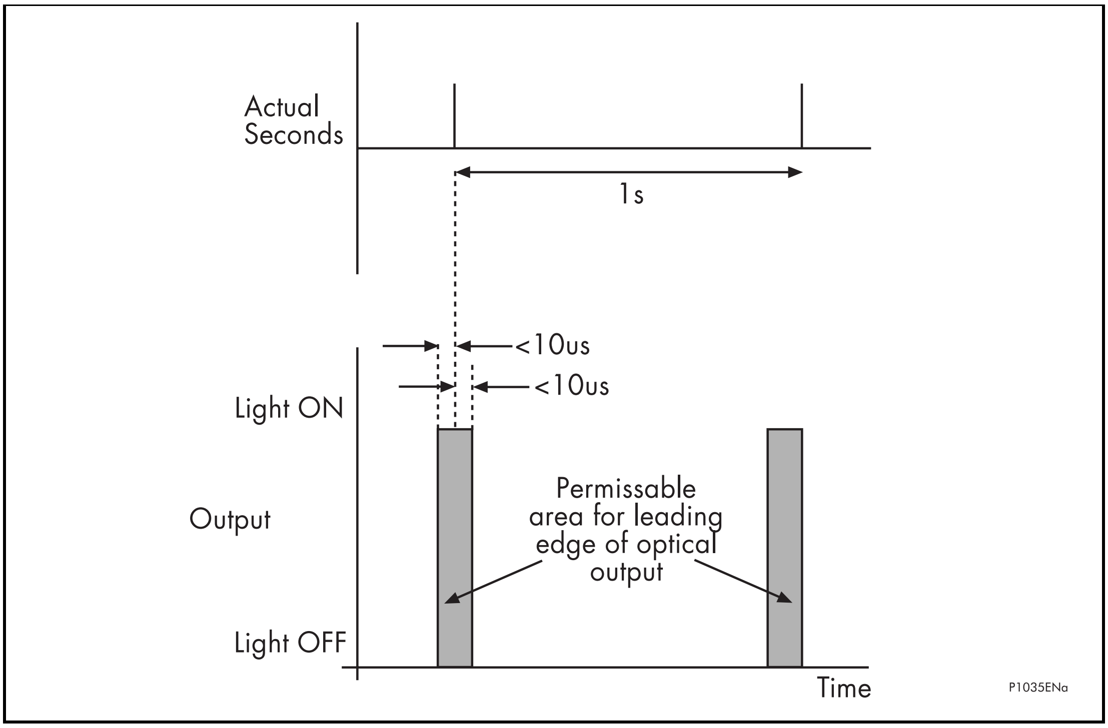


Figure 99: GPS synchronizing module output local end

The relative error between any two Timing Modules (which may be several kilometers apart) is less than 1.5 microseconds, see Figure 101. This includes variations in GPS receiver accuracy and in associated circuitry, and results in a minimal error of approximately 0.1% in the overall system.

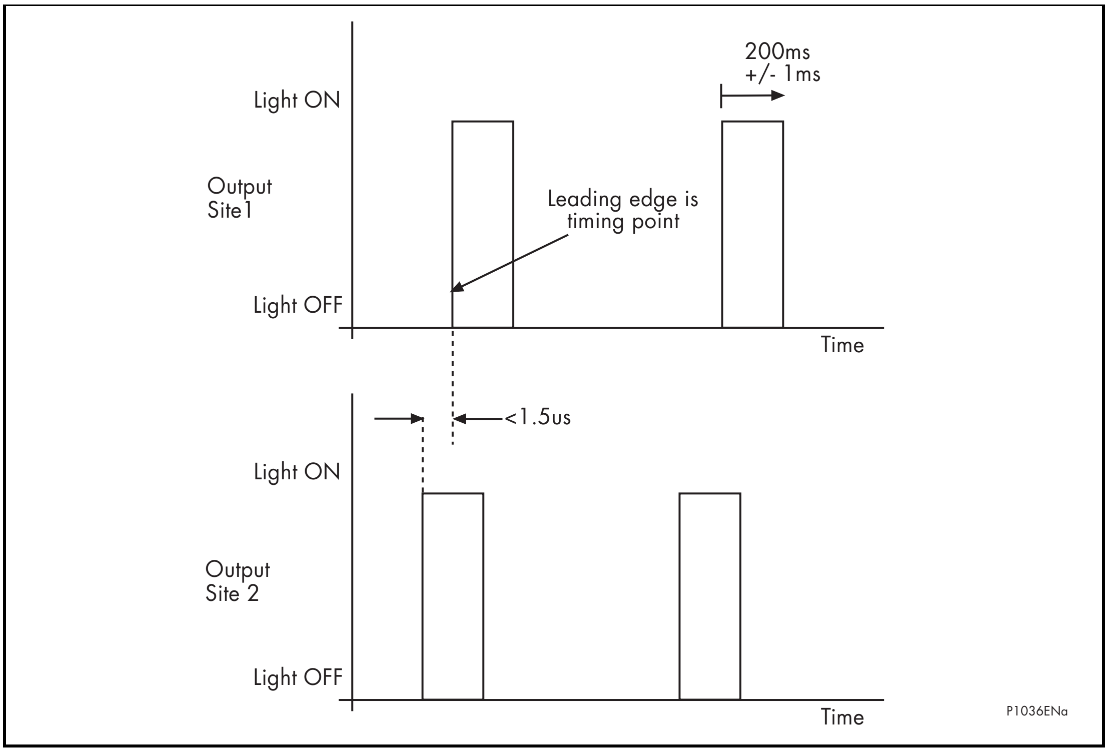


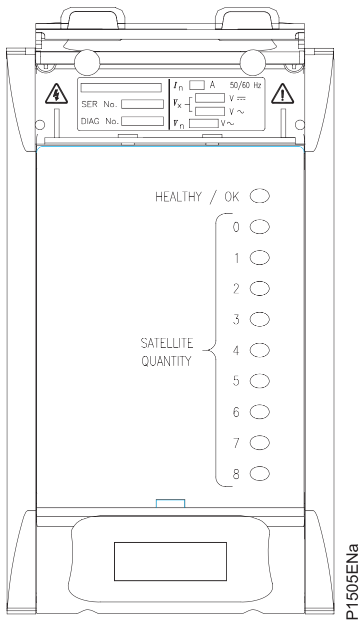
Figure 100: GPS Synchronizing module output local and remote ends

Note: That the 1PPS output is only present when it is synchronized to at least four valid satellites.

3.3.11 P594 Operation

The P594 is supplied with an antenna and mounting kit as described in section 3.3.12. On power up the green 'Healthy' LED illuminates and stays on indicating that the unit is healthy. Initially the red '0' LED will be illuminated indicating the P594 has not initialized and is not outputting a signal to the P54x. The remaining red LEDs '1-3' and green LEDs '4 – 8' indicate the number of satellites being seen by the P594. The P594 takes up to 3 hours to initialize after it detects four or more satellites before it starts to output a signal. This delay ensures the accuracy of the timing signal. Once initialized and provided the unit sees four or more satellites the red '0' LED is extinguished. If the number of satellites drops below four the output again turns off until the number of satellites exceeds four.

Once the initialization is complete if the antenna is disconnected and reconnected or if the number of satellites drops below four and recovers above four the output is turned on immediately without waiting for the power on initialization time. However, if the power to the P594 is lost it will take up to 3 hours to re-initialize.



During the commissioning it is required to measure the optical power, however most optical power meters cannot measure a signal which consists of 200ms light on and 800ms light off. To overcome this a commissioning feature has been added which is activated by disconnecting the antenna cable from the P594. This replaces the normal output signal by a 250kHz signal, which can then be measured. This condition is indicated by the green 'healthy' LED flashing. The P54x is immune to this signal and treats it as a loss of GPS.

3.3.12 P594 Options

The P594 requires an antenna, which is supplied as part of a kit. The basic kit contains the following:

– ONCORE™ TIMING200 antenna

– 25m of low loss cable

– Lighting/surge arrestor

– Mounting pole plus brackets

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For installations were the antenna must be mounted >25m from the P594 a second kit is required which contains the following:

– The basic kit

– 25m low loss cable

– Inline amplifier

The correct mounting of the antenna is critical to the correct operation of the P594 and P54x. See the installation guide for further details (P594/EN IN).

3.3.13 P594 Synchronizing module block diagram

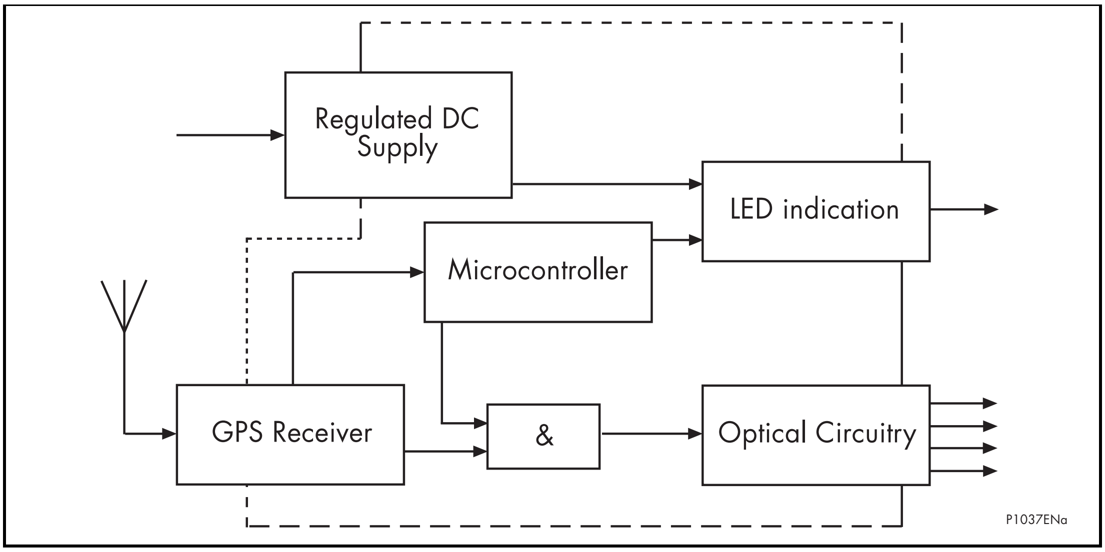

Figure 101: Synchronizing module block diagram

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APPLICATION NOTES

Date:	**7th August 2006**
Hardware Suffix:	**K**
Software Version:	**41 and 51**
Connection Diagrams:	**10P54302xx (xx = 01 to 02) & 10P54303xx (xx = 01 to 02)**
	10P54402xx (xx = 01 to 02) & 10P54403xx (xx = 01 to 02)
	10P54502xx (xx = 01 to 02) & 10P54503xx (xx = 01 to 02)
	10P54602xx (xx = 01 to 02) & 10P54603xx (xx = 01 to 02)

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FIGURES

1. INTRODUCTION

1.1 Protection of overhead line, cable, and hybrid circuits

Overhead lines, typically ranging from 10kV distribution lines to 800kV transmission lines, are probably the most fault susceptible items of plant in a modern power system. It is therefore essential that the protection associated with them provides secure and reliable operation.

For distribution systems, continuity of supply is of paramount importance. The majority of faults on overhead lines are transient or semi-permanent in nature. Multi-shot auto-reclose cycles are therefore commonly used in conjunction with instantaneous tripping elements to increase system availability. For permanent faults it is essential that only the faulted section of plant is isolated. As such, high speed, discriminative fault clearance is often a fundamental requirement of any protection scheme on a distribution network.

The requirements for a transmission network must also take into account system stability. Where systems are not highly interconnected the use of single phase tripping and high speed auto-reclosure is often required. This in turn dictates the need for very high speed protection to reduce overall fault clearance times.

Many line configurations exist which need to be addressed. Transmission applications may typically consist of 2 or 3 terminal applications, possibly fed from breaker and a half or mesh arrangements. Lower voltage applications may again be 2 or 3 terminal configurations with the added complications of in zone transformers or small teed load transformers.

Charging current may also adversely affect protection. This is a problem particularly with cables and long transmission lines. Both the initial inrush and steady state charging current must not cause relay maloperation and preferably should not compromise protection performance.

Physical distance must be taken into account. Some EHV transmission lines can be up to several hundred kilometers in length. If high speed, discriminative protection is to be applied, it will be necessary to transfer information between line ends. This not only puts the onus on the security of signaling equipment but also on the protection in the event of loss of this signal.

Back-up protection is also an important feature of any protection scheme. In the event of equipment failure, such as signaling equipment or switchgear, for example, it is necessary to provide alternative forms of fault clearance. It is desirable to provide back-up protection which can operate with minimum time delay and yet discriminate with both the main protection and protection elsewhere on the system.

Transmission systems are essential to route power from the point of generation to the region of demand. The means of transport is generally via overhead lines, which must have maximum in-service availability. The exposed nature of overhead lines make them fault-prone, and protection devices must trip to initiate isolation of any faulted circuit. In addition to fast fault clearance to prevent plant damage, the requirements for a transmission network must also take into account system stability. Where systems are not highly interconnected the use of single phase tripping and high speed auto-reclosure is often required. This in turn dictates the need for very high speed protection to reduce overall fault clearance times.

The MiCOM P54x provides fast, highly selective protection, to trip for genuine line faults. The current differential principle easily detects intercircuit, evolving and cross country faults amongst others as the relay works on a per phase basis. It is also immune to voltage measurement problems such as CVT transients and power swings on the system and the most important benefit of all; differential principle offers the most selective line protection.

A combination with a full scheme distance protection and aided directional earth fault (DEF) makes the relay a complete and versatile solution for line protection. Differential and distance protection can be set to operate to work separately or simultaneously. Distance can also be set to work upon failure of the relay protection communications. These options allow the user to set different protection schemes such as Differential as main 1 and Distance as main 2 or vice versa, Differential as main 1 and Distance as backup, etc.

Distance protection on MiCOM P54x offers advanced load blinding and disturbance detection techniques such as power swing blocking to ensure stability when no tripping is required. Selectable mho and quadrilateral (polygon) characteristics allow versatile deployment as main protection for all effectively-earthed transmission and distribution circuits, whether lines, cables or hybrid (a mix of part cable, part overhead line).

Back-up protection is also an important feature of any protection scheme. In the event of equipment failure, such as signaling equipment or switchgear, for example, it is necessary to provide alternative forms of fault clearance. It is desirable to provide back-up protection which can operate with minimum time delay and yet discriminate with both the main protection and protection elsewhere on the system.

2. APPLICATION OF INDIVIDUAL PROTECTION FUNCTIONS

The following sections detail the individual protection functions in addition to where and how they may be applied. Worked examples are provided, to show how the settings are applied to the relay.

2.1 Differential protection

2.1.1 Setting of the phase differential characteristic

The characteristic is determined by four protection settings. All of them are user adjustable. This flexibility in settings allows the relay characteristic to be tailored to suit particular sensitivity and CT requirements. To simplify the protection engineer's task, we strongly recommend three of the settings be fixed to:

Is2 = 2.0 pu

k1 = 30% Provides stability for small CT mismatches, whilst ensuring good sensitivity to resistive faults under heavy load conditions

k2 = 150% (2 terminal applications) or 100% (3 terminal applications). Provides stability under heavy through fault current conditions

These settings will give a relay characteristic suitable for most applications leaving only Is1 setting to be decided by the user.

Is1 This is the basic differential current setting which determines the minimum pick-up level of the relay. The value of this setting should be in excess of any mismatch between line ends, if any, and should also account for line charging current, where necessary.

If voltage inputs are connected to the relay, there is a feature to extract the charging current from the measured current before the differential quantity is calculated. In this case, it is necessary to enter the line positive sequence susceptance value. If capacitive charging current is enable, Is1 may be set below the value of line charging current if required, however it is suggested that Is1 is chosen only sufficiently below the charging current to offer the required fault resistance coverage as described here after.

The table below shows some typical steady state charging currents for various lines and cables.

Voltage (kV)	Core Formation and Spacing	Conductor Size in mm^2	Charging Current A/km
11 kV Cable	Three-core	120	1.2
33 kV Cable	Three-core	120	1.8
33 kV Cable	Close-trefoil	300	2.5
66 kV Cable	Flat, 127mm	630	10
132 kV Overhead Line		175	0.22
132 kV Overhead Line		400	0.44
132 kV Cable	Three-core	500	10
132 kV Cable	Flat, 520mm	600	20
275 kV Overhead Line		2 x 175	0.58
275 kV Overhead Line		2 x 400	0.58
275 kV Cable	Flat, 205mm	1150	19
275 kV Cable	Flat, 260mm	2000	24
400 kV Overhead Line		2 x 400	0.85
400 kV Overhead Line		4 x 400	0.98

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Voltage (kV)	Core Formation and Spacing	Conductor Size in mm^2	Charging Current A/km
400 kV Cable	Flat, 145mm	2000	28
400 kV Cable	Tref., 585mm	3000	33

Table 1. Typical cable/line charging currents (UK, 50Hz)

If capacitive charging current is disable, the setting of Is1 must be set above 2.5 times the steady state charging current. Where charging current is low or negligible, the recommended factory default setting of 0.2 In should be applied.

The tripping criteria can be formulated as:

1. for |Ibias| < Is2,

   |Idiff| > k1.| Ibias| + Is1

2. for |Ibias| > Is2,

   |Idiff| > k2.| Ibias| - (k2 - k1). Is2 + Is1

2.1.2 Relay sensitivity under heavy load conditions

The sensitivity of the relay is governed by its settings and also the magnitude of load current in the system. For a three-ended system, with relays X, Y and Z, the following applies:

$|Idiff| = |(I_X + I_Y + I_Z)|$

$|Ibias| = 0.5 (|I_X| + |I_Y| + |I_Z|)$

Assume a load current of IL flowing from end X to Y and Z. Assume also a high resistance fault of current IF being singly fed from end X. For worst case analysis, we can assume also IF to be in phase with IL:-

$I_X = I_L + I_F$

$I_Y = -yI_L$ where $0<y<1$

$I_Z = - (1-y) I_L$

$|Idiff| = |I_F|$

$|Ibias| = |I_L| + 0.5 |I_F|$

Relay sensitivity when |Ibias| < Is2:

For |Ibias| < Is2, the relay would operate if |Idiff| > k1 |Ibias| + Is1

or $|I_F| > k1 (|I_L| + 0.5 |I_F|) + Is1$

or $(1 - 0.5 k1) |I_F| > (k1 |I_L| + Is1)$

or $|I_F| > (k1 |I_L| + Is1) / (1 - 0.5 k1)$

For Is1 = 0.2 pu, k1 = 30% and Is2 =2.0 pu, then

1. for |IL| = 1.0 pu, the relay would operate if |IF| > 0.59 pu
2. for |IL| = 1.59 pu, the relay would operate if |IF| > 0.80 pu

If |IF| = 0.80 pu and |I| = 1.59 pu, then |Ibias| = 1.99 pu which reaches the limit of the low percentage bias curve.

Relay sensitivity when |Ibias| > Is2:

For |Ibias| > Is2, the relay would operate if

|Idiff| > k2 |Ibias| - (k2 - k1) Is2 + Is1

or |IF| > k2 (|IL| + 0.5 |IF|) - (k2 - k1) Is2 + Is1

or (1 - 0.5 k2) |IF| > (k2 |IL| - (k2 - k1) Is2 + Is1)

or |IF| > (k2 |IL| - (k2 - k1) Is2 + Is1) / (1 - 0.5 k2)

For Is1 = 0.2 pu, k1 = 30%, □s2 = 2.0 pu and k2 = 100%, then,

1. for |IL| = 2.0 pu, the relay would operate if |IF| > 1.6 pu
2. for |IL| = 2.5 pu, the relay would operate if |IF| > 2.6 pu

Fault resistance coverage:

Assuming the fault resistance, RF, is much higher than the line impedance and source impedance, then for a 33kV system and 400/1 CT:-

|IF| = (Vph-n /RF) * (1/CT ratio) pu

= $(33000 /\sqrt{3}\ )$/RF)/400 pu

= 47.63/RF pu

Based on the above analysis, the relay will detect a fault current in excess of 0.59 pu with a load current of 1 pu flowing. The fault resistance would have to be less than 47.63/0.59 = 81Ω in this case.

With a short time overload current of 2.0 pu, the relay will be able to detect a fault resistance of 47.63/1.6 = 30Ω or lower.

2.1.3 CT ratio correction (all models)

Ideally, the compensated current values should be arranged to be as close as possible to relay rated current to provide optimum relay sensitivity.

If there is not mismatch between the CTs, the CT correction factor should be set to 1:1.

2.1.4 Transformers in zone applications (P543 & P545 models)

In applying the well established principles of differential protection to transformers, a variety of considerations have to be taken into account. These include compensation for any phase shift across the transformer, possible unbalance of signals from current transformers either side of windings, and the effects of the variety of earthing and winding arrangements. In addition to these factors, which can be compensated for by correct application of the relay, the effects of normal system conditions on relay operation must also be considered. The differential element must restrain for system conditions which could result in maloperation of the relay, such as high levels of magnetizing current during inrush conditions.

In traditional transformer feeder differential schemes, the requirements for phase and ratio correction were met by correct selection of line current transformers. Within the P543 and P545, software interposing CTs (ICTs) are provided which can give the required compensation. The advantage of having replica interposing CTs is that it gives the P54x relays the flexibility to cater for line CTs connected in either star or delta, as well as being able to compensate for a variety of system earthing arrangements. The P543 and P545 relays also include a magnetizing inrush restraint facility.

Note that the P544 and P546 relays do not include any of the above features, except CT ratio mismatch compensation, and as such would not be suitable for the protection of in-zone transformer feeders.

On P543 or P545 relays where capacitive charging current compensation is available, there is a setting to select if capacitive charging current compensation is used or if interposing CTs are used.

2.1.4.1 CT ratio correction

In many cases the HV and LV current transformer primary ratings will not exactly match the transformer winding rated currents. The CT correction factor must be set to ensure that the signals to the differential algorithm are correct to guarantee current balance of the differential element under load and through fault conditions. To minimize unbalance due to tap changer operation, current inputs to the differential element should be matched for the mid-tap position. If there is not mismatch between the CTs, the CT correction factor should be set to 1:1

The compensated current values should be arranged to be as close as possible to relay rated current to provide optimum relay sensitivity

When a Star/Delta software interposing CT is chosen, no additional account has to be taken for the $\sqrt{3}$ factor which would be introduced by the delta winding. This is accounted for by the relay.

2.1.4.2 Phase correction and zero sequence current filtering

Selection of the phase correction settings will be dependant on the phase shift required across the transformer and on zero sequence filtering elements with CT correction factors, the phase correction is applied to each relay. Providing replica interposing CTs in software has the advantage of being able to cater for line CTs connected in either star as well as being able to cater for zero sequence current filtering

To aid selection of the correct setting on the relay menu, some examples of selection of phase compensation factors are shown in the following table:

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Transformer Connection	**Transformer Phase Shift**	**Vectorial Compensation (Relay Setting)**	
		HV	**LV**
Dy1	- 30o	Yy0 (0 deg)	Yd11 (+30 deg)
Yd1	- 30o	Yd1 (-30 deg)	Yy0 (0 deg)
Dy5	- 150o	Yy0 (0 deg)	Yd7 (+150 deg)
Yd5	- 150o	Yd5 (-150 deg)	Yy0 (0 deg)
Dy7	+ 150o	Yy0 (0 deg)	Yd5 (-150 deg)
Yd7	+ 150o	Yd7 (+150 deg)	Yy0 (0 deg)
Dy11	+ 30o	Yy0 (0 deg)	Yd1 (-30 deg)
Yd11	+ 30o	Yd11 (+30 deg)	Yy0 (0 deg)
YNyn	0o	Ydy0 (0 deg)	Ydy0 (0 deg)

As shown in the table, a delta winding is introduced with the Y side software interposing CT. This provides the required zero sequence trap, as would have been the case if the vector correction factor had been provided using an external interposing current transformer.

Whenever an in zone earthing connection is provided, a zero sequence trap should always be provided. For instance if a YNyn power transformer is in the protected zone, there will be some difference between HV and LV zero sequence magnetizing current of the transformer. This is normally small, but to avoid any problems with any application the above rule for zero sequence traps should be applied with earthed windings.

2.1.4.3 High set differential setting

When inrush restrain is enabled, a high set differential protection becomes active. This is provided to ensure rapid clearance for heavy internal faults with saturated CTs. Because high set is not restrained by magnetizing inrush, hence the setting must be set such that it will not operate for the largest inrush currents expected. It is difficult to accurately predict the maximum anticipated level of inrush current. Typical waveforms peak values are of the order of 8-10x rated current. A worst case estimation of inrush could me made by dividing the transformer full load current by the per unit leakage reactance quoted by the transformer manufacturer.

2.1.5 Mesh corner and 1½ breaker switched substations

Where a line is fed from a mesh corner or 1½ breaker switched substation, as shown in Figure 1, then two options are available for CT connections to the relay. The first is by paralleling the two sets of line CTs into a common input, ‘A’. The second is by using two separate inputs for each set of line CTs, ‘B’. The P544 and P546 relays are designed with an additional set of input CTs specifically for this purpose.

In the case of a through fault as shown, the relay connected to circuit ‘A’ should see no current and as such, will remain stable. Under this condition, it should be noted that no bias is produced in the relay. To ensure relay stability, the two sets of line CTs should be as near as identical in all characteristics, and equally loaded, such that the relaying connection is at the equipotential point of the secondary leads.

In the case of circuit ‘B’ no differential current should result. A large bias current will however exist, providing a high degree of stability in the event of a through fault. This bias will also ensure stability where CTs are not closely matched. Thus, circuit ‘B’ is the preferred connection for such applications and so the P544 and P546 relay models would normally be specified.

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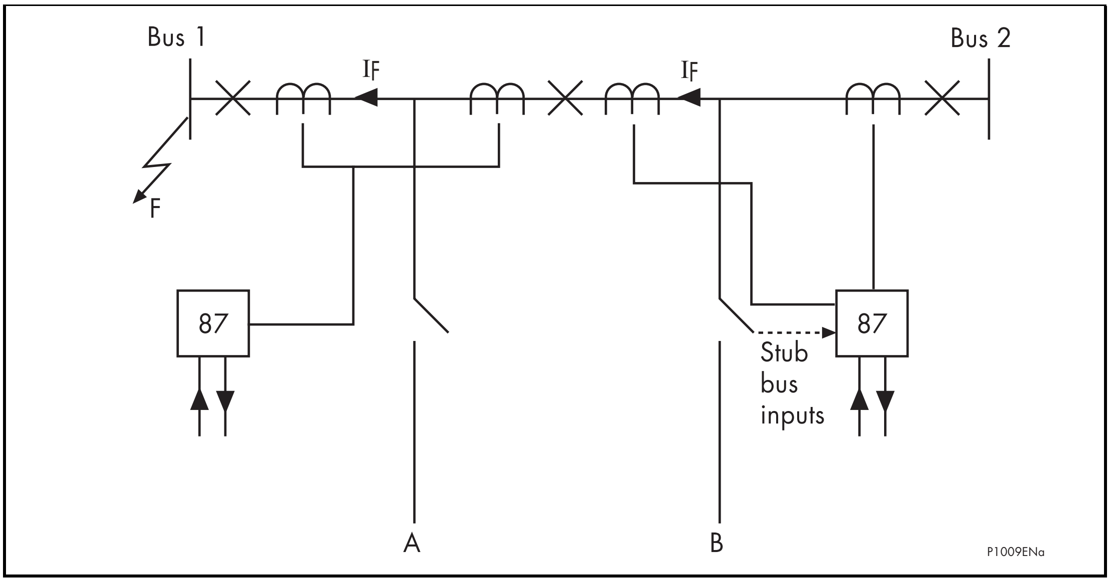

Figure 1: Breaker and a half switched substation

2.1.6 Small tapped loads (tee feeds)

Where transformer loads are tapped off the protected line it is not always necessary to install CTs at this location. Provided that the tee-off load is light, differential protection can be configured for the main line alone. The settings ‘Phase Char’, ‘Phase Time Delay’ and ‘TMS’ or ‘Time Dial’ in table 3 allow the differential element to time grade with IDMT overcurrent relays or fuses protecting the tap. This keeps stability of the differential protection for external faults on the tee circuit.

2.2 Distance protection and aided DEF

2.2.1 Simple and advanced setting mode

To the benefit of user, the MiCOM P54x offers two setting modes for distance protection: "*Simple*" and "*Advanced*". In the majority of cases, "Simple" setting is recommended, and allows the user merely to enter the line parameters such as length, impedances and residual compensation. Then, instead of entering distance zone impedance reaches in ohms, zone settings are entered in terms of **percentage of the protected line**. This makes the relay particularly suited to use along with any installed LFZP Optimho relays, as the reduced number of settings mimics the Autocalc facility within Opticom software.

The "*Advanced*" setting mode is recommended for the networks where the protected and adjacent lines are of dissimilar construction, requiring independent zone characteristic angles and residual compensation. In this setting mode all individual distance ohmic reach and residual compensation settings and operating current thresholds per each zone are accessible. This makes the relay adaptable to any specific application.

2.2.2 Line parameters settings

It is essential (especially when using the "simple" setting mode) that the data relating to 100% of the protected line is entered here. Take care to input the Line Impedance that correctly corresponds to either Primary or Secondary, whichever has been chosen as the basis for Settings Values in the Configuration column.

2.2.3 Residual compensation for earth/ground faults

For earth faults, residual current (derived as the vector sum of phase current inputs (Ia + Ib + Ic) is assumed to flow in the residual path of the earth loop circuit. Thus, the earth loop reach of any zone must generally be extended by a multiplication factor of (1 + kZN) compared to the positive sequence reach for the corresponding phase fault element.

Caution: The kZN Angle is different than previous LFZP, SHNB, and LFZR relays: When importing settings from these older products, subtract. angle $\angle$ Z_1.

2.2.4 Mutual compensation for parallel lines

Typically a mutual cut off factor of 1.5 is chosen to give a good margin of safety between the requirements of correct mutual compensation for faults inside the protected line and eliminating misoperations for faults on the adjacent line.

2.2.5 Selection of distance operating characteristic

In general, the following characteristics are recommended:

– Short line applications: Mho phase fault and quadrilateral earth fault zones.

– Open delta (vee-connected) VT applications: Mho phase fault, with earth fault distance **disabled**, and directional earth fault only used for earth fault protection.

– Series compensated lines: Recommend **always** to use mho characteristics for both phase and earth faults.

2.2.5.1 Phase characteristic

This phase characteristic selection is common to all zones, allowing mho or quadrilateral selection. Generally, the characteristic chosen will match the utility practice. If applied for line protection similarly to LFZP Optimho, LFZR, SHNB Micromho or SHPM Quadramho models in the Schneider Electric range, a mho selection is recommended. For cable applications, or to set similarly to the MiCOM P441/442/444 models, a quadrilateral selection is recommended.

Figure 2 shows the basic settings needed to configure a forward-looking mho zone, assuming that the load blinder is enabled. Figure 3 shows the basic settings needed to configure a forward-looking quadrilateral zone (blinder not shown).

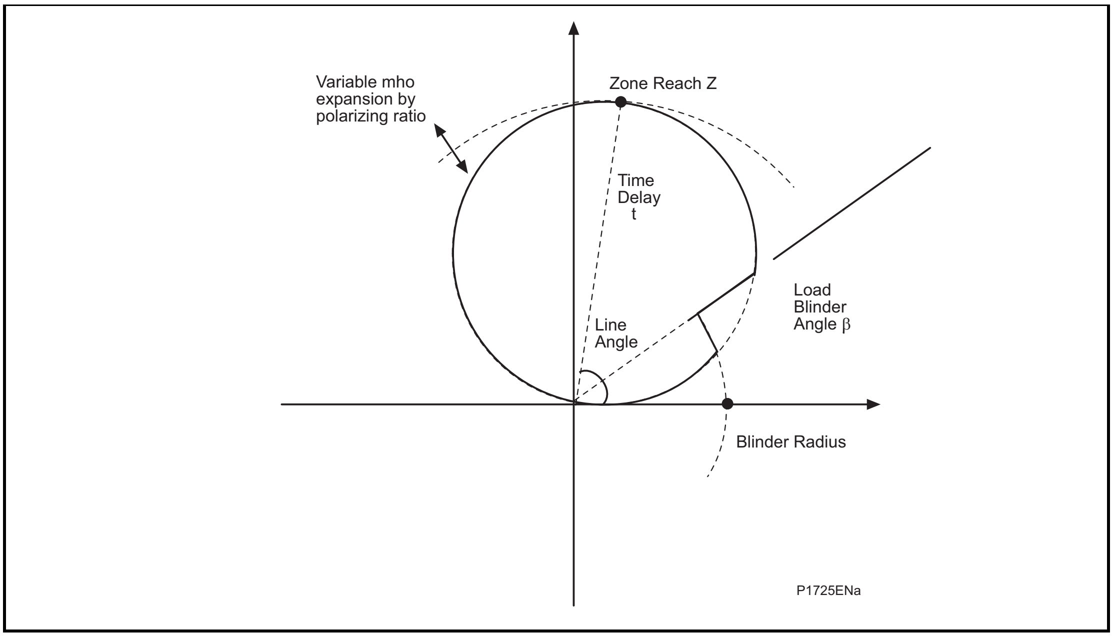

Figure 2: Settings required to apply a Mho zone

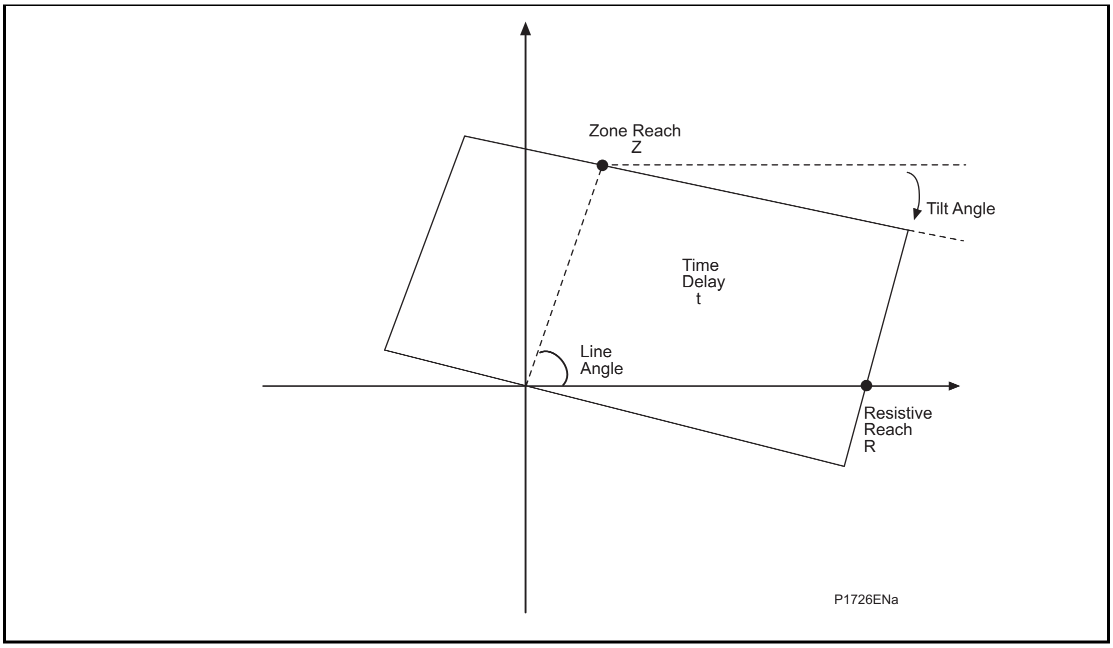

Figure 3: Settings required to apply a quadrilateral zone

2.2.5.2 Ground characteristic

In general, the same setting philosophy would be followed for ground distance protection as is used for the phase elements. This selection is common to all zones, allowing mho or quadrilateral selection and generally, the characteristic chosen will match the utility practice. If applied for long and medium length line protection similarly to LFZP Optimho, LFZR, SHNB Micromho or SHPM Quadramho models in the Schneider Electric range, a mho selection is recommended. For cable applications, or to set similarly to the MiCOM P441/442/444 models, a quadrilateral selection is recommended.

Quadrilateral ground characteristics are also recommended for all lines shorter than 10 miles (16km). This is to ensure that the resistive fault arc coverage is not dependent on mho circle dynamic expansion, but will be a known set value.

2.2.6 Zone reaches - recommended settings

The Zone 1 elements of a distance relay should be set to cover as much of the protected line as possible, allowing instantaneous tripping for as many faults as possible. In most applications the zone 1 reach (Z1) should not be able to respond to faults beyond the protected line. For an underreaching application the zone 1 reach must therefore be set to account for any possible overreaching errors. These errors come from the relay, the VTs and CTs and inaccurate line impedance data. It is therefore recommended that the reach of the zone 1 distance elements is restricted to 80% of the protected line impedance (positive phase sequence line impedance), with zone 2 elements set to cover the final 20% of the line.

The Zone 2 elements should be set to cover the 20% of the line not covered by zone 1. Allowing for underreaching errors, the zone 2 reach (Z2) should be set in excess of 120% of the protected line impedance for all fault conditions. Where aided tripping schemes are used; fast operation of the zone 2 elements is required. It is therefore beneficial to set zone 2 to reach as far as possible, such that faults on the protected line are well within reach. A constraining requirement is that, where possible, zone 2 does not reach beyond the zone 1 reach of adjacent line protection. For this reason the zone 2 reach should be set to cover ≤50% of the shortest adjacent line impedance, if possible.

The Zone 3 elements would usually be used to provide overall back-up protection for adjacent circuits. The zone 3 reach (Z3) is therefore set to approximately 120% of the combined impedance of the protected line plus the longest adjacent line. A higher apparent impedance of the adjacent line may need to be allowed where fault current can be fed from multiple sources or flow via parallel paths.

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Zone 3 may also be programmed with a slight reverse ("rev") offset, in which case its reach in the reverse direction is set as a percentage of the protected line impedance too. This would typically provide back-up protection for the local busbar, where the offset reach is set to 20% for short lines (<30km) or 10% for longer lines.

Zone P is a reversible directional zone. The setting chosen for Zone P, if used at all, will depend upon its application. Typical applications include its use as an additional time delayed zone or as a reverse back-up protection zone for busbars and transformers. Use of zone P as an additional forward zone of protection may be required by some users to line up with any existing practice of using more than three forward zones of distance protection.

The Zone 4 elements may also provide back-up protection for the local busbar. Where zone 4 is used to provide reverse directional decisions for Blocking or Permissive Overreach schemes, zone 4 must reach further behind the relay than zone 2 for the remote end relay. In such cases the reverse reach should be as below (depends on characteristic used):

Mho: $Z4 \geq$ ((Remote zone 2 reach) x 120%)

Quadrilateral: $Z4 \geq$ ((Remote zone 2 reach) x 120%) minus the protected line impedance

Note that in the case of the mho, the line impedance is not subtracted. This ensures that whatever the amount of dynamic expansion of the circle, the reverse looking zone will always detect all solid and resistive faults capable of detection by zone 2 at the remote line end.

2.2.7 Quadrilateral phase resistive reaches

Two setting modes are possible for resistive reach coverage:

Common - In this mode, all zones share one common fault resistive reach setting

Proportional - With this mode, the aspect ratio of (zone reach): (resistive reach) is the same for all zones. The "Fault Resistance" defines a reference fault at the remote end of the line, and depending on the zone reach percentage setting, the resistive reach will be at that same percentage of the Fault Resistance set. For example, if the zone 1 reach is 80% of the protected line, its resistive reach will be 80% of the reference "Fault Resistance".

Proportional setting is used to mimic Germanic protection practice, and to avoid zones being excessively broad (large resistive reach width compared to zone reach length). In general, for easiest injection testing, the aspect ratio of any zone is best within the 1 : 15 range:

1/15th ≤ Z reach / R reach setting ≤ 15

The resistive reach settings (RPh and RG) should be selected according to the utility practice. If no such guidance exists, a starting point for Zone 1 is:

Cables - Choose Resistive Reach = 3 x Zone 1 reach

Overhead lines - Choose Resistive Reach according to the following formula…

Resistive reach = [2.3 - 0.0045 x Line length (km)] x Zone 1 reach

Lines longer than 400km - Choose: 0.5 x Zone 1 reach

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2.2.8 Quadrilateral ground resistive reaches

Note that because the fault current for a ground fault may be limited by tower footing resistance, high soil resistivity, and weak infeeding; any arcing resistance is often higher than for a corresponding phase fault at the same location. It may thus be necessary to set the RG ground resistive settings to be higher than the RPh phase setting (i.e. boosted higher than the rule of thumb in the last subsection). A setting of RG three times that of RPh is not uncommon.

2.2.9 Phase fault zone settings

It can be noted that each zone has two additional settings that are not accessible in the Simple set mode. These settings are:

- A tilt angle on the top line of any quadrilateral set for phase faults;
- A minimum current sensitivity setting.

By factory defaults, the Top Line of quadrilateral characteristics is not fixed as a horizontal reactance line. To account for phase angle tolerances in the line CT, VT and relay itself, the line is tilted downwards, at a "droop" of -3^{o}. This tilt down helps to prevent zone 1 overreach.

The fixed ***Tilt*** setting on the phase elements may also be used to compensate for overreach effects when prefault heavy load export was flowing. In such cases, fault arc resistance will be phase shifted on the impedance polar plot, tilting down towards the resistive axis (i.e. not appearing to be fully resistive in nature). For long lines with heavy power flow, the Zone 1 top line might be tilted downwards within the range –5 to -15^{o}, mimicking the phase shift of the resistance. Note that a minus angle is used to set a downwards tilt gradient, and a positive angle to tilt upwards.

It should be noted that mho characteristics have an inherent tendency to avoid unwanted overreaching, making them very desirable for long line protection, and one of the reasons for their inclusion within the MiCOM P54x relay.

The current ***Sensitivity*** setting for each zone is used to set the minimum current that must be flowing in each of the faulted phases before a trip can occur. It is recommended to leave these settings at their default. The exception is where the relay is made more insensitive to match the lesser sensitivity of older relays existing on the power system, or to grade with the pickup setting of any ground overcurrent protection for tee-off circuits.

2.2.10 Distance directional principle and setup

2.2.11 Delta directional - selection of RCA

Distance zones are directionalized by the delta decision. For delta directional decisions, the RCA settings must be based on the average source + line impedance angle for a fault anywhere internal or external to the line. Typically, the “Delta Char Angle” is set to 60^o, as it is not essential for this setting to be precise. When a fault occurs, the delta current will never be close to the characteristic boundary, so an approximate setting is good enough.

2.2.12 Distance setup - filtering, load blinding and polarizing

2.2.12.1 Digital filtering

In most applications, it is recommended that *Standard* filtering is used. This will ensure that the relay offers fast, sub-cycle tripping. In certain rare cases, such as where lines are immediately adjacent to High Voltage DC (HVDC) transmission, the current and voltage inputs may be severely distorted under fault conditions. The resulting non-fundamental harmonics could affect the reach point accuracy of the relay. To prevent the relay being affected, a ‘*Special*’ set of filters are available. It is noted that when using the long line filter the instantaneous operating time is increased by about a quarter of a power frequency cycle.

2.2.12.2 CVTs with passive suppression of ferroresonance

Set a “*Passive*” CVT filter for any type 2 CVT (those with an anti-resonance design). An SIR cutoff setting needs to be applied, above which the relay operation is deliberately slowed by a quarter of a cycle. A typical setting is <u>SIR = 30</u>, below which the relay will trip sub-cycle, and if the infeed is weak the CVT filter adapts to slow the relay and prevent transient overreach.

2.2.12.3 CVTs with active suppression of ferroresonance

Set an “*Active*” CVT filter for any type 1 CVT.

2.2.13 Load blinding (load avoidance)

For security, it is highly recommended that the blinder is Enabled, especially for lines above 150km (90 miles), to prevent non harmonic low frequency transients causing load encroachment problems, and for any networks where power swings might be experienced.

The impedance radius must be set lower than the worst-case loading, and this is often taken as 120% overloading in one line, multiplied by two to account for increased loading during outages or fault clearance in an adjacent parallel circuit. Then an additional allowance for measuring tolerances results in a recommended setting typically 1/3rd (or even 1/4th in some countries such as UK) of the rated full load current:

$Z \quad \leq \quad$ (Rated phase voltage Vn)/(I_{FLC} x 3)

When the load is at the worst-case power factor, it should remain below the beta setting. So, if we assume a typical worst-case 0.85 power factor, then:

$\beta \quad \geq \quad Cos^{-1}$ (0.85) plus 15^o margin $\geq$ 47^o

– And, to ensure that line faults are detected, $\beta \leq$ (Line Angle -15^o).

In practice, an angle half way between the worst-case leading load angle, and the protected line impedance angle, is often used.

The MiCOM P54x has a facility to allow the load blinder to be bypassed any time the measured voltage for the phase in question falls below an undervoltage V< setting. Under such circumstances, the low voltage could not be explained by normal voltage excursion tolerances on-load. A fault is definitely present on the phase in question, and it is acceptable to override the blinder action and allow the distance zones to trip according to the entire zone shape. The benefit is that the resistive coverage for faults near to the relay location can be higher.

The undervoltage setting must be lower than the lowest phase-neutral voltage under heavy load flow and depressed system voltage conditions. The typical maximum V< setting is 70% Vn.

2.2.13.1 Recommended polarizing settings

Cable applications - Use only minimum 20% (0.2) memory. This avoids expansion to cover an upstream source Zs which is likely an overhead line or transformer having a very different Line Angle than that for the cable.

Series compensated lines - Use a mho with maximum memory polarizing (setting = 5). The large memory content will ensure correct operation even with the negative reactance effects of the compensation capacitors seen either within Zs, or within the line impedance.

Short lines - For lines shorter than 10 miles (16km), or with an SIR higher than 15, use maximum memory polarizing (setting = 5). This ensures sufficient characteristic expansion to cover fault arc resistance.

General line applications - Use any setting between 0.2 and 1.

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2.2.14 Distance elements basic scheme setting

The Zone 1 time delay (tZ1) is generally set to zero, giving instantaneous operation.

The Zone 2 time delay (tZ2) is set to co-ordinate with zone 1 fault clearance time for adjacent lines. The total fault clearance time will consist of the downstream zone 1 operating time plus the associated breaker operating time. Allowance must also be made for the zone 2 elements to reset following clearance of an adjacent line fault and also for a safety margin. A typical minimum zone 2 time delay is of the order of 200ms.

The Zone 3 time delay (tZ3) is typically set with the same considerations made for the zone 2 time delay, except that the delay needs to co-ordinate with the downstream zone 2 fault clearance. A typical minimum zone 3 operating time would be in the region of 400ms.

The Zone 4 time delay (tZ4) needs to co-ordinate with any protection for adjacent lines in the relay's reverse direction.

Note (1): The MiCOM P54x allows separate time delays to be applied to both phase and ground fault zones, for example where ground fault delays are set longer to time grade with external ground/earth overcurrent protection.

Note (2): Any zone ("#") which may reach through a power transformer reactance, and measure secondary side faults within that impedance zone should have a small time delay applied. This is to avoid tripping on the inrush current when energizing the transformer. As a general rule, if: Z# Reach $_{setting}$ > 50% X_T transformer reactance, set: tZ# $\geq$ 100ms. Alternatively, the 2nd harmonic detector that is available in the Programmable Scheme Logic may be used to block zones that may be at risk of tripping on inrush current. Settings for the inrush detector are found in the SUPERVISION menu column.

Figure 4 shows the typical application of the Basic scheme.

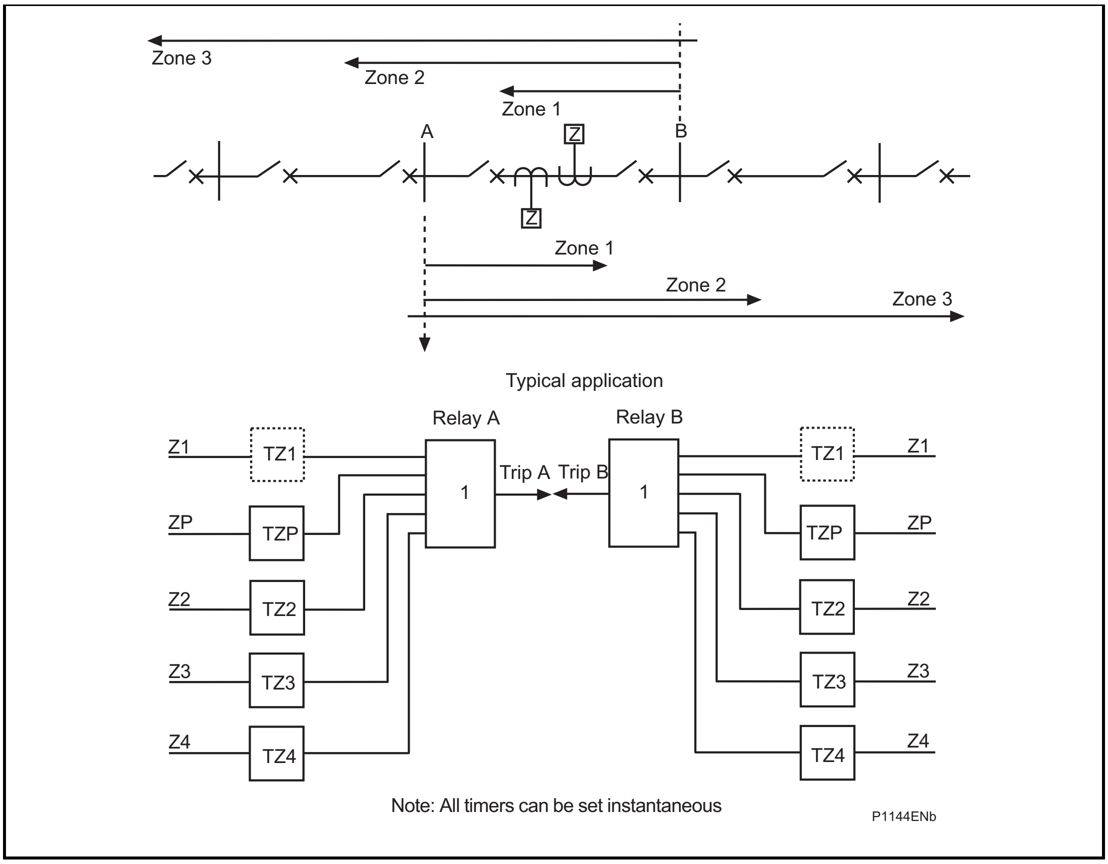

Figure 4: Basic time stepped distance scheme

2.2.15 Power swing alarming and blocking

The PSB technique employed in the MiCOM P54X has the significant advantage that it is adaptive and requires no user-set thresholds in order to detect swings. The PSB relies on the delta techniques internal to the relay, which automatically detect swings of any speed. There is no need to set any blinder or starter characteristics, as would have been the case with legacy devices. The user merely enables the feature, and decides which zones are required to be blocked.

Two timers are available:

The *PSB Reset Delay* is used to maintain the PSB status when ∆I naturally is low during the swing cycle (near the current maxima and minima in the swing envelope). A typical setting of 0.2s is used to seal-in the detection until ∆I has chance to appear again.

The *PSB Unblock Dly* is used to time the duration for which the swing is present. The intention is to allow the distinction between a stable and an unstable swing. If after the timeout period the swing has still not stabilized, the block for selected zones can be released (“unblocking”), giving the opportunity to split the system. If no unblocking is required at the location of this relay, set to maximum (10s).

PSB can be disabled on distribution systems, where power swings would not normally be experienced.

2.2.16 Out of step protection

P54x provides an integrated Out of Step protection, thus avoiding a need for a separate stand alone Out of Step relays. Unlike the power swing detection, the Out of Step protection requires settings and is completely independent from the setting free Power swing detection.

This section provides a discussion and a guidance of how to set the Out of Step protection.

Settings based on system studies must be applied when 'Predictive OST' operation mode is selected as the high setting accuracy is needed to avoid premature system splitting in the case of severe power oscillations that do not lead to pole slip conditions. For the 'OST' setting the same method may be used but an exhaustive stability study may not be required as it will be shown later that the total system impedance ZT and system split points are adequate to set the relay for this scenario.

2.2.17 Critical stability angle

What is the angle between two ends when a power system oscillation could be declared as a pole slip?

Consider the power angle curves as in Figure 5.

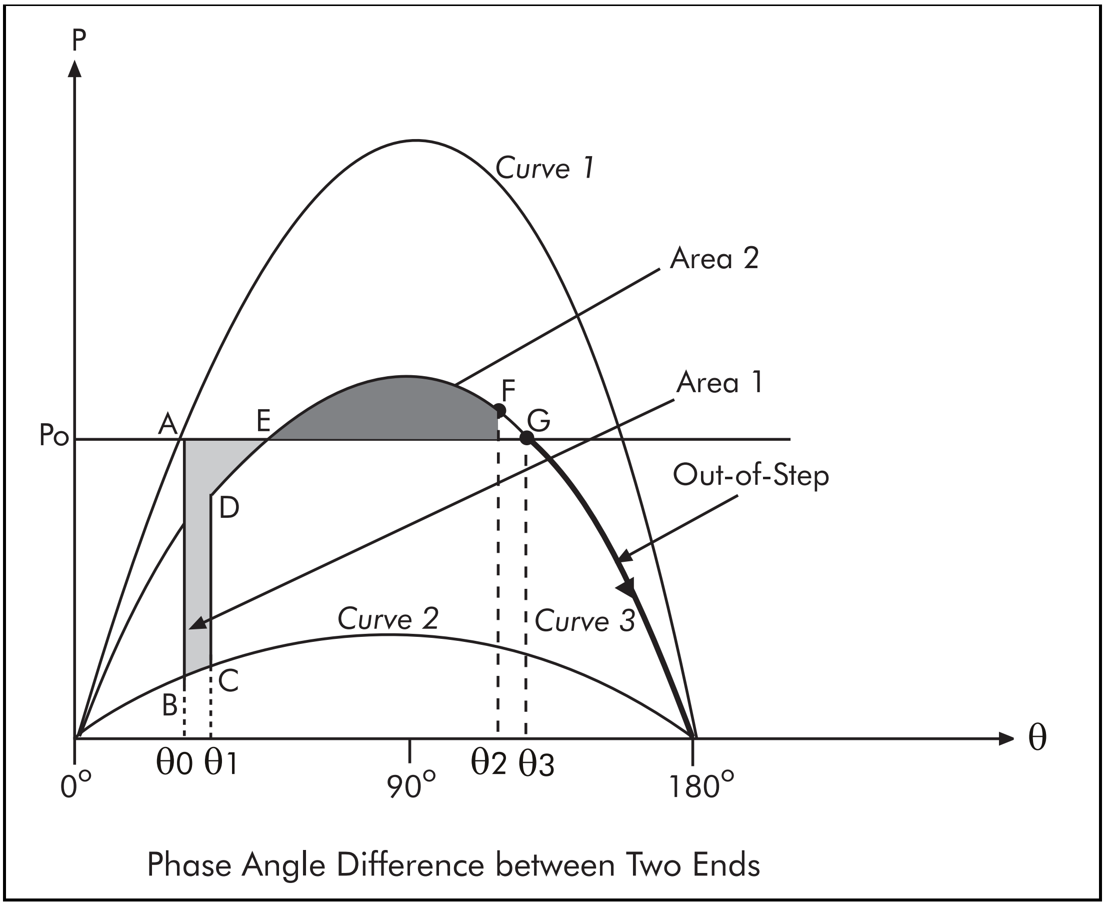

Figure 5: Power transfer in relation to angle difference θ between 2 ends

The figure above represents power angle curves, with no AR being performed, as follows:

Curve 1 - Pre-fault system operation via parallel lines where transmitted power is Po

Curve 2 - Transmitted power significantly reduced during two-phase to ground fault

Curve 3 - New power curve when the parallel line is tripped (fault cleared)

It can be seen that at a fault instance, the operating point A moves to B, with a lower transfer level. There is therefore a surplus of power ΔP=AB at the sending end and the corresponding deficit at the receiving end. The sending end machines start to speed up, and the receiving end machines to slow down, so phase angle θ increases, and the operating point moves along curve 2 until the fault is cleared, when the phase angle is θ1. The operating point now moves to point D on curve 3 which represents one line in service. There is still a power surplus at the sending end, and deficit at the receiving end, so the machines continue to drift apart and the operating point moves along curve 3. If, at some point between E and G (point F) the machines are rotating at the same speed, the phase angle will stop increasing. According to the Equal Area Criterion, this occurs when area 2 is equal to area 1. The sending end will now start to slow down and receiving end to speed up.

Therefore, the phase angle starts to decrease and the operating point moves back towards E. As the operating point passes E, the net sending end deficit again becomes a surplus and the receiving end surplus becomes a deficit, so the sending end machines begin to speed up and the receiving end machines begin to slow down. With no losses, the system operating point would continue to oscillate around point E on curve 3, but in practice the oscillation is dumped, and the system eventually settles at operating point E.

To resume, if area 1<area 2, the system will stay in synchronism. This swing is usually called a “recoverable power swing. If, on contrary, the system passes point G with a further increase in angle difference between sending and receiving ends, the system drifts out of synchronism and becomes unstable. This will happen if the initial power transfer Po was set too high in Figure 5, so that the area 1 is greater than area 2. This power swing is not recoverable and is usually called “out of step” or “out of synchronism” or “pole slip” condition. After this, only system separation and re-synchronizing of the machines can restore normal system operation.

In Figure 5, the point G is shown at approximately 120° deg, but it is not true in all cases. If, for example the pre-fault transmitted power (Po) was too high and if the fault clearance was slow, the area 1 will be greater so for the system to recover the angle θ would be close to 90 deg. On contrarily, if the pre-fault transmitted power Po was low and fault clearance fast, the area 1 will be small, so that based on area comparison, the angle θ could go closer to 180 deg and the system will still remain stable.

The actual angle difference at which system will become unstable could only be determined by a particular system studies, but for the purpose of settings recommendation where ‘OST’ setting is selected, the typical angle beyond which system will not recover is assumed to be 120 deg.

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2.2.17.1 Setting option recommendation

The relay provides 4 different setting options:

1. Disabled
2. Predictive OST
3. OST
4. Predictive OST or OST

Set **Option 1** on all lines except the line where tripping due to unrecoverable power oscillations is required or for the system where power oscillations are not severe - mainly in well interconnected systems operating with 3 phase tripping.

Setting **Option 2** (and 4) is the best setting option from the system point of view, perhaps not being widely used in the past. Some utilities prefer an early system split to minimize the angle shift between ends and maximize the chances for the remaining two halves to stabilize as quickly as possible. Special care must be taken when this method is applied to ensure that the actual circuit breaker opening does not occur when the internal voltages at two ends are in anti phase. This is due to the fact that most breakers are not designed to interrupt at double nominal voltage and any attempt to break at that point would lead to flash over and possible circuit breaker damage. The fact is that setting Option 2 (and 4) will be mainly applied do detect and trip fast power oscillations. When this is coupled with a typical 2 cycle circuit breaker operating time, the two voltages angles may rapidly move in opposite directions at the time of opening the circuit breaker. Therefore, if this setting option is chosen, the above facts must be taken into account so that the actual CB opening must occur well before the angle difference between two ends approaches 180 degrees. On that basis, accurate settings have to be determined based on exhaustive system studies.

Setting **Option 3** is the most commonly used approach. Once the Out of Step conditions are detected, the OST command will split the system at pre-determined points. The slight disadvantages of this method in comparison to Option 2 (and 4) is that the power oscillation will escalate further, thus causing more difficulties for the split parts to remain stable but the advantage is that the timing of the circuit breaker operation (‘tripping angle’) is easily controlled and the decision to split the system will be correct even if errors were made in the system data and setting parameters. This extra security is achieved by measuring and confirming the change of polarity of the resistive part of positive sequence impedance on zone 5 exit (reset).

Setting **Option 4** provides 2 stages of Out of Step detection and tripping. If the power system oscillation is very fast, the combination of ∆R and Delta t setting (as discussed below) must be set in such a way that 'Predictive OST' operates. If however the oscillation is slower, the condition for the 'Predictive OST' will not be met and the 'OST' will operate later upon Z5 reset, providing that the change in polarity of the resistive component was detected. This is to distinguish between a slower non-recoverable oscillation and recoverable swings.

2.2.17.2 Blinder limits determination

Consider the Out of Step characteristic versus angle θ between two ends.

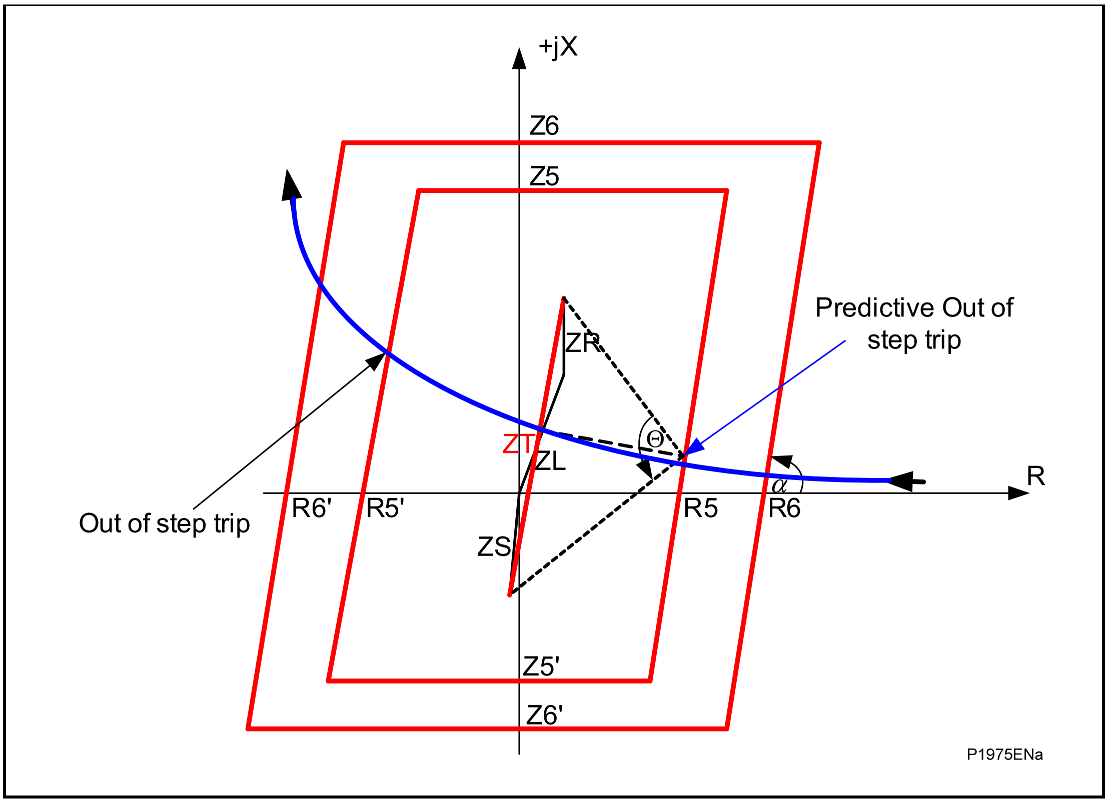

Figure 6: Setting determination for the positive sequence resistive component R5

Firstly, determine the minimum inner resistive reach R5.

From Figure 6 it can be seen that:

$$R5\min = \frac{\frac{ZT}{2}}{\tan{}^{\Theta}\!/_{2}},$$

Where ZT is a total system positive sequence impedance that equals to ZS + ZL + ZS, where ZS and ZR are equivalent positive sequence impedances at the sending and receiving ends and ZL positive sequence line impedance. 'θ' is an angle difference between the internal voltages at sending and receiving ends beyond which no system recovery is possible.

The next step is to determine the maximum (limit value) for the outer resistive reach R6. It must be insured that Point A in Figure 7 does not overlap with the load area for the worst assumed power factor of 0.85 and the lowest possible ZT angle α.

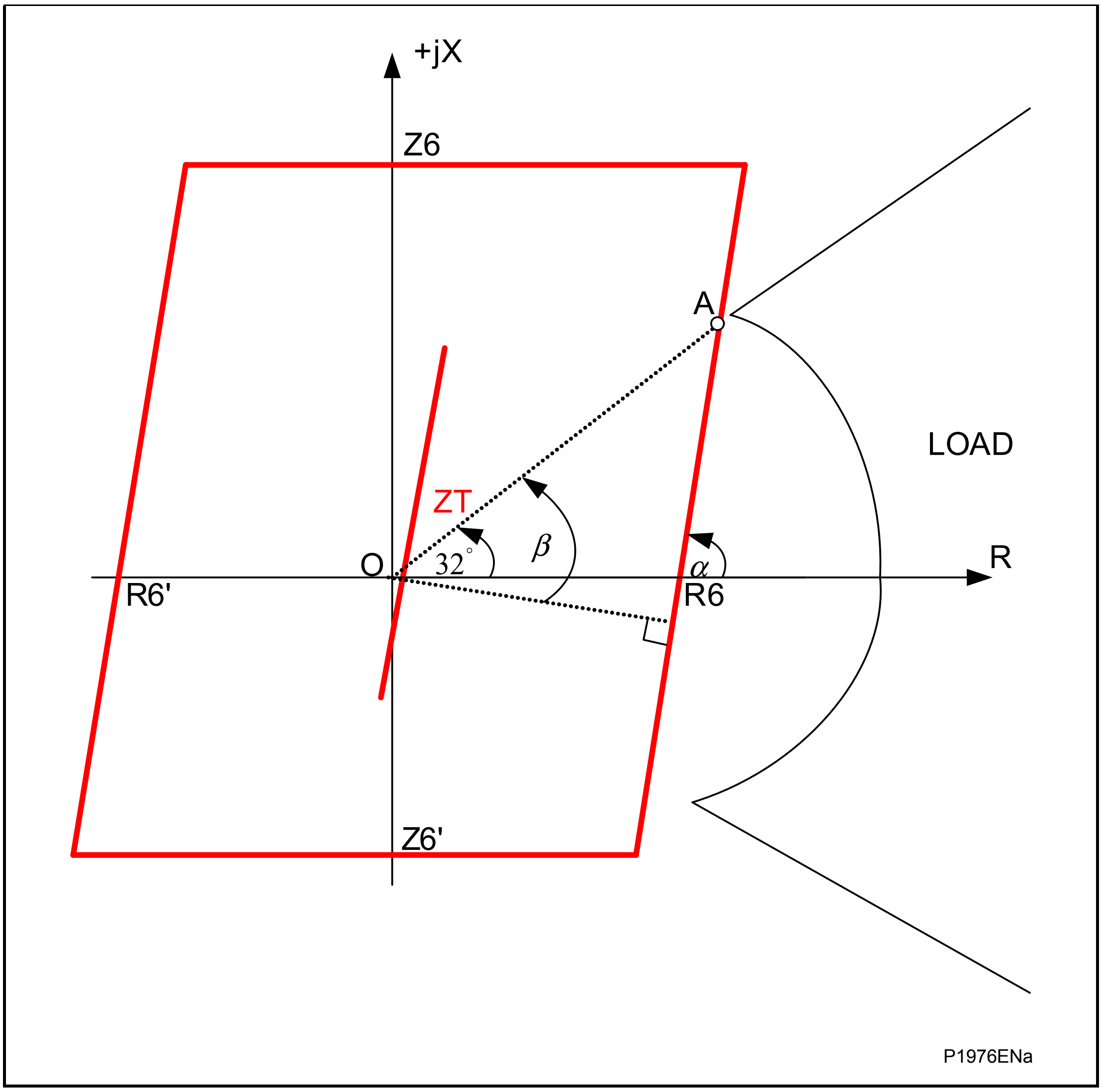

Figure 7: $R6_{MAX}$ determination

β = 32 + 90 – α

Z load min = OA

R6MAX < Zload min x cos β

Where:

- Zload min is the minimum load impedance radius calculated above which already has built in sufficient margin
- 32 deg is the load angle that corresponds to the lower power factor of 0.85
- 'α' is the load blinder angle that matches ZT angle

The setting of negative resistance R5' should equal the R5 to accommodate the 'load import' condition. Starting from the limit values $R5_{MIN}$ and $R6_{MAX}$ the actual R5 and R6 (including the corresponding R5' and R6') reaches will be set in conjunction with the 'Delta t' setting below.

Note: $R6_{MAX}$ reach must be greater than the maximum resistive reach of any distance zone to ensure correct initiation of the 25ms and 'Delta t' timers. However, the $R5_{MIN}$ reach could be set below the distance maximum resistive reach (inside the distance characteristic) if an extensive resistive coverage is required, meaning that Out of Step protection does not pose a restriction to the quad applications.

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Setting of reactance lines Z5 and Z6 will depend on how far from the relay location the power oscillations are to be detected. Normally, there is only one point where the system is to be initially split and that point will be determined by system studies. For that reason, the Out of Step protection must be enabled at that location and disabled on all others. To detect the Out of step conditions, the Z5'-Z5 and Z6'-Z6 setting must be set to comfortably encompass the total system impedance ZT, as per Figure 6. Typical setting could be:

Z5 = Z5' = 1/2 x 2 ZT = ZT

The Z6 and Z6' setting is not of great importance and could be set to Z6 = Z6' = 1.1 x Z5

2.2.17.3 Delta t, R5 and R6 setting determination

The $R5_{MIN}$ and $R6_{MAX}$ settings determined above are only limit values, the actual R5 and R6 need to be determine in relation to the 'Delta t' timer.

Predictive OST setting:

For the 'Predictive OST' setting it is important to:

- Set R6 (and R6') equal to $R6_{MAX}$
- Set R5 as close as practical to $R6_{MAX}$

The aim of pushing the R5 setting to the right is to detect the fast oscillation as soon as possible to gain sufficient time to operate the breaker before the two source voltages are in opposite direction. The only restriction would be the limitation of the 'Delta t' minimum time delay of 30ms and the speed of oscillation. Set 'Delta t' so that the following condition is satisfied:

'Delta t' does not expire after positive sequence impedance has passed the R6-R5 region

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For this setting, knowledge of the accurate rate of change of swing impedance when crossing the R6-R5 region is essential and therefore must be based on system studies.

Assumption that the rate of change of the positive sequence impedance during crossing the R6-R5 region is average rate of change for the whole swing cycle is wrong and could easily lead to incorrect 'Predictive OST' operation.

Note that for the fault, the R6-R5 region will be passed faster than 25ms, therefore even very fast oscillations of 7Hz will not be mistaken with the fault condition and 'Predictive OST' will not operate.

OST setting:

For the 'OST' setting option the precise setting of blinders and 'Delta t' is not necessary. This is based on the fact that:

The wider the ΔR region and the shorter the Δt setting, any oscillation will be successfully detected. The only condition is that the fault impedance must pass through the ΔR region faster than Δt setting.

Therefore, for the 'OST' setting assume that θ = 120° and set:

- R5 = R5' = $R5_{MIN}$ = ZT/3.46
- R6 = R6' = $R6_{MAX}$
- Delta t = 30ms

The point is that 'Delta t' always expires, therefore the above setting will secure the detection of a wide range of oscillations, starting from very slow oscillations caused by recoverable swings up to the fastest oscillation of 7Hz. It should be noted that any fault impedance will pass the R6-R5 region faster than the minimum settable 'Delta t' time of 30ms.

Predictive OST or OST setting:

As per 'Predictive OST' above.

2.2.17.4 Tost (trip delay) setting

Tost must be set zero for setting Option 2 and 4 above.

For setting Option 3, Tost should normally be set to zero. It is only the case if a user wants to operate breaker at the angle closer to 360 degrees (when voltages are in phase) when time delay could be applied.

2.2.17.5 Blinder angle setting

Set blinders angle 'α' same as total system impedance ZT angle.

2.2.17.6 Out of step operation on series compensated lines

The maximum phase currents during out of step condition rarely exceed 2xIn RMS, which corresponds to the minimum swing impedance passing through zone 1. Since the Metal-Oxide Varistors (MOV) bypass level is normally set between 2-3In, they will not operate during the power oscillations and therefore in majority of applications will not make any impact on Out of Step operation.

Consider a worst case scenario when the power oscillations are triggered upon fault clearance on the parallel line. In that case approximately twice the load current will start flowing through the remaining circuit, increase further and eventually exceed the MOV threshold. Since the R6-R5 region is usually set far from zone 1 the chances that the positive sequence impedance's trajectory may traverse in and out of the set ΔR region due to MOV's operation, are remote. If MOV's do operate within the ΔR region (see Figure 8), a timer, that has been initiated, may reset and be re-initiated or the impedance may remain within ΔR region for a slightly longer duration. This is due to the fact that resistive and capacitive components will be added to the measured impedance during MOV operation as per Figure 8. This effect may have an impact on the 'Delta t' measurement if 'Predictive OST' setting is used. If the recommendation to set $R5_{MIN}$ as close as practically possible to the $R6_{MAX}$ is followed, the chances that the swing currents will exceed MOV threshold within the ΔR region is very remote. If a study shows that the MOV's could operate within the ΔR region, it is recommended to set 'Predictive OST and OST' operating mode to cover all eventualities.

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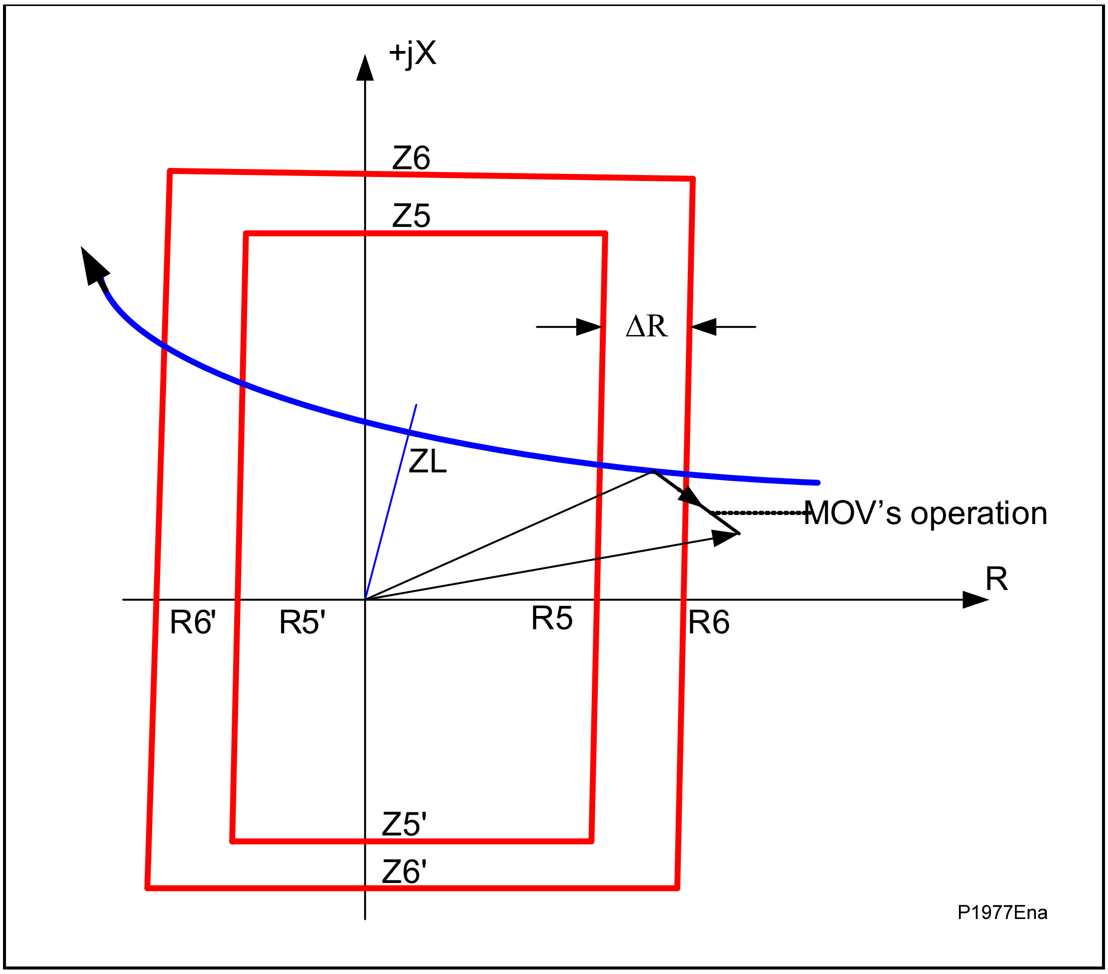

Figure 8: Example of timer reset due to MOV's operation

It should be noted that if 'OST' setting is chosen, the timer when triggered, will eventually expire as the power oscillations progress, therefore MOV operation will not have any impact on Out of Step operation.

2.2.18 Switch on to fault (SOTF) and trip on reclose (TOR)

2.2.19 Switch onto fault mode

To ensure fast isolation of faults (for example a closed three phase earth/grounding switch) upon energization, it is recommended this feature is enabled with appropriate zones selected.

<u>SOTF delay</u>	-	The time chosen should be longer than the slowest delayed-auto-reclose dead time, but shorter than the time in which the system operator might re-energize a circuit once it had opened/tripped. 110 seconds is recommended as a typical setting.
<u>SOTF pulse</u>	-	Typically this could be set to at 500 ms. This time is enough to establish completely the voltage memory of distance protection.
<u>TOC reset delay</u>	-	500ms is recommended as a typical setting (chosen to be in excess of the 16 cycles length of memory polarizing, allowing full memory charging before normal protection resumes).

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2.2.20 Trip on reclose mode

To ensure fast isolation of all faults upon energization, it is recommended this feature is enabled with appropriate zones selected. This feature is activated a fixed 200ms after any circuit breaker opening.

TOC reset delay - 500ms is recommended as a typical setting (as per SOTF).

2.2.21 Setup of DEF

DEF zero sequence polarization

In practice, the typical zero sequence voltage on a healthy system can be as high as 1% (i.e.: 3% residual), and the VT error could be 1% per phase. A *VNpol Set* setting between 1% and 4%.Vn is typical, to avoid spurious detection on standing signals. The residual voltage measurement provided in the "Measurements" column of the menu may assist in determining the required threshold setting during commissioning, as this will indicate the level of standing residual voltage present. The Virtual Current Polarizing feature will create a VNpol which is always large, regardless of whether actual VN is present.

With DEF, the residual current under fault conditions lies at an angle lagging the polarizing voltage. Hence, negative characteristic angle settings are required for DEF applications. This is set in cell ‘DEF Char Angle' in the relevant earth fault menu.

The following angle settings are recommended for a residual voltage polarized relay:-

Distribution systems (solidly earthed) ⇒ -45°

Transmissions systems (solidly earthed) ⇒ -60°

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2.2.22 DEF negative sequence polarization

For negative sequence polarization, the RCA settings must be based on the angle of the upstream nps source impedance. A typical setting is -60°.

2.2.23 General setting guidelines for DEF (directional ground overcurrent)

DEF threshold - This setting determines the current sensitivity (trip sensitivity) of the DEF aided scheme. This setting must be set higher than any standing residual current unbalance. A typical setting will be between 10 and 20% In.

There is no need to set a reverse current detector, as this has a fixed threshold equal to half of the forward DEF Threshold.

2.2.24 Channel aided schemes

The MiCOM P54x offers two sets of aided channel (“pilot”) schemes, which may be operated in parallel.

Aided Scheme 1 - May be keyed by distance and/or DEF

Aided Scheme 2 - May be keyed by distance and/or DEF

When schemes share the same channel, the same generic scheme type will be applied - i.e. ALL Permissive Overreach, or ALL Blocking.

2.2.25 Distance scheme PUR - permissive underreach transfer trip

This scheme is similar to that used in the LFZP Optimho, SHNB Micromho, LFZR, and MiCOM P44x [note 1] distance relays. (Note 1: matches PUP Z2 mode in P441/442/444). It allows an instantaneous Z2 trip on receipt of the signal from the remote end protection.

Send logic: Zone 1

Permissive trip logic: Zone 2 plus Channel Received

The “Dist dly” trip time setting should be set to Zero, for fast fault clearance.

2.2.26 Distance scheme POR - permissive overreach transfer trip

This scheme is similar to that used in the LFZP Optimho, SHNB Micromho, LFZR, and MiCOM P44x (note 2) distance relays. (Note 2: matches POP Z2 mode in P441/442/444, and POR2 scheme in LFZP/LFZR). Note that the POR scheme also uses the reverse looking zone 4 of the relay as a reverse fault detector. This is used in the current reversal logic and in the optional weak infeed echo feature.

Send logic: Zone 2

Permissive trip logic: Zone 2 plus Channel Received

The “Dist dly” trip time setting should be set to Zero, for fast fault clearance.

2.2.27 Permissive overreach scheme weak infeed features

Where weak infeed tripping is employed, a typical voltage setting is 70% of rated phase-neutral voltage. Weak infeed tripping is time delayed according to the “WI Trip Delay” value, usually set at 60ms.

2.2.28 Distance scheme BLOCKING

To allow time for a blocking signal to arrive, a short time delay on aided tripping, “Dist dly”, **must** be used, as follows:

Recommended Dly setting = Max. Signaling channel operating time + 1 power frequency cycle.

This scheme is similar to that used in the LFZP Optimho, SHNB Micromho, LFZR, and MiCOM P44x (note 3) distance relays. (Note 3: matches BOP Z2 mode in P441/442/444).

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Send logic: Reverse Zone 4

Trip logic: Zone 2, plus Channel NOT Received, delayed by Tp

Note that two variants of a Blocking scheme are provided, Blocking 1 and Blocking 2. Both schemes operate identically, except that the reversal guard timer location in the logic changes. Blocking 2 may sometimes allow faster unblocking when a fault evolves from external to internal, and hence a faster trip.

2.2.29 Permissive overreach schemes current reversal guard

The recommended setting is:

tREVERSAL GUARD = Maximum signaling channel reset time + 35ms.

2.2.30 Blocking scheme current reversal guard

The recommended setting is:

- Where Duplex signaling channels are used:

  tREVERSAL GUARD = Maximum signaling channel operating time + 20ms.

- Where Simplex signaling channels are used:

  tREVERSAL GUARD = Maximum signaling channel operating time - minimum signaling channel reset time + 20ms.

2.2.31 Aided DEF ground fault scheme - permissive overreach

This POR scheme is similar to that used in all other Schneider Electric relays.

Send logic: IN> Forward pickup

Permissive trip logic: IN> Forward plus Channel Received

Note: The Time Delay for a permissive scheme aided trip would normally be set to zero.

2.2.32 Aided DEF ground fault scheme - blocking

This scheme is similar to that used in all other Schneider Electric relays.

Send logic: DEF Reverse

Trip logic: IN> Forward, plus Channel NOT Received, with a small set delay

To allow time for a blocking signal to arrive, a short time delay on aided tripping **must** be used. The recommended Time Delay setting = max. Signaling channel operating time + 20ms.

2.3 Loss of load accelerated tripping (LoL)

For circuits with load tapped off the protected line, care must be taken in setting the loss of load feature to ensure that the I< level detector setting is above the tapped load current. When selected, the loss of load feature operates in conjunction with the main distance scheme that is selected. In this way it provides high speed clearance for end zone faults when the Basic scheme is selected or, with permissive signal aided tripping schemes, it provides high speed back-up clearance for end zone faults if the channel fails.

2.4 Phase fault overcurrent protection

Settings for the time delayed overcurrent element should be selected to ensure discrimination with surrounding protection. Setting examples for phase fault overcurrent protection can be found in the Network Protection and Automation Guide (NPAG), a comprehensive reference textbook available from Schneider Electric.

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Caution: The IEEE C.37.112 standard for IDMT curves permits some freedom to manufacturers at which time dial (TD) value the reference curve applies. Rather than pick a mid-range value, for the MiCOM P54x the reference curve norm applies at a time dial of 1. The time dial is merely a multiplier on the reference curve, in order to achieve the desired tripping time. Take care when grading with other suppliers' relays which may take TD = 5, or TD = 7 as a mid-range value to define the IDMT curve. The equivalent MiCOM P54x setting to match those relays is achieved by dividing the imported setting by 5 or 7.

2.4.1 Directional overcurrent characteristic angle settings

The relay uses a 90° connection angle for the DOC elements. The relay characteristic angles in this case are nominally set to:

- +30° Plain feeders, zero sequence source behind relay
- +45° Transformer feeder, zero sequence source in front of relay

Whilst it is possible to set the RCA to exactly match the system fault angle, it is recommended that the above figures are followed, as these settings have been shown to provide satisfactory performance and stability under a wide range of system conditions.

2.5 Thermal overload protection

Thermal overload protection can be used to prevent electrical plant from operating at temperatures in excess of the designed maximum withstand. Prolonged overloading causes excessive heating, which may result in premature ageing of the insulation, or in extreme cases, insulation failure.

2.5.1 Single time constant characteristic

The current setting is calculated as:

Thermal Trip = Permissible continuous loading of the plant item/CT ratio.

Typical time constant values are given in the following table. The relay setting, ‘Time Constant 1’, is in minutes.

Typical time constant values are given in the following table. The relay setting, 'Time Constant 1', is in minutes.

	Time Constant τ (minutes)	**Limits**
Air-core reactors	40	
Capacitor banks	10	
Overhead lines	10	Cross section ≥ 100 mm2 Cu or 150mm2 Al
Cables	60 - 90	Typical, at 66kV and above
Busbars	60	

An alarm can be raised on reaching a thermal state corresponding to a percentage of the trip threshold. A typical setting might be 'Thermal Alarm' = 70% of thermal capacity.

2.5.2 Dual time constant characteristic

The current setting is calculated as:

Thermal Trip = Permissible continuous loading of the transformer / CT ratio.

Typical time constants:

	τ1 (minutes)	**τ2 (minutes)**	**Limits**
Oil-filled transformer	5	120	Rating 400 - 1600 kVA

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An alarm can be raised on reaching a thermal state corresponding to a percentage of the trip threshold. A typical setting might be 'Thermal Alarm' = 70% of thermal capacity.

Note that the thermal time constants given in the above tables are typical only. Reference should always be made to the plant manufacturer for accurate information.

2.6 Earth fault (ground overcurrent) and sensitive earth fault (SEF) protection

Caution: The IEEE C.37.112 standard for IDMT curves permits some freedom to manufacturers at which time dial (TD) value the reference curve applies. Rather than pick a mid-range value, for the MiCOM P54x the reference curve norm applies at a time dial of 1. The time dial is merely a multiplier on the reference curve, in order to achieve the desired tripping time. Take care when grading with other suppliers' relays which may take TD = 5, or TD = 7 as a mid-range value to define the IDMT curve. The equivalent MiCOM P54x setting to match those relays is achieved by dividing the imported setting by 5 or 7.

2.6.1 Directional earth fault protection

2.6.1.1 Residual voltage polarization

It is possible that small levels of residual voltage will be present under normal system conditions due to system imbalances, VT inaccuracies, relay tolerances etc. Hence, the relay includes a user settable threshold (IN>VNPol Set) which must be exceeded in order for the DEF function to be operational. In practice, the typical zero sequence voltage on a healthy system can be as high as 1% (i.e.: 3% residual), and the VT error could be 1% per phase. A setting between 1% and 4% is typical. The residual voltage measurement provided in the "Measurements" column of the menu may assist in determining the required threshold setting during commissioning, as this will indicate the level of standing residual voltage present.

2.6.2 General setting guidelines for directional earth fault (ground overcurrent) protection

When setting the relay characteristic angle (RCA) for the directional earth fault element, a positive angle setting was specified. This was due to the fact that the quadrature polarizing voltage lagged the nominal phase current by 90°; i.e. the position of the current under fault conditions was leading he polarizing voltage and hence a positive RCA was required. With DEF, the residual current under fault conditions lies at an angle lagging the polarizing voltage. Hence, negative RCA settings are required for DEF applications. This is set in cell 'I>N' in the relevant earth fault menu.

The following angle settings are recommended for a residual voltage polarized relay:-

- Distribution systems (solidly earthed) -45°
- Transmissions systems (solidly earthed) -60°

For negative sequence polarization, the RCA settings must be based on the angle of the upstream nps source impedance.

2.7 Negative sequence overcurrent protection (NPS)

The following section describes how NPS overcurrent protection may be applied in conjunction with standard overcurrent and earth fault protection in order to alleviate some less common application difficulties:

– Negative phase sequence overcurrent elements give greater sensitivity to resistive phase-to-phase faults, where phase overcurrent elements may not operate.

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– In certain applications, residual current may not be detected by an earth fault relay due to the system configuration. For example, an earth fault relay applied on the delta side of a Dy (delta-wye) transformer is unable to detect earth faults on the star (wye) side. However, negative sequence current will be present on both sides of the transformer for any fault condition, irrespective of the transformer configuration. Therefore, a NPS overcurrent element may be employed to provide time-delayed back-up protection for any uncleared asymmetrical faults downstream.

– It may be required to simply alarm for the presence of negative phase sequence currents on the system. Operators may then investigate the cause of the unbalance.

2.7.1 Negative phase sequence current threshold, 'I2> current set'

The current pick-up threshold must be set higher than the negative phase sequence current due to the maximum normal load unbalance on the system. This can be set practically at the commissioning stage, making use of the relay measurement function to display the standing negative phase sequence current, and setting at least 20% above this figure.

Where the negative phase sequence element is required to operate for specific uncleared asymmetric faults, a precise threshold setting would have to be based upon an individual fault analysis for that particular system due to the complexities involved. However, to ensure operation of the protection, the current pick-up setting must be set approximately 20% below the lowest calculated negative phase sequence fault current contribution to a specific remote fault condition.

2.7.2 Time delay for the NPS overcurrent element, 'I2> time delay'

As stated above, correct setting of the time delay for this function is vital. It should also be noted that this element is applied primarily to provide back-up protection to other protective devices or to provide an alarm. Hence, in practice, it would be associated with a long time delay.

It must be ensured that the time delay is set greater than the operating time of any other protective device (at minimum fault level) on the system which may respond to unbalanced faults.

2.7.3 Directionalizing the negative phase sequence overcurrent element

Where negative phase sequence current may flow in either direction through a relay location, such as parallel lines, directional control of the element should be employed. Directionality is achieved by comparison of the angle between the negative phase sequence voltage and the negative phase sequence current and the element may be selected to operate in either the forward or reverse direction. A suitable relay characteristic angle setting (I2> Char Angle) is chosen to provide optimum performance. This setting should be set equal to the phase angle of the negative sequence current with respect to the inverted negative sequence voltage (– V2), in order to be at the center of the directional characteristic.

The angle that occurs between V2 and I2 under fault conditions is directly dependent upon the negative sequence source impedance of the system. However, typical settings for the element are as follows;

- For a transmission system the RCA should be set equal to -60°
- For a distribution system the RCA should be set equal to -45°

For the negative phase sequence directional elements to operate, the relay must detect a polarizing voltage above a minimum threshold, "I2> V2pol Set". This must be set in excess of any steady state negative phase sequence voltage. This may be determined during the commissioning stage by viewing the negative phase sequence measurements in the relay.

2.8 Undervoltage protection

In the majority of applications, undervoltage protection is not required to operate during system earth (ground) fault conditions. If this is the case, the element should be selected in the menu to operate from a phase to phase voltage measurement, as this quantity is less affected by single phase voltage depressions due to earth faults.

The voltage threshold setting for the undervoltage protection should be set at some value below the voltage excursions which may be expected under normal system operating conditions. This threshold is dependent upon the system in question but typical healthy system voltage excursions may be in the order of -10% of nominal value.

Similar comments apply with regard to a time setting for this element, i.e. the required time delay is dependent upon the time for which the system is able to withstand a depressed voltage.

2.9 Overvoltage protection

The inclusion of the two stages and their respective operating characteristics allows for a number of possible applications;

– Use of the IDMT characteristic gives the option of a longer time delay if the overvoltage condition is only slight but results in a fast trip for a severe overvoltage. As the voltage settings for both of the stages are independent, the second stage could then be set lower than the first to provide a time delayed alarm stage if required.

– Alternatively, if preferred, both stages could be set to definite time and configured to provide the required alarm and trip stages.

– If only one stage of overvoltage protection is required, or if the element is required to provide an alarm only, the remaining stage may be disabled within the relay menu.

This type of protection must be co-ordinated with any other overvoltage relays at other locations on the system. This should be carried out in a similar manner to that used for grading current operated devices.

2.10 Residual overvoltage (neutral displacement) protection

On a healthy three phase power system, the addition of each of the three phase to earth voltages is nominally zero, as it is the vector addition of three balanced vectors at 120° to one another. However, when an earth (ground) fault occurs on the primary system this balance is upset and a ‘residual’ voltage is produced. Note that this condition causes a rise in the neutral voltage with respect to earth which is commonly referred to as “neutral voltage displacement” or NVD.

Figures 9 and 10 show the residual voltages that are produced during earth fault conditions occurring on a solid and impedance earthed power system respectively.

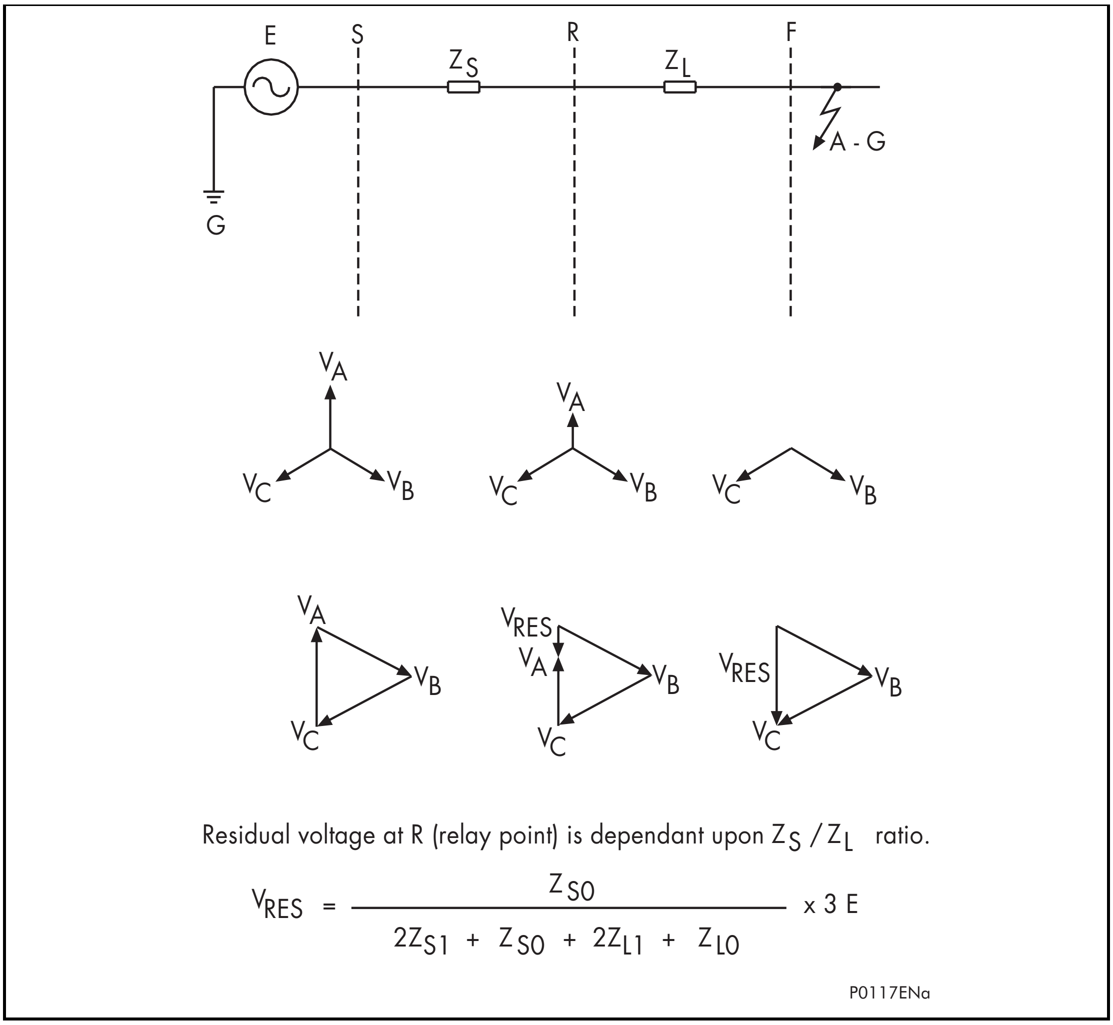

Figure 9: Residual voltage, solidly earthed system

As can be seen in Figure 9 the residual voltage measured by a relay for an earth fault on a solidly earthed system is solely dependent upon the ratio of source impedance behind the relay to line impedance in front of the relay, up to the point of fault. For a remote fault, the Zs/Zl ratio will be small, resulting in a correspondingly small residual voltage. As such, depending upon the relay setting, such a relay would only operate for faults up to a certain distance along the system. The value of residual voltage generated for an earth fault condition is given by the general formula shown.

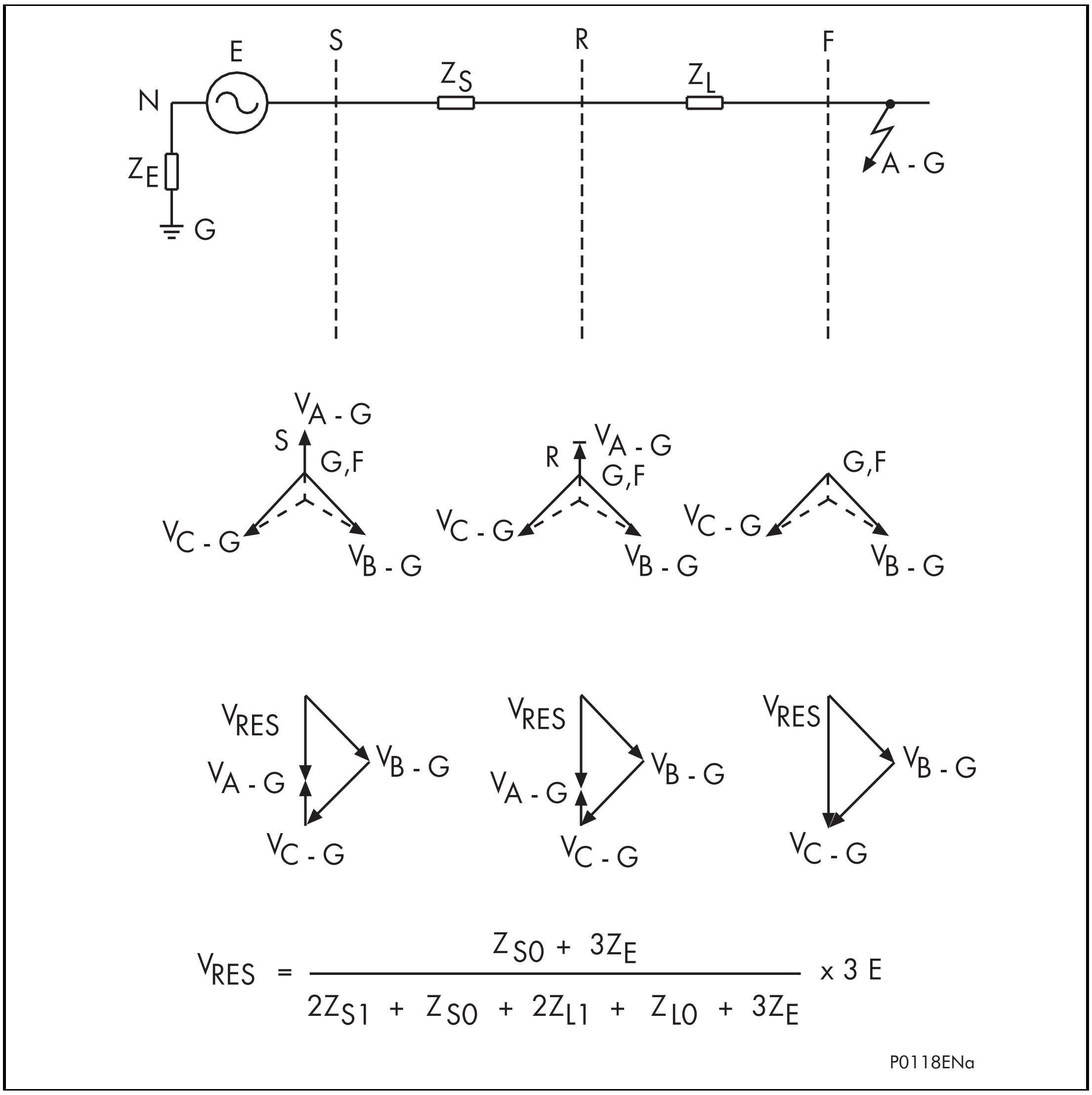

Figure 10: Residual voltage, resistance earthed system

Figure 10 shows that a resistance earthed system will always generate a relatively large degree of residual voltage, as the zero sequence source impedance now includes the earthing impedance. It follows then, that the residual voltage generated by an earth fault on an insulated system will be the highest possible value (3 x phase-neutral voltage), as the zero sequence source impedance is infinite.

From the above information it can be seen that the detection of a residual overvoltage condition is an alternative means of earth fault detection, which does not require any measurement of zero sequence current. This may be particularly advantageous at a tee terminal where the infeed is from a delta winding of a transformer (and the delta acts as a zero sequence current trap).

It must be noted that where residual overvoltage protection is applied, such a voltage will be generated for a fault occurring anywhere on that section of the system and hence the NVD protection must co-ordinate with other earth/ground fault protection.

2.10.1 Setting guidelines

The voltage setting applied to the elements is dependent upon the magnitude of residual voltage that is expected to occur during the earth fault condition. This in turn is dependent upon the method of system earthing employed and may be calculated by using the formulae previously given in Figures 9 and 10. It must also be ensured that the relay is set above any standing level of residual voltage that is present on the system.

Note that IDMT characteristics are selectable on the first stage of NVD in order that elements located at various points on the system may be time graded with one another.

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2.11 Circuit breaker fail protection (CBF)

2.11.1 Breaker fail timer settings

Typical timer settings to use are as follows:

CB Fail Reset Mechanism	tBF Time Delay	Typical Delay for 2 ½ Cycle Circuit Breaker
Initiating element reset	CB interrupting time + element reset time (max.) + error in tBF timer + safety margin	50 + 45 + 10 + 50 = 155 ms
CB open	CB auxiliary contacts opening/closing time (max.) + error in tBF timer + safety margin	50 + 10 + 50 = 110 ms
Undercurrent elements	CB interrupting time + undercurrent element (max.) + safety margin	50 + 25 + 50 = 125 ms

Note that all CB Fail resetting involves the operation of the undercurrent elements. Where element reset or CB open resetting is used the undercurrent time setting should still be used if this proves to be the worst case.

The examples above consider direct tripping of a 2½ cycle circuit breaker. Note that where auxiliary tripping relays are used, an additional 10-15 ms must be added to allow for trip relay operation.

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2.11.2 Breaker fail undercurrent settings

The phase undercurrent settings (I<) must be set less than load current, to ensure that I< operation indicates that the circuit breaker pole is open. A typical setting for overhead line or cable circuits is 20% In, reduced to 10% or 5% where the infeed has a high SIR ratio (e.g. at a spur terminal with embedded generation infeed).

The sensitive earth fault protection (SEF) undercurrent element must be set less than the respective trip setting, typically as follows:

ISEF< = (ISEF> trip) / 2

2.12 Broken conductor detection

The majority of faults on a power system occur between one phase and ground or two phases and ground. These are known as shunt faults and arise from lightning discharges and other overvoltages which initiate flashovers. Alternatively, they may arise from other causes such as birds on overhead lines or mechanical damage to cables etc. Such faults result in an appreciable increase in current and hence in the majority of applications are easily detectable.

Another type of unbalanced fault that can occur on the system is the series or open circuit fault. These can arise from broken conductors, maloperation of single phase switchgear, or single-phasing of fuses. Series faults will not cause an increase in phase current on the system and hence are not readily detectable by standard protection. However, they will produce an unbalance and a resultant level of negative phase sequence current, which can be detected.

It is possible to apply a negative phase sequence overcurrent relay to detect the above condition. However, on a lightly loaded line, the negative sequence current resulting from a series fault condition may be very close to, or less than, the full load steady state unbalance arising from CT errors, load unbalance etc. A negative sequence element therefore would not operate at low load levels.

2.12.1 Setting guidelines

For a broken conductor affecting a single point earthed power system, there will be little zero sequence current flow and the ratio of I2/I1 that flows in the protected circuit will approach 100%. In the case of a multiple earthed power system (assuming equal impedance's in each sequence network), the ratio I2/I1 will be 50%.

In practice, the levels of standing negative phase sequence current present on the system govern this minimum setting. This can be determined from a system study, or by making use of the relay measurement facilities at the commissioning stage. If the latter method is adopted, it is important to take the measurements during maximum system load conditions, to ensure that all single-phase loads are accounted for.

Note that a minimum value of 8% negative phase sequence current is required for successful relay operation.

Since sensitive settings have been employed, it can be expected that the element will operate for any unbalance condition occurring on the system (for example, during a single pole auto-reclose cycle). Hence, a long time delay is necessary to ensure co-ordination with other protective devices. A 60 second time delay setting may be typical.

The example following information was recorded by the relay during commissioning;

Ifull load = 500A

I2 = 50A

therefore the quiescent I2/I1 ratio is given by;

I2/I1 = 50/500 = 0.1

To allow for tolerances and load variations a setting of 20% of this value may be typical: Therefore set I2/I1 = 0.2

In a double circuit (parallel line) application, using a 40% setting will ensure that the broken conductor protection will operate only for the circuit that is affected. Setting 0.4 results in no pick-up for the parallel healthy circuit.

Set I2/I1 Time Delay = 60s to allow adequate time for short circuit fault clearance by time delayed protections.

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2.13 Communication between relays

2.13.1 Optical budgets

When applying any of the P54x range of current differential relays it is important to select the appropriate protection communications interface. This will depend on the fiber used and distance between devices. The following table shows the optical budgets of the available communications interfaces.

	850nm Multi Mode	**1300nm Multi Mode**	**1300nm Single Mode**	**1550nm Single Mode**
Min. transmit output level (average power)	-19.8dBm	-10dBm	-10dBm	-10dBm
Receiver sensitivity (average power)	-25.4dBm	-37dBm	-37dBm	-37dBm
Optical budget	5.6dB	27.0dB	27.0dB	27.0dB
Less safety margin (3dB)	2.6dB	24.0dB	24.0dB	24.0dB
Typical cable loss	2.6dB/km	0.8dB/km	0.4dB/km	0.3dB/km
Max. transmission distance	1km	30.0km	60.0km	80km

The total optical budget is given by transmitter output level minus the receiver sensitivity and will indicate the total allowable losses that can be tolerated between devices. A safety margin of 3dB is also included in the above table. This allows for degradation of the fiber as a result of ageing and any losses in cable joints. The remainder of the losses will come from the fiber itself. The figures given are typical only and should only be used as a guide.

In general, the 1300nm and 1550nm interfaces will be used for direct connections between relays. The 850nm would be used where multiplexing equipment is employed.

2.13.2 Clock source setting

The Clock Source should be set to "Internal" at all system ends, where they are connected by direct optical fiber, as the P54x at each end has to supply the clock.

The Clock Source should be set to "External" at all system ends, where the ends are connected by multiplexer equipment which is receiving a master clock signal from the multiplexer network. It is important that there is a single master clock source on the multiplexer network and that the multiplexer equipment at each end is synchronized to this clock.

Note that this setting is not applicable if IEEE C37.94 mode selected.

2.13.3 Data rate

The data rate for signaling between the two or three ends may be set to either 64kbit/sec or 56kbit/sec as appropriate.

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If there is a direct fiber connection between the ends, the data rate would usually be set to 64kbit/sec, as this gives a slightly faster trip time.

If there is a multiplexer network between the ends, then this will determine the data rate to be used by the P54x system. The electrical interface to the multiplexer (G.703 co-directional, V.35, or X.21) will be provided on either a 64kbit/sec or 56kbit/sec channel, and the P54x at each end must be set to match this data rate.

Generally, North American multiplexer networks are based on 56kbit/sec (and multiples thereof) channels, whereas multiplexer networks in the rest of the world are based on 64kbit/sec (and multiples thereof) channels.

This setting is not applicable if IEEE C37.94 mode selected.

2.14 InterMiCOM^{64} ("Fiber InterMiCOM")

2.14.1 IMx command type

Due to the fast data rate, there is not so much difference in real performance between the three generic modes of teleprotection (Direct Intertrip, Permissive and Blocking), so only two are implemented for InterMiCOM^{64}. Direct Intertripping is available, with the second mode a combined mode for Permissive/Blocking (the latter is named as '*Permissive*' in the menu). To increase the security for Intertripping (Direct transfer tripping), the InterMiCOM^{64} Direct command is issued only when 2 valid consecutive messages are received. The recommended setting is:

- For Blocking schemes set 'Permissive'
- For Permissive scheme set 'Permissive'
- For Transfer (inter)tripping set 'Direct'

The setting files provide independent setting for each of the first 8 commands. Due to the fast data rate, there will be minimal speed difference between the two mode options. Both will give a typical operating time (PSL trigger at the send relay, to PSL state change at the receive relay) as shown below:

Channel Mode Setting	Application	Typical Delay (ms)	Maximum (ms)	Comments
Permissive	Direct Fiber	3 to 7	9	Assuming no repeaters (no source of digital "noise")
	Multiplexed Link	5 to 8 + MUX	12 + MUX	For channel bit error rate up to 1×10^{-3}
Direct Intertrip	Direct Fiber	4 to 8	10	Assuming no repeaters (no source of digital "noise")
	Multiplexed link	6 to 8 + MUX	13 + MUX	For channel bit error rate up to 1×10^{-3}

These figures are for InterMiCOM^{64} used as a standalone feature. For use with differential message, add 2 ms for permissive mode and 4 ms for direct intertrip at 64 Kb/sec.

When using InterMiCOM^{64} to implement Aided Scheme 1 or Aided Scheme 2, it is suggested to assume a conservative worst-case channel delay of **15ms** (pickup and reset delay), for the purposes of blocking and reversal guard calculations. The delay of the multiplexer should be added if applicable, taking into account longer standby path re-routings which might be experienced in the event of self-healing in a SONET/SDH telecomms network.

When using InterMiCOM^{64} as a standalone feature in 3-terminal applications, where fallback to "chain" topology is possible in the event of failure of one communications leg in the triangle, longer times may be experienced. In fallback mode, retransmission of the messages occurs so the path length is doubled. Overall command times to the final end can be doubled.

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2.14.2 IMx fallback mode

When the 'Default' setting is selected, the following 'IMx Default Value' settings are recommended: For Intertripping schemes set **0**, for Blocking schemes set **1**. In Permissive applications, the user may prefer to latch the last healthy received state for a period of time.

3. WORKED EXAMPLE AND OTHER PROTECTION TIPS

3.1 Differential protection setting examples

3.1.1 Differential element

All four settings are user adjustable. This flexibility in settings allows the relay characteristic to be tailored to suit particular sensitivity and CT requirements. To simplify the protection engineer's task, we strongly recommend three of the settings be fixed to:

Is2 = 2.0 pu

k1 = 30%

k2 = 150% (2 terminal applications) or 100% (3 terminal applications)

These settings will give a relay characteristic suitable for most applications. It leaves only the Is1 setting to be decided by the user. The value of this setting should be in excess of any mismatch between line ends, if any, and should also account for line charging current, where necessary.

By considering the circuit shown in Figure 11, the settings for the phase current differential element can be established.

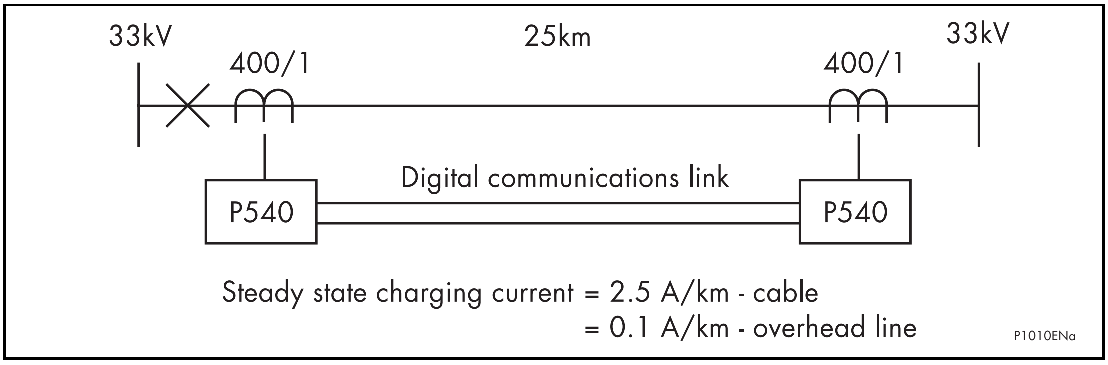

Figure 11: Typical plain feeder circuit

The following settings should be set as follows:

Is2 = 2.0 pu

k1 = 30%

k2 = 150% (for a two terminal application)

This leaves the setting of Is1 to be established.

In the case that voltage inputs are not in place, no facility to account for line charging current is available. The setting of Is1 must therefore be set above 2.5 times the steady state charging current value. In this example, assume a cable is used and there are not VT inputs connected to the relay:

Is1 > 2.5 x Ich

Is1 > 2.5 x (25km x 2.5 A/km)

Is1 > 156.25 A

The line CTs are rated at 400 amps primary. The setting of Is1 must therefore exceed 156.25/400 = 0.391 pu.

Therefore select:

Is1 = 0.4 pu

If VT is connected, a facility exists to overcome the effects of the line charging current. It will be necessary in this case to enter the line positive sequence susceptance value. This can be calculated from the line charging current as follows (assuming a VT ratio of 33kV / 110V):

Ich = 25 x 2.5 A = 62.5A

Susceptance B = ωC = Ich/V

B = 62.5 A/(33/$\sqrt{3}$) kV primary

B = 3.28 x 10-3 S primary

Therefore set:

B = 3.28 mS primary (= 2.46 mS secondary)

Is1 may now be set below the value of line charging current if required, however it is suggested that Is1 is chosen only sufficiently below the charging current to offer the required fault resistance coverage as described in section 2.1.2 Where charging current is low or negligible, the recommended factory default setting of 0.2 In should be applied.

3.1.2 Transformer feeder examples

Ratio correction example:

P543 and P545 relays are suitable for the protection of transformer feeders. An example is shown in Figure 12.

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20MVA Transformer, Dyn1, 33/11kV

HV CT ratio - 400/1

LV CT ratio - 1500/1

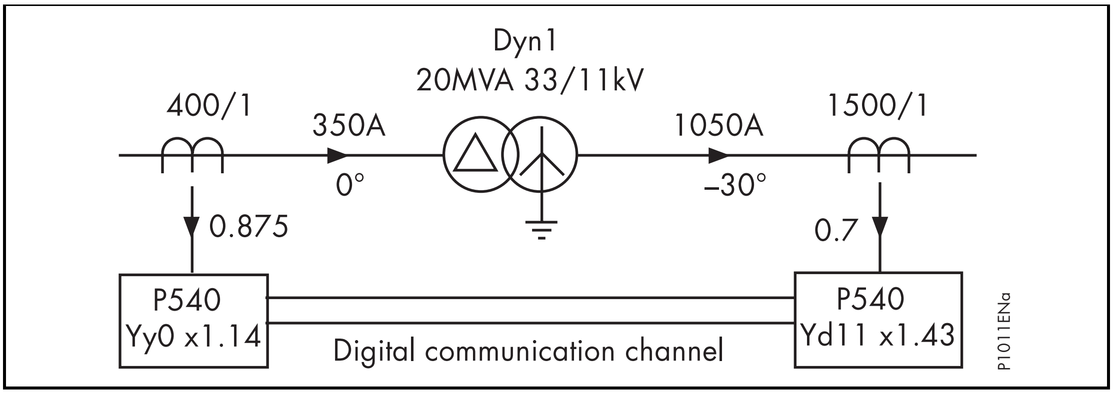

Figure 12: Typical transformer feeder circuit

It is necessary to calculate the required ratio correction factor to apply to the relays' at each line end.

33kV full load current = 20 MVA/(33kV.$\sqrt{3}$) = 350A

Secondary current = 350 x 1/400 = 0.875A

11kV full load current = 20 MVA/(11kV.$\sqrt{3}$) = 1050A

Secondary current = 1050 x 1/1500 = 0.7A

Each of these secondary currents should be corrected to relay rated current; in this case 1A.

HV ratio correction factor 1/0.875 = 1.14 [Setting applied to relay]

LV ratio correction factor 1/0.7 = 1.43 [Setting applied to relay]

When a Star/Delta software interposing CT is chosen, no additional account has to be taken for the $\sqrt{3}$ factor which would be introduced by the delta winding. This is accounted for by the relay.

Phase Correction Example:

Using the same transformer as shown in Figure 12 it is now necessary to correct for the phase shift between the HV and LV windings.

The transformer connection shows that the delta connected high voltage line current leads the low voltage line current by 30°. To ensure that this phase shift does not create a differential current, the phase shift must be corrected in the LV secondary circuit. The LV relay software interposing CT is effectively a winding replica of the main power transformer. It not only provides a +30° phase shift, but also performs the necessary function of filtering out any LV zero sequence current component.

Hence, the HV relay setting requires no phase shift or zero sequence current filtering (as HV winding is delta connected). The LV relay setting requires phase shifting by +30° and also requires zero sequence current filtering (as LV winding is star connected).

Set: HV = Yy0

LV = Yd11 (+30°)

It is important when considering the software ICT connection, to account for both the phase shift and zero sequence current filtering. For example, with the transformer in Figure 12, it would have been possible to provide phase compensation by applying Yd1 and Yy0 settings to the HV and LV relays respectively. Although this provides correct phase shift compensation, no zero sequence current filtering exists on the LV side and hence relay maloperation could occur for an external earth fault.

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3.1.3 Teed feeder example

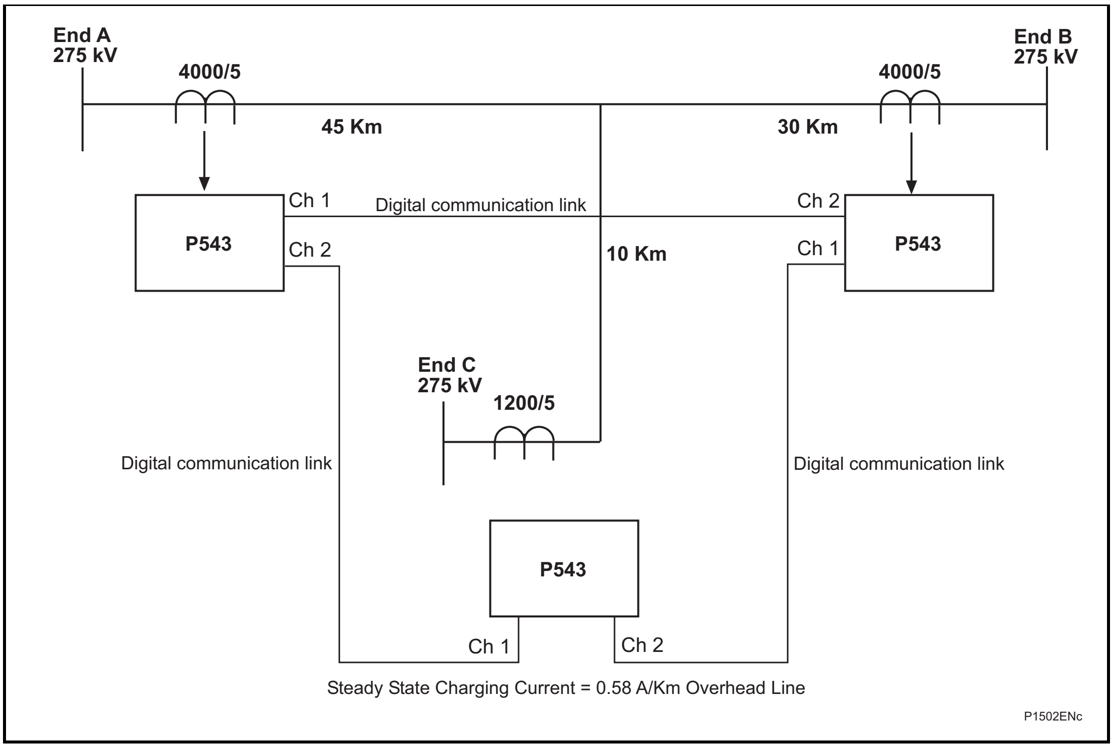

Figure 13: Typical teed feeder application

If there are not VT inputs connected, P54x relays have not facilities to account for charging line current, therefore the setting Is1 must be 2.5 times the steady state charging current.

If VT inputs are connected, there is a facility to overcome the effect of charging current. As mentioned before, it is necessary to enter the positive sequence susceptance value.

Considering the charging current on the circuit shown in Figure 13, the following calculation is done:

– Ich = 0.58 A (45 + 30 + 10) = 49.3 A

– Susceptance = ω C = Ich/V

– B = 49.3 A/(275/ $\sqrt{3}$) kV primary

– B = 0.31 x 10-3 S primary.

As the CT ratio on the three ends are different, it is necessary to apply a correction factor in order to ensure secondary currents balance for all conditions:

To calculate the correction factor (CF), the same primary current must be used even this current is not the expected load transfer for every branch. This will ensure secondary current balance for all conditions.

A good approximation to calculate the correction factor, would be to use the primary rated current of the smallest CT ratio as a base current. In this case we will use the primary rated CT current at End C, in order to correct the secondary currents to the relay rated current:

For End A 1200 A

Secondary current =1200x 5/4000 = 1.5 A

CF = 5/1.5 = 3.33

For End B 1200 A

Secondary current =1200x 5/4000 = 1.5 A

CF = 5/1.5 = 3.33

For End C 1200 A prim = 5 A sec

Secondary current =1200x 5/1200 = 5 A

CF = 5/5 = 1

As mentioned on example 3.1.1, the following settings are recommended:

Is1 = 0.2 In

Is2 = 2 In

K1 = 30%

K2 = 100%

Therefore, settings in secondary values for each end are:

Is1 = 0.2In =1 A

Is2 = 2In =10 A

Note that settings shown in primary values at ends A and B appear different compared with end C. This is not a problem as the currents at ends A and B will be multiplied by the Correction Factor, when the differential calculation is done. There would not be a requirement to alter settings by CF as the relay works in secondary values.

Susceptance settings:

For Ends A and B

With a VT ratio 275kV/110V and CT ratio 4000/5

RCT = 800

RVT = 2500

B = 310 μS

Secondary susceptance = 310 μS x RVT/ RCT = 968 μS

For End C

With a VT ratio 275kV/110V and CT ratio 1200/5

B = 310 μS

Secondary susceptance = 310 μS x RVT/ RCT = 3.22mS sec.

3.1.4 Three winding transformer in zone with different rated CTs example

P543 and P545 relays are suitable for the protection of three winding transformers in zone. An example is shown in Figure 14.

100MVA/100MVA/30MVA Transformer, Ynyn0d1, 400kV/110kV/30kV

HV, 400kV CT ratio - 600/1

MV, 110 kV CT ratio - 1200/1

LV, 30kV CT ratio - 2000/5

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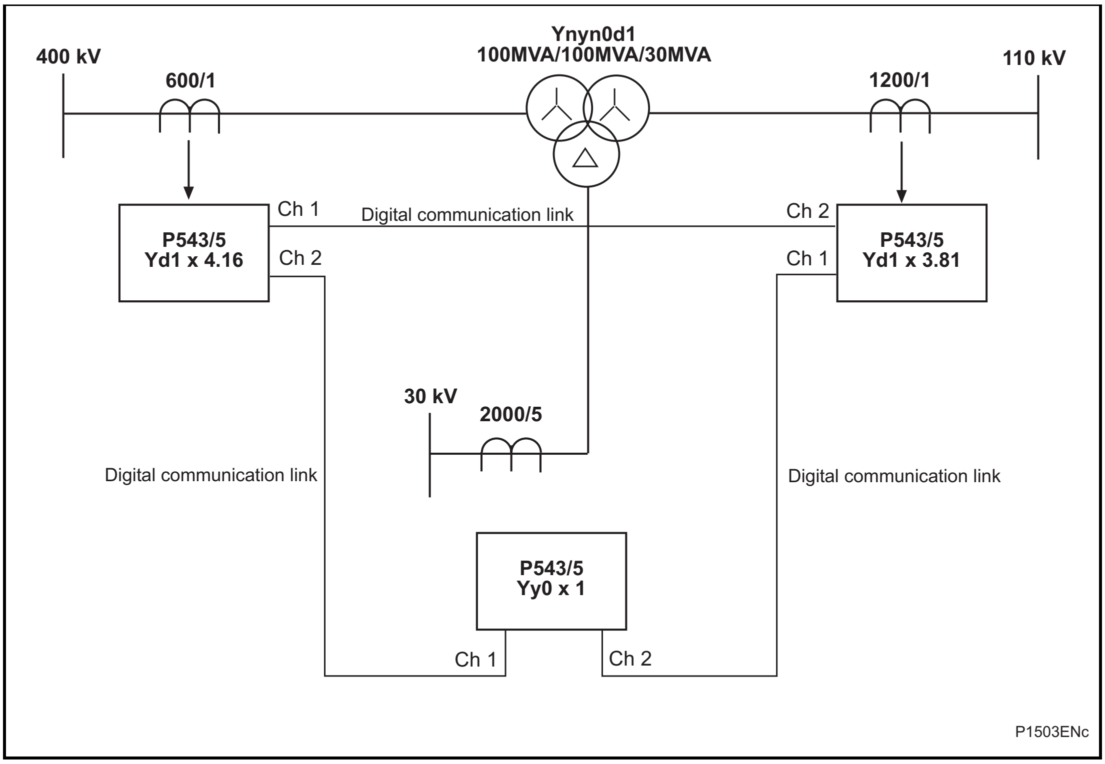

Figure 14: Three winding transformer in zone application

These three relays must be rated differently, i.e. 1A for HV and MV side and 5 A for 30 kV side. This does not present a problem for P54x relays as the digital signals representing the currents are in pu.

It is necessary to calculate the required ratio correction factor (CF) as well as the phase correction factor for each end. To choose the appropriate vector compensation, it is necessary to account for phase current and zero sequence current filtering as explained in example 3.1.2.

To calculate the correction factor range, it is necessary to use the same MVA base for the three sides of the transformer although the third winding actually has a lower rated MVA. This is to ensure secondary current balance for all conditions.

For HV side:	100 MVA/ (400 kV.√3)	=	144.34 A.
	Secondary current	=	144.34 x 1/600 = 0.24 A
For MV side:	100 MVA/ (110 kV.√3)	=	524.86 A.
	Secondary current	=	524.86 x 1/1200 = 0.44 A
For LV side:	100 MVA/ (30 kV.√3)	=	1924.5 A.
	Secondary current	=	1924.5x 5/2000 = 4.81 A

Each secondary current should be corrected to relay rated current, in this case 1A for HV and MV side and 5 A for 30 kV side

HV ratio correction factor = 1/0.24 = 4.16

MV ratio correction factor = 1/0.44 = 2.29

LV ratio correction factor = 5/4.81 = 1.04

To choose the vector compensation connection, it should be noted that the Wye connected HV line is in phase with the MV line current and leads the LV line current by 30^{o}. Therefore for LV side, the phase shift must be compensated.

To account for the zero sequence current filtering in the case of an external earth fault, it is necessary to connect the Wye connected power transformer windings to an interposing current transformer (internal relay ICT) to trap the zero sequence current (the secondary side being connected delta).

To account for both vector compensation and zero sequence current filtering, the following vectorial compensation setting is recommended:

– For HV side = Yd1 (-30 deg)

– For MV side = Yd1 (-30 deg)

– For LV side = Yy0 (0 deg)

Note that it is not necessary to include the √3 factor in the calculation as this is incorporated in the relay algorithm.

P543 and P545 relays are suitable for transformer applications, as such an inrush restrain is provided on these relay models. By enabling inrush restrain, an additional current differential high setting (Id High set) becomes enable.

When the inrush restrain feature is enabled, it is necessary that this function is enabled in the relay at each line end (3 ends).

For the differential calculation the same recommended settings for the previous examples are recommended:

– Is1 = 0.2 In

– Is2 = 2 In

– K1 = 30%

– K2 = 100%

Therefore, settings in secondary values are:

For relays rated to 1A (HV and MV sides) Is1 = 200 mA and Is2 = 2 A

For relay rated to 5A (LV side) Is1 = 1A and Is2 = 10 A

For the current differential high setting (Id High set) the setting must be in excess of the anticipated inrush current after ratio correction. Assuming that maximum inrush is 12 times the nominal transformer current, it would be safe to set the relays at 15 times the nominal current, therefore the setting would be:

– Id high set : for HV side = 15In = 15A

for MV side = 15In = 15A

for LV side = 15In = 75 A

3.2 Distance protection setting example

3.2.1 Objective

To protect the 100km double circuit line between Green Valley and Blue River substations using a MiCOM P54x in distance POR Permissive Overreach mode and to set the relay at Green Valley substation, shown in Figure 15. It is assumed that mho characteristics will be used.

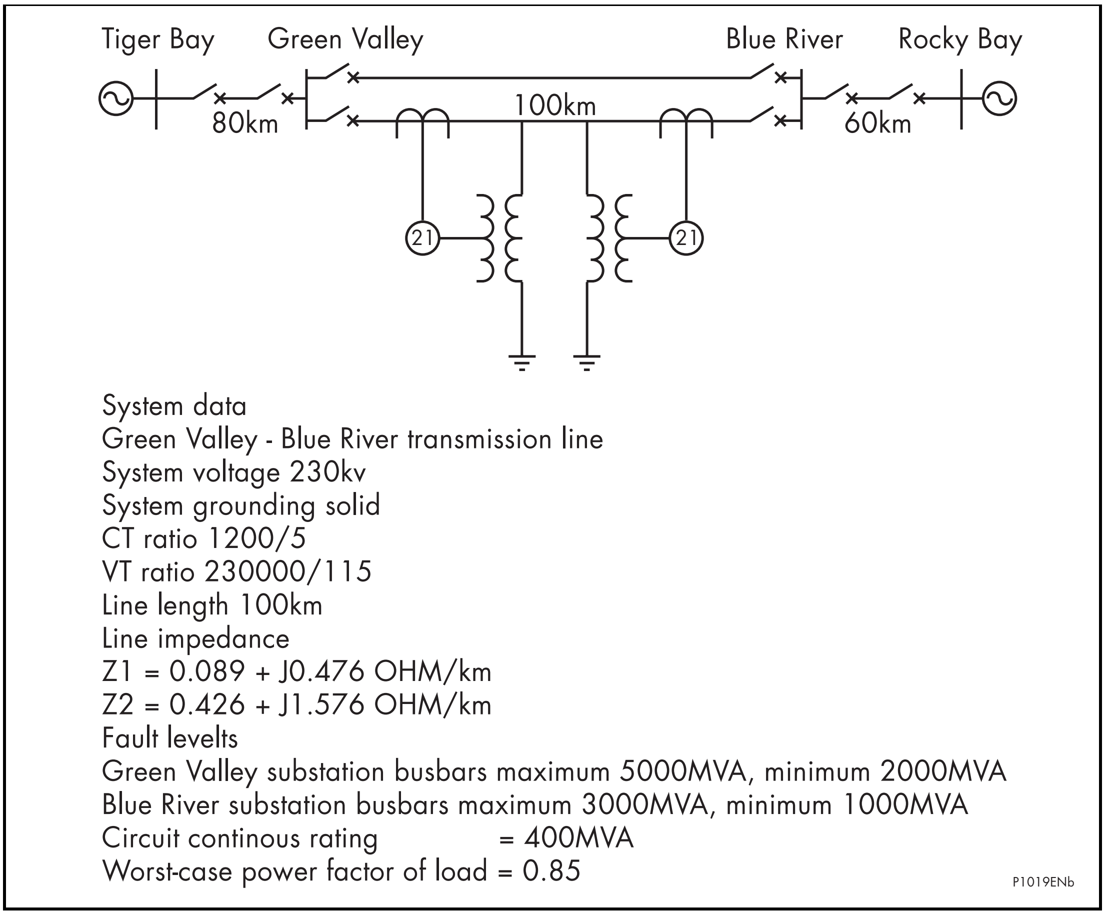

Figure 15: System assumed for worked example

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3.2.2 System data

Line length: **100km**

Line impedances: Z_1 = 0.089 + j0.476 = 0.484 $\angle$79.4° Ω/km

Z_0 = 0.426 + j1.576 = 1.632 $\angle$74.8° Ω/km

Z_0/Z_1 = 3.372 $\angle$-4.6°

CT ratio: 1 200/5

VT ratio: 230 000/115

3.2.3 Relay settings

It is assumed that Zone 1 Extension is not used and that only three forward zones are required. Settings on the relay can be performed in primary or secondary quantities and impedances can be expressed as either polar or rectangular quantities (menu selectable). For the purposes of this example, secondary quantities are used.

3.2.4 Line impedance

Ratio of secondary to primary impedance $= \frac{1200 / 5}{230000 / 115} = 0.12$

Line impedance secondary = ratio CT/VT x line impedance primary.

Line Impedance = 100 x 0.484 $\angle$79.4° (primary) x 0.124

= 5.81 $\angle$79.4° Ω secondary.

Select Line Angle = 80° for convenience.

Therefore set Line Impedance and Line Angle: = 5.81 $\angle$80° Ω secondary.

3.2.5 Residual compensation for ground fault elements

The residual compensation factor can be applied independently to certain zones if required. This feature is useful where line impedance characteristics change between sections or where hybrid circuits are used. In this example, the line impedance characteristics do not change and as such a common KZN factor can be applied to each zone. This is set as a ratio “kZN Res. Comp”, and an angle “kZN Angle”:

kZN Res. Comp, $|kZN|$ = (Z0 - Z1) / 3Z1 i.e.: As a ratio

kZN Angle, $\angle$kZN = $\angle$ (Z0 - Z1) / 3Z1 Set in degrees

ZL0 - ZL1 = (0.426 + j1.576) - (0.089 + j0.476)

= 0.337 + j1.1

= 1.15 $\angle$72.9°

$$kZN = \frac{1.15\angle 72.9°}{3\times 0.484\angle 79.4°} = 0.79\ \angle{-6.5°}$$

Therefore, select:

kZN Res. Comp = 0.7

kZN Angle = - 6.5°

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3.2.6 Zone 1 phase and ground reach settings

Required Zone 1 reach is to be 80% of the line impedance between Green Valley and Blue River substations.

Setting the Relay in the SIMPLE setting mode (recommended):

– Set Zone 1 Ph and Zone 1 Gnd reach = 80%

From this the relay will automatically calculate the required ohmic reaches, or they can be entered manually in the ADVANCED mode, as follows:

Required Zone 1 reach = $0.8 \times 100 \times 0.484 \angle 79.4° \times 0.12$

Z1 = $4.64 \angle 79.4°\ \Omega$ secondary

The Line Angle = 80°

Therefore actual Zone 1 reach, Z1 = $4.64 \angle 80°\ \Omega$ secondary.

3.2.7 Zone 2 phase and ground reach settings

Required Zone 2 impedance = (Green Valley-Blue River) line impedance + 50% (Blue River-Rocky Bay) line impedance

Z2 = $(100+30) \times 0.484 \angle 79.4° \times 0.12 = 7.56 \angle 79.4°\ \Omega$ secondary.

The Line Angle = 80°

Actual Zone 2 reach setting = $7.56 \angle 80°\ \Omega$ secondary

Alternatively, in SIMPLE setting mode, this reach can be set as a percentage of the protected line. Typically a figure of at least 120% is used.

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3.2.8 Zone 3 phase and ground reach settings

Required Zone 3 forward reach = (Green Valley-Blue River + Blue River-Rocky Bay) x 1.2

= $(100+60) \times 1.2 \times 0.484 \angle 79.4° \times 0.12$

Z3 = $11.15 \angle 79.4°$ ohms secondary

Actual Zone 3 forward reach setting = $11.16 \angle 80°$ ohms secondary

Alternatively, in SIMPLE setting mode, this reach can be set as a percentage of the protected line.

3.2.9 Zone 3 reverse reach

In the absence of other special requirements, Zone 3 can be given a small reverse reach setting, of Z3' = 10%. This is acceptable because the protected line length is > 30km.

Zone 4 Reverse Settings with POR and BLOCKING schemes

Where zone 4 is used to provide reverse directional decisions for Blocking or Permissive Overreach schemes, zone 4 must reach further behind the relay than zone 2 for the remote relay. This can be achieved by setting: Z4 ≥ ((Remote zone 2 reach) x 120%), where mho characteristics are used.

Remote Zone 2 reach = (Blue River-Green Valley) line impedance + 50% (Green Valley-Tiger Bay) line impedance

= $(100+40) \times 0.484 \angle 79.4° \times 0.12$

= $8.13 \angle 79.4°\ \Omega$ secondary

$Z4 \geq ((8.13 \angle 79.4°) \times 120\%) - (5.81 \angle 79.4°)$

$= 3.95 \angle 79.4°$

Minimum zone 4 reverse reach setting $= 3.96 \angle 80°$ ohms secondary

3.2.10 Load avoidance

The maximum full load current of the line can be determined from the calculation:

$I_{FLC} = [(\text{Rated } MVA_{FLC}) / (\sqrt{3} \times \text{Line kV})]$

In practice, relay settings must allow for a level of overloading, typically a maximum current of 120% IFLC prevailing on the system transmission lines. Also, for a double circuit line, during the auto-reclose dead time of fault clearance on the adjacent circuit, twice this level of current may flow on the healthy line for a short period of time. Thus, the circuit current loading could be 2.4 x IFLC.

With such a heavy load flow, the system voltage may be depressed, typically with phase voltages down to 90% of Vn nominal.

Allowing for a tolerance in the measuring circuit inputs (line CT error, VT error, relay tolerance, and safety margin), this results in a load impedance which might be 3 times the expected “rating”.

To avoid the load, the blinder impedance needs to be set:

$Z \leq$ (Rated phase-ground voltage Vn) / (IFLC x 3)

$= (115/\sqrt{3})$ / (IFLC x 3)

Set the V< Blinder voltage threshold at the recommended 70% of Vn = 66.4 x 0.7 = 45V.

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3.2.11 Additional settings for quadrilateral applications

3.2.11.1 Phase fault resistive reaches (Rph)

In primary impedance terms, RPh reaches must be set to cover the maximum expected phase-to-phase fault resistance. Ideally, RPh must be set greater than the maximum fault arc resistance for a phase-phase fault, calculated as follows:

$Ra = (28710 \times L)/If^{1.4}$

Where:

If = Minimum expected phase-phase fault current (A);

L = Maximum phase conductor separation (m);

Ra = Arc resistance, calculated from the van Warrington formula (Ω).

Typical figures for Ra (primary Ω) are given in the table below, for different values of minimum expected phase fault current.

Conductor Spacing (m)	**Typical System Voltage (kV)**	**If = 1kA**	**If = 2kA**	**If = 3kA**
4	110 - 132	7.2Ω	2.8Ω	1.6Ω
8	220 - 275	14.5Ω	5.5Ω	3.1Ω
11	380 - 400	19.9Ω	7.6Ω	4.3Ω

Note that dual-end infeed effects will make a fault resistance appear higher, because each relay cannot measure the current contribution from the remote line end. The apparent fault resistance increase factor could be 2 to 8 times the calculated resistance. Therefore it is recommended that the Zone resistive reaches are set to say, 4 times the primary arc resistance calculation.

In the example, the minimum phase fault level is 1000MVA. This is equivalent to an effective short-circuit fault feeding impedance of:

Z = kV 2/MVA = 2302/1000 = 53Ω (primary)

The lowest phase fault current level is equivalent to:

Ifault = (MVA x 1000)/(√3 x kV)

= (1000 x 1000)/(√3 x 230)

= 2.5kA

And this fault current in the van Warrington formula would give an arc resistance of:

Ra = 4Ω

As this impedance is relatively small compared to the value "Z" calculated above, there is no need to perform an iterative equation to work out the actual expected Ifault (which would in reality be lower due to the added Ra arc resistance in the fault loop). It will suffice to increase the calculated Ra by the recommended factor of four, and a little extra to account for the fault current being lower than that calculated. So, in this case use a minimum setting of 5 x Ra, which is 20Ω primary.

It is obvious that the setting could easily be set above 20Ω on the primary system (perhaps following the rule of thumb formula in section 2.2.7). Typically, all zone resistive reaches would be set greater than this 20Ω primary figure, and ideally less than the load impedance (see "load avoidance" section).

3.2.11.2 Ground fault resistive reaches (RGnd)

Fault resistance would comprise arc-resistance and tower footing resistance. A typical resistive reach coverage setting would be 40Ω on the primary system.

For high resistance earth faults, the situation may arise where no distance elements could operate. In this case it will be necessary to provide supplementary earth fault protection, for example using the relay Channel Aided DEF protection. In such cases it is not essential to set large resistive reaches for ground distance, and then RGnd can be set according to the rule of thumb formula in section 2.2.8.

3.3 Teed feeder protection

The application of distance relays to three terminal lines is fairly common. However, several problems arise when applying distance protection to three terminal lines.

3.3.1 The apparent impedance seen by the distance elements

Figure 16 shows a typical three terminal line arrangement. For a fault at the busbars of terminal B the impedance seen by a relay at terminal A will be equal to:

Za = Zat + Zbt + [Zbt.(Ic/Ia)]

Relay A will underreach for faults beyond the tee-point with infeed from terminal C. When terminal C is a relatively strong source, the underreaching effect can be substantial. For a zone 2 element set to 120% of the protected line, this effect may result in non-operation of the element for internal faults. This not only effects time delayed zone 2 tripping but also channel-aided schemes. Where infeed is present, it will be necessary for Zone 2 elements at all line terminals to overreach both remote terminals with allowance for the effect of tee-point infeed. Zone 1 elements must be set to underreach the true impedance to the nearest terminal without infeed. Both these requirements can be met through use of the alternative setting groups.

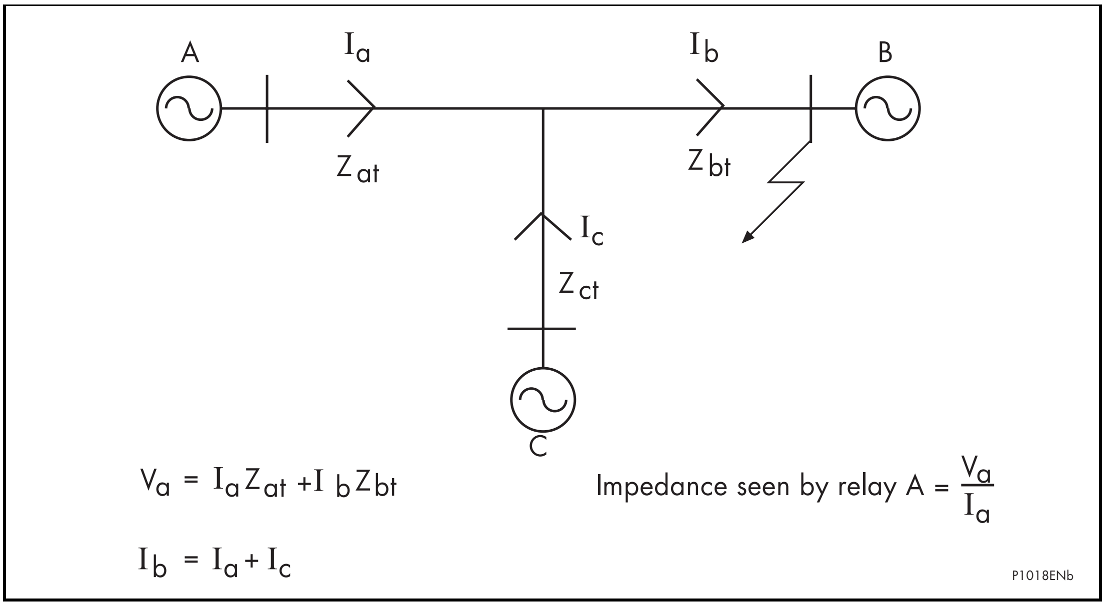

Figure 16: Teed feeder application - apparent impedances seen by RELAY

3.3.2 Permissive overreach schemes

To ensure operation for internal faults in a POR scheme, the relays at the three terminals should be able to see a fault at any point within the protected feeder. This may demand very large zone 2 reach settings to deal with the apparent impedances seen by the relays.

A POR scheme requires the use of two signaling channels. A permissive trip can only be issued upon operation of zone 2 and receipt of a signal from both remote line ends. The requirement for an 'AND' function of received signals must be realized through use of contact logic external to the relay, or the internal Programmable Scheme Logic. Although a POR scheme can be applied to a three terminal line, the signaling requirements make its use unattractive.

3.3.3 Permissive underreach schemes

For a PUR scheme, the signaling channel is only keyed for internal faults. Permissive tripping is allowed for operation of zone 2 plus receipt of a signal from either remote line end. This makes the signaling channel requirements for a PUR scheme less demanding than for a POR scheme. A common power line carrier (PLC) signaling channel or a triangulated signaling arrangement can be used. This makes the use of a PUR scheme for a teed feeder a more attractive alternative than use of a POR scheme.

The channel is keyed from operation of zone 1 tripping elements. Provided at least one zone 1 element can see an internal fault then aided tripping will occur at the other terminals if the overreaching zone 2 setting requirement has been met. There are however two cases where this is not possible:

– Figure 17 (i) shows the case where a short tee is connected close to another terminal. In this case, zone 1 elements set to 80% of the shortest relative feeder length do not overlap. This leaves a section not covered by any zone 1 element. Any fault in this section would result in zone 2 time delayed tripping.

– Figure 17 (ii) shows an example where terminal 'C' has no infeed. Faults close to this terminal will not operate the relay at 'C' and hence the fault will be cleared by the zone 2 time-delayed elements of the relays at 'A' and 'B'.

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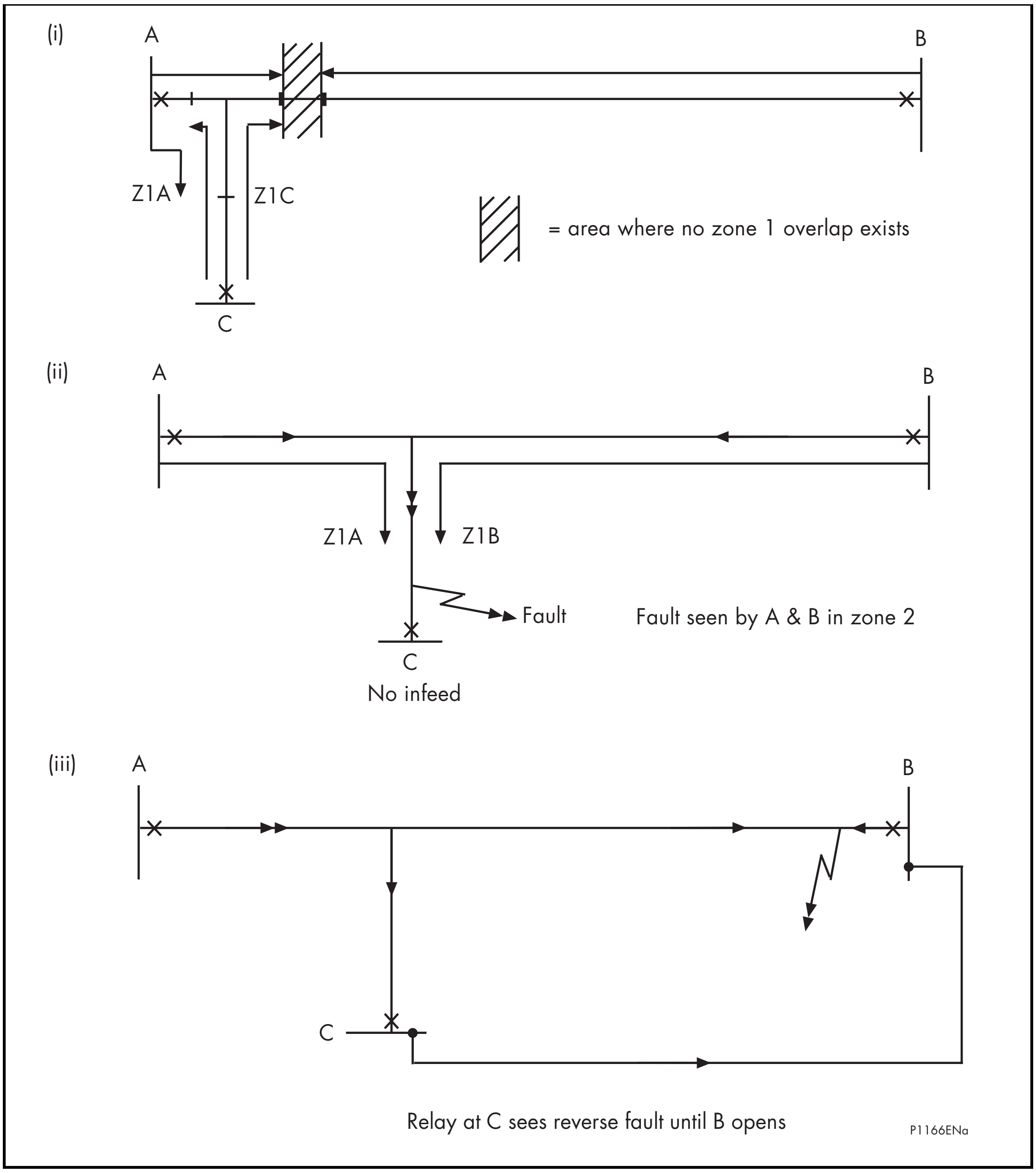

Figure 17: Teed feeder applications

Figure 17 (iii) illustrates a further difficulty for a PUR scheme. In this example current is outfed from terminal 'C' for an internal fault. The relay at 'C' will therefore see the fault as reverse and not operate until the breaker at 'B' has opened; i.e. sequential tripping will occur.

3.3.4 Blocking schemes

Blocking schemes are particularly suited to the protection of teed feeders, since high speed operation can be achieved where there is no current infeed from one or more terminals. The scheme also has the advantage that only a common simplex channel or a triangulated simplex channel is required.

The major disadvantage of blocking schemes is highlighted in Figure 17 (iii) where fault current is outfed from a terminal for an internal fault condition. Relay 'C' sees a reverse fault condition. This results in a blocking signal being sent to the two remote line ends, preventing tripping until the normal zone 2 time delay has expired.

3.4 VT connections

3.4.1 Open delta (vee connected) VT's

The MiCOM P54x relay can be used with vee connected VTs by connecting the VT secondary's to:

C19, C20 and C21 input terminals, with the C22 input left unconnected for P543 and P544

D19, D20 and D21 input terminals, with the D22 input left unconnected for P545 and P546

This type of VT arrangement cannot pass zero-sequence (residual) voltage to the relay, or provide any phase to neutral voltage quantities. Therefore any protection that is dependent upon phase to neutral voltage measurements should be disabled.

The ground directional comparison elements, ground distance elements, neutral voltage displacement (residual overvoltage) and CT supervision all use phase-to-neutral voltage signals for their operation and should be disabled. The DEF elements should be selected for negative sequence polarization to avoid the use of phase-to-neutral voltages. Under and over voltage protection can be set as phase-to-phase measuring elements, whereas all other protection elements should remain operational.

The accuracy of the single phase voltage measurements can be impaired when using vee connected VT's. The relay attempts to derive the phase to neutral voltages from the phase to phase voltage vectors. If the impedance of the voltage inputs were perfectly matched the phase to neutral voltage measurements would be correct, provided the phase to phase voltage vectors were balanced. However, in practice there are small differences in the impedance of the voltage inputs, which can cause small errors in the phase to neutral voltage measurements. This may give rise to an apparent residual voltage. This problem also extends to single phase power measurements that are also dependent upon their respective single phase voltages.

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The phase to neutral voltage measurement accuracy can be improved by connecting 3, well matched, load resistors between the phase voltage inputs (C19, C20, C21 for P543 and P544 or D19, D20, D21 for P545 and P546) and neutral C22 for P543 and P544 or D22 for P545 and P546 thus creating a 'virtual' neutral point. The load resistor values must be chosen so that their power consumption is within the limits of the VT. It is recommended that 10kΩ ±1% (6W) resistors are used for the 110V (Vn) rated relay, assuming the VT can supply this burden.

3.4.2 VT single point earthing

The MiCOM P54x will function correctly with conventional 3 phase VT's earthed at any one point on the VT secondary circuit. Typical earthing examples being neutral earthing, or B-phase (UK: "yellow phase" earthing).

3.5 Trip circuit supervision (TCS)

The trip circuit, in most protective schemes, extends beyond the relay enclosure and passes through components such as fuses, links, relay contacts, auxiliary switches and other terminal boards. This complex arrangement, coupled with the importance of the trip circuit, has led to dedicated schemes for its supervision.

Several trip circuit supervision scheme variants are offered. Although there are no dedicated settings for TCS, in the MiCOM P54x the following schemes can be produced using the programmable scheme logic (PSL). A user alarm is used in the PSL to issue an alarm message on the relay front display. If necessary, the user alarm can be re-named using the menu text editor to indicate that there is a fault with the trip circuit.

3.5.1 TCS scheme 1

3.5.1.1 Scheme description

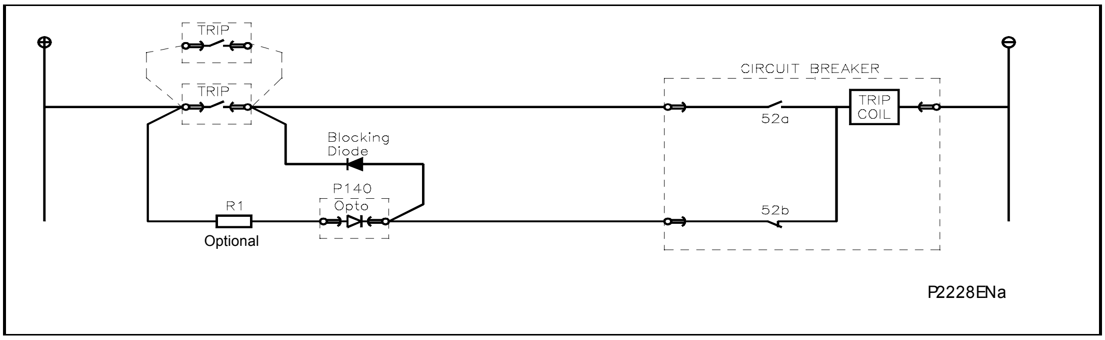

Figure 18: TCS scheme 1

This scheme provides supervision of the trip coil with the breaker open or closed, however, pre-closing supervision is not provided. This scheme is also incompatible with latched trip contacts, as a latched contact will short out the opto for greater than the recommended DDO timer setting of 400ms. If breaker status monitoring is required a further 1 or 2 opto inputs must be used. Note, a 52a CB auxiliary contact follows the CB position and a 52b contact is in the opposite state.

When the breaker is closed, supervision current passes through the opto input, blocking diode and trip coil. When the breaker is open current still flows through the opto input and into the trip coil via the 52b auxiliary contact. Hence, no supervision of the trip path is provided whilst the breaker is open. Any fault in the trip path will only be detected on CB closing, after a 400ms delay.

Resistor R1 is an optional resistor that can be fitted to prevent mal-operation of the circuit breaker if the opto input is inadvertently shorted, by limiting the current to <60mA. The resistor should not be fitted for auxiliary voltage ranges of 30/34 volts or less, as satisfactory operation can no longer be guaranteed. The table below shows the appropriate resistor value and voltage setting (OPTO CONFIG menu) for this scheme.

This TCS scheme will function correctly even without resistor R1, since the opto input automatically limits the supervision current to less that 10mA. However, if the opto is accidentally shorted the circuit breaker may trip.

Auxiliary Voltage (Vx)	Resistor R1 (ohms)	Opto Voltage Setting with R1 Fitted
48/54	1.2k	24/27
110/250	2.5k	48/54
220/250	5.0k	110/125

Note: When R1 is not fitted the opto voltage setting must be set equal to supply voltage of the supervision circuit.

3.5.1.2 Scheme 1 PSL

Figure 19 shows the scheme logic diagram for the TCS scheme 1. Any of the available opto inputs can be used to indicate whether or not the trip circuit is healthy. The delay on drop off timer operates as soon as the opto is energized, but will take 400ms to drop off / reset in the event of a trip circuit failure. The 400ms delay prevents a false alarm due to voltage dips caused by faults in other circuits or during normal tripping operation when the opto input is shorted by a self-reset trip contact. When the timer is operated the NC (normally closed) output relay opens and the LED and user alarms are reset.

The 50ms delay on pick-up timer prevents false LED and user alarm indications during the relay power up time, following an auxiliary supply interruption.

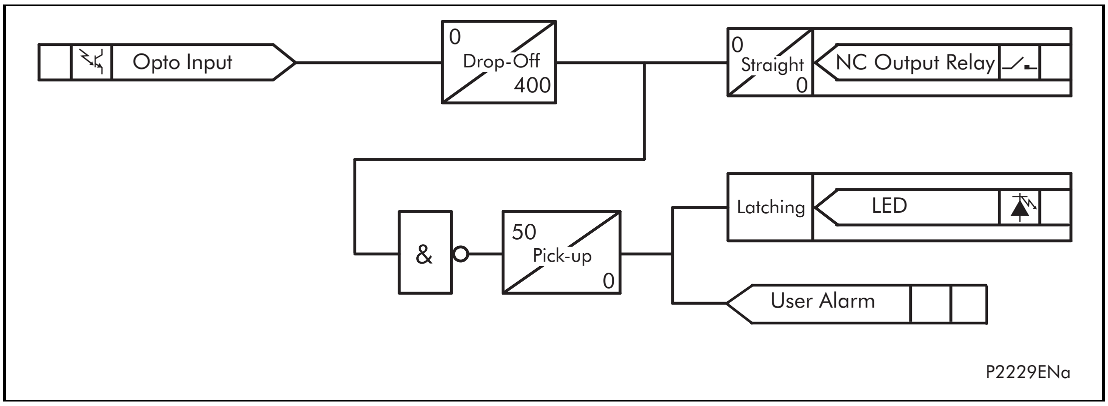

Figure 19: PSL for TCS schemes 1 and 3

3.5.2 TCS scheme 2

3.5.2.1 Scheme description

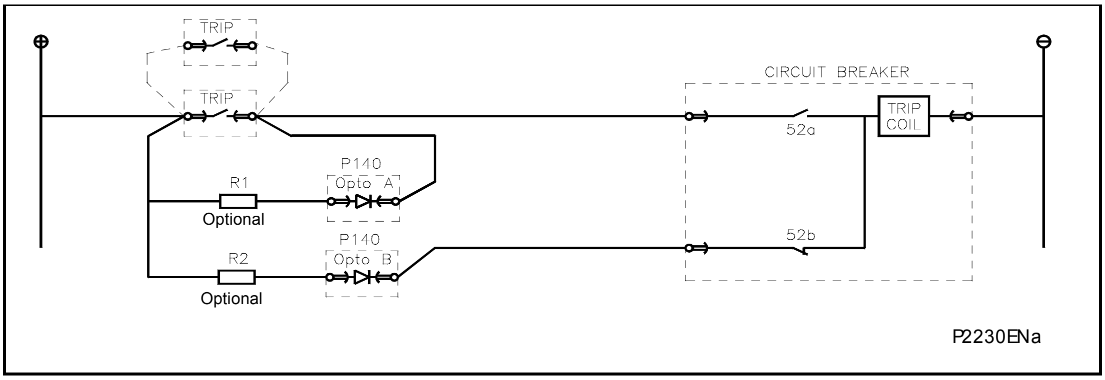

Figure 20: TCS scheme 2

Much like scheme 1, this scheme provides supervision of the trip coil with the breaker open or closed and also does not provide pre-closing supervision. However, using two opto inputs allows the relay to correctly monitor the circuit breaker status since they are connected in series with the CB auxiliary contacts. This is achieved by assigning Opto A to the 52a contact and Opto B to the 52b contact. Provided the "Circuit Breaker Status" is set to "52a and 52b" (CB CONTROL column) the relay will correctly monitor the status of the breaker. This scheme is also fully compatible with latched contacts as the supervision current will be maintained through the 52b contact when the trip contact is closed.

When the breaker is closed, supervision current passes through opto input A and the trip coil. When the breaker is open current flows through opto input B and the trip coil. As with scheme 1, no supervision of the trip path is provided whilst the breaker is open. Any fault in the trip path will only be detected on CB closing, after a 400ms delay.

As with scheme 1, optional resistors R1 and R2 can be added to prevent tripping of the CB if either opto is shorted. The resistor values of R1 and R2 are equal and can be set the same as R1 in scheme 1.

3.5.2.2 Scheme 2 PSL

The PSL for this scheme (Figure 21) is practically the same as that of scheme 1. The main difference being that both opto inputs must be off before a trip circuit fail alarm is given.

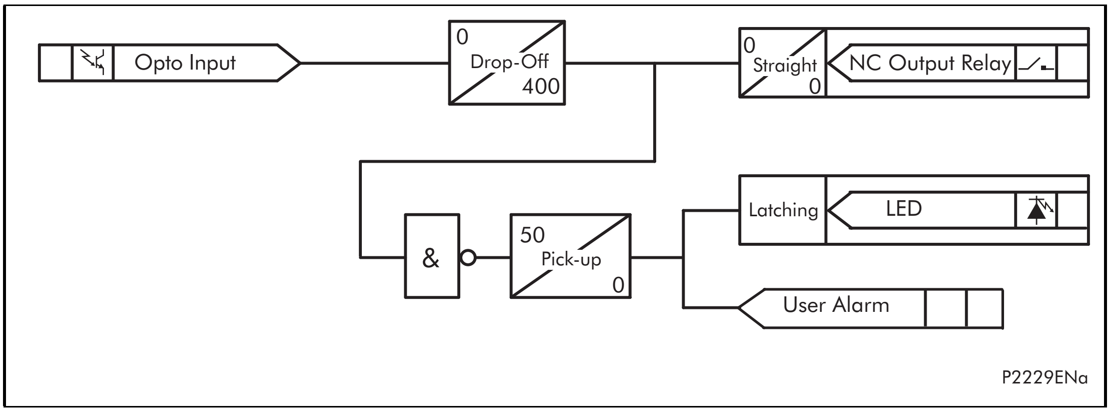

Figure 21: PSL for TCS scheme 2

3.5.3 TCS scheme 3

3.5.3.1 Scheme description

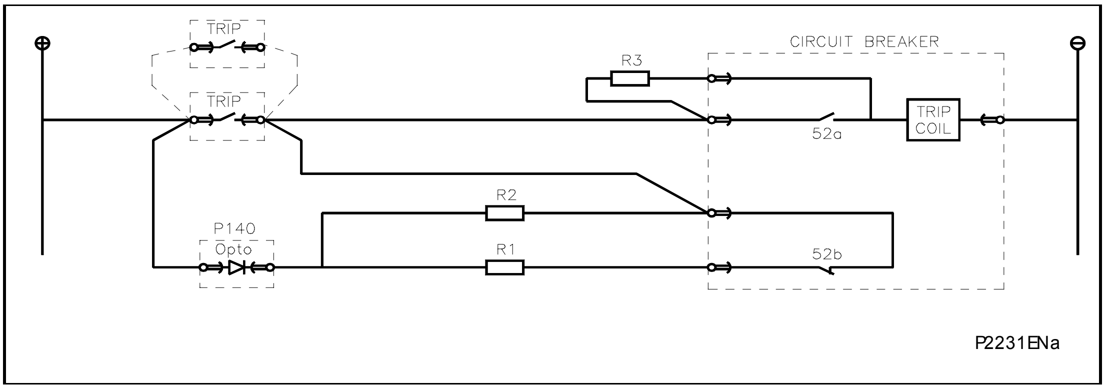

Figure 22: TCS scheme 3

Scheme 3 is designed to provide supervision of the trip coil with the breaker open or closed, but unlike schemes 1 and 2, it also provides pre-closing supervision. Since only one opto input is used, this scheme is not compatible with latched trip contacts. If circuit breaker status monitoring is required a further 1 or 2 opto inputs must be used.

When the breaker is closed, supervision current passes through the opto input, resistor R2 and the trip coil. When the breaker is open current flows through the opto input, resistors R1 and R2 (in parallel), resistor R3 and the trip coil. Unlike schemes 1 and 2, supervision current is maintained through the trip path with the breaker in either state, thus giving full pre-closing supervision.

As with schemes 1 and 2, resistors R1 and R2 are used to prevent false tripping, if the opto-input is accidentally shorted. However, unlike the other two schemes, this scheme is dependent upon the position and value of these resistors. Removing them would result in incomplete trip circuit monitoring. The table below shows the resistor values and voltage settings required for satisfactory operation.

Auxiliary Voltage (Vx)	Resistor R1 & R2 (ohms)	Resistor R3 (ohms)	Opto Voltage Setting
48/54	1.2k	0.6k	24/27
110/250	2.5k	1.2k	48/54
220/250	5.0k	2.5k	110/125

Note: Scheme 3 is not compatible with auxiliary supply voltages of 30/34 volts and below.

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3.5.3.2 Scheme 3 PSL

The PSL for scheme 3 is identical to that of scheme 1 (see Figure 19).

4. APPLICATION OF NON PROTECTION FUNCTIONS

4.1 Single and three phase auto-reclosing

4.1.1 Time delayed and high speed auto-reclosing

Note: Auto-reclose is not available in P544 and P546.

An analysis of faults on any overhead line network has shown that 80-90% are transient in nature.

In the majority of fault incidents, if the faulty line is immediately tripped out, and time is allowed for the fault arc to de-ionize, reclosure of the circuit breakers will result in the line being successfully re-energized. Auto-reclose schemes are employed to automatically reclose a switching device a set time after it has been opened due to operation of protection, where transient and semi-permanent faults are prevalent.

The principal benefit gained by the application of auto-reclosing to overhead line feeders is improved supply continuity and possibly reduced costs since fewer personnel may be required. On some systems the application of high speed auto-reclose may permit a higher level of power transfer while retaining transient stability for most faults which are likely to occur. High speed single phase auto-reclosure can offer increased benefits over high speed three phase auto-reclosure in terms of a higher power transfer limit and reduced stress on reclosing.

4.1.2 Auto-reclose logic operating sequence

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The standard scheme logic is configured to permit control of one circuit breaker.
Auto-reclosure of two circuit breakers in a 1½ circuit breaker scheme is not supported by the standard logic (although PSL schemes to allow such operations do exist - contact your local Schneider Electric support team for advice).

For high speed auto-reclose only the instantaneous protection would normally be set to initiate auto-reclose. This is because for best results when applying high speed auto-reclose to improve a system stability limit, it is important that the fault should be cleared as quickly as possible from both line ends.

4.1.3 Setting guidelines

4.1.3.1 CB healthy

This check can be disabled by not allocating an opto input to this function, and <u>deliberate application of a logic “1” onto this DDB signal within the PSL</u>. Assigning a PSL gate with no inputs and an inverted output will mean that the signal is always high, and the circuit breaker deemed to be “healthy”. Alternatively, it is possible to energize the CB healthy opto input from a circuit breaker open auxiliary contact (52b).

4.1.3.2 Number of shots

An important consideration is the ability of the circuit breaker to perform several trip close operations in quick succession and the effect of these operations on the maintenance period.

The fact that 80 - 90% of faults are transient highlights the advantage of single shot schemes. If statistical information for the power system shows that a moderate percentage of faults are semi-permanent, further DAR shots may be used provided that system stability is not threatened. Note that DAR shots will always be three pole.

4.1.3.3 Dead timer setting

High speed auto-reclose may be required to maintain stability on a network with two or more power sources. For high speed auto-reclose the system disturbance time should be minimized by using fast protection, <30 ms, such as distance or feeder differential protection and fast circuit breakers <60 ms. For stability between two sources a system dead time of

≤300 ms may typically be required. The minimum system dead time considering just the CB is the trip mechanism reset time plus the CB closing time.

Minimum relay dead time settings are governed primarily by two factors:

– Time taken for de-ionization of the fault path

– Circuit breaker characteristics

Also it is essential that the protection fully resets during the dead time, so that correct time discrimination will be maintained after reclosure onto a fault. For high speed auto-reclose instantaneous reset of protection is required.

For highly interconnected systems synchronism is unlikely to be lost by the tripping out of a single line. Here the best policy may be to adopt longer dead times, to allow time for power swings on the system resulting from the fault to settle.

4.1.3.4 De-ionizing time

The de-ionization time of a fault arc depends on circuit voltage, conductor spacing, fault current and duration, wind speed and capacitive coupling from adjacent conductors. As circuit voltage is generally the most significant, minimum de-ionizing times can be specified as in Table 30 below.

Note: For single pole HSAR, the capacitive current induced from the healthy phases can increase the time taken to de-ionize fault arcs.

Line Voltage (kV)	Minimum De-Energization Time (s)
66	0.1
110	0.15
132	0.17
220	0.28
275	0.3
400	0.5

Minimum Fault Arc De-Ionizing Time (Three Pole Tripping)

AP

4.1.3.5 Example minimum dead time calculation

The following circuit breaker and system characteristics are to be used:

CB Operating time (Trip coil energized → Arc interruption): 50ms (a);

CB Opening + Reset time (Trip coil energized → Trip mechanism reset): 200ms (b);

Protection reset time: < 80ms (c);

CB Closing time (Close command → Contacts make): 85ms (d).

De-ionizing time for 220kV line:

280ms (e) for a three phase trip. (560ms for a single pole trip).

The minimum relay dead time setting is the greater of:

(a) + (c) = 50 + 80 = 130ms, to allow protection reset;

(a) + (e) - (d) = 50 + 280 - 85 = 245ms, to allow de-ionizing (three pole);

= 50 + 560 - 85 = 525ms, to allow de-ionizing (single pole).

In practice a few additional cycles would be added to allow for tolerances, so Dead Time 1 could be chosen as ≥ 300ms, and 1Pole Dead Time could be chosen as ≥ 600ms. The overall system dead time is found by adding (d) to the chosen settings, and then subtracting (a). (This gives 335ms and 635ms respectively here).

4.1.3.6 Reclaim timer setting

A number of factors influence the choice of the reclaim timer, such as;

- Fault incidence/Past experience - Small reclaim times may be required where there is a high incidence of recurrent lightning strikes to prevent unnecessary lockout for transient faults
- Spring charging time - For high speed auto-reclose the reclaim time may be set longer than the spring charging time. A minimum reclaim time of >5s may be needed to allow the CB time to recover after a trip and close before it can perform another trip-close-trip cycle. This time will depend on the duty (rating) of the CB. For delayed auto-reclose there is no need as the dead time can be extended by an extra CB healthy check AR Inhibit Time window time if there is insufficient energy in the CB
- Switchgear Maintenance - Excessive operation resulting from short reclaim times can mean shorter maintenance intervals
- The Reclaim Time setting is generally set greater than the tZ2 distance zone delay

4.2 Current transformer supervision

4.3 Standard CTS

The residual voltage setting, "CTS Vn< Inhibit" and the residual current setting, "CTS In> set", should be set to avoid unwanted operation during healthy system conditions. For example "CTS Vn< Inhibit" should be set to at least 120% of the maximum steady state residual voltage. The "CTS In> set" will typically be set below minimum load current. The time-delayed alarm, "CTS Time Delay", is generally set to 5 seconds.

AP

Where the magnitude of residual voltage during a ground/earth fault is unpredictable, the element can be disabled to prevent protection elements being blocked during fault conditions.

Standard CTS must not be used to inhibit the operation of Current differential protection as this is a local supervision and therefore it will not be fast enough to inhibit the operation of the differential protection at the remote end.

4.4 Differential CTS

“Phase Is1 CTS” setting must be set above the phase current of the maximum load transfer expected, normally at 1.2 In. This setting defines the minimum pick-up level of the current differential protection once the current transformer supervision CTS is detected.

"CTS i1>” setting, once exceeded, indicates that the circuit is loaded. A default setting of 0.1 In is considered suitable for most applications, but could be lowered in case of oversized CTs.

“CTS i2/i1>” This setting should be in excess of the worst unbalanced load expected in the circuit under normal operation. It is recommended to read out the values of i2 and i1 in the MEASUREMENT 1 column and set the ratio above 5% of the actual ratio.

“CTS i2/i1>>” We strongly recommend to keep the default setting (40% In). If the ratio i2/i1 exceeds the value of this setting at only one end, the CT failure is declared. Note that the minimum generated i2/i1 ratio will be 50% (case of one CT secondary phase lead being lost), and therefore setting of 40% is considered appropriate to guarantee sufficient operating speed.

Any of the previous methods will always block protection elements operating from derived quantities: Broken Conductor, Earth Fault and Neg Seq O/C. Other protections can be selectively blocked by customizing the PSL, gating DDB 928: CTS Block (originated by either method) or DDB 929 CTS Block Diff with the protection function logic.

If Differential CTS is in use and there is a failure of the differential communications channel, the user could change setting groups in order to enable standard CTS (by selecting standard CTS in the new setting group). Once the differential communications channel is restored, the scheme should ensure that the relay returns to the original setting group in order to activate the differential CTS.

4.5 Circuit breaker condition monitoring

4.5.1 Setting the Σ I^ thresholds

Where overhead lines are prone to frequent faults and are protected by oil circuit breakers (OCB's), oil changes account for a large proportion of the life cycle cost of the switchgear. Generally, oil changes are performed at a fixed interval of circuit breaker fault operations. However, this may result in premature maintenance where fault currents tend to be low, and hence oil degradation is slower than expected. The Σ I^ counter monitors the cumulative severity of the duty placed on the interrupter allowing a more accurate assessment of the circuit breaker condition to be made.

For OCB's, the dielectric withstand of the oil generally decreases as a function of $\Sigma\ I^2t$. This is where 'I' is the fault current broken, and 't' is the arcing time within the interrupter tank (not the interrupting time). As the arcing time cannot be determined accurately, the relay would normally be set to monitor the sum of the broken current squared, by setting 'Broken I^' = 2.

For other types of circuit breaker, especially those operating on higher voltage systems, practical evidence suggests that the value of 'Broken I^' = 2 may be inappropriate. In such applications 'Broken I^' may be set lower, typically 1.4 or 1.5. An alarm in this instance may be indicative of the need for gas/vacuum interrupter HV pressure testing, for example. The setting range for 'Broken I^' is variable between 1.0 and 2.0 in 0.1 steps. It is imperative that any maintenance program must be fully compliant with the switchgear manufacturer's instructions.

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4.5.2 Setting the number of operations thresholds

Every operation of a circuit breaker results in some degree of wear for its components. Thus, routine maintenance, such as oiling of mechanisms, may be based upon the number of operations. Suitable setting of the maintenance threshold will allow an alarm to be raised, indicating when preventative maintenance is due. Should maintenance not be carried out, the relay can be set to lockout the auto-reclose function on reaching a second operations threshold. This prevents further reclosure when the circuit breaker has not been maintained to the standard demanded by the switchgear manufacturer's maintenance instructions.

Certain circuit breakers, such as oil circuit breakers (OCB's) can only perform a certain number of fault interruptions before requiring maintenance attention. This is because each fault interruption causes carbonizing of the oil, degrading its dielectric properties. The maintenance alarm threshold "No CB Ops. Maint." may be set to indicate the requirement for oil sampling for dielectric testing, or for more comprehensive maintenance. Again, the lockout threshold "No CB Ops. Lock" may be set to disable auto-reclosure when repeated further fault interruptions could not be guaranteed. This minimizes the risk of oil fires or explosion.

4.5.3 Setting the operating time thresholds

Slow CB operation is also indicative of the need for mechanism maintenance. Therefore, alarm and lockout thresholds (CB Time Maint./CB Time Lockout) are provided and are settable in the range of 5 to 500ms. This time is set in relation to the specified interrupting time of the circuit breaker.

4.5.4 Setting the excessive fault frequency thresholds

Persistent faults will generally cause auto-reclose lockout, with subsequent maintenance attention. Intermittent faults such as clashing vegetation may repeat outside of any reclaim time, and the common cause might never be investigated. For this reason it is possible to set a frequent operations counter on the relay which allows the number of operations "Fault Freq. Count" over a set time period "Fault Freq. Time" to be monitored. A separate alarm and lockout threshold can be set.

5. CURRENT TRANSFORMER REQUIREMENTS

5.1 Recommended CT classes (British and IEC)

Class X current transformers with a knee point voltage greater or equal than that calculated can be used.

Class 5P protection CTs can be used, noting that the knee point voltage equivalent these offer can be approximated from:

Vk = (VA x ALF)/In + (RCT x ALF x In)

Where:

VA = Voltampere burden rating

ALF = Accuracy limit factor

In = CT nominal secondary current

5.2 Current differential requirements

For accuracy, class X or class 5P current transformers (CTs) are strongly recommended. The knee point voltage of the CTs should comply with the minimum requirements of the formulae shown below.

Vk ≥ K. In (Rct + 2 RL)

AP

Where:

Vk = Required IEC knee point voltage

K = Dimensioning factor

In = CT nominal secondary current

Rct = CT resistance

RL = One-way lead impedance from CT to relay

K is a constant depending on:

If = Maximum value of through fault current for stability (multiple of In)

X/R = Primary system X/R ratio

K is determined as follows:

For relays set at Is1 = 20%, Is2 = 2 In, k1 = 30%, k2 = 150%:

K must be the highest of:

K ≥ 40 + (0.07 x (If x X/R))

Or

K ≥ 65

This is valid for (If x X/R) ≤ 1000

For higher (If x X/R) up to 1600:

K = 107

For relays set at Is1 = 20%, Is2 = 2 In, k1 = 30%, k2 = 100%:

K must be the highest of:

K ≥ 40 + (0.35 x (If x X/R))

Or

K $\geq$ 65

This is valid for (If x X/R) $\leq$ 600

For higher (If x X/R) up to 1600:

K = 256

5.3 Zone 1 reach point accuracy (RPA)

Vk $\geq$ K_{RPA} x IF Z1 x (1+ X/R). (RCT + RL)

Where:

Vk = Required CT knee point voltage (volts)

K_{RPA} = Fixed dimensioning factor = **always 0.6**

IF $_{Z1}$ = Max. secondary phase fault current at Zone 1 reach point (A)

X/R = Primary system reactance/resistance ratio

RCT = CT secondary winding resistance (Ω)

RL = Single lead resistance from CT to relay (Ω)

5.4 Zone 1 close-up fault operation

An additional calculation must be performed for all cables, and any lines where the source impedance ratio might be less than SIR = 2.

Vk $\geq$ Kmax x IF max x (RCT + RL)

Where:

Kmax = Fixed dimensioning factor = **always 1.4**

IF max = Max. secondary phase fault current (A).

Then, the highest of the two calculated knee points must be used. Note that it is not necessary to repeat the calculation for earth faults, as the phase reach calculation (3φ) is the worst-case for CT dimensioning.

5.5 Determining Vk for an IEEE “C" class CT

Where American/IEEE standards are used to specify CTs, the C class voltage rating can be checked to determine the equivalent Vk (knee point voltage according to IEC). The equivalence formula is:

Vk = [(C rating in volts) x 1.05] + [100 x RCT]

AP

6. AUXILIARY SUPPLY FUSE RATING

In the Safety Information section of this manual, the maximum allowable fuse rating of 16A is quoted. To allow time grading with fuses upstream, a lower fuselink current rating is often preferable. Use of standard ratings of between 6A and 16A is recommended. Low voltage fuselinks, rated at 250V minimum and compliant with IEC60269-2 general application type gG are acceptable, with high rupturing capacity. This gives equivalent characteristics to HRC "red spot" fuses type NIT/TIA often specified historically.

The table below recommends advisory limits on relays connected per fused spur. This applies to MiCOM Px40 series devices with hardware suffix C and higher, as these have inrush current limitation on switch-on, to conserve the fuse-link.

Maximum Number of MiCOM Px40 Relays Recommended Per Fuse				
Battery Nominal Voltage	**6A**	**10A Fuse**	**15 or 16A Fuse**	**Fuse Rating > 16A**
24 to 54V	2	4	6	Not permitted
60 to 125V	4	8	12	Not permitted
138 to 250V	6	10	16	Not permitted

Alternatively, miniature circuit breakers (MCB) may be used to protect the auxiliary supply circuits.

PROGRAMMABLE LOGIC

PL

Date:	**7th August 2006**
Hardware Suffix:	**K**
Software Version:	**41 and 51**
Connection Diagrams:	**10P54302xx (xx = 01 to 02) & 10P54303xx (xx = 01 to 02)**
	10P54402xx (xx = 01 to 02) & 10P54403xx (xx = 01 to 02)
	10P54502xx (xx = 01 to 02) & 10P54503xx (xx = 01 to 02)
	10P54602xx (xx = 01 to 02) & 10P54603xx (xx = 01 to 02)

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1. PROGRAMMABLE LOGIC

1.1 Overview

The purpose of the programmable scheme logic (PSL) is to allow the relay user to configure an individual protection scheme to suit their own particular application. This is achieved through the use of programmable logic gates and delay timers.

The input to the PSL is any combination of the status of opto inputs. It is also used to assign the mapping of functions to the opto inputs and output contacts, the outputs of the protection elements, e.g. protection starts and trips, and the outputs of the fixed protection scheme logic. The fixed scheme logic provides the relay's standard protection schemes. The PSL itself consists of software logic gates and timers. The logic gates can be programmed to perform a range of different logic functions and can accept any number of inputs. The timers are used either to create a programmable delay, and/or to condition the logic outputs, e.g. to create a pulse of fixed duration on the output regardless of the length of the pulse on the input. The outputs of the PSL are the LEDs on the front panel of the relay and the output contacts at the rear.

The execution of the PSL logic is event driven; the logic is processed whenever any of its inputs change, for example as a result of a change in one of the digital input signals or a trip output from a protection element. Also, only the part of the PSL logic that is affected by the particular input change that has occurred is processed. This reduces the amount of processing time that is used by the PSL; even with large, complex PSL schemes the relay trip time will not lengthen.

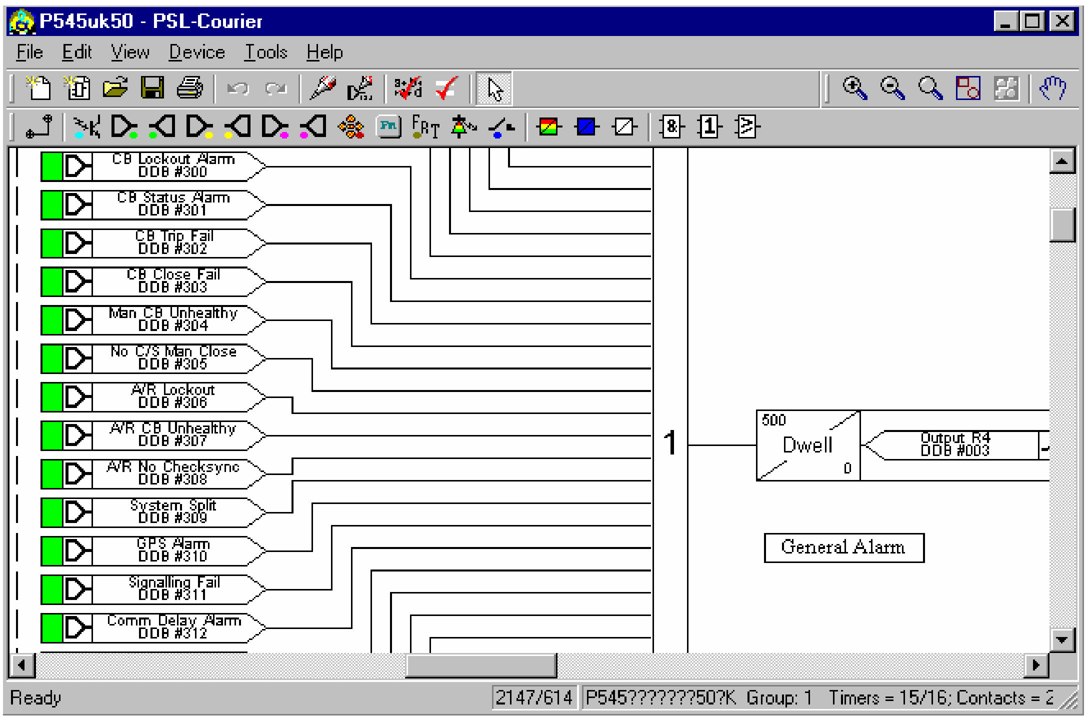
This system provides flexibility for the user to create their own scheme logic design. However, it also means that the PSL can be configured into a very complex system; hence setting of the PSL is implemented through the PC support package MiCOM S1.

PL

1.2 MiCOM S1 Px40 PSL editor

To access the Px40 PSL Editor menu click on 

The PSL Editor module enables you to connect to any MiCOM device front port, retrieve and edit its Programmable Scheme Logic files and send the modified file back to a MiCOM Px40 device.



1.3 How to use MiCOM Px40 PSL editor

With the MiCOM Px40 PSL Module you can:

- Start a new PSL diagram
- Extract a PSL file from a MiCOM Px40 IED
- Open a diagram from a PSL file
- Add logic components to a PSL file
- Move components in a PSL file
- Edit link of a PSL file
- Add link to a PSL file
- Highlight path in a PSL file
- Use a conditioner output to control logic
- Download PSL file to a MiCOM Px40 IED
- Print PSL files

For a detailed discussion on how to use these functions, please refer to MiCOM S1 Users Manual.

1.4 Warnings

Before the scheme is sent to the relay checks are done. Various warning messages may be displayed as a result of these checks.

The Editor first reads in the model number of the connected relay, and then compares it with the stored model number. A "wildcard" comparison is employed. If a model mismatch occurs then a warning will be generated before sending commences. Both the stored model number and that read-in from the relay are displayed along with the warning; the onus is on you to decide if the settings to be sent are compatible with the connected relay. Wrongly ignoring the warning could lead to undesired behavior in the relay.

If there are any potential problems of an obvious nature then a list will be generated. The types of potential problems that the program attempts to detect are:

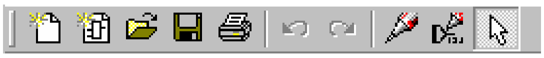
- One or more gates, LED signals, contact signals, and/or timers have their outputs linked directly back to their inputs. An erroneous link of this sort could lock up the relay, or cause other more subtle problems to arise.
- Inputs to Trigger (ITT) exceeds the number of inputs. A programmable gate has its ITT value set to greater than the number of actual inputs; the gate can never activate. Note that there is no lower ITT value check. A 0-value does not generate a warning.
- Too many gates. There is a theoretical upper limit of 256 gates in a scheme, but the practical limit is determined by the complexity of the logic. In practice the scheme would have to be very complex, and this error is unlikely to occur.
- Too many links. There is no fixed upper limit to the number of links in a scheme. However, as with the maximum number of gates, the practical limit is determined by the complexity of the logic. In practice the scheme would have to be very complex, and this error is unlikely to occur.

1.5 Toolbar and commands

There are a number of toolbars available for easy navigation and editing of PSL.

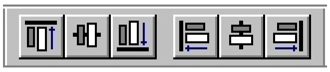
1.5.1 Standard tools

- For file management and printing.



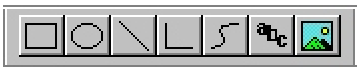
1.5.2 Alignment tools

- To snap logic elements into horizontally or vertically aligned groupings.



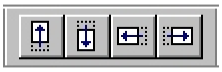
1.5.3 Drawing tools

- To add text comments and other annotations, for easier reading of PSL schemes.



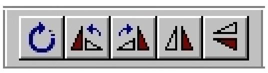
1.5.4 Nudge tools

- To move logic elements.



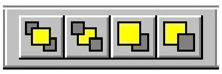
1.5.5 Rotation tools

- Tools to spin, mirror and flip.



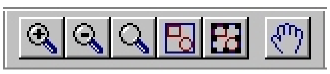
1.5.6 Structure tools

- To change the stacking order of logic components.

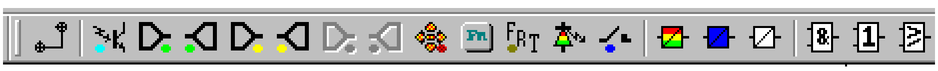


1.5.7 Zoom and pan tools

- For scaling the displayed screen size, viewing the entire PSL, or zooming to a selection.

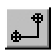


1.5.8 Logic symbols



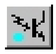
This toolbar provides icons to place each type of logic element into the scheme diagram. Not all elements are available in all devices. Icons will only be displayed for those elements available in the selected device.

Link



Create a link between two logic symbols.

Opto Signal



Create an opto signal.

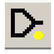
Input Signal

Create an input signal.

Output Signal

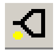
Create an output signal.

GOOSE In



Create an input signal to logic to receive a GOOSE message transmitted from another IED.
Used in either UCA2.0 or IEC 61850 GOOSE applications only.

GOOSE Out



Create an output signal from logic to transmit a GOOSE message to another IED.
Used in either UCA2.0 or IEC 61850 GOOSE applications only.

Control In

Create an input signal to logic that can be operated from an external command.

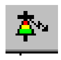
Function Key

Create a function key input signal.

Trigger Signal

Create a fault record trigger.

LED Signal

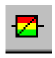


Create an LED input signal that repeats the status of tri-color LED.

Contact Signal

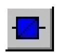
Create a contact signal.

LED Conditioner



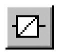
Create an LED conditioner.

Contact Conditioner



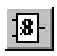
Create a contact conditioner.

Timer



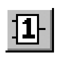
Create a timer.

AND Gate



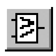
Create an AND Gate.

OR Gate



Create an OR Gate.

Programmable Gate



Create a programmable gate.

1.6 PSL logic signals properties

The logic signal toolbar is used for the selection of logic signals.

Performing a right-mouse click on any logic signal will open a context sensitive menu and one of the options for certain logic elements is the **Properties** command. Selecting the Properties option will open a Component Properties window, the format of which will vary according to the logic signal selected.

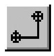
Properties of each logic signal, including the Component Properties windows, are shown in the following sub-sections:

Signal Properties Menu

The **Signals List** tab is used for the selection of logic signals.

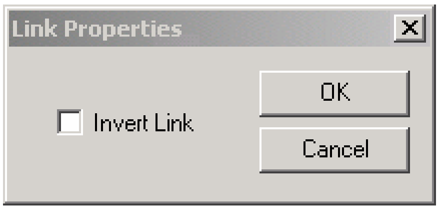
The signals listed will be appropriate to the type of logic symbol being added to the diagram. They will be of one of the following types:

1.6.1 Link properties



Links form the logical link between the output of a signal, gate or condition and the input to any element.

Any link that is connected to the input of a gate can be inverted via its properties window. An inverted link is indicated with a “bubble” on the input to the gate. It is not possible to invert a link that is not connected to the input of a gate.



Links can only be started from the output of a signal, gate, or conditioner, and can only be ended on an input to any element.

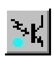
Since signals can only be either an input or an output then the concept is somewhat different. In order to follow the convention adopted for gates and conditioners, input signals are connected from the left and output signals to the right. The Editor will automatically enforce this convention.

A link attempt will be refused where one or more rules would otherwise be broken. A link will be refused for the following reasons:

- An attempt to connect to a signal that is already driven. The cause of the refusal may not be obvious, since the signal symbol may appear elsewhere in the diagram. Use “Highlight a Path” to find the other signal.
- An attempt is made to repeat a link between two symbols. The cause of the refusal may not be obvious, since the existing link may be represented elsewhere in the diagram.

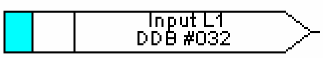
1.6.2 Opto signal properties

Opto Signal



Each opto input can be selected and used for programming in PSL. Activation of the opto input will drive an associated DDB signal.

For example activating opto input L1 will assert DDB 032 in the PSL.



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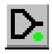
1.6.3 Input signal properties

Input Signal 

Relay logic functions provide logic output signals that can be used for programming in PSL. Depending on the relay functionality, operation of an active relay function will drive an associated DDB signal in PSL.

For example DDB 671 will be asserted in the PSL should the active earth fault 1, stage 1 protection operate/trip.

1.6.4 Output signal properties

Output Signal 

Relay logic functions provide logic input signals that can be used for programming in PSL. Depending on the relay functionality, activation of the output signal will drive an associated DDB signal in PSL and cause an associated response to the relay function

For example, if DDB 409 is asserted in the PSL, it will block the sensitive earth function stage 1 timer.

1.6.5 GOOSE input signal properties

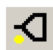
GOOSE In 

The Programmable Scheme Logic interfaces with the GOOSE Scheme Logic (see S1 users manual) by means of 32 Virtual inputs. The Virtual Inputs can be used in much the same way as the Opto Input signals.

The logic that drives each of the Virtual Inputs is contained within the relay's GOOSE Scheme Logic file. It is possible to map any number of bit-pairs, from any subscribed device, using logic gates onto a Virtual Input (see S1 Users manual for more details).

For example DDB 224 will be asserted in PSL should virtual input 1 operate.

1.6.6 GOOSE output signal properties

GOOSE Out 

The Programmable Scheme Logic interfaces with the GOOSE Scheme Logic by means of 32 Virtual outputs.

It is possible to map virtual outputs to bit-pairs for transmitting to any subscribed devices (see S1 Users manual for more details).

For example if DDB 256 is asserted in PSL, Virtual Output 32 and its associated mappings will operate.

1.6.7 Control in signal properties

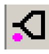
Control In

There are 32 control inputs which can be activated via the relay menu, 'hotkeys' or via rear communications. Depending on the programmed setting i.e. latched or pulsed, an associated DDB signal will be activated in PSL when a control input is operated.

For example operate control input 1 to assert DDB 192 in the PSL.

1.6.8 InterMiCOM In commands properties

InterMiCOM Out



There are 16 InterMiCOM outputs that could be selected and use for teleprotection, remote commands, etc. "InterMiCOM Out" is a send command to a remote end that could be mapped to any logic output or opto input. This will be transmitted to the remote end as corresponding "InterMiCOM In" command

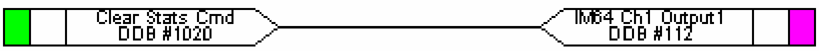
InterMiCOM In

There are 16 InterMiCOM inputs that could be selected and use for teleprotection, remote commands, etc. "InterMiCOM In" is a received signal from remote end that could be mapped to a selected output relay or logic input.

Example

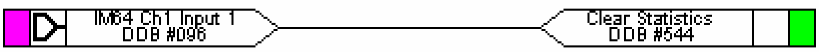
Relay End A

At end A, InterMiCOM Output 1 is mapped to the command indication "Clear Statistics" (issued at end A)



Relay End B

At end B, InterMiCOM Input 1 is mapped to the command "Clear Statistics"



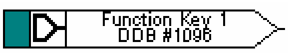
Upon receive of IM64 1 from relay at end A, the relay at end B will reset its statistics.

1.6.9 Function key properties

Function Key

Each function key can be selected and used for programming in PSL. Activation of the function key will drive an associated DDB signal and the DDB signal will remain active depending on the programmed setting i.e. toggled or normal. Toggled mode means the DDB signal will remain latched or unlatched on key press and normal means the DDB will only be active for the duration of the key press.

For example operate function key 1 to assert DDB 1096 in the PSL.



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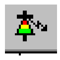
1.6.10 Fault recorder trigger properties

Fault Record Trigger 

The fault recording facility can be activated, by driving the fault recorder trigger DDB signal.

For example assert DDB 702 to activate the fault recording in the PSL.

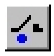
1.6.11 LED signal properties

LED 

All programmable LEDs will drive associated DDB signal when the LED is activated.

For example DDB 1036 will be asserted when LED 7 is activated.

1.6.12 Contact signal properties

Contact Signal 

All relay output contacts will drive associated DDB signal when the output contact is activated.

For example DDB 009 will be asserted when output R10 is activated.

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1.6.13 LED conditioner properties

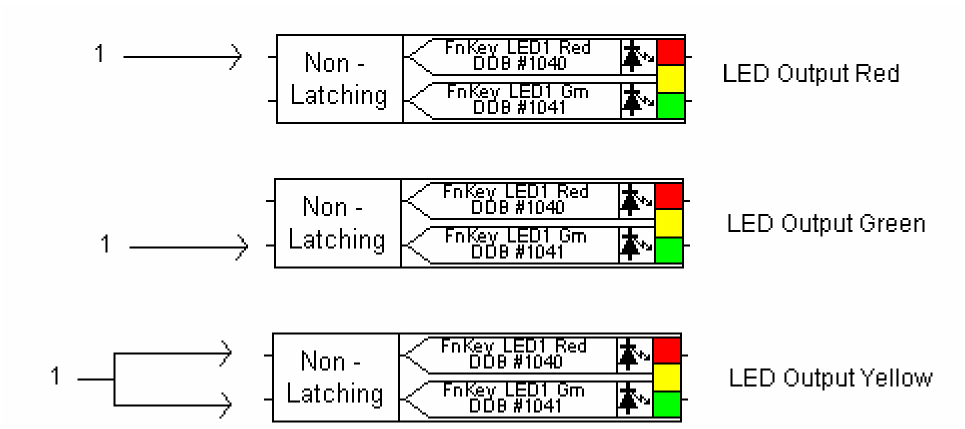
LED Conditioner 

1. Select the **LED name** from the list (only shown when inserting a new symbol).
2. Configure the LED output to be Red, Yellow or Green.

   Configure a Green LED by driving the Green DDB input.

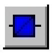
   Configure a RED LED by driving the RED DDB input.

   Configure a Yellow LED by driving the RED and GREEN DDB inputs simultaneously.

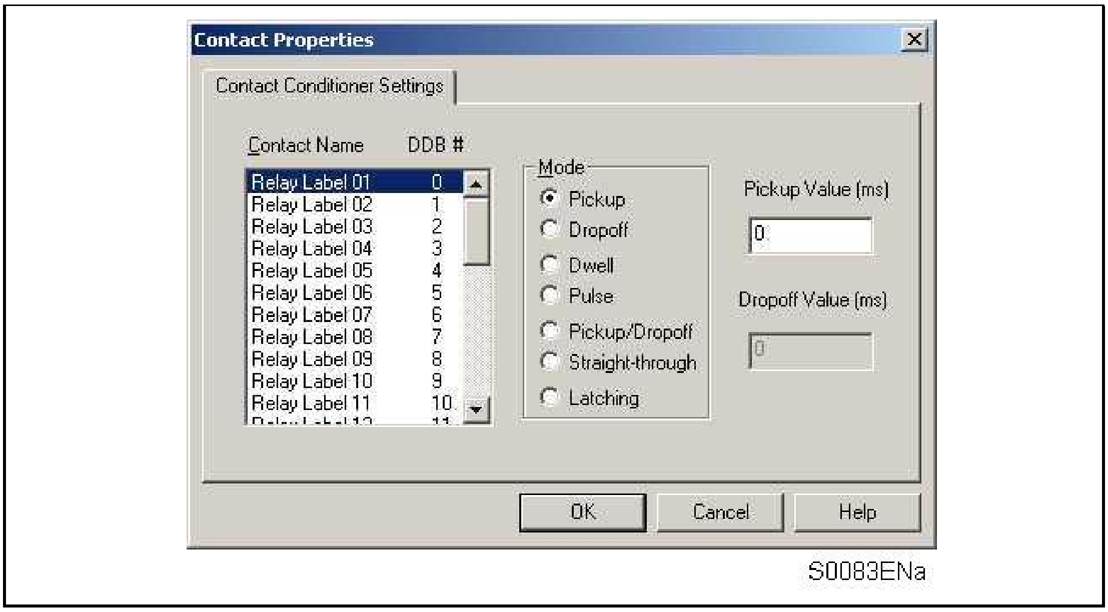


3. Configure the LED output to be latching or non-latching.

1.6.14 Contact conditioner properties

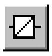


Each contact can be conditioned with an associated timer that can be selected for pick up, drop off, dwell, pulse, pick-up/drop-off, straight-through, or latching operation. “Straight-through” means it is not conditioned in any way whereas “latching” is used to create a sealed-in or lockout type function.

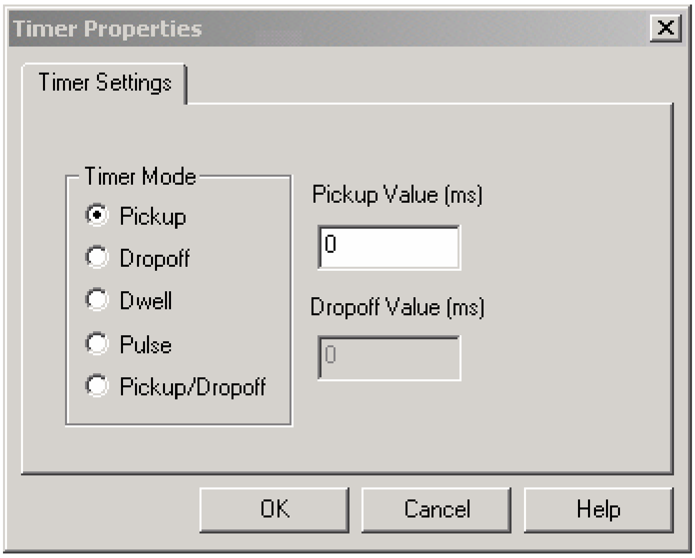


4. Select the contact **name** from the **Contact Name** list (only shown when inserting a new symbol).
5. Choose the conditioner type required in the **Mode** tick list.
6. Set the **Pick-up** Time (in milliseconds), if required.
7. Set the **Drop-off** Time (in milliseconds), if required.

1.6.15 Timer properties



Each timer can be selected for pick up, drop off, dwell, pulse or pick-up/drop-off operation.



1. Choose the operation mode from the **Timer Mode** tick list.
2. Set the Pick-up Time (in milliseconds), if required.
3. Set the Drop-off Time (in milliseconds), if required.

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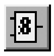
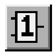
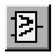
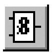
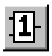
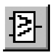
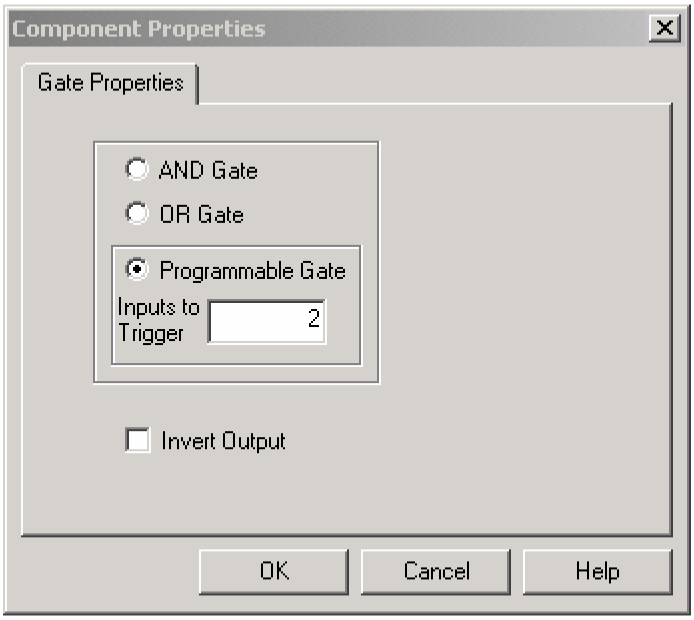
1.6.16 Gate properties  or  or 

A Gate may be an AND, OR, or programmable gate.

An **AND** gate  requires that all inputs are TRUE for the output to be TRUE.

An **OR** gate  requires that one or more input is TRUE for the output to be TRUE.

A **Programmable** gate  requires that the number of inputs that are TRUE is equal to or greater than its 'Inputs to Trigger' setting for the output to be TRUE.



1. Select the Gate type AND, OR, or Programmable.
2. Set the number of inputs to trigger when Programmable is selected.
3. Select if the output of the gate should be inverted using the Invert Output check box. An inverted output is indicated with a "bubble" on the gate output.

PL

1.7 Description of logic nodes

DDB No.	English Text	Source	Description
0	Output Label 1 (Setting)	Output Conditioner	Assignment of signal to drive output Relay 1
31	31	Output Conditioner	Assignment of signal to drive output Relay 32
32	Opto Label 1 (Setting)	Opto Input	From opto input 1- when opto energized
55	Opto Label 24 (Setting)	Opto Input	From opto input 24 - when opto energized
96	IM64 Ch1 Input 1	IM64	IM64 Ch1 input 1 - is driven by a message from the remote line end
103	IM64 Ch1 Input 8	IM64	IM64 Ch1 input 8 - is driven by a message from the remote line end
104	IM64 Ch2 Input 1	IM64	IM64 Ch2 input 1 - is driven by a message from the remote line end
111	IM64 Ch2 Input 8	IM64	IM64 Ch2 input 8 - is driven by a message from the remote line end
112	IM64 Ch1 Output 1	PSL	IM64 Ch1 output 1 - mapping what will be sent to the remote line end
119	IM64 Ch1 Output 8	PSL	IM64 Ch1 output 8 - mapping what will be sent to the remote line end
120	IM64 Ch2 Output 1	PSL	IM64 Ch2 output 1 - mapping what will be sent to the remote line end
127	IM64 Ch2 Output 8	PSL	IM64 Ch2 output 8 - mapping what will be sent to the remote line end
128	Relay Cond 1	PSL	Input to relay 1 output conditioner
159	Relay Cond 32	PSL	Input to relay 32 output conditioner
160	Timer in 1	PSL	Input to auxiliary timer 1
175	Timer in 16	PSL	Input to auxiliary timer 16
176	Timer out 1	Auxiliary Timer	Output from auxiliary timer 1
191	Timer out 16	Auxiliary Timer	Output from auxiliary timer 16
192	Control Input 1	Control Input Command	Control input 1 - for SCADA and menu commands into PSL
223	Control Input 32	Control Input Command	Control input 32 - for SCADA and menu commands into PSL
256	Virtual Output 1	PSL	Virtual output 1 - allows user to control a binary signal which can be mapped via SCADA protocol output to other devices
287	Virtual Output32	PSL	Virtual output 32 - allows user to control a binary signal which can be mapped via SCADA protocol output to other devices
288	SG-opto Invalid	Group Selection	Setting group selection opto inputs have detected an invalid (disabled) settings group
289	Prot'n Disabled	Commissioning Test	Protection disabled - typically out of service due to test mode
290	Static Test Mode	Commissioning Test	Static test mode option bypasses the delta phase selectors, power swing detection and reverts to conventional directional line and cross polarization to allow testing with test sets that can not simulate a real fault
291	Test Loopback	C Diff	Loopback test in service (external or internal)
292	Test IM64	C Diff	Indication that relay is in test mode
293	VT Fail Alarm	VT Supervision	VTS indication alarm- failed VT (fuse blow) detected by VT supervision

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DDB No.	English Text	Source	Description
294	CT Fail Alarm	CT Supervision	CTS indication alarm (CT supervision alarm) In the cases of two CTs: - If standard CTS is used, this indication is ON in case of failure on any of the CTs - If Diff CTS is used this indication is ON in case of failure on CT1
295	CT2 Fail Alarm	CT Supervision	CT2S indication alarm (CT supervision alarm). This indication is ON If Diff CTS is used and there is a failure on CT2
296	Remote CT Alarm	CT Supervision	CTS remote indication alarm (CT supervision alarm)
297	Power Swing	Powerswing Blocking	Powerswing blocking will block any distance zone selected in the setting file
298	CB Fail Alarm	CB Fail	Circuit breaker fail alarm
299	CB Monitor Alarm	CB Monitoring	This alarm indicates that DDB I ^ Maint. Alarm (1106) or DDB CB OPs Maint. (1108) or DDB CB Time Maint. (1110)
300	CB Lockout Alarm	CB Monitoring	This alarm indicates that DDB I ^ Lockout Alarm (1107) or DDB CB Ops Lock (1109) or DDB CB Time lockout (1111)
301	CB Status Alarm	CB Status	Indication of problems by circuit breaker state monitoring - example defective auxiliary contacts
302	CB Trip Fail	CB Control	Circuit breaker failed to trip (after a manual/operator) trip command
303	CB Close Fail	CB Control	Circuit breaker failed to close (after a manual/operator or auto-reclose close command)
304	Man CB Unhealthy	CB Control	Manual circuit breaker unhealthy output signal indicating that the circuit breaker has not closed successfully after a manual close command. (A successful close also requires The circuit breaker healthy signal to reappear within the "healthy window" timeout)
305	No C/S Man Close	CB Control	Indicates that the check synchronism signal has failed to appear for a manual close
306	A/R Lockout	Auto-reclose	Indicates an auto-reclose lockout condition - no further auto-reclosures possible until resetting
307	A/R CB Unhealthy	Auto-reclose	Auto-reclose circuit breaker unhealthy signal, output from auto-reclose logic. Indicates during auto-reclose in progress, if the circuit breaker has to become healthy within the circuit breaker healthy time window
308	A/R No Checksync	Auto-reclose	Indicates during auto-reclose in progress, if system checks have not been satisfied within the check synchronizing time window
309	System Split	Check sync	System split alarm - will be raised if the system is split (remains permanently out of synchronism) for the duration of the system split timer
310	GPS Alarm	C Diff	Indicates that GPS is lost
311	Signaling fail	C Diff	If a differential protection communication path has remained failed during “Comms Fail Timer”, this alarm is ON
312	Comm Delay Alarm	C Diff	If successive calculated propagation times exceed time delay setting “Comm Delay Tol”, this alarms is ON
313	C Diff Failure	C Diff	It indicates that differential protection communications are completely lost and therefore C diff does not work
314	IM64 SchemeFail		It indicates that communications between relays are completely lost and therefore IM64 does not work

DDB No.	English Text	Source	Description
315	IEEE C37.94 Fail	C Diff	It will appear in case of at least one of the following: CH1 (or CH2) loss of signal, CH1 (or CH2) PATH_YELLOW or CH1 (or CH2) BAD_RX_N
316	C Diff Inhibited	C Diff	Indicate that a differential protection has been inhibited
317	Aid 1 Chan Fail	PSL	Aided channel scheme 1 - channel out of service indication, indicating channel failure
318	Aid 2 Chan Fail	PSL	Aided channel scheme 2 - channel out of service indication, indicating channel failure
319	F out of Range	Frequency Tracking	Frequency out of range alarm
320	CB2 Fail Alarm	CB2 Fail	Circuit breaker 2 fail alarm
321 to 322	Not used		
323	CB2 Status Alarm	CB2 Status	Indication of problems by circuit breaker 2 state monitoring - example defective auxiliary contacts
324	CB2 Trip Fail	CB2 Control	Circuit breaker 2 failed to trip (after a manual/operator) trip command
325	CB2 Close Fail	CB2 Control	Circuit breaker 2 failed to close (after a manual/operator or auto-reclose close command)
326	Man CB2 Unhealthy	CB2 Control	Manual circuit breaker unhealthy output signal indicating that the circuit breaker 2 has not closed successfully after a manual close command. (A successful close also requires The circuit breaker healthy signal to reappear within the "healthy window" timeout)
327 to 331	Not used		
332	Incompatible Rly	C Diff	Indicates that inrush is enabled at one end and not at the other end
332	Not used		
333	InValid Mesg Fmt	C Diff	Indicates different message length from each end (example: IM64 enabled at one end and C diff enabled at the other end)
334	Main Prot. Fail	Co-processor Interface	Indicates a failure in differential or distance or DEF
335	Config Error	C Diff	In three ended schemes on power up, the relays check to see if one of them should be configured out. Under some circumstances it is possible for them to fail to resolve this in which case they produce the DDB_CONFIGURATION_ERROR alarm
336	Re-Config Error	C Diff	Indicates that RESTORE or RECONFIGURE or CONFIGURE operations have failed
335, 336	Not used		
337	Comms Changed	C Diff	This is an alarm which indicates that C3794 comms have been changed to standard or vice versa and relay must be rebooted
338 to 343	Not used		
344	SR User Alarm 1	PSL	Triggers user alarm 1 message to be alarmed on LCD display (self-resetting)
347	SR User Alarm 8	PSL	Triggers user alarm 8 message to be alarmed on LCD display (self-resetting)
348	MR User Alarm 9	PSL	Triggers user alarm 9 message to be alarmed on LCD display (manual-resetting)
351	MR User Alarm 16	PSL	Triggers user alarm 16 message to be alarmed on LCD display (manual-resetting)
352	Battery Fail	Self Monitoring	Front panel miniature battery failure - either battery removed from slot, or low voltage
353	Field Volts Fail	Self Monitoring	48V field voltage failure

DDB No.	English Text	Source	Description
354	Rear Comm 2 Fail	Self Monitoring	Comm2 hardware failure - second rear communications board
355	GOOSE IED Absent		The IED is not subscribed to a publishing IED in the current scheme
356	NIC Not Fitted		Ethernet board not fitted
357	NIC No Response		Ethernet board not responding
358	NIC Fatal Error		Ethernet board unrecoverable error
359 to 361	Not used		
362	NIC Link Fail		Ethernet link lost
363	NIC SW Mis-Match		Ethernet board software not compatible with main CPU
364	IP Addr Conflict		The IP address of the IED is already used by another IED
365	IM Loopback	InterMiCOM	InterMiCOM indication that loopback testing is in progress
366	IM Message Fail	InterMiCOM	InterMiCOM message failure alarm
367	IM Data CD Fail	InterMiCOM	InterMiCOM data channel detect fail
368	IM Channel Fail	InterMiCOM	InterMiCOM channel failure alarm
370 to 383	Not used		
384	Block Zone 1 Gnd	PSL	Zone 1 ground basic scheme blocking
385	Block Zone 1 Phs	PSL	Zone 1 phase basic scheme blocking
386	Block Zone 2 Gnd	PSL	Zone 2 ground basic scheme blocking
387	Block Zone 2 Phs	PSL	Zone 2 phase basic scheme blocking
388	Block Zone 3 Gnd	PSL	Zone 3 ground basic scheme blocking
389	Block Zone 3 Phs	PSL	Zone 3 phase basic scheme blocking
390	Block Zone P Gnd	PSL	Zone P ground basic scheme blocking
391	Block Zone P Phs	PSL	Zone P phase basic scheme blocking
392	Block Zone 4 Gnd	PSL	Zone 4 ground basic scheme blocking
393	Block Zone 4 Phs	PSL	Zone 4 phase basic scheme blocking
394	Aid1 InhibitDist	PSL	Block distance aided scheme 1 tripping
395	Aid1 Inhibit DEF	PSL	Block DEF aided scheme 1 tripping
396	Not used		
397	Aid2 InhibitDist	PSL	Block distance aided scheme 2 tripping
398	Aid2 Inhibit DEF	PSL	Block DEF aided scheme 2 tripping
399	Not used		
400	Time Synch	PSL	Time synchronism by opto pulse
401	I>1 Timer Block	PSL	Block phase overcurrent stage 1 time delayed tripped trip
402	I>2 Timer Block	PSL	Block phase overcurrent stage 2 time delayed tripped trip
403	I>3 Timer Block	PSL	Block phase overcurrent stage 3 time delayed trip
404	I>4 Timer Block	PSL	Block phase overcurrent stage 4 time delayed trip
405	IN>1 Timer Block	PSL	Block standby earth fault stage 1 time delayed trip
406	IN>2 Timer Block	PSL	Block standby earth fault stage 2 time delayed trip
407	IN>3 Timer Block	PSL	Block standby earth fault stage 3 time delayed trip
408	IN>4 Timer Block	PSL	Block standby earth fault stage 4 time delayed trip
409	ISEF>1 Timer Blk	PSL	Block sensitive earth fault stage 1 time delayed trip
410	ISEF>2 Timer Blk	PSL	Block sensitive earth fault stage 2 time delayed trip

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DDB No.	English Text	Source	Description
411	ISEF>3 Timer Blk	PSL	Block sensitive earth fault stage 3 time delayed trip
412	ISEF>4 Timer Blk	PSL	Block sensitive earth fault stage 4 time delayed trip
413	I2> Timer Block	PSL	Block negative sequence phase overcurrent time delayed trip
414	V<1 Timer Block	PSL	Block phase undervoltage stage 1 time delayed trip
415	V<2 Timer Block	PSL	Block phase undervoltage stage 2 time delayed trip
416	V>1 Timer Block	PSL	Block phase overvoltage stage 1 time delayed trip
417	V>2 Timer Block	PSL	Block phase overvoltage stage 2 time delayed trip
418	VN>1 Timer Block	PSL	Block residual overvoltage stage 1 time delayed trip
419	VN>2 Timer Block	PSL	Block residual overvoltage stage 2 time delayed trip
420	CB Aux 3ph(52-A)	PSL	52-A (CB closed) CB auxiliary input (3 phase)
421	CB Aux A(52-A)	PSL	52-A (CB A phase closed) CB auxiliary
422	CB Aux B(52-A)	PSL	52-A (CB B phase closed) CB auxiliary
423	CB Aux C(52-A)	PSL	52-A (CB C phase closed) CB auxiliary
424	CB Aux 3ph(52-B)	PSL	52-B (CB open) CB auxiliary input (3 phase)
425	CB Aux A(52-B)	PSL	52-B (CB A phase open) CB auxiliary input
426	CB Aux B(52-B)	PSL	52-B (CB B phase open) CB auxiliary input
427	CB Aux C(52-B)	PSL	52-B (CB C phase open) CB auxiliary input
428	CB2 Aux 3ph(52-A)	PSL	52-A (CB2 closed) CB2 auxiliary input (3 phase)
429	CB2 Aux A(52-A)	PSL	52-A (CB2 A phase closed) CB2 auxiliary
430	CB2 Aux B(52-A)	PSL	52-A (CB2 B phase closed) CB2 auxiliary
431	CB2 Aux C(52-A)	PSL	52-A (CB2 C phase closed)CB2 auxiliary
432	CB2 Aux 3ph(52-B)	PSL	52-B (CB2 open) CB2 auxiliary input (3 phase)
433	CB2 Aux A(52-B)	PSL	52-B (CB2 A phase open) CB2 auxiliary input
434	CB2 Aux B(52-B)	PSL	52-B (CB2 B phase open) CB2 auxiliary input
435	CB2 Aux C(52-B)	PSL	52-B (CB2 C phase open) CB2 auxiliary input
436	CB Healthy	PSL	Circuit breaker healthy (input to auto-recloser - that the CB has enough energy to allow re-closing)
437	CB2 Healthy	PSL	Circuit breaker healthy (input to auto-recloser - that the CB has enough energy to allow re-closing)
438	MCB/VTS	PSL	VT supervision input - signal from external miniature circuit breaker showing MCB tripped
439	Trip CB	PSL	Initiate tripping of circuit breaker from a manual command
440	Close CB	PSL	Initiate closing of circuit breaker from a manual command
441	Init Trip CB2	PSL	Initiate tripping of circuit breaker 2 from a manual command
442	Init Close CB2	PSL	Initiate closing of circuit breaker 2 from a manual command
443	Reset Close Dly	PSL	Reset manual circuit breaker close time delay
444	Reset Relays/LED	PSL	Reset latched relays & LEDs (manual reset of any lockout trip contacts, auto-reclose lockout, and LEDs)
445	Reset Thermal	PSL	Reset thermal state to 0%
446	Reset Lockout	PSL	Manual control to reset auto-recloser from lockout
447	Reset CB Data	PSL	Reset circuit breaker maintenance values

DDB No.	English Text	Source	Description
448	BAR	PSL	Block the auto-reclose function from an external input
449	En 1pole reclose	PSL	Enable 1 pole reclose from an external input
450	En 3pole reclose	PSL	Enable 3 pole reclose from an external input
451	Pole Discrepancy	PSL	Pole discrepancy (from external detector) - input used to force a 2nd single pole trip to move to a 3 pole auto-reclose cycle
452	Loopback Mode	PSL	To enable loopback mode via opto input
453	Perm Intertrip		Permissive intertrip mapping what will be sent to the remote line end
454	Stub Bus Enabled		To enable stub bus protection in relays with two CT inputs. When enabled, all current values transmitted to the remote relays, and all those received from remote relays, are set to zero. Differential intertrip signals are not sent The protection provides differential protection for the stub zone
455	Inhibit C Diff		When linked to an opto input, inhibits differential relay at the local end and send an inhibit command to the remote end
456	Recon Interlock		This must be energized (along with DDB 455 - inhibit C Diff) at the time that a relay configuration is changed from 3 ended to 2 ended scheme. This usually should be driven from a 52-B contact of the CB connected to the line end that is taken out of service
457	Prop Delay Equal	PSL	If a P54x relay working with GPS sample synchronization loses GPS and there is a further switch in the protection communications network, the relay becomes Inhibit. If GPS become active again, the relay will automatically reset. But if not, the user can remove the inhibited condition by energizing this DDB signal as long as it is ensured that propagation delay times are equal
458	Inhibit WI	PSL	Inhibit weak infeed aided scheme logic
459	Test Mode	PSL	Commissioning tests - automatically places relay in test mode
460	Command Blocking	PSL	For IEC-870-5-103 protocol only, used for "Command Blocking" (relay ignores SCADA commands)
461	Monitor Blocking	PSL	For IEC-870-5-103 protocol only, used for "Monitor Blocking" (relay is quiet - issues no messages via SCADA port)
462	Not used		
463	Inhibit I>1	PSL	Inhibit stage 1 overcurrent protection
464	Inhibit I>2	PSL	Inhibit stage 2 overcurrent protection
465	Inhibit I>3	PSL	Inhibit stage 3 overcurrent protection
466	Inhibit I>4	PSL	Inhibit stage 4 overcurrent protection
467	Inhibit IN>1	PSL	Inhibit stage 1 earth fault protection
468	Inhibit IN>2	PSL	Inhibit stage 2 earth fault protection
469	Inhibit IN>3	PSL	Inhibit stage 3 earth fault protection
470	Inhibit IN>4	PSL	Inhibit stage 4 earth fault protection
471	Inhibit V<1	PSL	Inhibit stage 1 undervoltage protection
472	Inhibit V<2	PSL	Inhibit stage 2 undervoltage protection
473	Inhibit V>1	PSL	Inhibit stage 1 overvoltage protection
474	Inhibit V>2	PSL	Inhibit stage 2 overvoltage protection
475	Inhibit VN>1	PSL	Inhibit stage 1 residual overvoltage protection

DDB No.	English Text	Source	Description
476	Inhibit VN>2	PSL	Inhibit stage 2 residual overvoltage protection
477	Inhibit I2>	PSL	Inhibit neg seq overcurrent protection
478	Inhibit Thermal	PSL	Inhibit thermal overload protection
479	Inhibit CB Status	PSL	Inhibit circuit breaker state monitoring (no alarm for defective/stuck auxiliary contact)
480	Inhibit CB Fail	PSL	Inhibit circuit breaker fail protection
481	Inhibit OpenLine	PSL	Broken conductor protection
482	Inhibit VTS	PSL	Inhibit VT supervision (including turn OF MCB's) via PSL
483	Inhibit CTS	PSL	Inhibit CT supervision (both differential and standard CTS) via PSL
484	InhibitChecksync	PSL	Inhibit checksync
485	Inhibit TOR	PSL	Inhibit trip on reclose (TOR)
486	Inhibit SOTF	PSL	Inhibit switch onto fault (SOTF)
487	Disable Diff CTS	PSL	To disable differential CTS via PSL
488	Set SOTF	PSL	To enable SOTF logic by an external pulse. When this input is energized by en external pulse, SOTF becomes enabled during "SOTF Pulse" time setting
489	AR Reset Z1 EXT	Zone 1 Extension Scheme	AR reset Z1X reach back to Z1 reach in Z1 extension scheme
490	Reset Zone 1 Ext	PSL	Reset zone Z1X back to Z1 reach using logic input (i.e. case when external AR and Z1 extension scheme are used)
491	Inhibit LoL	PSL	Inhibit Loss of Load scheme function
492	Aided 1 COS/LGS	PSL	Aided 1 channel out of service signal (COS) or loss of guard signal (LGS) in distance unblocking schemes
493	Aided1 Scheme Rx	PSL	Aided channel 1 - external signal received, for input to distance fixed scheme logic
494	Aided 1 Receive	Aided Scheme Logic	Aided channel 1 - internal signal received generated in the signal receive logic
495	Not used		
496	Aid1 Block Send	PSL	Prevent sending by customized logic - aided scheme 1
497	Aid1 Custom Send	PSL	Programmable send logic for special customized scheme (aided channel 1)
498	Aided 1 Send	Aided Scheme Logic	Aided channel 1 send - internal send signal generated in signal send logic
499	Aid1 Custom T In	PSL	When using a custom programmable aided scheme 1, the user is able to include a current reversal guard timer. Energizing this DDB will additionally start this timer, from PSL
500	Aid1 CustomT Out	Aided Scheme Logic	When using customized aided scheme 1, this signal is used to indicate any additional condition that should be treated as permission for an aided trip (for example a permissive signal received could be connected, or a blocking signal could be inverted and then connected)
501	Aid1 Trip Enable	Aided Scheme Logic	Aided scheme 1 trip enable - this is a permissive signal used to accelerate zone 2, or a blocking signal which has been inverted. It is a signal output, part-way through the internal fixed logic of aided schemes
502	Aid1 Custom Trip	PSL	Aid1 custom trip enable
503	Aid 1 Dist Trip	Aided Scheme Logic	Aided scheme 1 distance trip command (output from aided tripping logic)

DDB No.	English Text	Source	Description
504	Not used		
505	Aid 1 DEF Trip	Aided Scheme Logic	Aided scheme 1 DEF trip command (output from aided tripping logic)
506	Aided 2 COS/LGS	PSL	Aided 2 channel out of service signal (COS) or loss of guard signal (LGS) in distance unblocking schemes
507	Aided2 Scheme Rx	PSL	Aided channel 2 - external signal received, for input to distance fixed scheme logic
508	Aided 2 Receive	Aided Scheme Logic	Aided channel 2 - internal signal received generated in the signal receive logic
509 to 511	Not used		
512	Aid2 Block Send	PSL	Prevent sending by customized logic - aided scheme 2
513	Aid2 Custom Send	PSL	Programmable send logic for special customized scheme (aided channel 2)
514	Aided 2 Send	Aided Scheme Logic	Aided channel 2 send - internal send signal generated in signal send logic
515	Aid2 Custom T In	PSL	When using a custom programmable aided scheme 2, the user is able to include a current reversal guard timer. Energizing this DDB will additionally start this timer, from PSL
516	Aid2 CustomT Out	Aided Scheme Logic	When using customized aided scheme 2, this signal is used to indicate any additional condition that should be treated as permission for an aided trip (for example a permissive signal received could be connected, or a blocking signal could be inverted and then connected)
517	Aid2 Trip Enable	Aided Scheme Logic	Aided scheme 2 trip enable - this is a permissive signal used to accelerate zone 2, or a blocking signal which has been inverted. It is a signal output, part-way through the internal fixed logic of aided schemes
518	Aid2 Custom Trip	PSL	Aid2 custom trip enable
519	Aid 2 Dist Trip	Aided Scheme Logic	Aided scheme 2 distance trip command (output from aided tripping logic)
520	Not used		
521	Aid 2 DEF Trip	Aided Scheme Logic	Aided scheme 2 DEF trip command (output from aided tripping logic)
522	Any Trip	Trip Conversion Logic	Any trip signal - can be used as the trip command in three-pole tripping applications
523	Trip Output A	Trip Conversion Logic	Trip signal for phase A - used as a command to drive trip A output contact(s). Takes the output from the internal trip conversion logic
524	Trip Output B	Trip Conversion Logic	Trip signal for phase B - used as a command to drive trip B output contact(s). Takes the output from the internal trip conversion logic
525	Trip Output C	Trip Conversion Logic	Trip signal for phase C - used as a command to drive trip C output contact(s). Takes the output from the internal trip conversion logic
526	Trip 3ph	Trip Conversion Logic	3 phase trip command
527	2/3 Ph Fault	Trip Conversion Logic	2 or 3 phase fault indication - used to flag whether the fault is polyphase. Typically used to control auto-reclose logic, where auto-reclosing is allowed only for single phase faults
528	3 Ph Fault	Trip Conversion Logic	3 phase fault indication. Typically used to control auto-reclose logic, where auto-reclosing is blocked for faults affecting all three phases together
529	Trip Inputs 3Ph	PSL	Trip 3 phase - input to trip latching logic

DDB No.	English Text	Source	Description
530	Trip Inputs A	PSL	A phase trip - input to trip conversion logic. Essential to ensure correct single or three pole trip command results (e.g. converts a 2 pole trip to 3 phase)
531	Trip Inputs B	PSL	B phase trip - input to trip conversion logic. Essential to ensure correct single or three pole trip command results (e.g. converts a 2 pole trip to 3 phase)
532	Trip Inputs C	PSL	C phase trip - input to trip conversion logic. Essential to ensure correct single or three pole trip command results (e.g. converts a 2 pole trip to 3 phase)
533	Force 3Pole Trip	PSL	Force any trip which is issued to always be 3 pole (trip conversion - used in single pole trip applications, to signal when single pole tripping and re-closing is either unwanted, or impossible)
534	External Trip3ph (or CB1 Ext Trip3Ph)	PSL	External trip 3 phase - allows external protection to initiate breaker fail, circuit breaker condition monitoring statistics, and internal auto-reclose (if enabled)
535	External Trip A (or CB1 Ext Trip A)	PSL	External trip A phase - allows external protection to initiate breaker fail, circuit breaker condition monitoring statistics, and internal auto-reclose (if enabled)
536	External Trip B (or CB1 Ext Trip B)	PSL	External trip B phase - allows external protection to initiate breaker fail, circuit breaker condition monitoring statistics, and internal auto-reclose (if enabled)
537	External Trip C (or CB1 Ext Trip C)	PSL	External trip C phase - allows external protection to initiate breaker fail, circuit breaker condition monitoring statistics, and internal auto-reclose (if enabled)
538	CB2 Ext Trip3ph	PSL	External trip 3 phase - allows external protection to initiate breaker 2 fail
539	CB2 Ext Trip A	PSL	External trip A phase - allows external protection to initiate breaker 2 fail
540	CB2 Ext Trip B	PSL	External trip B phase - allows external protection to initiate breaker 2 fail
541	CB2 Ext Trip C	PSL	External trip C phase - allows external protection to initiate breaker 2 fail
542	SG Select x1	PSL	Setting group selector X1 (low bit)-selects SG2 if only DDB 542 signal is active. SG1 is active if both DDB 542 & DDB 543=0 SG4 is active if both DDB 542 & DDB 543=1
543	SG Select 1x	PSL	Setting group selector 1X (high bit)-selects SG3 if only DDB 543 is active. SG1 is active if both DDB 542 & DDB 543=0 SG4 is active if both DDB 542 & DDB 543=1
544	Clear Statistics	PSL	To reset all statistics values cumulated on the relay. If mapped, the input for this signal could come from a command of the remote end (DDB 1020 - clear stats cmd -) via IM64
550	Inhibit Predictive OST	PSL	Block predictive out of step tripping command
551	Predictive OST	PSL	Predictive out of step trip
552	Inhibit OST	PSL	Block out of step tripping command
553	OST	PSL	Out of step trip
554	Start Z5	PSL	Positive sequence impedance is detected in Z5
555	Start Z6	PSL	Positive sequence impedance is detected in Z6

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DDB No.	English Text	Source	Description
556 to 575	Not Used		
545 to 575	Not used		
576	AR Trip Test	Commissioning Test	Auto-reclose trip test cycle in progress. Indication that a manually-initiated test cycle is in progress
577	AR Trip Test A	Commissioning Test	Auto-reclose trip test A phase. Indication that a manually-initiated test cycle is in progress
578	AR Trip Test B	Commissioning Test	Auto-reclose trip test B phase. Indication that a manually-initiated test cycle is in progress
579	AR Trip Test C	Commissioning Test	Auto-reclose trip test C phase. Indication that a manually-initiated test cycle is in progress
580	AR Init 3Ph	Auto-Reclose	Initiate 3 phase auto-reclose (signal to an external re-closer)
581	Block AR	Auto-Reclose	Block auto-reclose (BAR signal to an external re-closer)
582	Diff Trip	C Diff	Current differential trip
583	Diff Trip A	C Diff	Current differential A phase trip
584	Diff Trip B	C Diff	Current differential B phase trip
585	Diff Trip C	C Diff	Current differential C phase trip
586	Diff InterTrip	C Diff	Current differential intertrip
587	Diff InterTrip A	C Diff	Current differential A phase intertrip
588	Diff InterTrip B	C Diff	Current differential B phase intertrip
589	Diff InterTrip C	C Diff	Current differential C phase intertrip
590	Perm InterTrip	C Diff	Permissive intertrip
591	Stub Bus Trip	C Diff	Stub bus trip
592 to 607	Not used		
608	Zone 1 Trip	Distance Basic Scheme	Zone 1 trip
609	Zone 1 A Trip	Distance Basic Scheme	Zone 1 A phase trip
610	Zone 1 B Trip	Distance Basic Scheme	Zone 1 B phase trip
611	Zone 1 C Trip	Distance Basic Scheme	Zone 1 C phase trip
612	Zone 1 N Trip	Distance Basic Scheme	Zone 1 N trip
613	Zone 2 Trip	Distance Basic Scheme	Zone 2 trip
614	Zone 2 A Trip	Distance Basic Scheme	Zone 2 A phase trip
615	Zone 2 B Trip	Distance Basic Scheme	Zone 2 B phase trip
616	Zone 2 C Trip	Distance Basic Scheme	Zone 2 C phase trip
617	Zone 2 N Trip	Distance Basic Scheme	Zone 2 N trip
618	Zone 3 Trip	Distance Basic Scheme	Zone 3 trip
619	Zone 3 A Trip	Distance Basic Scheme	Zone 3 A phase trip
620	Zone 3 B Trip	Distance Basic Scheme	Zone 3 B phase trip
621	Zone 3 C Trip	Distance Basic Scheme	Zone 3 C phase trip

DDB No.	English Text	Source	Description
622	Zone 3 N Trip	Distance Basic Scheme	Zone 3 N trip
623	Zone P Trip	Distance Basic Scheme	Zone P trip
624	Zone P A Trip	Distance Basic Scheme	Zone P A phase trip
625	Zone P B Trip	Distance Basic Scheme	Zone P B phase trip
626	Zone P C Trip	Distance Basic Scheme	Zone P C phase trip
627	Zone P N Trip	Distance Basic Scheme	Zone P N trip
628	Zone 4 Trip	Distance Basic Scheme	Zone 4 trip
629	Zone 4 A Trip	Distance Basic Scheme	Zone 4 A phase trip
630	Zone 4 B Trip	Distance Basic Scheme	Zone 4 B phase trip
631	Zone 4 C Trip	Distance Basic Scheme	Zone 4 C phase trip
632	Zone 4 N Trip	Distance Basic Scheme	Zone 4 N phase trip
633	Aided 1 Trip A	Aided Scheme Logic	Aided channel scheme 1 trip A phase
634	Aided 1 Trip B	Aided Scheme Logic	Aided channel scheme 1 trip B phase
635	Aided 1 Trip C	Aided Scheme Logic	Aided channel scheme 1 trip C phase
636	Aided 1 Trip N	Aided Scheme Logic	Aided channel scheme 1 trip involving ground (N)
637	Aid 1 WI Trip A	Aided Scheme Logic	Aided scheme 1 weak infeed trip phase A
638	Aid 1 WI Trip B	Aided Scheme Logic	Aided scheme 1 weak infeed trip phase B
639	Aid 1 WI Trip C	Aided Scheme Logic	Aided scheme 1 weak infeed trip phase C
640	Not used		
641	Aid1 DEF Trip3Ph	Aided Scheme Logic	Aided 1 directional earth fault scheme trip 3 phase
642	Aid1 WI Trip 3Ph	Aided Scheme Logic	Aided channel scheme 1 - weak infeed logic trip 3 phase
643	Aided 2 Trip A	Aided Scheme Logic	Aided channel scheme 2 trip A phase
644	Aided 2 Trip B	Aided Scheme Logic	Aided channel scheme 2 trip B phase
645	Aided 2 Trip C	Aided Scheme Logic	Aided channel scheme 2 trip C phase
646	Aided 2 Trip N	Aided Scheme Logic	Aided channel scheme 2 trip involving ground (N)
647	Aid 2 WI Trip A	Aided Scheme Logic	Aided scheme 2 weak infeed trip phase A
648	Aid 2 WI Trip B	Aided Scheme Logic	Aided scheme 2 weak infeed trip phase B
649	Aid 2 WI Trip C	Aided Scheme Logic	Aided scheme 2 weak infeed trip phase C
650	Not used		
651	Aid2 DEF Trip3Ph	Aided Scheme Logic	Aided 2 directional earth fault scheme trip 3 phase
652	Aid2 WI Trip 3Ph	Aided Scheme Logic	Aided channel scheme 2 - weak infeed logic trip 3 phase
653	Not used		
654	Loss of Load Trip	Loss of Load Logic	Loss of load trip
655	I>1 Trip	Overcurrent	1st stage phase overcurrent trip 3 phase
656	I>1 Trip A	Overcurrent	1st stage phase overcurrent trip phase A
657	I>1 Trip B	Overcurrent	1st stage phase overcurrent trip phase B
658	I>1 Trip C	Overcurrent	1st stage phase overcurrent trip phase C

DDB No.	English Text	Source	Description
659	I>2 Trip	Overcurrent	2nd stage phase overcurrent trip 3 phase
660	I>2 Trip A	Overcurrent	2nd stage phase overcurrent trip phase A
661	I>2 Trip B	Overcurrent	2nd stage phase overcurrent trip phase B
662	I>2 Trip C	Overcurrent	2nd stage phase overcurrent trip phase C
663	I>3 Trip	Overcurrent	3rd stage phase overcurrent trip 3 phase
664	I>3 Trip A	Overcurrent	3rd stage phase overcurrent trip phase A
665	I>3 Trip B	Overcurrent	3rd stage phase overcurrent trip phase B
666	I>3 Trip C	Overcurrent	3rd stage phase overcurrent trip phase C
667	I>4 Trip	Overcurrent	4th stage phase overcurrent trip 3 phase
668	I>4 Trip A	Overcurrent	4th stage phase overcurrent trip phase A
669	I>4 Trip B	Overcurrent	4th stage phase overcurrent trip phase B
670	I>4 Trip C	Overcurrent	4th stage phase overcurrent trip phase C
671	IN>1 Trip	Earth Fault	1st stage stand by earth fault (SBEF) protection trip
672	IN>2 Trip	Earth Fault	2nd stage stand by earth fault (SBEF) protection trip
673	IN>3 Trip	Earth Fault	3rd stage stand by earth fault (SBEF) protection trip
674	IN>4 Trip	Earth Fault	4th stage stand by earth fault (SBEF) protection trip
675	ISEF>1 Trip	Sensitive Earth Fault	1st stage sensitive earth fault (SEF) protection trip
676	ISEF>2 Trip	Sensitive Earth Fault	2nd stage sensitive earth fault (SEF) protection trip
677	ISEF>3 Trip	Sensitive Earth Fault	3rd stage sensitive earth fault (SEF) protection trip
678	ISEF>4 Trip	Sensitive Earth Fault	4th stage sensitive earth fault (SEF) protection trip
679	Broken Wire Trip	Broken Conductor	Broken conductor trip
680	Thermal Trip	Thermal Overload	Thermal overload trip
683	V<1 Trip	Undervoltage	Undervoltage stage 1, three phase trip
684	V<1 Trip A/AB	Undervoltage	Undervoltage stage 1 A phase trip
685	V<1 Trip B/BC	Undervoltage	Undervoltage stage 1 B phase trip
686	V<1 Trip C/CA	Undervoltage	Undervoltage stage 1 C phase trip
687	V<2 Trip	Undervoltage	Undervoltage stage 2, three phase trip
688	V<2 Trip A/AB	Undervoltage	Undervoltage stage 2 A phase trip
689	V<2 Trip B/BC	Undervoltage	Undervoltage stage 2 B phase trip
690	V<2 Trip C/CA	Undervoltage	Undervoltage stage 2 C phase trip
691	V>1 Trip	Overvoltage	Overvoltage stage 1, three phase trip
692	V>1 Trip A/AB	Overvoltage	Overvoltage stage 1 A phase trip
693	V>1 Trip B/BC	Overvoltage	Overvoltage stage 1 B phase trip
694	V>1 Trip C/CA	Overvoltage	Overvoltage stage 1 C phase trip
695	V>2 Trip	Overvoltage	Overvoltage stage 2, three phase trip
696	V>2 Trip A/AB	Overvoltage	Overvoltage stage 2 A phase trip
697	V>2 Trip B/BC	Overvoltage	Overvoltage stage 2 B phase trip
698	V>2 Trip C/CA	Overvoltage	Overvoltage stage 2 C phase trip
699	Pole Discrepancy	Pole Discrepancy	Pole discrepancy signal to force a three pole trip conversion, if the relay detects one pole dead, and no auto-reclose in progress
700	VN>1 Trip	Residual overvoltage	Residual overvoltage stage 1 trip

DDB No.	English Text	Source	Description
701	VN>2 Trip	Residual Overvoltage	Residual overvoltage stage 2 trip
702	Fault REC TRIG	PSL	Trigger for fault recorder
703	I2> Trip	Neg Sequence Overcurrent	Negative sequence overcurrent trip
704	TOR Trip Zone 1	Trip on Close	TOR trip zone 1 (trip on reclose)
705	TOR Trip Zone 2	Trip on Close	TOR trip zone 2
706	TOR Trip Zone 3	Trip on Close	TOR trip zone 3
707	TOR Trip Zone 4	Trip on Close	TOR trip zone 4
708	TOR Trip Zone P	Trip on Close	TOR trip zone P
709	SOTF Trip Zone 1	Trip on Close	SOTF trip zone 1 (switch on to fault)
710	SOTF Trip Zone 2	Trip on Close	SOTF trip zone 2
711	SOTF Trip Zone 3	Trip on Close	SOTF trip zone 3
712	SOTF Trip Zone 4	Trip on Close	SOTF trip zone 4
713	SOTF Trip Zone P	Trip on Close	SOTF trip zone P
714 to 735	Not used		
736	Any Start		Any start
737	Diff Start	C Diff	Current differential start
738	Diff Start A	C Diff	Current differential A phase start
739	Diff Start B	C Diff	Current differential B phase start
740	Diff Start C	C Diff	Current differential C phase start
741	Zone 1 A Start	Distance Basic Scheme	Zone 1 A phase start
742	Zone 1 B Start	Distance Basic Scheme	Zone 1 B phase start
743	Zone 1 C Start	Distance Basic Scheme	Zone 1 C phase start
744	Zone 1 N Start	Distance Basic Scheme	Zone 1 ground element start
745	Zone 2 A Start	Distance Basic Scheme	Zone 2 A phase start
746	Zone 2 B Start	Distance Basic Scheme	Zone 2 B phase start
747	Zone 2 C Start	Distance Basic Scheme	Zone 2 C phase start
748	Zone 2 N Start	Distance Basic Scheme	Zone 2 ground element start
749	Zone 3 A Start	Distance Basic Scheme	Zone 3 A phase start
750	Zone 3 B Start	Distance Basic Scheme	Zone 3 B phase start
751	Zone 3 C Start	Distance Basic Scheme	Zone 3 C phase start
752	Zone 3 N Start	Distance Basic Scheme	Zone 3 N start
753	Zone P A Start	Distance Basic Scheme	Zone P A phase start
754	Zone P B Start	Distance Basic Scheme	Zone P B phase start
755	Zone P C Start	Distance Basic Scheme	Zone P C phase start

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DDB No.	English Text	Source	Description
756	Zone P N Start	Distance Basic Scheme	Zone P N start
757	Zone 4 A Start	Distance Basic Scheme	Zone 4 A phase start
758	Zone 4 B Start	Distance Basic Scheme	Zone 4 B phase start
759	Zone 4 C Start	Distance Basic Scheme	Zone 4 C phase start
760	Zone 4 N Start	Distance Basic Scheme	Zone 4 N start
761	I>1 Start	Overcurrent	1st stage overcurrent start 3 phase
762	I>1 Start A	Overcurrent	1st stage overcurrent start phase A
763	I>1 Start B	Overcurrent	1st stage overcurrent start phase B
764	I>1 Start C	Overcurrent	1st stage overcurrent start phase C
765	I>2 Start	Overcurrent	2nd stage overcurrent start 3 phase
766	I>2 Start A	Overcurrent	2nd stage overcurrent start phase A
767	I>2 Start B	Overcurrent	2nd stage overcurrent start phase B
768	I>2 Start C	Overcurrent	2nd stage overcurrent start phase C
769	I>3 Start	Overcurrent	3rd stage overcurrent start 3 phase
770	I>3 Start A	Overcurrent	3rd stage overcurrent start phase A
771	I>3 Start B	Overcurrent	3rd stage overcurrent start phase B
772	I>3 Start C	Overcurrent	3rd stage overcurrent start phase C
773	I>4 Start	Overcurrent	4th stage overcurrent start 3 phase
774	I>4 Start A	Overcurrent	4th stage overcurrent start phase A
775	I>4 Start B	Overcurrent	4th stage overcurrent start phase B
776	I>4 Start C	Overcurrent	4th Stage overcurrent start phase C
777	IN>1 Start	Earth Fault	1st stage stand by earth fault (SBEF) overcurrent start
778	IN>2 Start	Earth Fault	2nd stage stand by earth fault (SBEF) overcurrent start
779	IN>3 Start	Earth Fault	3rd stage stand by earth fault (SBEF) overcurrent start
780	IN>4 Start	Earth Fault	4th stage stand by earth fault (SBEF) overcurrent start
781	ISEF>1 Start	Sensitive Earth Fault	1st stage sensitive earth fault (SEF) overcurrent start
782	ISEF>2 Start	Sensitive Earth Fault	2nd stage sensitive earth fault (SEF) overcurrent start
783	ISEF>3 Start	Sensitive Earth Fault	3rd stage sensitive earth fault (SEF) overcurrent start
784	ISEF>4 Start	Sensitive Earth Fault	4th stage sensitive earth fault (SEF) overcurrent start
785	Thermal Alarm	Thermal Overload	Thermal overload alarm
786,787	Not used		
788	V<1 Start	Undervoltage	Undervoltage stage 1, three phase start
789	V<1 Start A/AB	Undervoltage	Undervoltage stage 1, A phase start
790	V<1 Start B/BC	Undervoltage	Undervoltage stage 1, B phase start
791	V<1 Start C/CA	Undervoltage	Undervoltage stage 1, C phase start
792	V<2 Start	Undervoltage	Undervoltage stage 2, three phase start
793	V<2 Start A/AB	Undervoltage	Undervoltage stage 2, A phase start

DDB No.	English Text	Source	Description
794	V<2 Start B/BC	Undervoltage	Undervoltage stage 2, B phase start
795	V<2 Start C/CA	Undervoltage	Undervoltage stage 2, C phase start
796	V>1 Start	Overvoltage	Overvoltage stage 1, three phase start
797	V>1 Start A/AB	Overvoltage	Overvoltage stage 1, A phase start
798	V>1 Start B/BC	Overvoltage	Overvoltage stage 1, B phase start
799	V>1 Start C/CA	Overvoltage	Overvoltage stage 1, C phase start
800	V>2 Start	Overvoltage	Overvoltage stage 2, three phase start
801	V>2 Start A/AB	Overvoltage	Overvoltage stage 2, A phase start
802	V>2 Start B/BC	Overvoltage	Overvoltage stage 2, B phase start
803	V>2 Start C/CA	Overvoltage	Overvoltage stage 2, C phase start
804	VN>1 Start	Residual Overvoltage	Residual overvoltage stage 1 start
805	VN>2 Start	Residual Overvoltage	Residual overvoltage stage 2 start
806	I2>Start	Neg Sequence Overcurrent	Negative sequence overcurrent stage 1 start
807 to 828	Not used		
829	VA< Start	Poledead	Phase A undervoltage level detector used in the pole dead logic. Detectors have a fixed threshold: undervoltage pickup 38.1V-drop off 43.8 V
830	VB< Start	Poledead	Phase B undervoltage level detector used in the pole dead logic. Detectors have a fixed threshold: undervoltage pickup 38.1V-drop off 43.8 V
831	VC< Start	Poledead	Phase C undervoltage level detector used in the pole dead logic. Detectors have a fixed threshold: undervoltage pickup 38.1V-drop off 43.8 V
832	VTS Fast Block	VT Supervision	VT supervision fast block - blocks elements which would otherwise maloperate immediately a fuse failure event occurs
833	VTS Slow Block	VT Supervision	VT supervision slow block - blocks elements which would otherwise maloperate some time after a fuse failure event occurs
834	Bfail1 Trip 3ph	CB Fail	tBF1 trip 3Ph - three phase output from circuit breaker failure logic, stage 1
835	Bfail2 Trip 3ph	CB Fail	tBF2 trip 3Ph - three phase output from circuit breaker failure logic, stage 2
836	CB2 Fail1 Trip	CB Fail	tBF1 trip 3Ph - three phase output from circuit breaker failure 2 logic, stage 1
837	CB2 Fail2 Trip	CB Fail	tBF2 trip 3Ph - three phase output from circuit breaker failure 2 logic, stage 2
838	Control Trip	CB Control	Control trip - operator trip instruction to the circuit breaker, via menu, or SCADA. (Does not operate for protection element trips)
839	Control Close	CB Control	Control close command to the circuit breaker. Operates for a manual close command (menu, SCADA), and additionally is driven by the auto-reclose close command
840	Control Trip 2	CB Control	Control trip - operator trip instruction to the circuit breaker 2, via menu, or SCADA. (Does not operate for protection element trips)
841	Control Close 2	CB Control	Control close command to the circuit breaker 2. Operates for a manual close command (menu, SCADA)
842	Close in Prog	CB Control	Control close in progress - the relay has been given an instruction to close the circuit breaker, but the manual close timer delay has not yet finished timing out

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DDB No.	English Text	Source	Description
843	Block Main Prot	Auto-Reclose	Auto-reclose block main protection
844	AR 3pole in prog	Auto-Reclose	Auto-reclose 3 pole in progress (dead time is running)
845	AR 1pole in prog	Auto-Reclose	Single pole auto-reclose in progress (dead time is running)
846	Seq Counter = 0	Auto-Reclose	Auto-reclose sequence counter is at zero - no previous faults have been cleared within recent history. The sequence count is at zero because no reclaim times are timing out, and the auto-recloser is not locked out. The recloser is awaiting the first protection trip, and all programmed cycles are free to follow
847	Seq Counter = 1	Auto-Reclose	The first fault trip has happened in a new auto-reclose sequence. Dead time 1, or reclaim time 1 are in the process of timing out
848	Seq Counter = 2	Auto-Reclose	Auto-reclose sequence counter is at 2. This means that the initial fault trip happened, and then another trip followed, moving the counter on to 2
849	Seq Counter = 3	Auto-Reclose	Auto-reclose sequence counter is at 3. This means that the initial fault trip happened, and then 2 trips followed, moving the counter on to 3
850	Seq Counter = 4	Auto-Reclose	Auto-reclose sequence counter is at 4. This means that the initial fault trip happened, and then 3 trips followed, moving the counter on to 4
852	Successful Close	Auto-Reclose	Successful re-closure indication. The circuit breaker was re-closed by the AR function, and stayed closed. This indication is raised at the expiry of the reclaim time
853	Dead T in Prog	Auto-Reclose	Auto-reclose dead time in progress
854	Auto Close	Auto-Reclose	Auto-reclose command to the circuit breaker
855	Not used		
856	A/R Status 3P	Auto-Reclose	3 Pole auto-recloser in service - the auto-reclose function has been enabled either in the relay menu, or by an opto input
857	AR Status 1P	Auto-Reclose	Single pole auto-recloser in service - the auto-reclose function has been enabled either in the relay menu, or by an opto input
858	Force 3 pole	Auto-Reclose	Due to the sequence count reached, lockout, or any outage of the internal auto-recloser - this signal instructs any other trips to be forced to three pole trips
859	AR Blocked	Auto-Reclose	It indicates that AR has been blocked (ex. from external input BAR)
860	Lockout Alarm	CB Control	Composite lockout alarm - circuit breaker locked out due to auto-recloser, or condition monitoring reasons
861 to 863	Not used		
864	IA< Start	Undercurrent	A phase undercurrent level detector pickup (detects low current). It is used for breaker failure in models with one CT input and also it is used for fault record reset (as the sum CTs in models with two CTs)
865	IB< Start	Undercurrent	B phase undercurrent level detector pickup (detects low current). It is used for breaker failure in models with one CT input and also it is used for fault record reset (as the sum CTs in models with two CTs)
866	IC< Start	Undercurrent	C phase undercurrent level detector pickup (detects low current). It is used for breaker failure in models with one CT input and also it is used for fault record reset (as the sum CTs in models with two CTs)

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DDB No.	English Text	Source	Description
867	CB1 IA< Start	Undercurrent	A phase undercurrent level detector pickup (detects low current in CT1). It is used for breaker failure in models with two CT inputs
868	CB1 IB< Start	Undercurrent	B phase undercurrent level detector pickup (detects low current in CT1). It is used for breaker failure in models with two CT inputs
869	CB1 IC< Start	Undercurrent	C phase undercurrent level detector pickup (detects low current in CT1). It is used for breaker failure in models with two CT inputs
870	CB2 IA< Start	Undercurrent	A phase undercurrent level detector pickup (detects low current in CT2). It is used for breaker failure in models with two CT inputs
871	CB2 IB< Start	Undercurrent	B phase undercurrent level detector pickup (detects low current in CT2). It is used for breaker failure in models with two CT inputs
872	CB2 IC< Start	Undercurrent	C phase undercurrent level detector pickup (detects low current in CT2). It is used for breaker failure in models with two CT inputs
873	ISEF< Start	Undercurrent	SEF undercurrent level detector pickup (detects low current in CT SEF)
874 to 875	Not used		
876	Z1X Active	Zone 1 Extension Scheme	Zone 1 extension active - zone 1 is operating in its reach extended mode
877	TOC Active	Trip on Close	Trip on close functions (either SOTF or TOR) active. These elements are in-service for a period of time following circuit breaker closure
878	TOR Active	Trip on Close	Trip on re-close protection is active - indicated 200ms after circuit breaker opening, and remains in-service on auto-reclosure for the duration of the trip on close window
879	SOTF Active	Trip on Close	Switch on to fault protection is active - in service on manual breaker closure, and then remains in-service for the duration of the trip on close window
880	SysChks Inactive	Check Sync	System checks inactive (output from the check synchronism, and other voltage checks)
881	CS1 Enabled	PSL	Check sync. stage 1 enabled
882	CS2 Enabled	PSL	Check sync. stage 2 enabled
883	Check Sync 1 OK	Check Sync	Check sync. stage 1 OK
884	Check Sync 2 OK	Check Sync	Check sync. stage 2 OK
885	SysSplit Enabled	PSL	System split function enabled
886	Live Bus	Voltage Monitoring	Indicates live bus condition is detected
887	Dead Bus	Voltage Monitoring	Indicates dead bus condition is detected
888	Live Line	Voltage Monitoring	Indicates live line condition is detected
889	Dead Line	Voltage Monitoring	Indicates dead line condition is detected
890	All Poles Dead	Pole Dead Logic	Pole dead logic detects 3 phase breaker open
891	Any Pole Dead	Pole Dead Logic	Pole dead logic detects at least one breaker pole open
892	Pole Dead A	Pole Dead Logic	Phase A pole dead
893	Pole Dead B	Pole Dead Logic	Phase B pole dead
894	Pole Dead C	Pole Dead Logic	Phase C pole dead
897	AR Check Sync OK	PSL	Input to the auto-reclose logic to indicate system in synchronism
898	Ctl Check Sync	PSL	Input to the circuit breaker control logic to indicate manual check synchronization conditions are satisfied

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DDB No.	English Text	Source	Description
899	AR Sys Checks OK	PSL	Input to the auto-reclose logic to indicate system checks conditions are satisfied
900 to 902	Not used		
903	CB Open 3 ph	CB Status	Circuit breaker is open, all three phases
904	CB Open A ph	CB Status	Circuit breaker A phase is open
905	CB Open B ph	CB Status	Circuit breaker A phase is open
906	CB Open C ph	CB Status	Circuit breaker A phase is open
907	CB Closed 3 ph	CB Status	Circuit breaker is closed, all three phases
908	CB Closed A ph	CB Status	Circuit breaker A phase is closed
909	CB Closed B ph	CB Status	Circuit breaker B phase is closed
910	CB Closed C ph	CB Status	Circuit breaker C phase is closed
911	CB2 Open 3 ph	CB Status	Circuit breaker 2 is open, all three phases
912	CB2 Open A ph	CB Status	Circuit breaker 2 A phase is open
913	CB2 Open B ph	CB Status	Circuit breaker 2 A phase is open
914	CB2 Open C ph	CB Status	Circuit breaker 2 A phase is open
915	CB2 Closed 3 ph	CB Status	Circuit breaker 2 is closed, all three phases
916	CB2 Closed A ph	CB Status	Circuit breaker 2 A phase is closed
917	CB2 Closed B ph	CB Status	Circuit breaker 2 B phase is closed
918	CB2 Closed C ph	CB Status	Circuit breaker 2 C phase is closed
919 to 927	Not used		
928	CTS Block	CT Supervision	Standard or differential CT supervision block (current transformer supervision)
929	CTS Block Diff	CT Supervision	Differential CT supervision block (current transformer supervision)
930	CTS Restrain	CT Supervision	Differential CT supervision restrain (current transformer supervision)
931	CT1 L i1>	CT Supervision	Positive sequence current in local end CT1 exceed CTS i1> setting
932	CT2 L i1>	CT Supervision	Positive sequence current in local end CT2 exceed CTS i1> setting
933	CT1 R1 i1>	CT Supervision	Positive sequence current in remote 1 end CT1 exceed CTS i1> setting
934	CT2 R1 i1>	CT Supervision	Positive sequence current in remote 1 end CT2 exceed CTS i1> setting
935	CT1 R2 i1>	CT Supervision	Positive sequence current in remote 2 end CT1 exceed CTS i1> setting
936	CT2 R2 i1>	CT Supervision	Positive sequence current in remote 2 end CT2 exceed CTS i1> setting
937	CT1 L i2/i1>	CT Supervision	i2/i1 ratio in local end CT1 exceed CTS i2/i1> setting
938	CT2 L i2/i1>	CT Supervision	i2/i1 ratio in local end CT2 exceed CTS i2/i1> setting
939	CT1 R1 i2/i1>	CT Supervision	i2/i1 ratio in remote 1 end CT1 exceed CTS i2/i1> setting
940	CT2 R1 i2/i1>	CT Supervision	i2/i1 ratio in remote 1 end CT2 exceed CTS i2/i1> setting
941	CT1 R2 i2/i1>	CT Supervision	i2/i1 ratio in remote 2 end CT1 exceed CTS i2/i1> setting
942	CT2 R2 i2/i1>	CT Supervision	i2/i1 ratio in remote 2 end CT2 exceed CTS i2/i1> setting
943	CT1 L i2/i1>>	CT Supervision	i2/i1 ratio in local end CT1 exceed CTS i2/i1>> setting

DDB No.	English Text	Source	Description
944	CT2 L i2/i1>>	CT Supervision	i2/i1 ratio in local end CT2 exceed CTS i2/i1>> setting
945	CT1 R1 i2/i1>>	CT Supervision	i2/i1 ratio in remote 1 end CT1 exceed CTS i2/i1>> setting
946	CT2 R1 i2/i1>>	CT Supervision	i2/i1 ratio in remote 1 end CT2 exceed CTS i2/i1>> setting
947	CT1 R2 i2/i1>>	CT Supervision	i2/i1 ratio in remote 2 end CT1 exceed CTS i2/i1>> setting
948	CT2 R2 i2/i1>>	CT Supervision	i2/i1 ratio in remote 2 end CT2 exceed CTS i2/i1>> setting
949 to 951	Not used		
952	Faulted Phase A	PSL	Faulted phase A - must be assigned, as this sets the start flag used in records, and on the LCD display
953	Faulted Phase B	PSL	Faulted phase B - must be assigned, as this sets the start flag used in records, and on the LCD display
954	Faulted Phase C	PSL	Faulted phase C - must be assigned, as this sets the start flag used in records, and on the LCD display
955	Faulted Phase N	PSL	Faulted phase N (fault involves ground) - must be assigned, as this sets the start flag used in records, and on the LCD display
956	Started Phase A	PSL	Started phase A - must be assigned, as this sets the start flag used in records, and on the LCD display
957	Started Phase B	PSL	Started phase B - must be assigned, as this sets the start flag used in records, and on the LCD display
958	Started Phase C	PSL	Started phase C - must be assigned, as this sets the start flag used in records, and on the LCD display
959	Started Phase N	PSL	Started phase N (fault involves ground) - must be assigned, as this sets the start flag used in records, and on the LCD display
960	Zone1 AN Element	Distance Elements	Zone 1 AN ground fault element
961	Zone1 BN Element	Distance Elements	Zone 1 BN ground fault element
962	Zone1 CN Element	Distance Elements	Zone 1 CN ground fault element
963	Zone1 AB Element	Distance Elements	Zone 1 AB phase fault element
964	Zone1 BC Element	Distance Elements	Zone 1 BC phase fault element
965	Zone1 CA Element	Distance Elements	Zone 1 CA phase fault element
966	Zone2 AN Element	Distance Elements	Zone 2 AN ground fault element
967	Zone2 BN Element	Distance Elements	Zone 2 BN ground fault element
968	Zone2 CN Element	Distance Elements	Zone 2 CN ground fault element
969	Zone2 AB Element	Distance Elements	Zone 2 AB phase fault element
970	Zone2 BC Element	Distance Elements	Zone 2 BC phase fault element
971	Zone2 CA Element	Distance Elements	Zone 2 CA phase fault element
972	Zone3 AN Element	Distance Elements	Zone 3 AN ground fault element
973	Zone3 BN Element	Distance Elements	Zone 3 BN ground fault element
974	Zone3 CN Element	Distance Elements	Zone 3 CN ground fault element
975	Zone3 AB Element	Distance Elements	Zone 3 AB phase fault element
976	Zone3 BC Element	Distance Elements	Zone 3 BC phase fault element
977	Zone3 CA Element	Distance Elements	Zone 3 CA phase fault element

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DDB No.	English Text	Source	Description
978	ZoneP AN Element	Distance Elements	Zone P AN ground fault element
979	ZoneP BN Element	Distance Elements	Zone P BN ground fault element
980	ZoneP CN Element	Distance Elements	Zone P CN ground fault element
981	ZoneP AB Element	Distance Elements	Zone P AB phase fault element
982	ZoneP BC Element	Distance Elements	Zone P BC phase fault element
983	ZoneP CA Element	Distance Elements	Zone P CA phase fault element
984	Zone4 AN Element	Distance Elements	Zone 4 AN ground fault element
985	Zone4 BN Element	Distance Elements	Zone 4 BN ground fault element
986	Zone4 CN Element	Distance Elements	Zone 4 CN ground fault element
987	Zone4 AB Element	Distance Elements	Zone 4 AB phase fault element
988	Zone4 BC Element	Distance Elements	Zone 4 BC phase fault element
989	Zone4 CA Element	Distance Elements	Zone 4 CA phase fault element
990 to 995	Not used		
996	DEF Forward	Directional Earth Fault	DEF forward (directional earth fault aided scheme detector)
997	DEF Reverse	Directional Earth Fault	DEF reverse (directional earth fault aided scheme detector)
998	Delta Dir FWD AN	Delta Directional Element	Delta directional scheme forward AN detection
999	Delta Dir FWD BN	Delta Directional Element	Delta directional scheme forward BN detection
1000	Delta Dir FWD CN	Delta Directional Element	Delta directional scheme forward CN detection
1001	Delta Dir FWD AB	Delta Directional Element	Delta directional scheme forward AB detection
1002	Delta Dir FWD BC	Delta Directional Element	Delta directional scheme forward BC detection
1003	Delta Dir FWD CA	Delta Directional Element	Delta directional scheme forward CA detection
1004	Delta Dir Rev AN	Delta Directional Element	Delta directional scheme reverse AN detection
1005	Delta Dir Rev BN	Delta Directional Element	Delta directional scheme reverse BN detection
1006	Delta Dir Rev CN	Delta Directional Element	Delta directional scheme reverse CN detection
1007	Delta Dir Rev AB	Delta Directional Element	Delta directional scheme reverse AB detection
1008	Delta Dir Rev BC	Delta Directional Element	Delta directional scheme reverse BC detection
1009	Delta Dir Rev CA	Delta Directional Element	Delta directional scheme reverse CA detection
1010	Phase Select A	Phase Selector	Phase selector - phase A pickup
1011	Phase Select B	Phase Selector	Phase selector - phase B pickup
1012	Phase Select C	Phase Selector	Phase selector - phase C pickup
1013	Phase Select N	Phase Selector	Phase selector - neutral indication
1014	P Swing Detector	Powerswing Blocking	Power swing detected
1015	PSB Fault	Powerswing Blocking	Power swing block fault
1016	I(2)/I(1)> A	Inrush Detector	2nd harmonic current ratio exceeds threshold on phase A (may be used to block any instantaneous distance elements that reach through the reactance of a power transformer)

DDB No.	English Text	Source	Description
1017	I(2)/I(1)> B	Inrush Detector	2nd harmonic current ratio exceeds threshold on phase B (may be used to block any instantaneous distance elements that reach through the reactance of a power transformer)
1018	I(2)/I(1)> C	Inrush Detector	2nd harmonic current ratio exceeds threshold on phase C (may be used to block any instantaneous distance elements that reach through the reactance of a power transformer)
1019	I(2)/I(1)> N	Inrush Detector	2nd harmonic current ratio exceeds threshold on neutral current measurement (may be used to block any instantaneous distance elements that reach through the reactance of a power transformer)
1020	Clear Stats Cmd	PSL	This is an indication of the command “Clear Statistics” available in the PSL. This DDB could be used to reset statistics at the remote end (via IM64) by linking it to DDB 544 - clear statistics - at the remote end
1021 to 1023	Not used		
1024	LED1 Red	Output Conditioner	Programmable LED 1 red is energized
1025	LED1 Grn.	Output Conditioner	Programmable LED 1 green is energized
1038	LED8 Red	Output Conditioner	Programmable LED 8 red is energized
1039	LED8 Grn.	Output Conditioner	Programmable LED 8 green is energized
1040	FnKey LED1 Red	Output Conditioner	Programmable function key LED 1 red is energized
1041	FnKey LED1 Grn.	Output Conditioner	Programmable function key LED 1 green is energized
1058	FnKey LED10 Red	Output Conditioner	Programmable function key LED 10 red is energized
1059	FnKey LED10 Grn.	Output Conditioner	Programmable function key LED 10 green is energized
1060	LED1 Con R	PSL	Assignment of input signal to drive output LED 1 red
1061	LED1 Con G	PSL	Assignment of signal to drive output LED 1 green. To drive LED 1 yellow DDB 676 and DDB 677 must be driven at the same time
1074	LED8 Con R	PSL	Assignment of signal to drive output LED 8 red
1075	LED8 Con G	PSL	Assignment of signal to drive output LED 8 green. To drive LED 8 yellow DDB 690 and DDB 691 must be active at the same time
1076	FnKey LED1 ConR	PSL	Assignment of signal to drive output function key LED 1 red. This LED is associated with function key 1
1077	FnKey LED1 ConG	PSL	Assignment of signal to drive output function key LED 1 green. This LED is associated with function key 1. To drive function key LED, yellow DDB 692 and DDB 693 must be active at the same time
1094	FnKey LED10 ConR	PSL	Assignment of signal to drive output function key LED 10 red. This LED is associated with function key 10
1095	FnKey LED10 ConG	PSL	Assignment of signal to drive output function key LED 10 green. This LED is associated with function key 10. To drive function key LED1 yellow, DDB 710 and DDB 711 must be active at the same time
1096	Function Key 1	Function Key	Function key 1 is activated. In ‘Normal’ mode it is high on keypress and in ‘Toggle’ mode remains high/low on single keypress

DDB No.	English Text	Source	Description
1105	Function Key 10	Function Key	Function key 10 is activated. In 'Normal' mode it is high on keypress and in 'Toggle' mode remains high/low on single keypress
1106	I^ Maint. Alarm	CB Monitoring	Broken current maintenance alarm - circuit breaker cumulative duty alarm set-point
1107	I^ Lockout Alarm	CB Monitoring	Broken current lockout alarm - circuit breaker cumulative duty has been exceeded
1108	CB OPs Maint.	CB Monitoring	No of circuit breaker operations maintenance alarm - indicated due to circuit breaker trip operations threshold
1109	CB OPs Lockout	CB Monitoring	No of circuit breaker operations maintenance lockout - excessive number of circuit breaker trip operations, safety lockout
1110	CB Op Time Maint	CB Monitoring	Excessive circuit breaker operating time maintenance alarm - excessive operation time alarm for the circuit breaker (slow interruption time)
1111	CB Op Time Lockout	CB Monitoring	Excessive circuit breaker operating time lockout alarm - excessive operation time alarm for the circuit breaker (too slow interruption)
1112	Fault Freq. Lock	CB Monitoring	Excessive fault frequency lockout alarm
1113 to 1119	Not used		
1120	SignalFail Ch1Rx	C Diff	Reception from channel 1 is lost
1121	SignalFail Ch1Tx	C Diff	Transmission from channel 1 is lost
1122	Ch 1 GPS Fail	C Diff	It indicates that GPS sampling synchronization (for protection purposes) running on channel 1 is lost
1123	Ch1 Mux Clk	Fiber Monitor Bits	This is an alarm that appears if the channel 1 baud rate is outside the limits 52Kbis/s or 70 Kbits/s
1124	Ch1 Signal Lost	Fiber Monitor Bits	Mux indicates signal lost over channel 1
1125	Ch1 Path Yellow	Fiber Monitor Bits	One way communication. Local relay that is sending over Ch1 indicates that remote end is not receiving
1126	Ch1 Mismatch RxN	Fiber Monitor Bits	Indication of mismatch between Ch1 N*64kbits/s setting and Mux
1127	Ch1 Timeout	Fiber Monitor Bits	Indication that no valid message is received over channel 1 during 'Channel Timeout' window
1128	Ch1 Degraded	Fiber Monitor Bits	Indicates poor channel 1 quality
1129	Ch1 Passthrough	Fiber Monitor Bits	Ch1 data received via Ch 2 in 3 ended configuration - self healing indication -
1130	SignalFail Ch2Rx	C Diff	Reception from channel 2 is lost
1131	SignalFail Ch2Tx	C Diff	Transmission from channel 2 is lost
1132	Ch 2 GPS Fail	C Diff	It indicates that GPS sampling synchronization (for protection purposes) running on channel 2 is lost
1133	Ch2 Mux Clk	Fiber Monitor Bits	This is an alarm that appears if the channel 2 baud rate is outside the limits 52Kbis/s or 70 Kbits/s
1134	Ch2 Signal Lost	Fiber Monitor Bits	Mux indicates signal lost over channel 2
1135	Ch2 Path Yellow	Fiber Monitor Bits	One way communication. Local relay that is sending over Ch2 indicates that remote end is not receiving
1136	Ch2 Mismatch RxN	Fiber Monitor Bits	Indication of mismatch between InterMiCOM^{64} Ch 2 setting and Mux
1137	Ch2 Timeout	Fiber Monitor Bits	Indication that no valid message is received over channel 2 during 'Channel Timeout' window
1138	Ch2 Degraded	Fiber Monitor Bits	Indicates poor channel 2 quality

DDB No.	English Text	Source	Description
1139	Ch2 Passthrough	Fiber Monitor Bits	Ch2 data received via Ch 1 in 3 ended configuration - self healing indication -
1176	HMI Access Lvl 1		It indicates that level access 1 for HMI interface is enabled
1177	HMI Access Lvl 2		It indicates that level access 2 for HMI interface is enabled
1178	FPort AccessLvl1		It indicates that level access 1 for the front port interface is enabled
1179	FPort AccessLvl2		It indicates that level access 2 for the front port interface is enabled
1180	RPrt1 AccessLvl1		It indicates that level access 1 for the rear port 1 interface is enabled
1181	RPrt1 AccessLvl2		It indicates that level access 2 for the rear port 1 interface is enabled
1182	RPrt2 AccessLvl1		It indicates that level access 1 for the rear port 2 interface is enabled
1183	RPrt2 AccessLvl2		It indicates that level access 2 for the rear port 2 interface is enabled
1184	Monitor Bit 1	Commissioning Test	Monitor port signal 1 - allows mapped monitor signals to be mapped to disturbance recorder or contacts
1191	Monitor Bit 8	Commissioning Test	Monitor port signal 8
1193	Not used		
1194	PSL Int 1	PSL	PSL internal node
1293	PSL Int 100	PSL	PSL internal node
1294	VTS Ia>	VT Supervision	“VTS I> Inhibit “ setting has been exceeded in phase a
1295	VTS Ib>	VT Supervision	“VTS I> Inhibit “ setting has been exceeded in phase b
1296	VTS Ic>	VT Supervision	“VTS I> Inhibit “ setting has been exceeded in phase c
1297	VTS Va>	VT Supervision	Va has exceed 30 volts (drop off at 10 volts)
1298	VTS Vb>	VT Supervision	Vb has exceed 30 volts (drop off at 10 volts)
1299	VTS Vc>	VT Supervision	Vc has exceed 30 volts (drop off at 10 volts)
1300	VTS I2>	VT Supervision	“VTS I2> Inhibit “ setting has been exceeded
1301	VTS V2>	VT Supervision	V2 has exceed 10 volts
1302	VTS Ia delta>	VT Supervision	Superimposed phase a current has exceed 0.1In
1303	VTS Ib delta>	VT Supervision	Superimposed phase b current has exceed 0.1In
1304	VTS Ic delta>	VT Supervision	Superimposed phase c current has exceed 0.1In
1375	Teleprotection Disturbed		This is an output signal available in the PSL, that could be mapped to “C Diff Failure” for IEC870-5-103
1376	I>> Back Up Supervision		This applies only if distance primary FUN is selected (in IEC870-5-103) This signal is ON if an overcurrent stage is selected to be enabled on VTS and distance is blocked by VTS
1377	O/C Trip By VTS		This applies only if distance primary FUN is selected (in IEC870-5-103) This signal is ON if DDB 1376 is ON and one of the overcurrent stages set to be enabled on VTS condition trips

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DDB No.	English Text	Source	Description
1378	Teleprotection Sent		This applies only if distance primary FUN is selected (in IEC870-5-103) This is an output signal available in the PSL, which could be mapped to a signal send of one of the two teleprotection channels
1379	Teleprotection Received		This applies only if distance primary FUN is selected (in IEC870-5-103) This is an output signal available in the PSL, which could be mapped to a signal receive of one of the two teleprotection channels
1380	Group Warning		This is an output signal available in the PSL, which can be mapped in IEC870-5-103 to a minor defect which does not shut down the main protection
1381	Group Alarm		This is an output signal available in the PSL, which can be mapped in IEC870-5-103 to a major problem normally linked to the watchdog
1382	AR On Pulse		This is an output signal available in the PSL, which can be mapped to enable AR via pulse
1383	AR OFF Pulse		This is an output signal available in the PSL, which can be mapped to disable AR via pulse
1384	AR Enable		This is an output signal available in the PSL, which can be mapped to enable AR
1385	AR In Service		Auto-reclose in service

1.8 Factory default programmable scheme logic

The following section details the default settings of the PSL.

The P54xmodel options are as follows:

Model	Opto Inputs	Relay Outputs
P543xxx?xxxxxxK	16	14
P543xxx#xxxxxxK	16	7 standard and 4 high break
P544xxx?xxxxxxK	16	14
P544xxx#xxxxxxK	16	7 standard and 4 high break
P545xxx?xxxxxxK	24	32
P545xxx#xxxxxxK	24	16 standard and 8 high break
P546xxx?xxxxxxK	24	32
P546xxx#xxxxxxK	24	16 standard and 8 high break

Note: ? is for models with only standard output contacts = A, B, C, D, E, F, G, H, J, K, L, M or R.

is for models with standard and high break contacts = S, T, U, V, W, X, Z, 0, 1, 2, 3, 4 or 5.

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1.9 Logic input mappings

The default mappings for each of the opto-isolated inputs are as shown in the following table:

Opto-Input Number	P543 Relay Text	Function
1	Input L1	L1 Inhibit Diff
2	Input L2	L2 Interlock
3	Input L3	L3 Aid 1 Receive
4	Input L4	L4 Aid 1 COS/LGS
5	Input L5	L5 Reset LEDs
6	Input L6	L6 Ext Trip A
7	Input L7	L7 Ext Trip B
8	Input L8	L8 Ext Trip C
9	Input L9	L9 CB AuxA 52-B
10	Input L10	L10 CB AuxB 52-B
11	Input L11	L11 CB AuxC 52-B
12	Input L12	L12 MCB/VTS
13	Input L13	L13 CB Close Man
14	Input L14	L14 Reset Lckout
15	Input L15	L15 CB Healthy
16	Input L16	L16 BAR

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Opto-Input Number	P544 Relay Text	Function
1	Input L1	L1 Inhibit Diff
2	Input L2	L2 Interlock
3	Input L3	L3 Aid 1 Receive
4	Input L4	L4 Aid 1 COS/LGS
5	Input L5	L5 Reset LEDs
6	Input L6	L6 CB2 AuxA 52-B
7	Input L7	L7 CB2 AuxB 52-B
8	Input L8	L8 CB2 AuxC 52-B
9	Input L9	L9 CB AuxA 52-B
10	Input L10	L10 CB AuxB 52-B
11	Input L11	L11 CB AuxC 52-B
12	Input L12	L12 MCB/VTS
13	Input L13	L13 CB1 CloseMan
14	Input L14	L14 CB2 CloseMan
15	Input L15	L15 Not Used
16	Input L16	L16 Stub Bus En

Opto-Input Number	P545 Relay Text	Function
1	Input L1	L1 Inhibit Diff
2	Input L2	L2 Interlock
3	Input L3	L3 Aid 1 Receive
4	Input L4	L4 Aid 1 COS/LGS
5	Input L5	L5 Reset LEDs
6	Input L6	L6 Ext Trip A
7	Input L7	L7 Ext Trip B
8	Input L8	L8 Ext Trip C
9	Input L9	L9 CB AuxA 52-B
10	Input L10	L10 CB AuxB 52-B
11	Input L11	L11 CB AuxC 52-B
12	Input L12	L12 MCB/VTS
13	Input L13	L13 CB Close Man
14	Input L14	L14 Reset Lckout
15	Input L15	L15 CB Healthy
16	Input L16	L16 BAR
17	Input L17	L17 PIT
18	Input L18	L18 Prop Dly Eq
19	Input L19	L19 IM64 1
20	Input L20	L20 IM64 2
21	Input L21	L21 IM64 3
22	Input L22	L22 IM64 4
23	Input L23	L23 Not Used
24	Input L24	L24 Not Used

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Opto-Input Number	P546 Relay Text	Function
1	Input L1	L1 Inhibit Diff
2	Input L2	L2 Interlock
3	Input L3	L3 Aid 1 Receive
4	Input L4	L4 Aid 1 COS/LGS
5	Input L5	L5 Reset LEDs
6	Input L6	L6 CB2 AuxA 52-B
7	Input L7	L7 CB2 AuxB 52-B
8	Input L8	L8 CB2 AuxC 52-B
9	Input L9	L9 CB AuxA 52-B
10	Input L10	L10 CB AuxB 52-B
11	Input L11	L11 CB AuxC 52-B
12	Input L12	L12 MCB/VTS

Opto-Input Number	P546 Relay Text	Function
13	Input L13	L13 CB1 CloseMan
14	Input L14	L14 CB2 CloseMan
15	Input L15	L15 Not Used
16	Input L16	L16 Stub Bus En
17	Input L17	L17 PIT
18	Input L18	L18 Prop Dly Eq
19	Input L19	L19 IM64 1
20	Input L20	L20 IM64 2
21	Input L21	L21 IM64 3
22	Input L22	L22 IM64 4
23	Input L23	L23 Not Used
24	Input L24	L24 Not Used

1.10 Standard relay output contact mappings

The default mappings for each of the relay output contacts are as shown in the following table:

Relay Contact Number	P543 Relay Text	P543 Relay Conditioner	Function
1	Output R1	Straight-through	R1 Trip Z1
2	Output R2	Straight-through	R2 SignalingFail
3	Output R3	Dwell 100ms	R3 Any Trip
4	Output R4	Dwell 500ms	R4 General Alarm
5	Output R5	Straight-through	R5 IM64 1
6	Output R6	Dwell 100ms	R6 CB Fail Time1
7	Output R7	Straight-through	R7 Cntl CB Close
8	Output R8	Straight-through	R8 Cntl CB Trip
9	Output R9	Dwell 100ms	R9 Trip A
10	Output R10	Dwell 100ms	R10 Trip B
11	Output R11	Dwell 100ms	R11 Trip C
12	Output R12	Straight-through	R12 AR in Prog
13	Output R13	Straight-through	R13 SuccessClose
14	Output R14	Straight-through	R14 AR Lockout

Relay Contact Number	P544 Relay Text	P544 Relay Conditioner	Function
1	Output R1	Straight-through	R1 Trip Diff/Z1
2	Output R2	Straight-through	R2 SignalingFail
3	Output R3	Dwell 100ms	R3 Any Trip
4	Output R4	Dwell 500ms	R4 General Alarm
5	Output R5	Straight-through	R5 IM64 1
6	Output R6	Dwell 100ms	R6 CB1 Fail1Trip
7	Output R7	Straight-through	R7 Cntl CB1 Close
8	Output R8	Straight-through	R8 Cntl CB1 Trip
9	Output R9	Dwell 100ms	R9 Trip A
10	Output R10	Dwell 100ms	R10 Trip B
11	Output R11	Dwell 100ms	R11 Trip C
12	Output R12	Dwell 100ms	R12 CB2 Fail1Trip
13	Output R13	Straight-through	R13 CntlCB2Close
14	Output R14	Straight-through	R14 Cntl CB2Trip

PL

Relay Contact Number	P545 Relay Text	P545 Relay Conditioner	Function
1	Output R1	Straight-through	R1 Trip Z1
2	Output R2	Straight-through	R2 SignalingFail
3	Output R3	Dwell 100ms	R3 Any Trip
4	Output R4	Dwell 500ms	R4 General Alarm
5	Output R5	Straight-through	R5 IM64 1
6	Output R6	Dwell 100ms	R6 CB Fail Time1
7	Output R7	Straight-through	R7 Cntl CB Close
8	Output R8	Straight-through	R8 Cntl CB Trip
9	Output R9	Dwell 100ms	R9 Trip A
10	Output R10	Dwell 100ms	R10 Trip B
11	Output R11	Dwell 100ms	R11 Trip C
12	Output R12	Straight-through	R12 AR in Prog
13	Output R13	Straight-through	R13 SuccessClose
14	Output R14	Straight-through	R14 AR Lockout
15	Output R15	Straight-through	R15 AR InService
16	Output R16	Straight-through	R16 BAR
17	Output R17	Dwell 100ms	R17 Trip A
18	Output R18	Dwell 100ms	R18 Trip B
19	Output R19	Dwell 100ms	R19 Trip C
20	Output R20	Straight-through	R20 DistInst Trp

Relay Contact Number	P545 Relay Text	P545 Relay Conditioner	Function
21	Output R21	Straight-through	R21 Dist Dly Trp
22	Output R22	Straight-through	R22 Aid DEF Trip
23	Output R23	Straight-through	R23 Any Start
24	Output R24	Straight-through	R24 Aid 1 Send
25	Output R25	Straight-through	R25 GPS Fail
26	Output R26	Straight-through	R26 Diff Trip
27	Output R27	Straight-through	R27 VTS
28	Output R28	Straight-through	R28 PSB
29	Output R29	Straight-through	R29 IM64 2
30	Output R30	Straight-through	R30 IM64 3
31	Output R31	Straight-through	R31 IM64 4
32	Output R32	Straight-through	R32 Not Used

Relay Contact Number	P546 Relay Text	P546 Relay Conditioner	Function
1	Output R1	Straight-through	R1 Trip Z1
2	Output R2	Straight-through	R2 SignalingFail
3	Output R3	Dwell 100ms	R3 Any Trip
4	Output R4	Dwell 500ms	R4 General Alarm
5	Output R5	Straight-through	R5 IM64 1
6	Output R6	Dwell 100ms	R6 CB1 Fail1Trip
7	Output R7	Straight-through	R7 Cntl CB1 Close
8	Output R8	Straight-through	R8 Cntl CB1 Trip
9	Output R9	Dwell 100ms	R9 Trip A
10	Output R10	Dwell 100ms	R10 Trip B
11	Output R11	Dwell 100ms	R11 Trip C
12	Output R12	Dwell 100ms	R12 CB2 Fail1Trip
13	Output R13	Straight-through	R13 CntlCB2Close
14	Output R14	Straight-through	R14 Cntl CB2Trip
15	Output R15	Dwell 100ms	R15 CB1 Fail2Trip
16	Output R16	Dwell 100ms	R16 CB2 Fail2Trip
17	Output R17	Dwell 100ms	R17 Trip A
18	Output R18	Dwell 100ms	R18 Trip B
19	Output R19	Dwell 100ms	R19 Trip C
20	Output R20	Straight-through	R20 DistInst Trp
21	Output R21	Straight-through	R21 Dist Dly Trp
22	Output R22	Straight-through	R22 Aid DEF Trip

Relay Contact Number	P546 Relay Text	P546 Relay Conditioner	Function
23	Output R23	Straight-through	R23 Any Start
24	Output R24	Straight-through	R24 Aid 1 Send
25	Output R25	Straight-through	R25 GPS Fail
26	Output R26	Straight-through	R26 Diff Trip
27	Output R27	Straight-through	R27 VTS
28	Output R28	Straight-through	R28 PSB
29	Output R29	Straight-through	R29 IM64 2
30	Output R30	Straight-through	R30 IM64 3
31	Output R31	Straight-through	R31 IM64 4
32	Output R32	Straight-through	R32 Not Used

Note: A fault record can be generated by connecting one or a number of contacts to the “Fault Record Trigger” in PSL. It is recommended that the triggering contact be ‘self reset’ and not a latching. If a latching contact were chosen the fault record would not be generated until the contact had fully reset.

1.11 Optional high break relay output contact mappings

The default mappings for each of the standard and high break relay output contacts are as shown in the following table:

PL

High break contacts are shown in grey shaded cells.

Relay Contact Number	P543 Relay Text	P543 Relay Conditioner	Function
1	Output R1	Straight-through	R1 Trip Diff/Z1
2	Output R2	Straight-through	R2 SignalingFail
3	Output R3	Dwell 100ms	R3 Any Trip
4	Output R4	Dwell 500ms	R4 General Alarm
5	Output R5	Straight-through	R5 IM64 1
6	Output R6	Dwell 100ms	R6 CB Fail Time1
7	Output R7	Straight-through	R7 Cntl CB Close
8	Output R8	Dwell 100ms	R8 Trip A
9	Output R9	Dwell 100ms	R9 Trip B
10	Output R10	Dwell 100ms	R10 Trip C
11	Output R11	Dwell 100ms	R11 Any Trip

Relay Contact Number	P544 Relay Text	P544 Relay Conditioner	Function
1	Output R1	Straight-through	R1 Trip Diff/Z1
2	Output R2	Straight-through	R2 SignalingFail
3	Output R3	Dwell 100ms	R3 Any Trip
4	Output R4	Dwell 500ms	R4 General Alarm
5	Output R5	Straight-through	R5 IM64 1
6	Output R6	Dwell 100ms	R6 CB1 Fail1Trip
7	Output R7	Straight-through	R7 CB2 Fail1Trip
8	Output R8	Dwell 100ms	R8 Trip A
9	Output R9	Dwell 100ms	R9 Trip B
10	Output R10	Dwell 100ms	R10 Trip C
11	Output R11	Dwell 100ms	R11 Any Trip

Relay Contact Number	P545 Relay Text	P545 Relay Conditioner	Function
1	Output R1	Straight-through	R1 Trip Z1
2	Output R2	Straight-through	R2 SignalingFail
3	Output R3	Dwell 100ms	R3 Any Trip
4	Output R4	Dwell 500ms	R4 General Alarm
5	Output R5	Straight-through	R5 IM64 1
6	Output R6	Dwell 100ms	R6 CB Fail Time1
7	Output R7	Straight-through	R7 Cntl CB Close
8	Output R8	Straight-through	R8 Cntl CB Trip
9	Output R9	Dwell 100ms	R9 Trip A
10	Output R10	Dwell 100ms	R10 Trip B
11	Output R11	Dwell 100ms	R11 Trip C
12	Output R12	Straight-through	R12 AR in Prog
13	Output R13	Straight-through	R13 SuccessClose
14	Output R14	Straight-through	R14 AR Lockout
15	Output R15	Straight-through	R15 AR InService
16	Output R16	Straight-through	R16 Aid 1 Send
17	Output R17	Dwell 100ms	R17 Trip A
18	Output R18	Dwell 100ms	R18 Trip B
19	Output R19	Dwell 100ms	R19 Trip C
20	Output R20	Dwell 100ms	R20 Any Trip
21	Output R21	Dwell 100ms	R21 Trip A
22	Output R22	Dwell 100ms	R22 Trip B
23	Output R23	Dwell 100ms	R23 Trip C

PL

Relay Contact Number	P545 Relay Text	P545 Relay Conditioner	Function
24	Output R24	Dwell 100ms	R24 Any Trip

Relay Contact Number	P546 Relay Text	P546 Relay Conditioner	Function
1	Output R1	Straight-through	R1 Trip Z1
2	Output R2	Straight-through	R2 SignalingFail
3	Output R3	Dwell 100ms	R3 Any Trip
4	Output R4	Dwell 500ms	R4 General Alarm
5	Output R5	Straight-through	R5 IM64 1
6	Output R6	Dwell 100ms	R6 CB1 Fail1Trip
7	Output R7	Straight-through	R7 Cntl CB1 Close
8	Output R8	Straight-through	R8 Cntl CB1 Trip
9	Output R9	Dwell 100ms	R9 Trip A
10	Output R10	Dwell 100ms	R10 Trip B
11	Output R11	Dwell 100ms	R11 Trip C
12	Output R12	Dwell 100ms	R12 Any Start
13	Output R13	Straight-through	R13 CntlCB2Close
14	Output R14	Straight-through	R14 Cntl CB2Trip
15	Output R15	Dwell 100ms	R15 CB2 Fail1Trip
16	Output R16	Dwell 100ms	R16 Aid 1 Send
17	Output R17	Dwell 100ms	R17 Trip A
18	Output R18	Dwell 100ms	R18 Trip B
19	Output R19	Dwell 100ms	R19 Trip C
20	Output R20	Dwell 100ms	R20 Any Trip
21	Output R21	Dwell 100ms	R21 Trip A
22	Output R22	Dwell 100ms	R22 Trip B
23	Output R23	Dwell 100ms	R23 Trip C
24	Output R24	Dwell 100ms	R24 Any Trip

Note: A fault record can be generated by connecting one or a number of contacts to the “Fault Record Trigger” in PSL. It is recommended that the triggering contact be ‘self reset’ and not a latching. If a latching contact were chosen the fault record would not be generated until the contact had fully reset.

1.12 Programmable LED output mappings

The default mappings for each of the programmable LEDs are as shown in the following table:

LED Number	LED Input Connection/Text	Latched	P543 LED Function Indication
1	LED 1 Red	Yes	Diff Trip
2	LED 2 Red	Yes	Dist Inst Trip
3	LED 3 Red	Yes	Dist Delay Trip
4	LED 4 Red	No	Signaling Fail
5	LED 5 Red	No	Any Start
6	LED 6 Red	No	AR in Progress
7	LED 7 Grn.	No	AR Lockout
8	LED 8 Red	No	Test Loopback
9	FnKey LED1 Red	No	Not Mapped
10	FnKey LED2 Red	No	Not Mapped
11	FnKey LED3 Red	No	Not Mapped
12	FnKey LED4 Red	No	Not Mapped
13	FnKey LED5 Red	No	Not Mapped
14	FnKey LED6 Red	No	Not Mapped
15	FnKey LED7 Red	No	Not Mapped
16	FnKey LED8 Red	No	Not Mapped
17	FnKey LED9 Red	No	Not Mapped
18	FnKey LED10 Red	No	Not Mapped

PL

LED Number	LED Input Connection/Text	Latched	P544 LED Function Indication
1	LED 1 Red	Yes	Diff Trip
2	LED 2 Red	Yes	Dist Inst Trip
3	LED 3 Red	Yes	Dist Delay Trip
4	LED 4 Red	No	Signaling Fail
5	LED 5 Red	No	Any Start
6	LED 6 Red	No	Not Used
7	LED 7 Grn.	No	Not Used
8	LED 8 Red	No	Test Loopback
9	FnKey LED1 Red	No	Not Mapped
10	FnKey LED2 Red	No	Not Mapped
11	FnKey LED3 Red	No	Not Mapped
12	FnKey LED4 Red	No	Not Mapped
13	FnKey LED5 Red	No	Not Mapped
14	Funky LED6 Red	No	Not Mapped

LED Number	LED Input Connection/Text	Latched	P544 LED Function Indication
15	Funky LED7 Red	No	Not Mapped
16	Funky LED8 Red	No	Not Mapped
17	Funky LED9 Red	No	Not Mapped
18	Funky LED10 Red	No	Not Mapped

LED Number	LED Input Connection/Text	Latched	P545 LED Function Indication
1	LED 1 Red	Yes	Diff Trip
2	LED 2 Red	Yes	Dist Inst Trip
3	LED 3 Red	Yes	Dist Delay Trip
4	LED 4 Red	No	Signaling Fail
5	LED 5 Red	No	Any Start
6	LED 6 Red	No	AR in Progress
7	LED 7 Grins.	No	AR Lockout
8	LED 8 Red	No	Test Loopback
9	Funky LED1 Red	No	Not Mapped
10	Funky LED2 Red	No	Not Mapped
11	Funky LED3 Red	No	Not Mapped
12	Funky LED4 Red	No	Not Mapped
13	Funky LED5 Red	No	Not Mapped
14	Funky LED6 Red	No	Not Mapped
15	Funky LED7 Red	No	Not Mapped
16	Funky LED8 Red	No	Not Mapped
17	Funky LED9 Red	No	Not Mapped
18	Funky LED10 Red	No	Not Mapped

PL

LED Number	LED Input Connection/Text	Latched	P546 LED Function Indication
1	LED 1 Red	Yes	Diff Trip
2	LED 2 Red	Yes	Dist Inst Trip
3	LED 3 Red	Yes	Dist Delay Trip
4	LED 4 Red	No	Signaling Fail
5	LED 5 Red	No	Any Start
6	LED 6 Red	No	Not Used
7	LED 7 Grins.	No	Not Used
8	LED 8 Red	No	Test Loopback
9	Funky LED1 Red	No	Not Mapped
10	Funky LED2 Red	No	Not Mapped
11	Funky LED3 Red	No	Not Mapped

LED Number	LED Input Connection/Text	Latched	P546 LED Function Indication
12	Funky LED4 Red	No	Not Mapped
13	Funky LED5 Red	No	Not Mapped
14	Funky LED6 Red	No	Not Mapped
15	Funky LED7 Red	No	Not Mapped
16	Funky LED8 Red	No	Not Mapped
17	Funky LED9 Red	No	Not Mapped
18	Funky LED10 Red	No	Not Mapped

1.13 Fault recorder start mappings

The default mappings for the signal which initiates a fault record is as shown in the following table:

Initiating Signal	Fault Trigger
DDB Any Trip (522)	Initiate fault recording from main protection trip

1.14 PSL DATA column

The MiCOM P54x relay contains a PSL DATA column that can be used to track PSL modifications. A total of 12 cells are contained in the PSL DATA column, 3 for each setting group. The function for each cell is shown below:

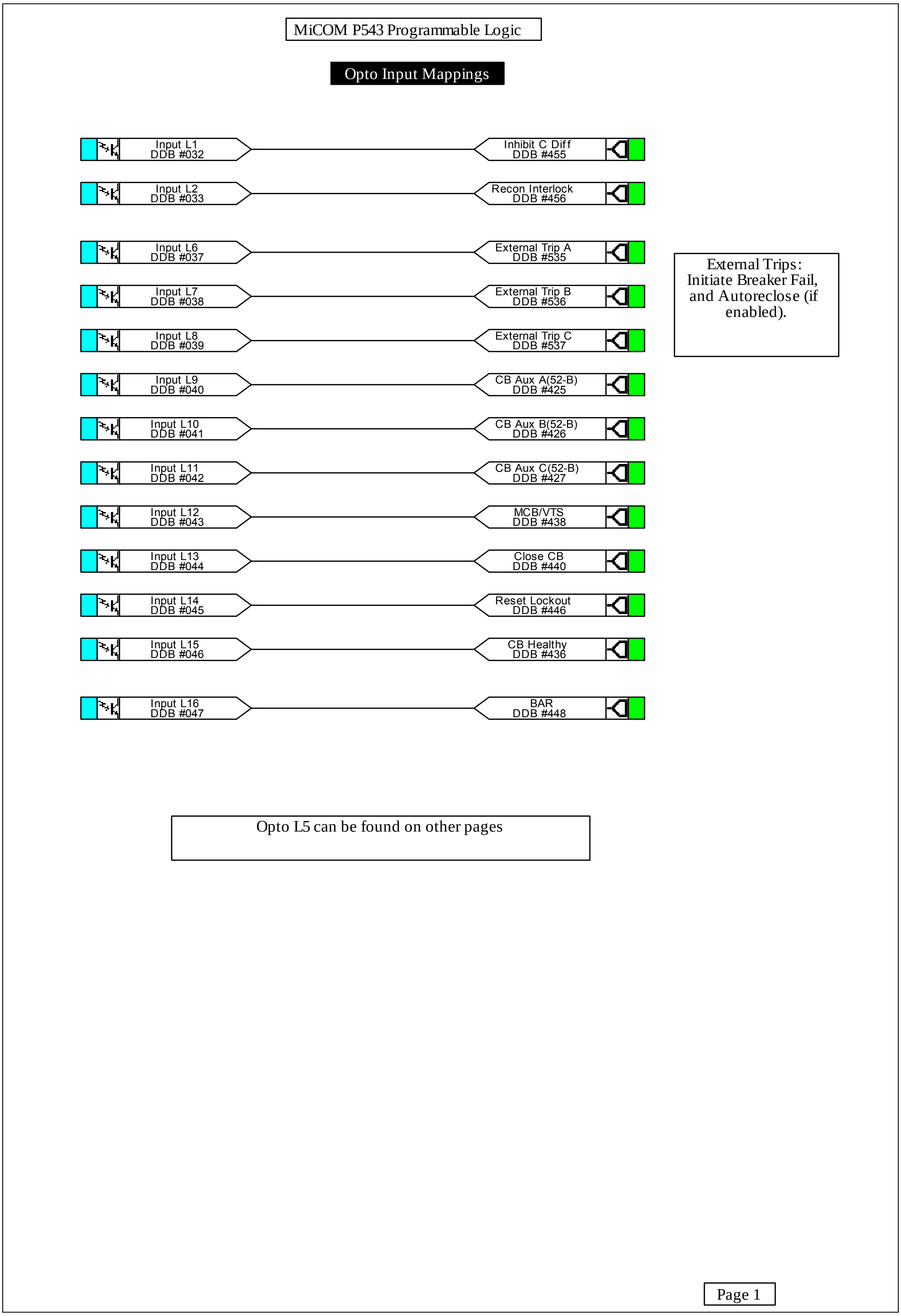
Grp. PSL Ref.	When downloading a PSL to the relay, the user will be prompted to enter which group the PSL is for and a reference identifier. The first 32 characters of the reference ID will be displayed in this cell. The ◁ and ▷ keys can be used to scroll through 32 characters as only 16 can be displayed at any one time.
18 Nov 2002 08:59:32.047	This cell displays the date and time when the PSL was down loaded to the relay.
Grp. 1 PSL ID - 2062813232	This is a unique number for the PSL that has been entered. Any change in the PSL will result in a different number being displayed.

Note: The above cells are repeated for each setting group.

PL

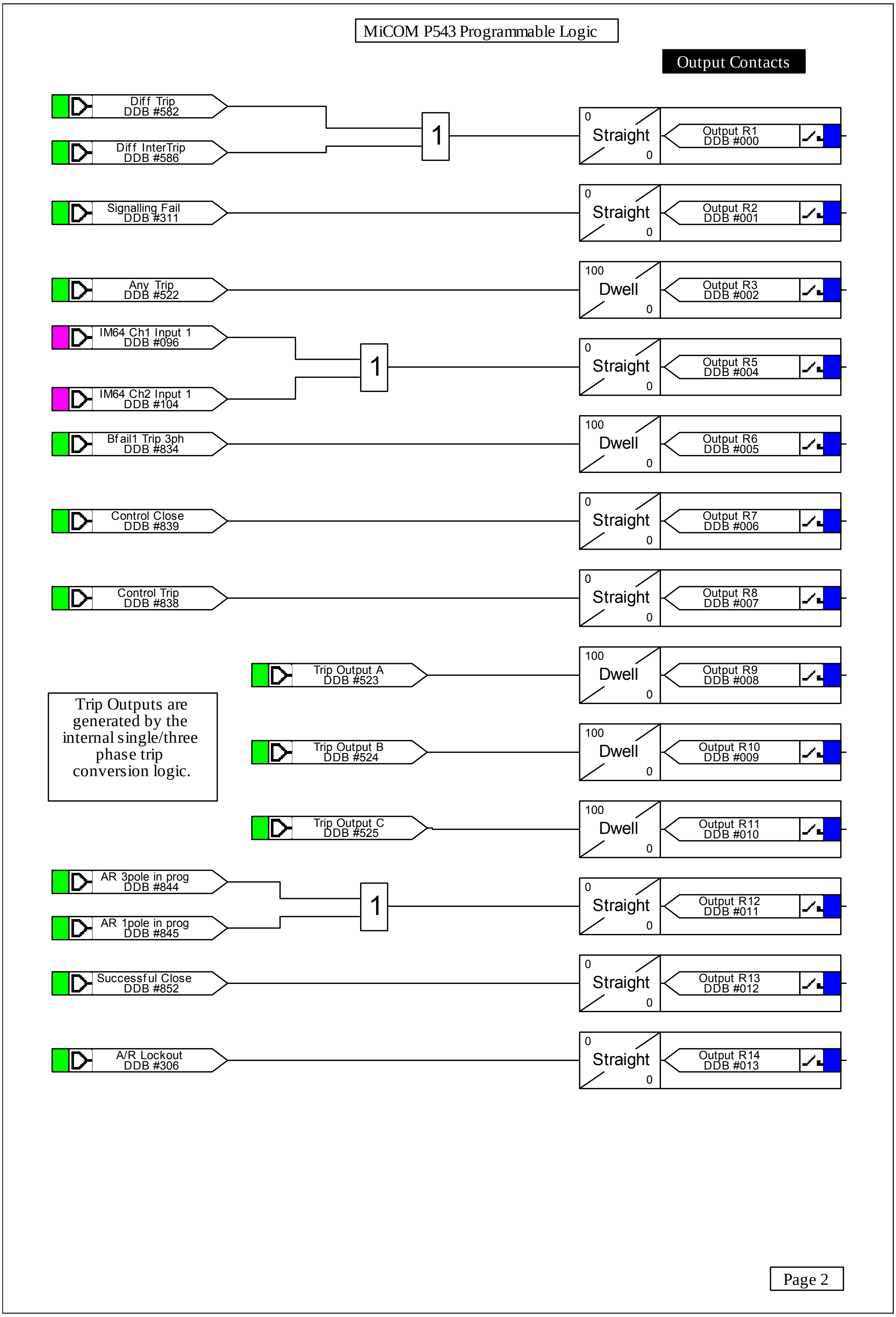
MiCOM P543 WITH NO DISTANCE OPTION AND STANDARD CONTACTS PROGRAMMABLE SCHEME LOGIC

Opto Input Mappings



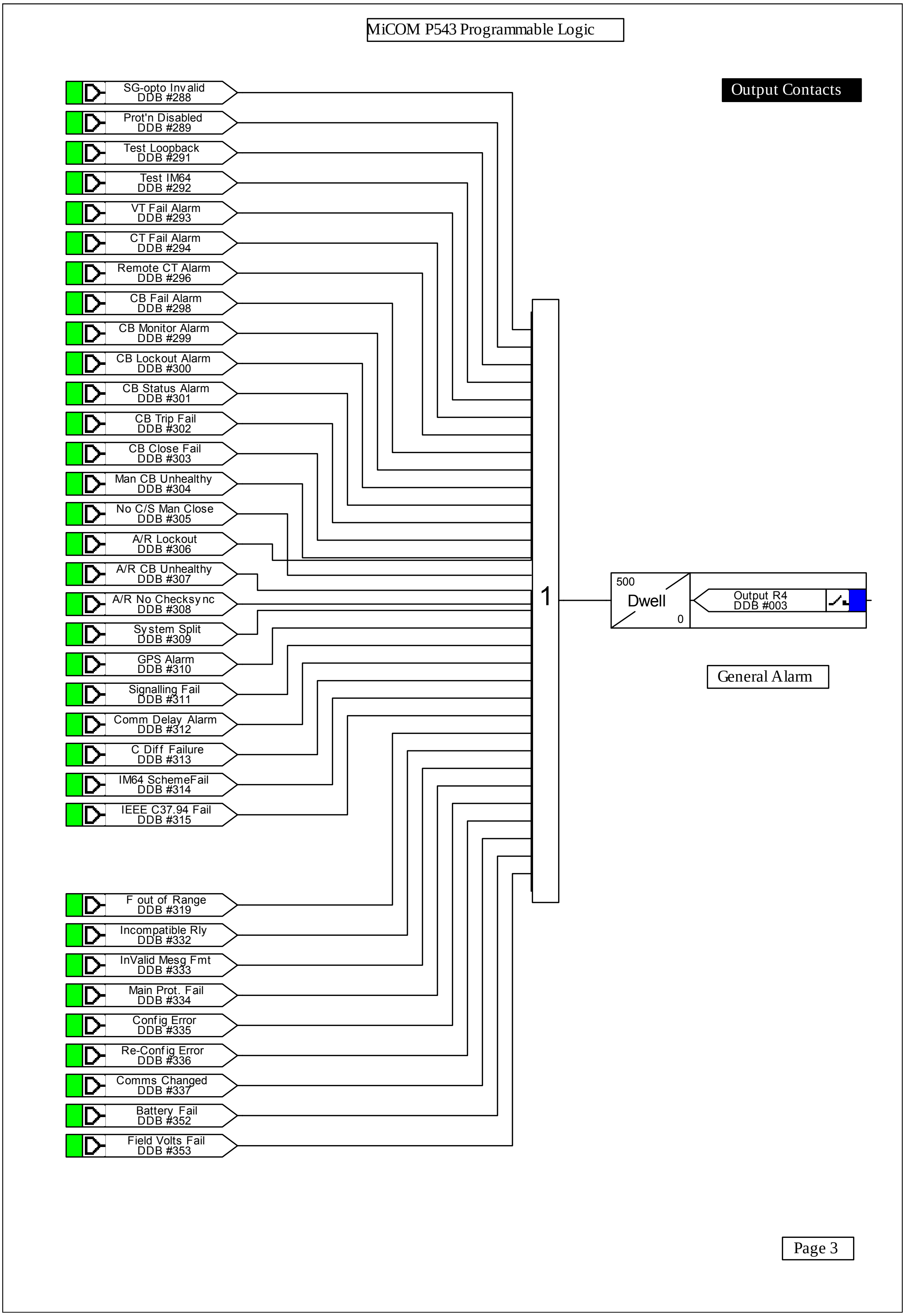
PL

Output Relay Mappings



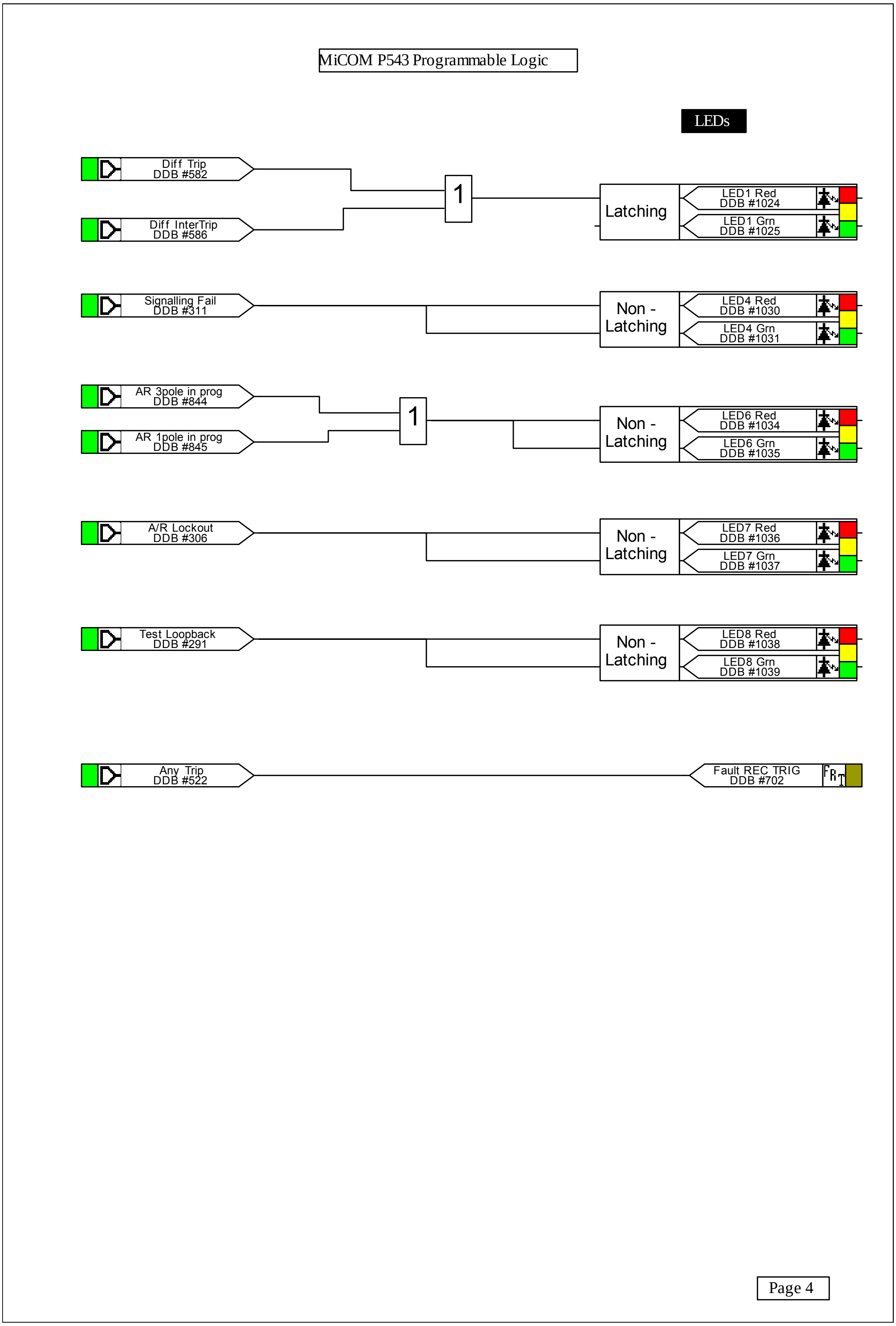
PL

Output Relay Mappings

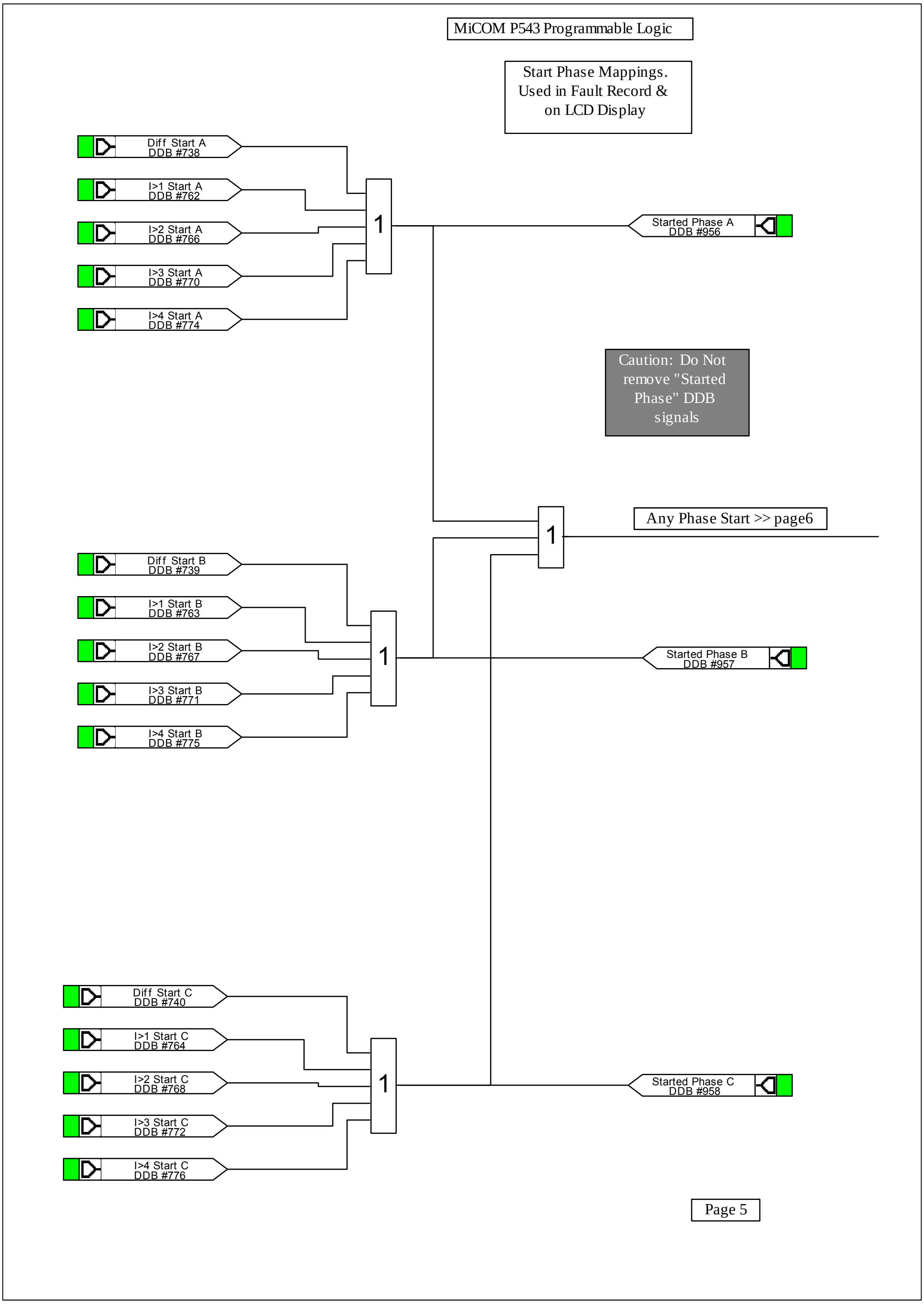


PL

LED Mappings

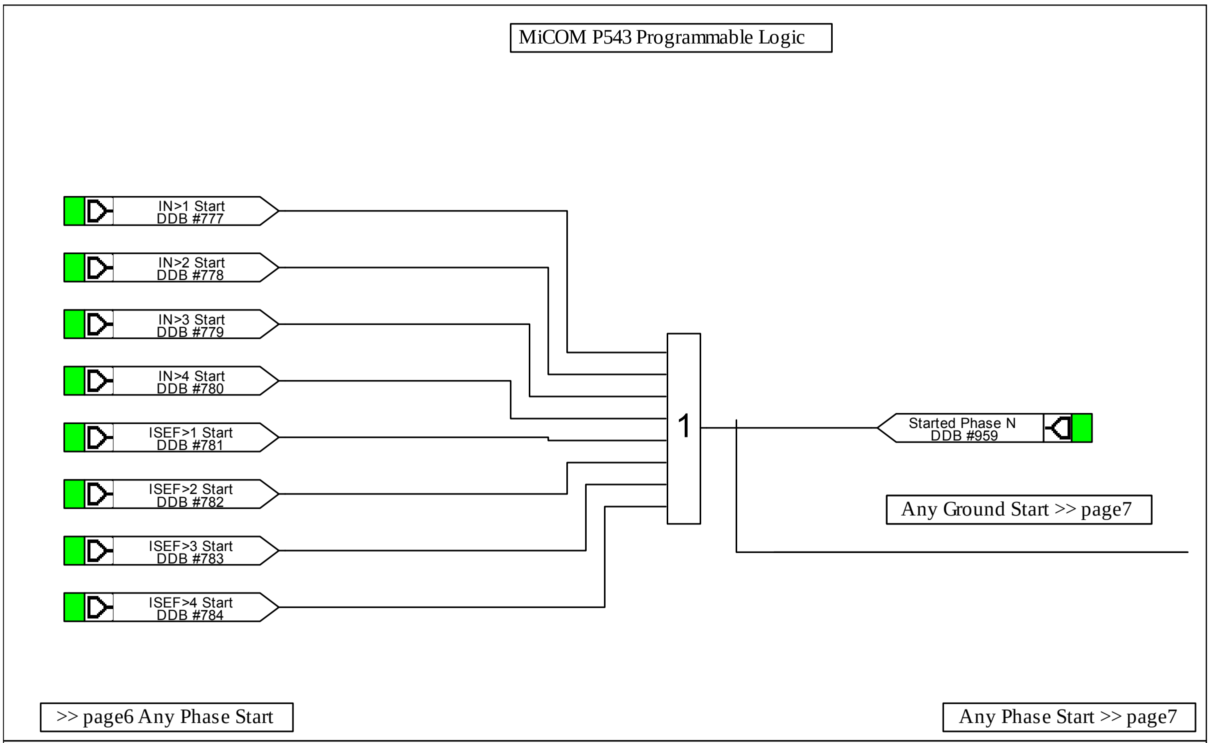


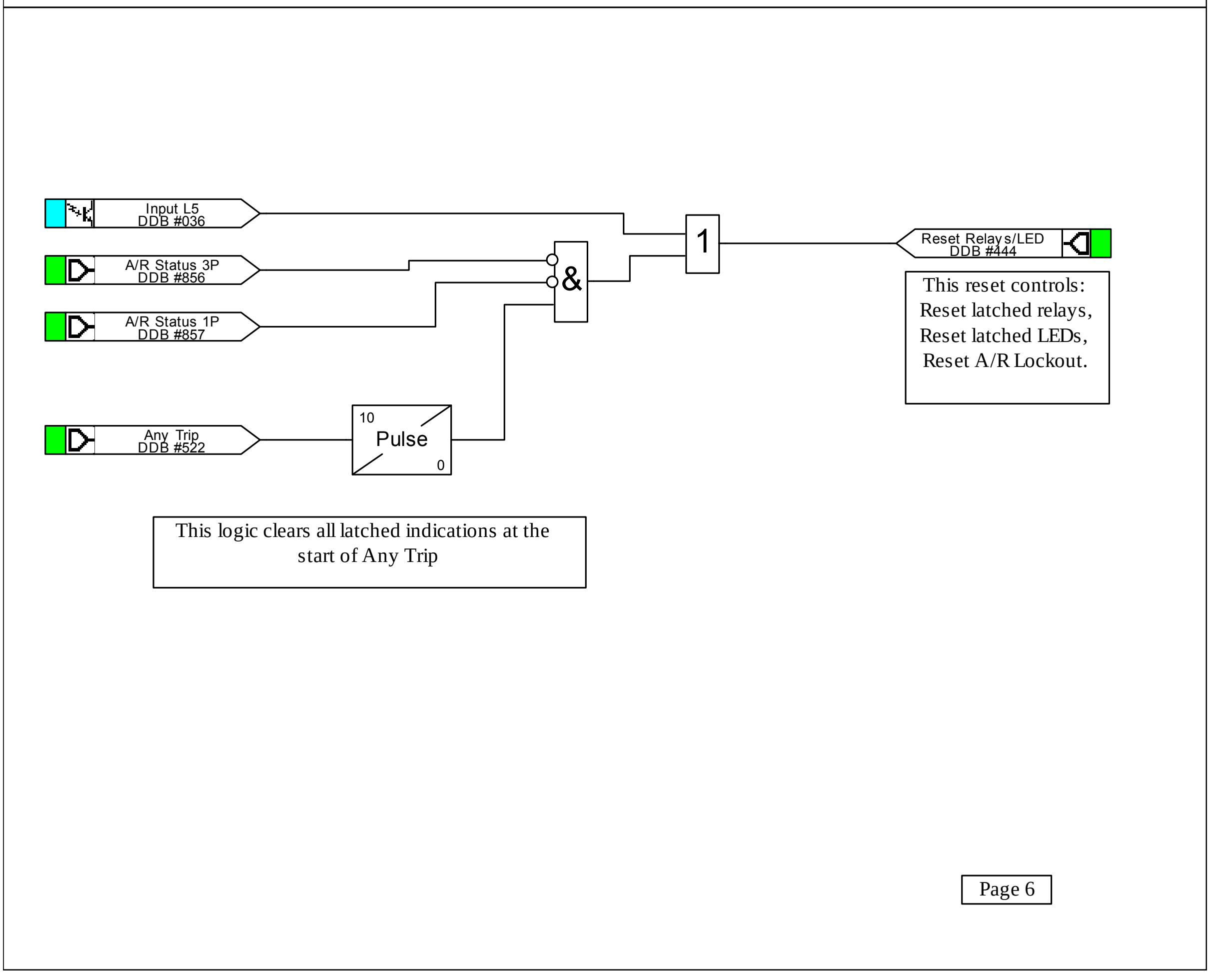
Start Mappings



PL

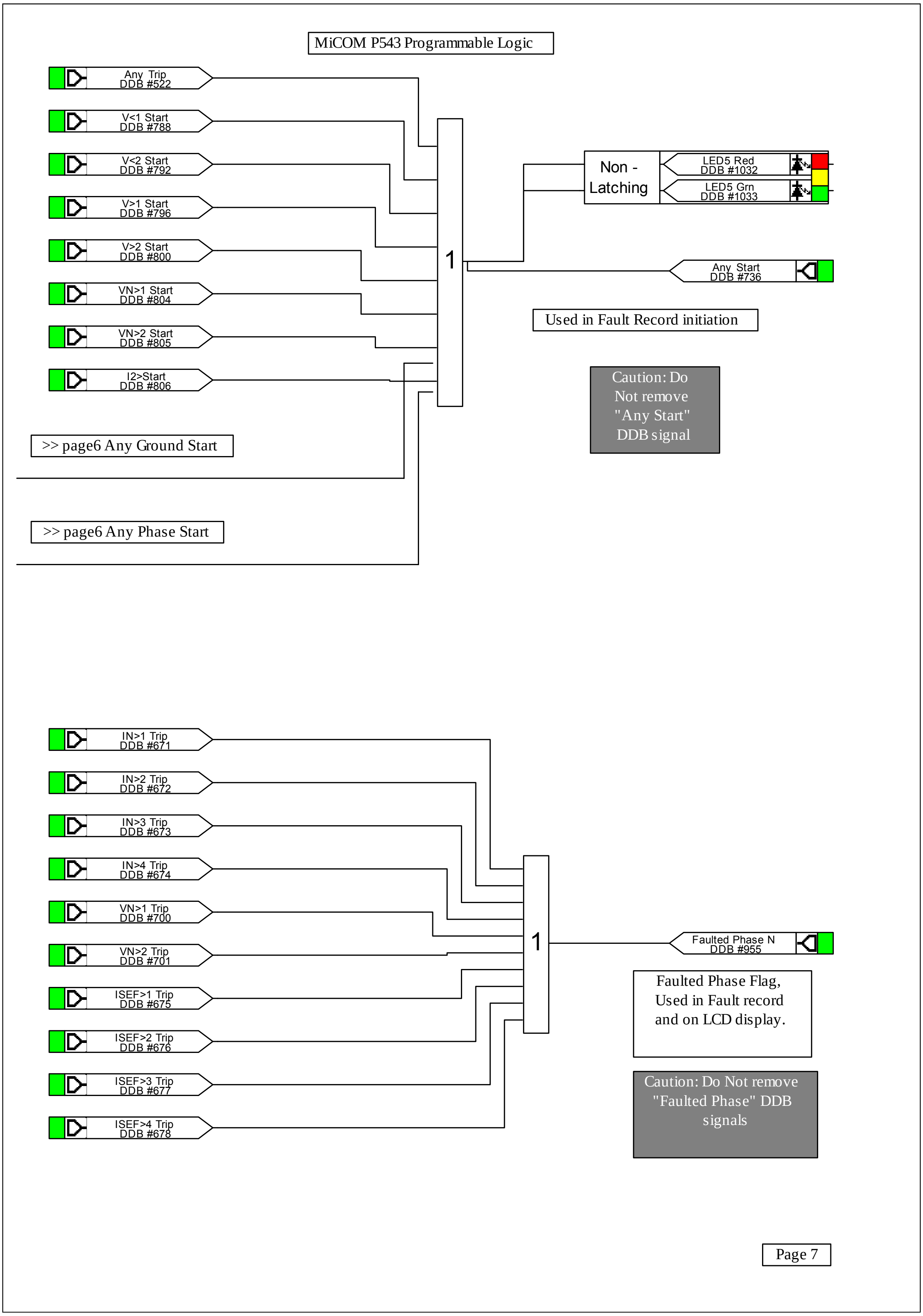
Start Mappings





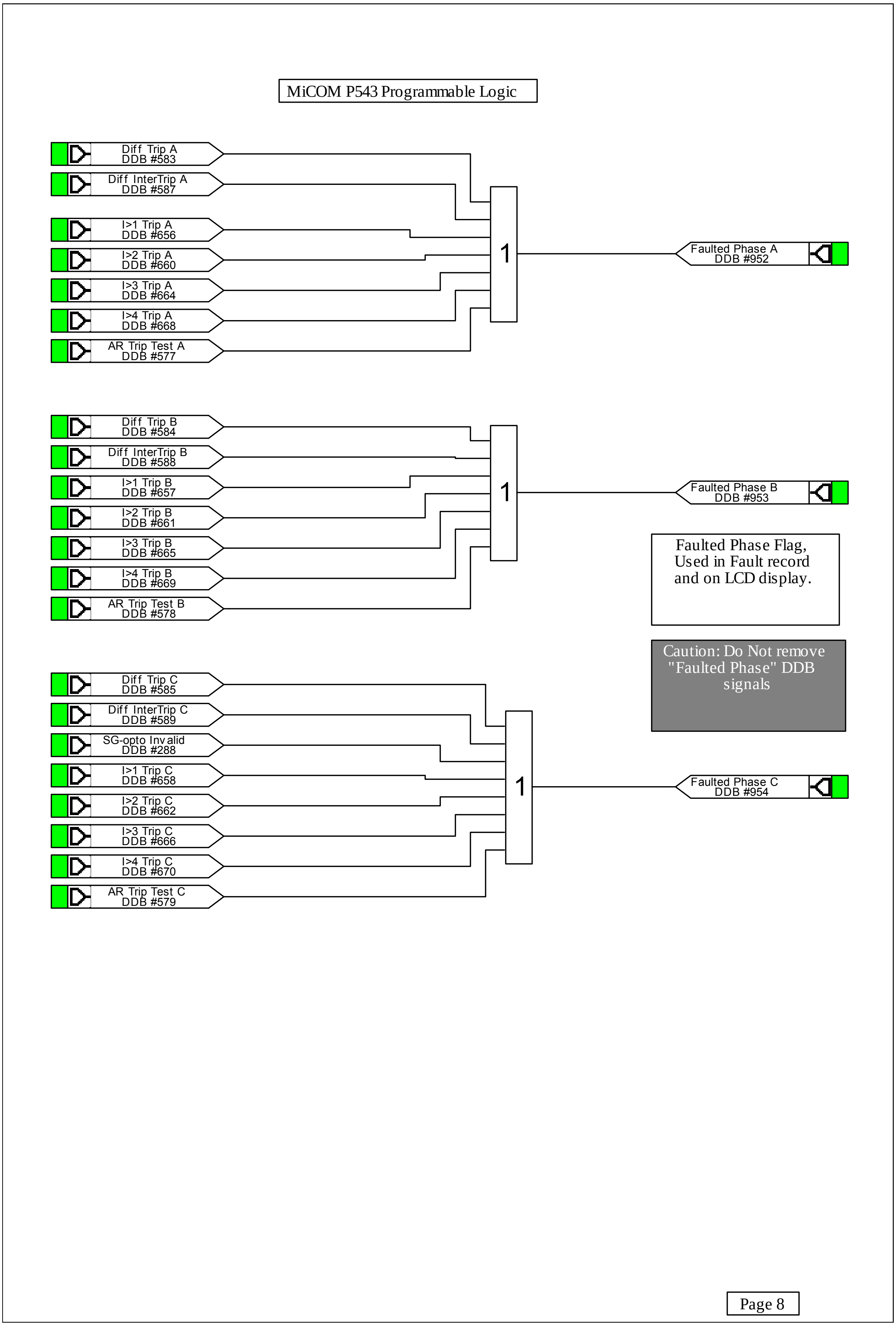
PL

Start Mappings

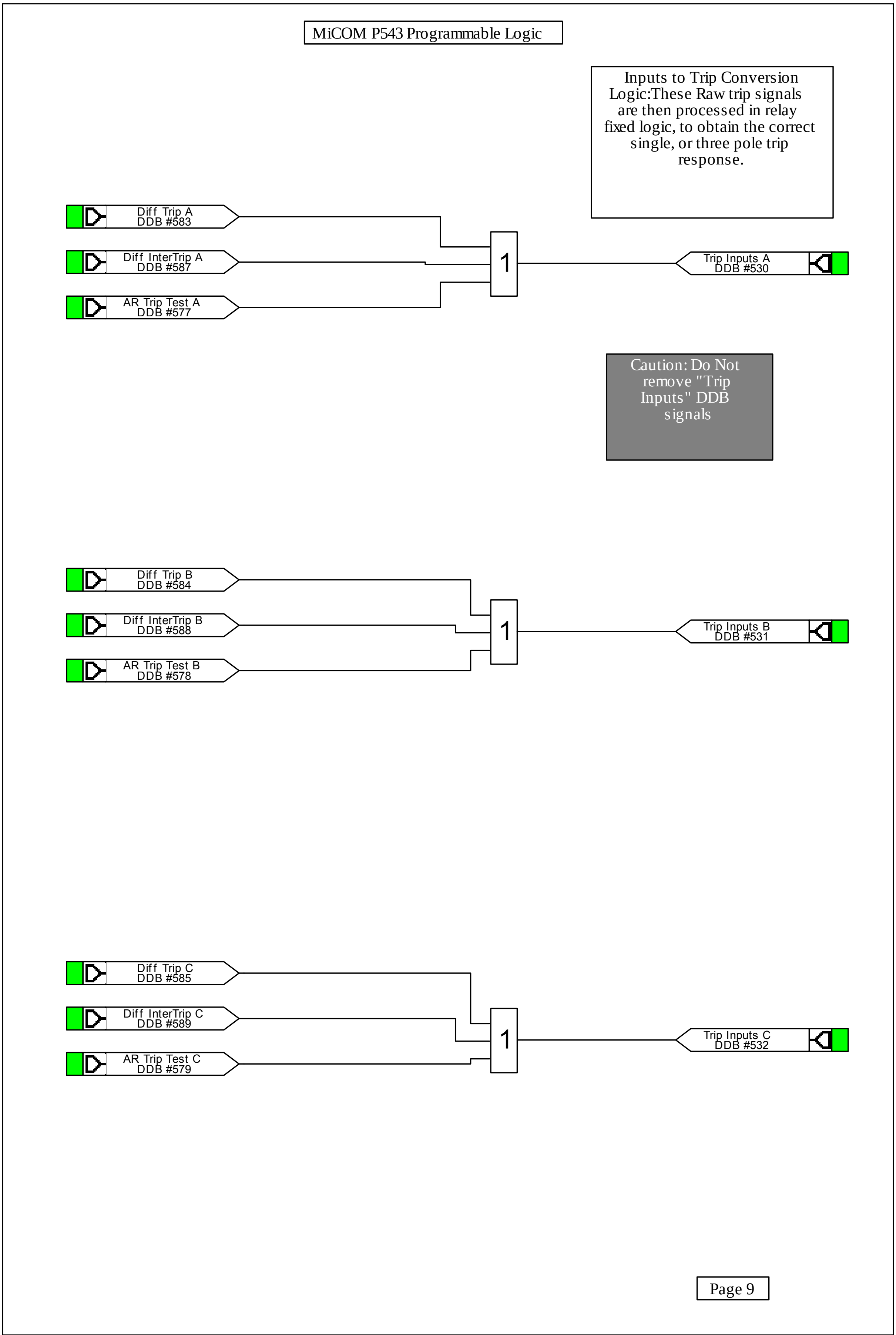


PL

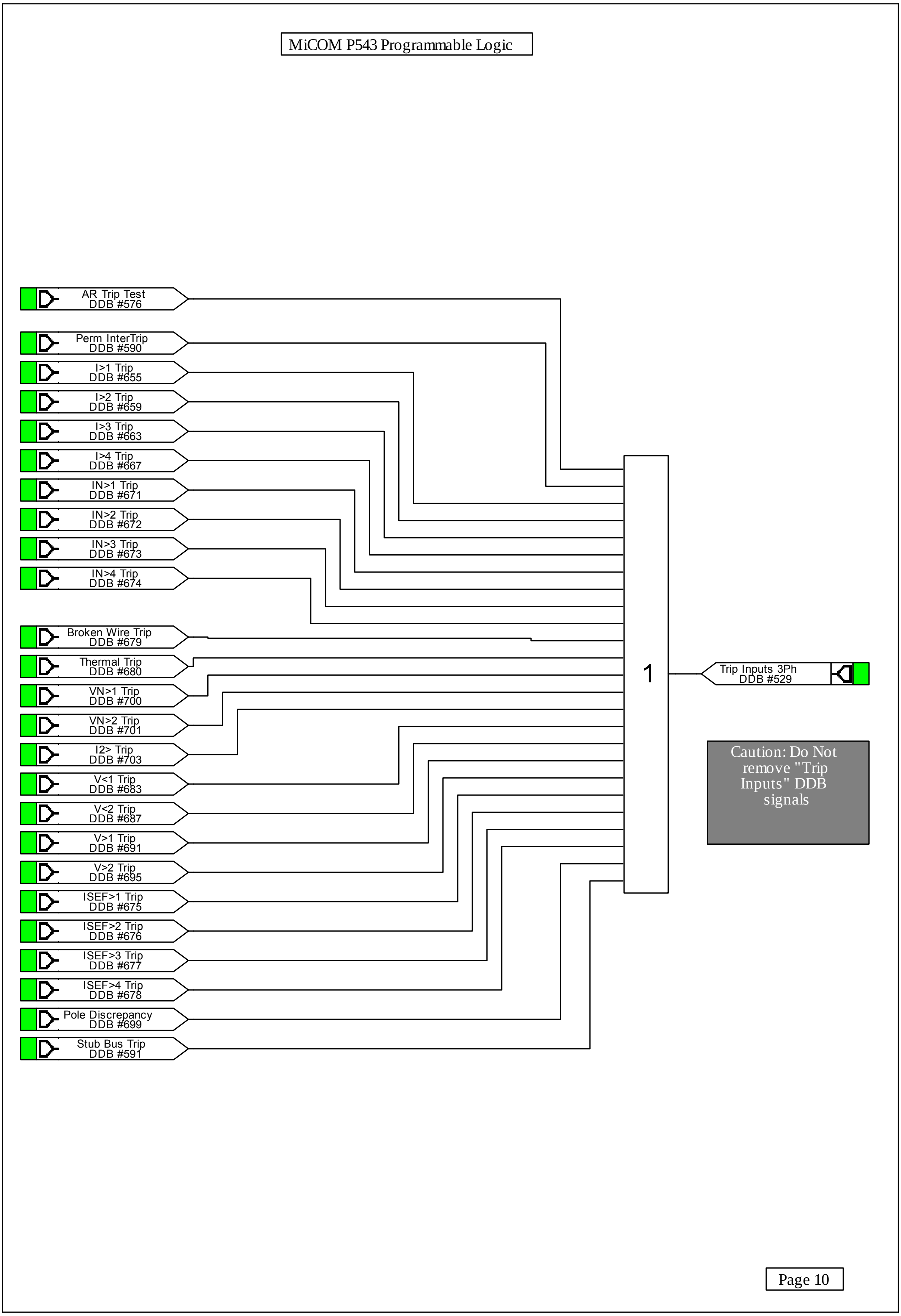
Faulted Phase Mappings



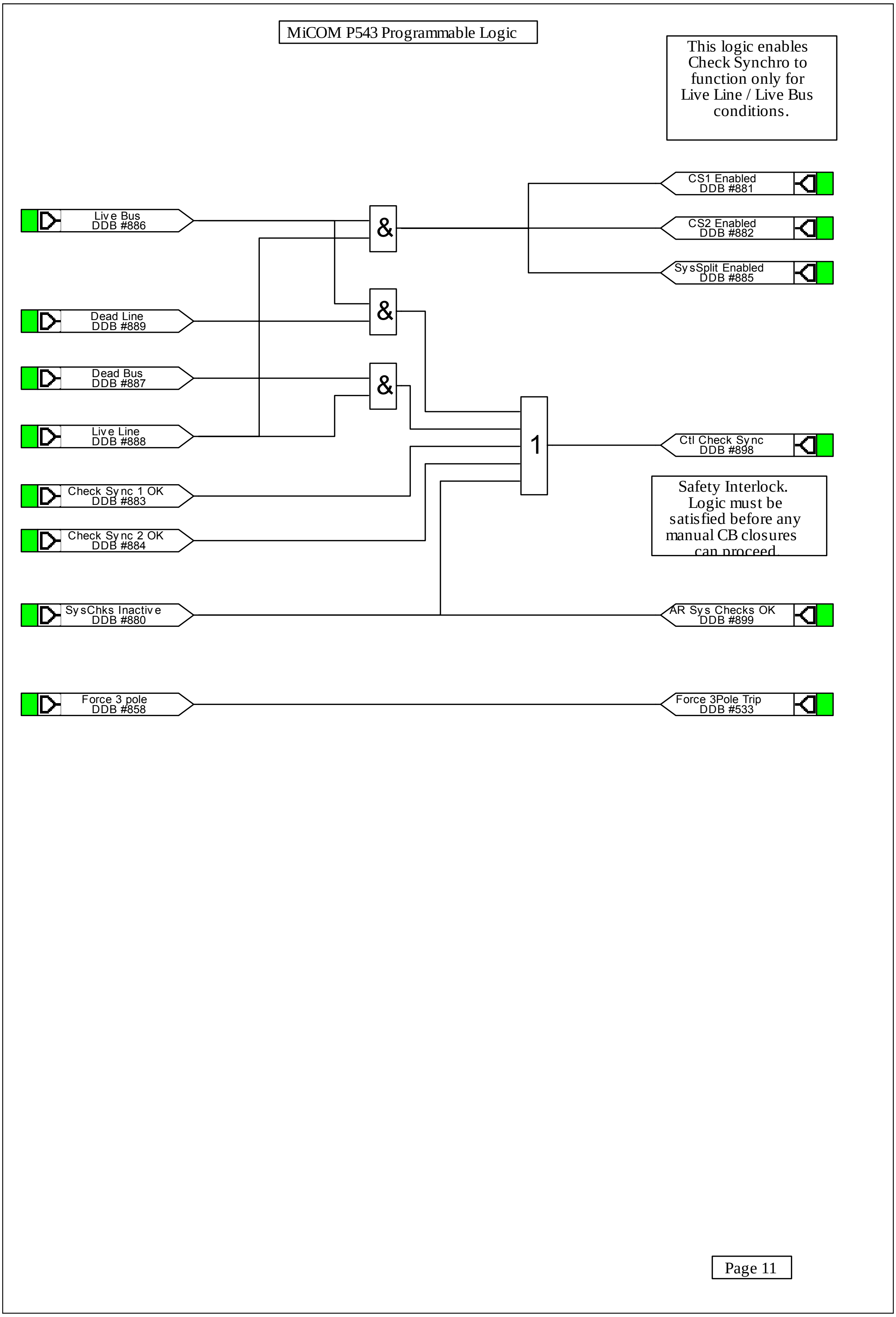
Trip Inputs Mappings



Trip Inputs Mappings

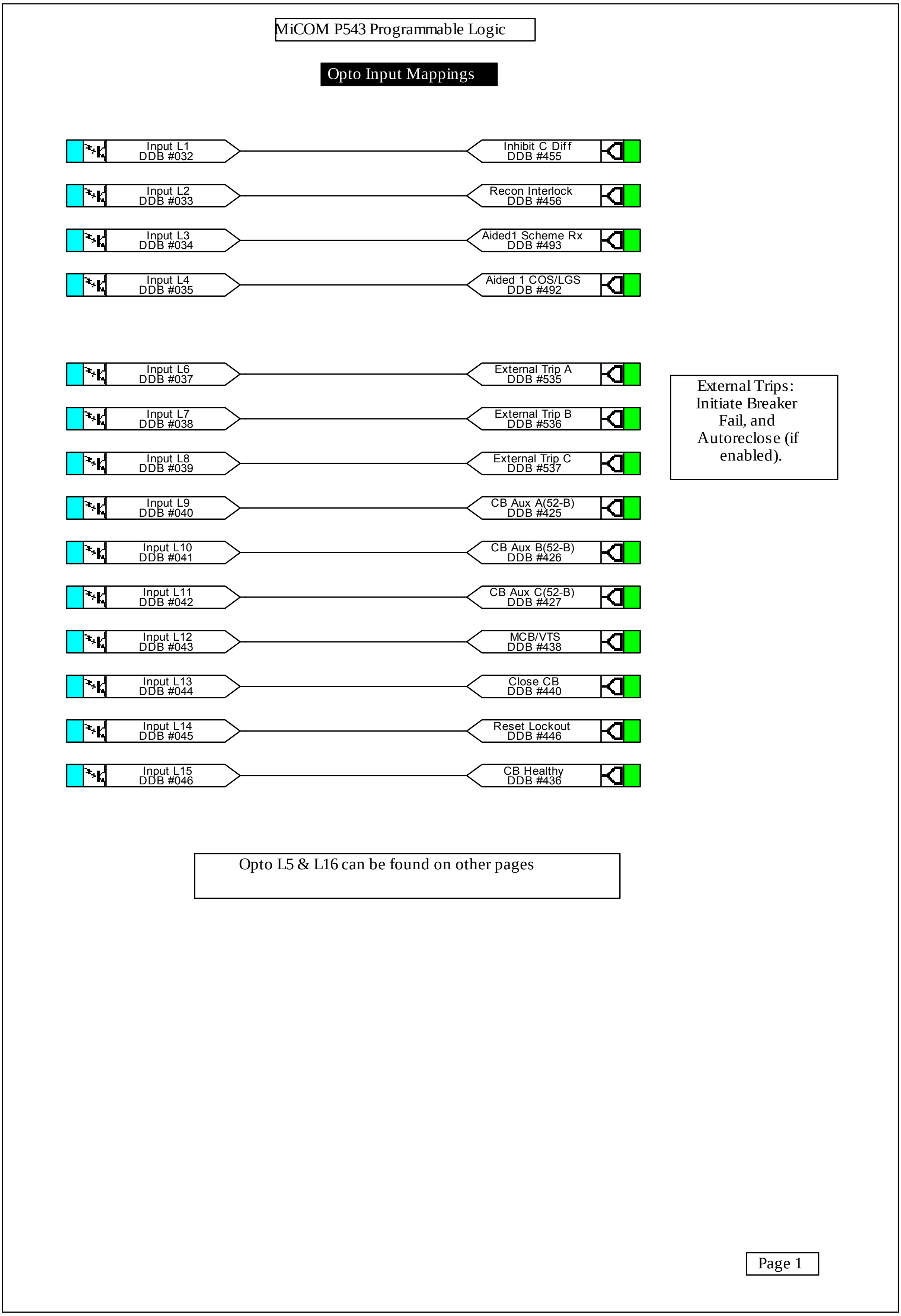


Check Sync & Auto-Reclose Function Mappings

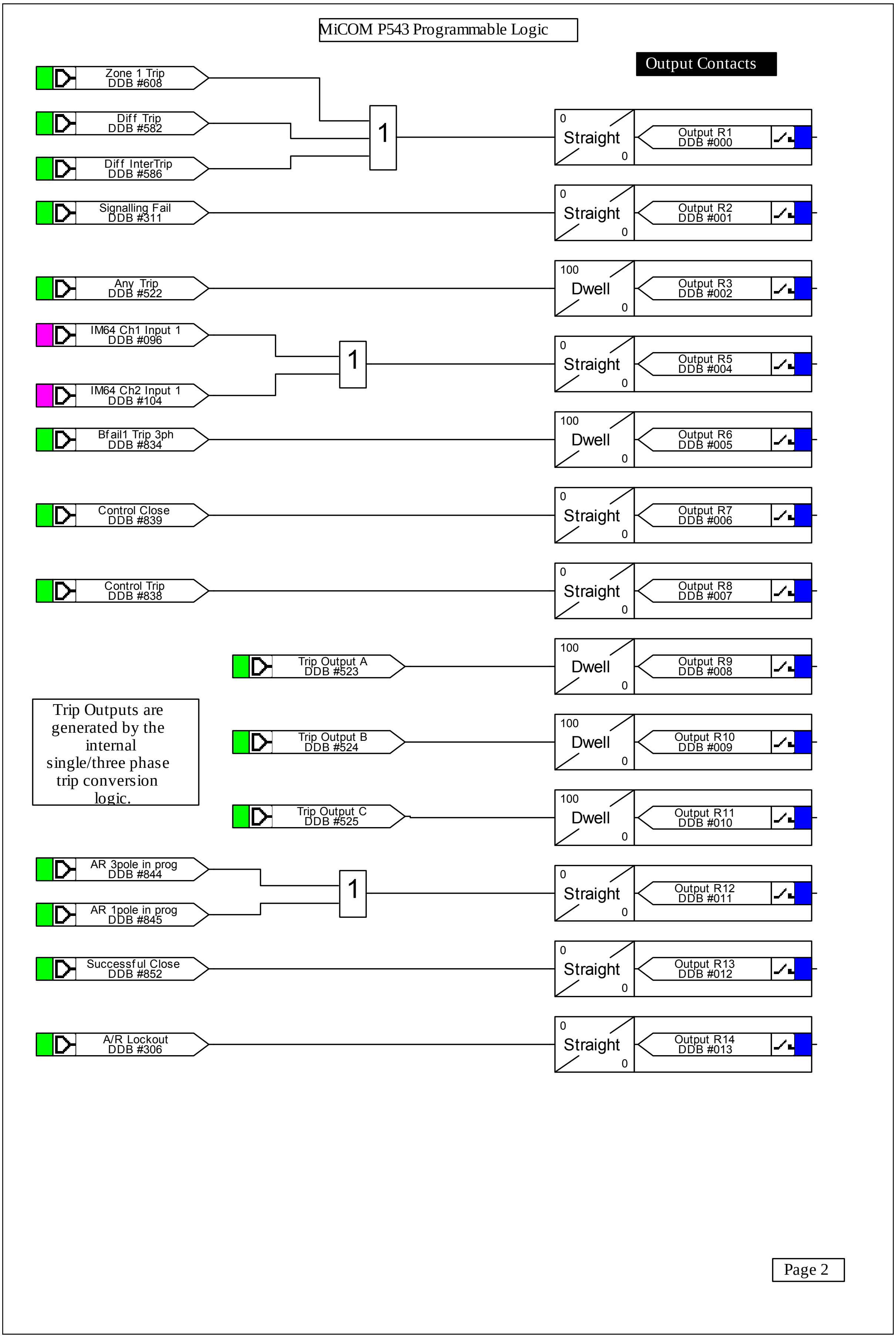


MiCOM P543 WITH DISTANCE OPTION PROGRAMMABLE SCHEME LOGIC

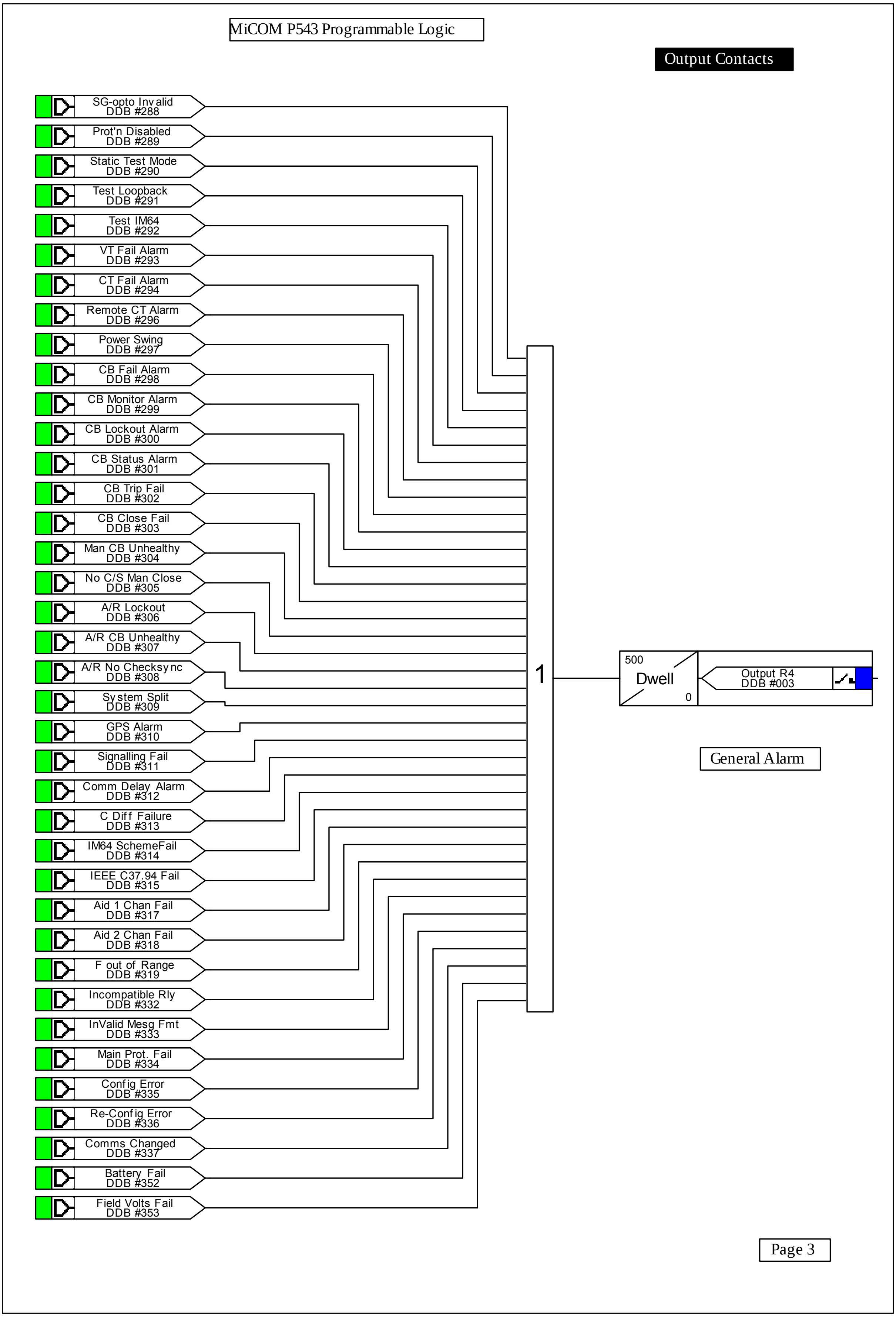
Opto Input Mappings



Output Relay Mappings

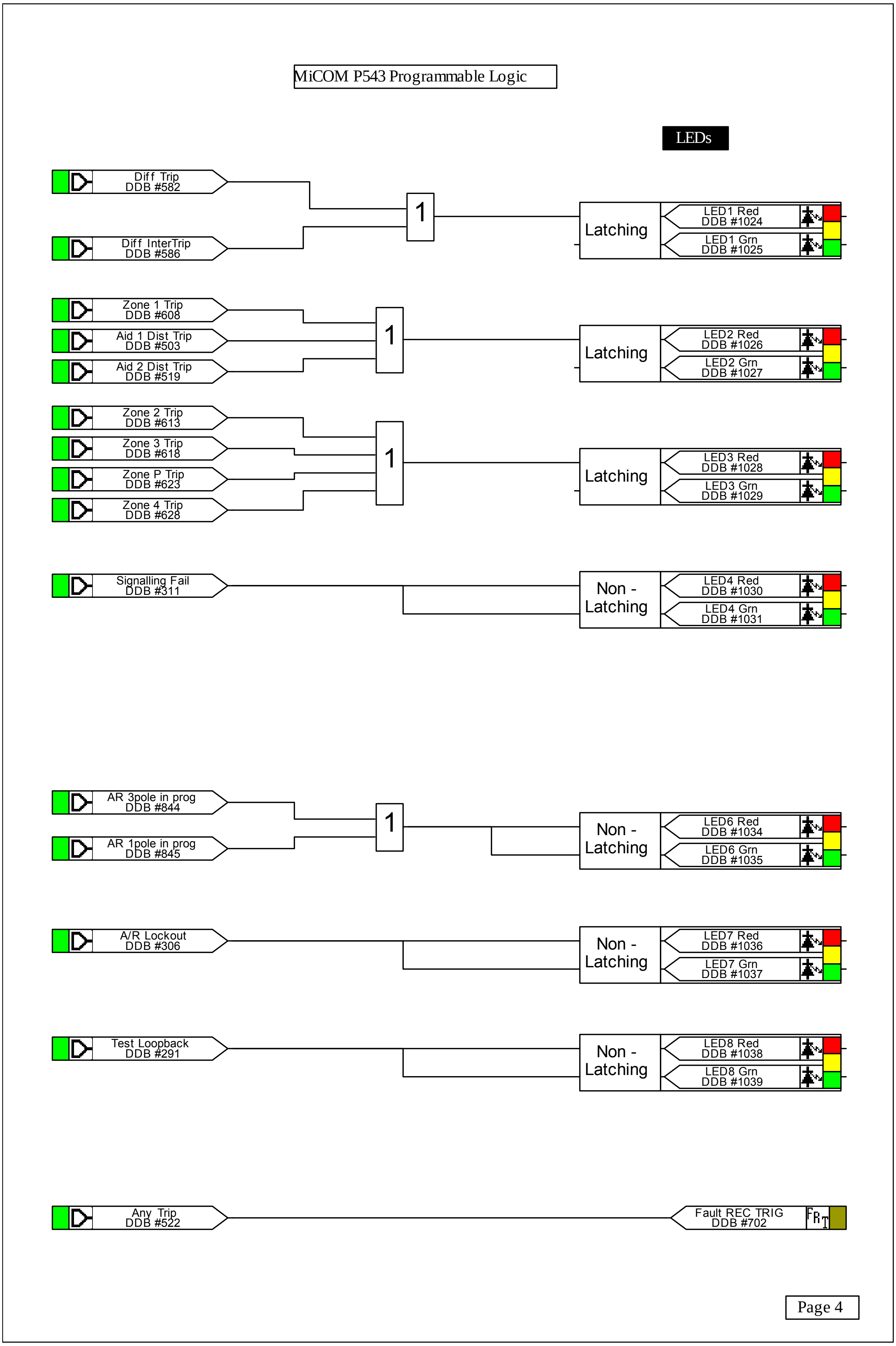


Output Relay Mappings

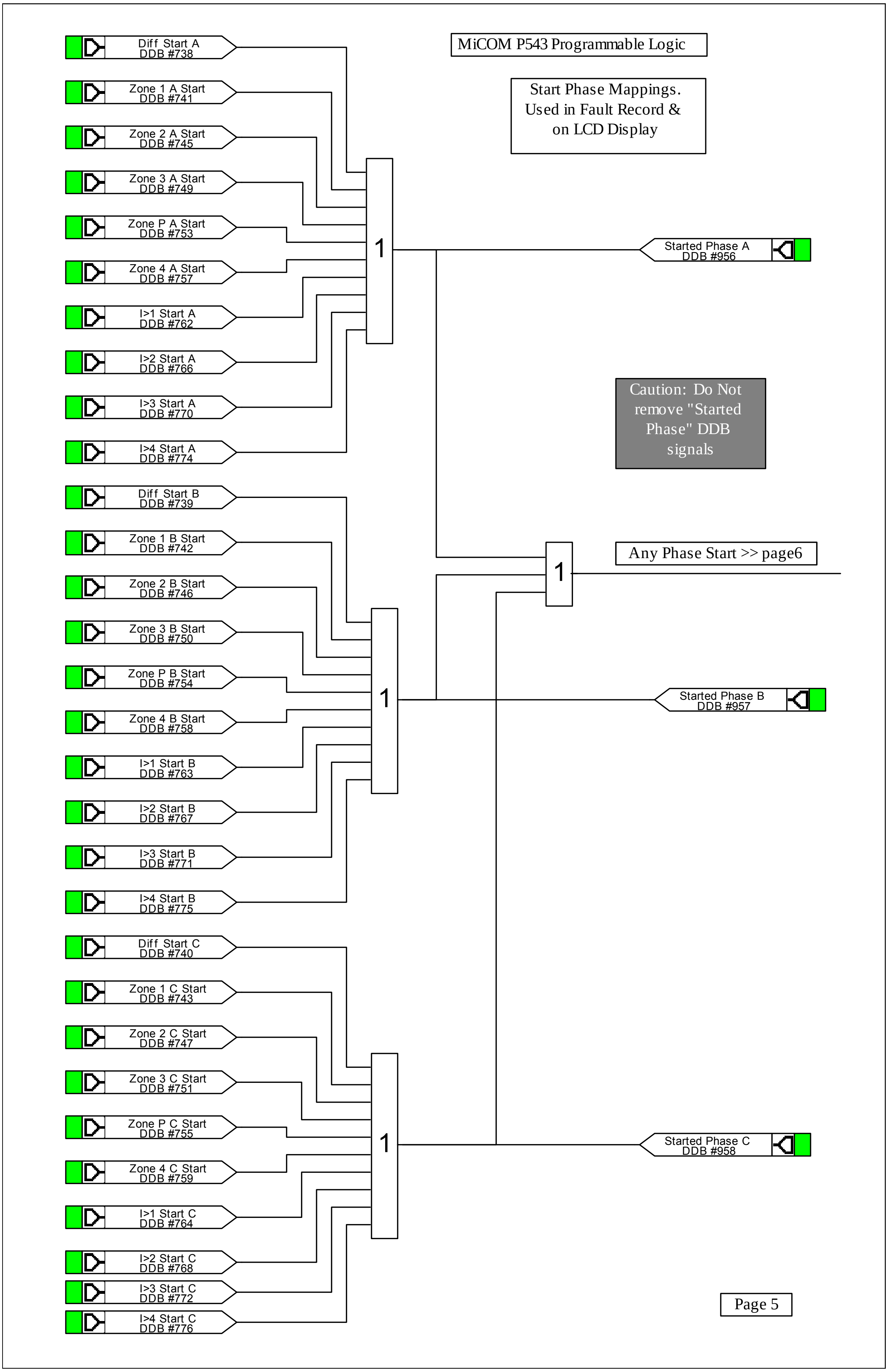


PL

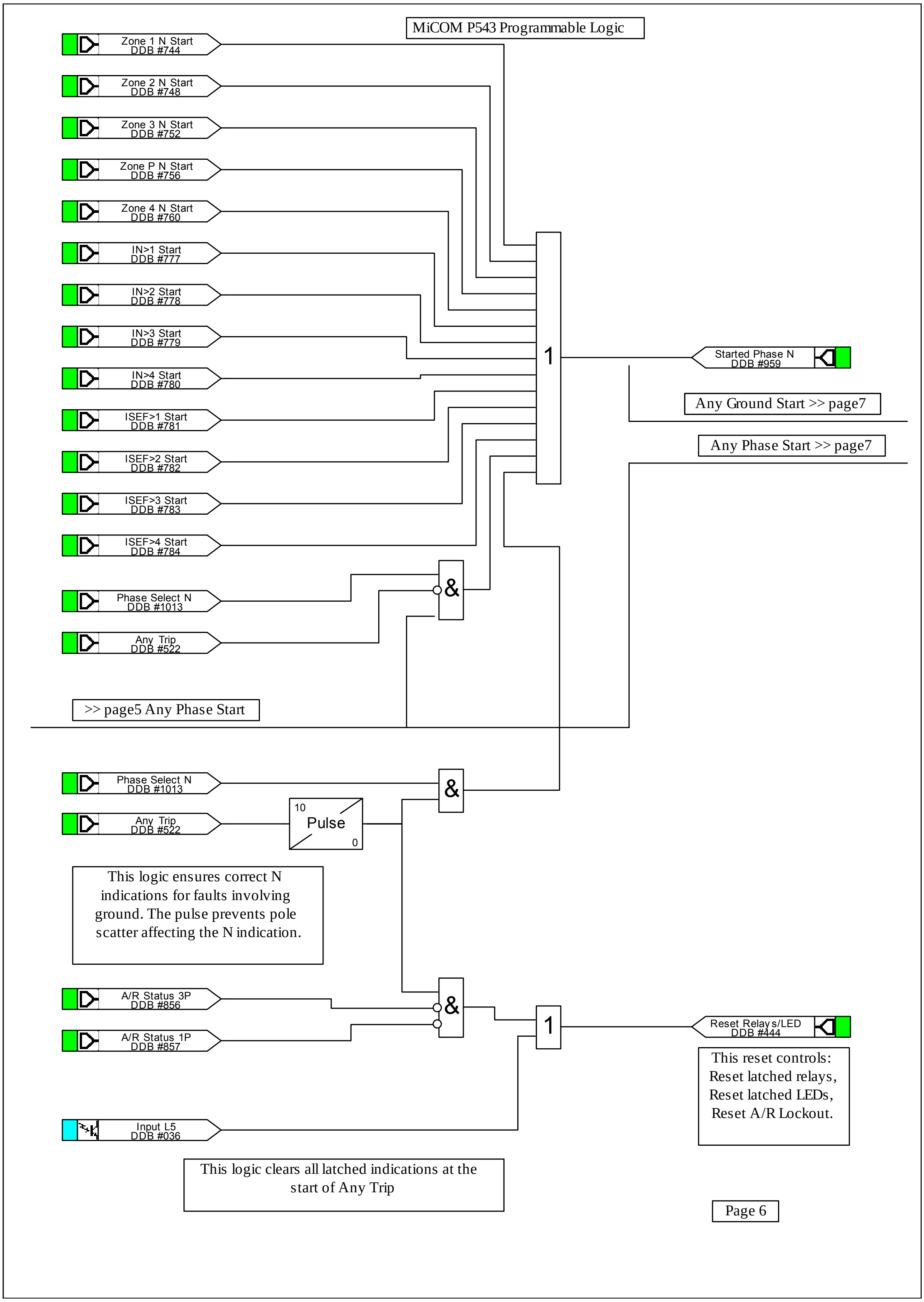
LED Mappings



Start Mappings

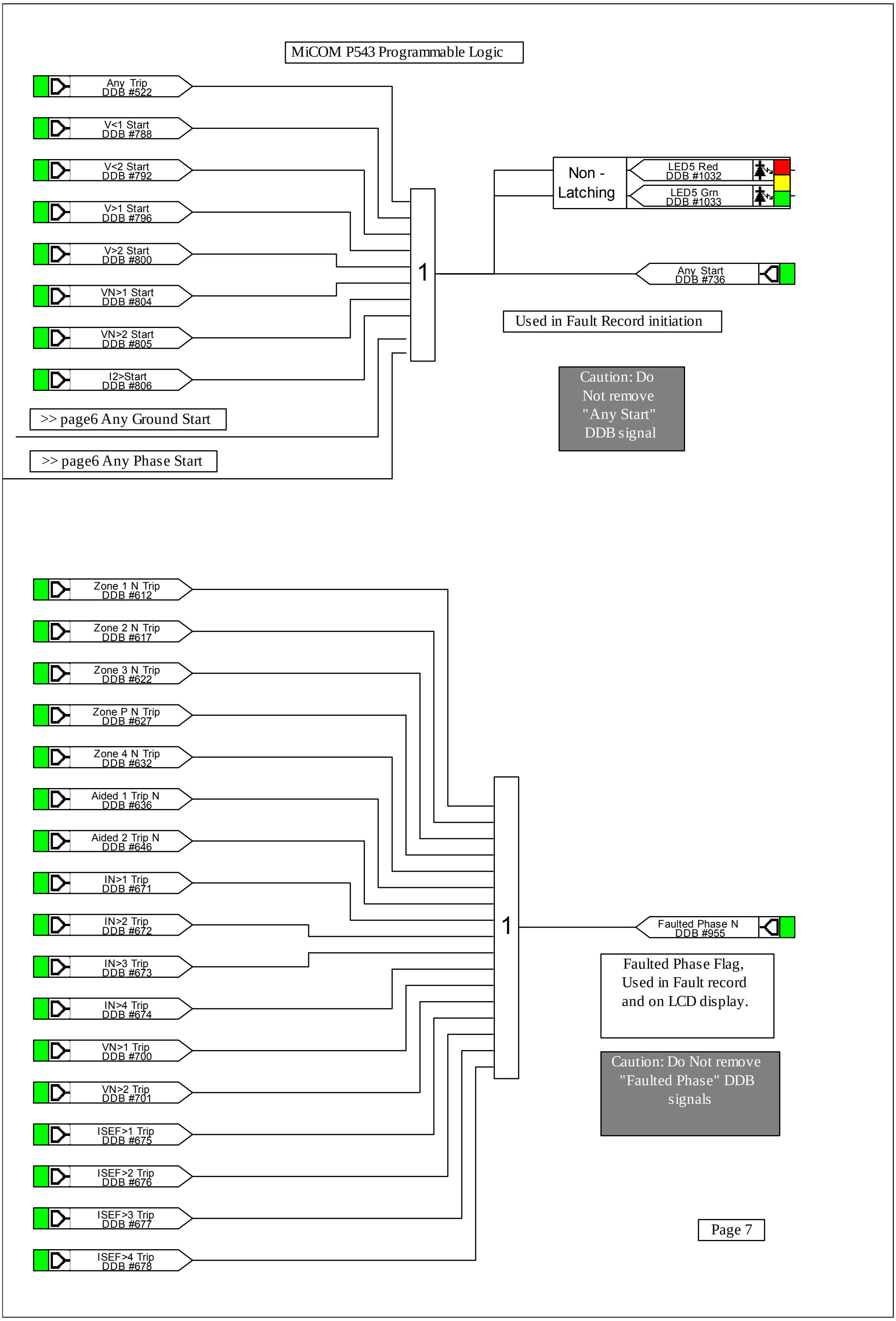


Start Mappings



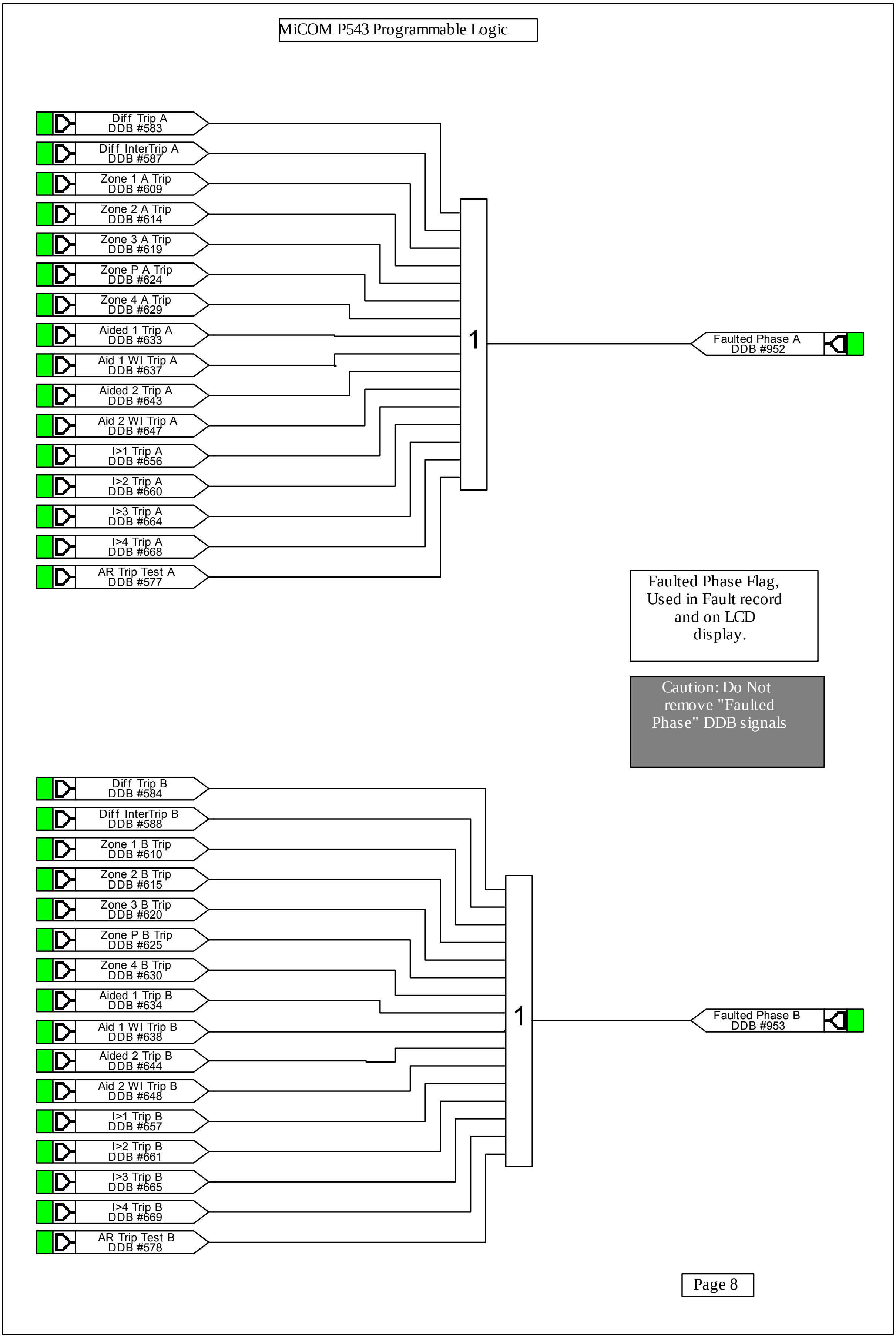
PL

Start Mappings



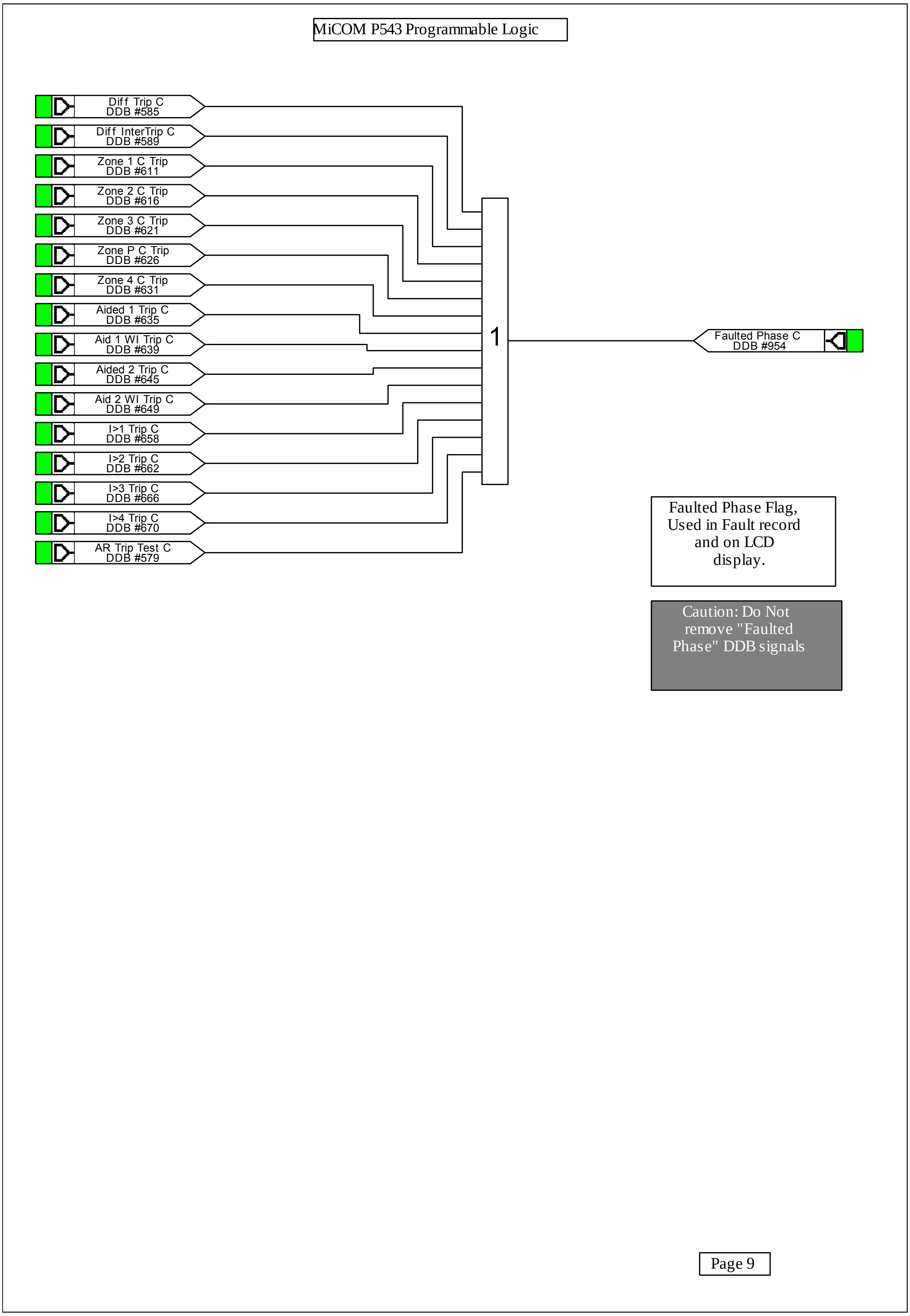
PL

Faulted Phase Mappings

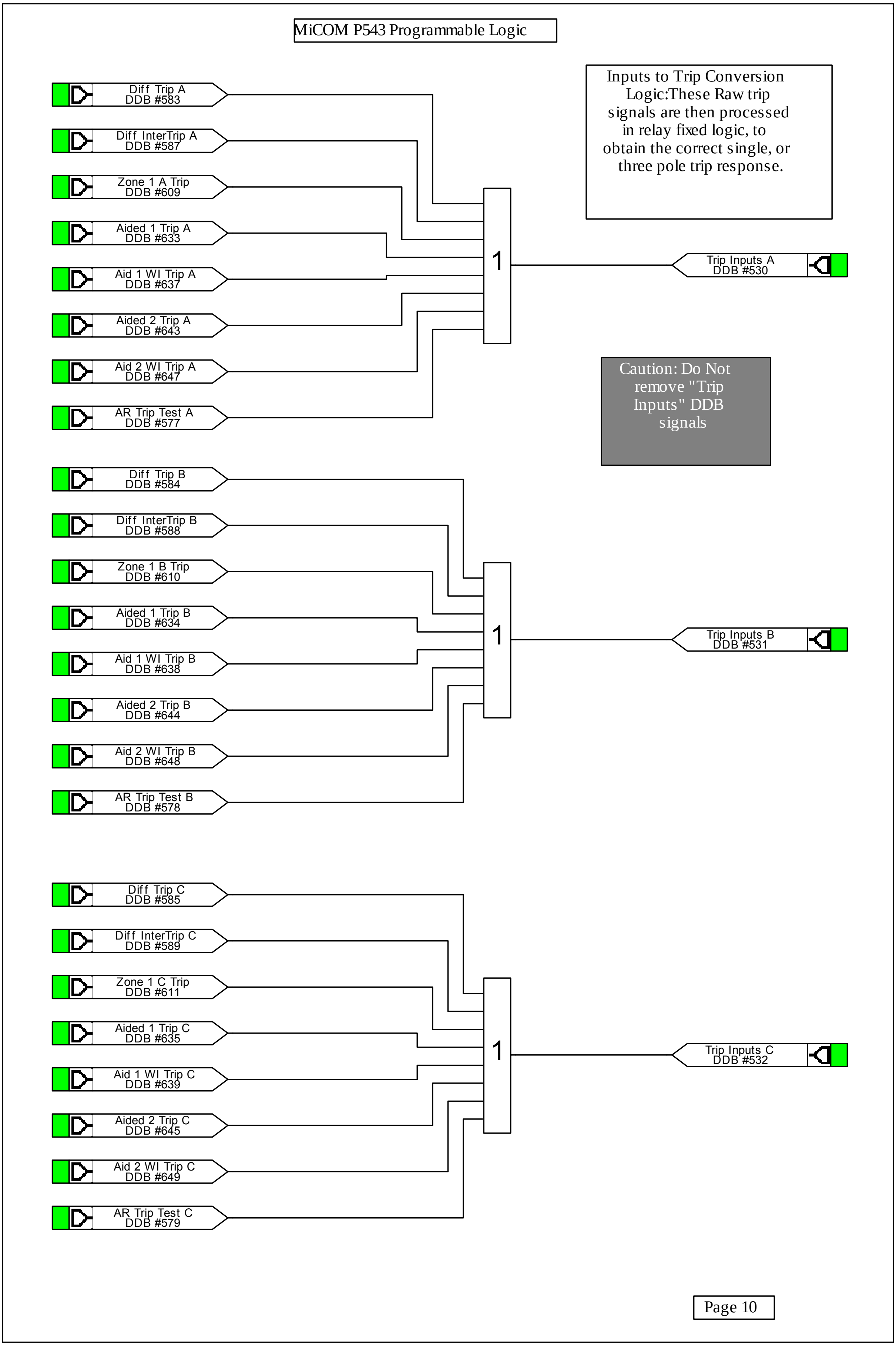


PL

Faulted Phase Mappings

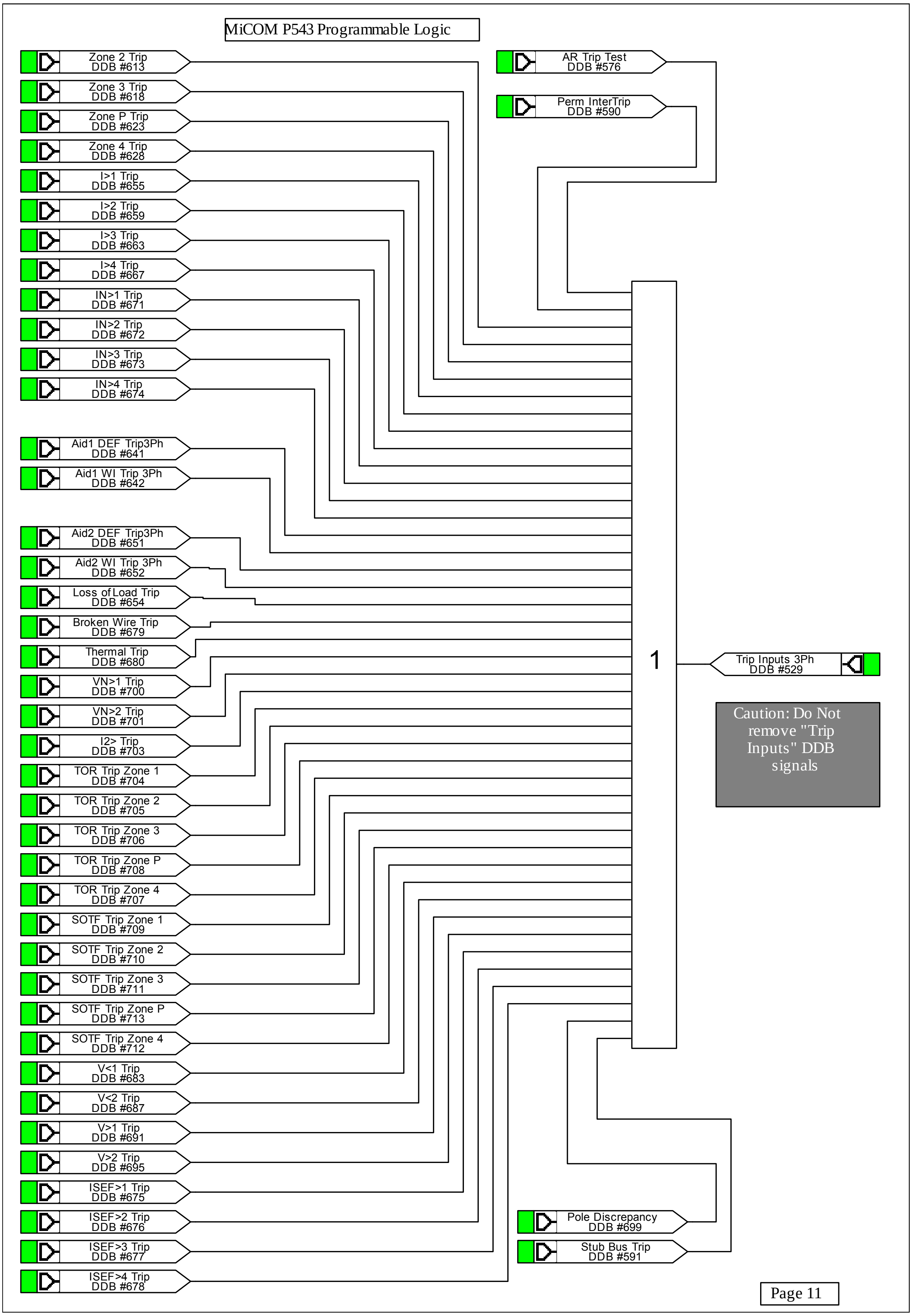


Trip Inputs

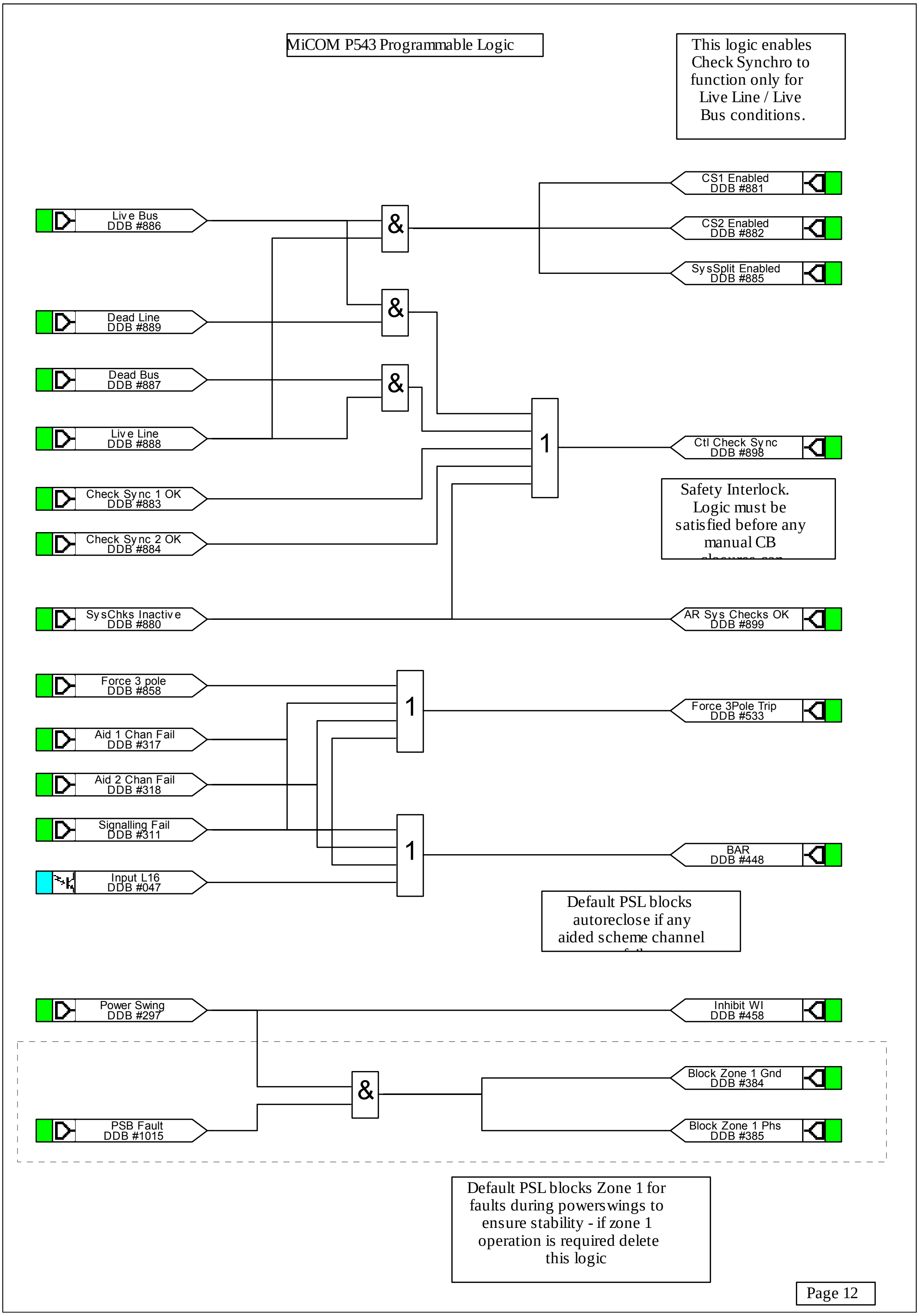


PL

Trip Inputs


MiCOM P543 Programmable Logic
Zone 2 Trip DDB #613
Zone 3 Trip DDB #618
Zone P Trip DDB #623
Zone 4 Trip DDB #628
I>1 Trip DDB #655
I>2 Trip DDB #659
I>3 Trip DDB #663
I>4 Trip DDB #667
IN>1 Trip DDB #671
IN>2 Trip DDB #672
IN>3 Trip DDB #673
IN>4 Trip DDB #674
Aid1 DEF Trip3Ph DDB #641
Aid1 WI Trip 3Ph DDB #642
Aid2 DEF Trip3Ph DDB #651
Aid2 WI Trip 3Ph DDB #652
Loss of Load Trip DDB #654
Broken Wire Trip DDB #679
Thermal Trip DDB #680
VN>1 Trip DDB #700
VN>2 Trip DDB #701
I2> Trip DDB #703
TOR Trip Zone 1 DDB #704
TOR Trip Zone 2 DDB #705
TOR Trip Zone 3 DDB #706
TOR Trip Zone P DDB #708
TOR Trip Zone 4 DDB #707
SOTF Trip Zone 1 DDB #709
SOTF Trip Zone 2 DDB #710
SOTF Trip Zone 3 DDB #711
SOTF Trip Zone P DDB #713
SOTF Trip Zone 4 DDB #712
V<1 Trip DDB #683
V<2 Trip DDB #687
V>1 Trip DDB #691
V>2 Trip DDB #695
ISEF>1 Trip DDB #675
ISEF>2 Trip DDB #676
ISEF>3 Trip DDB #677
ISEF>4 Trip DDB #678
AR Trip Test DDB #576
Perm InterTrip DDB #590
1
Trip Inputs 3Ph DDB #529
Caution: Do Not remove "Trip Inputs" DDB signals
Pole Discrepancy DDB #699
Stub Bus Trip DDB #591
Page 11

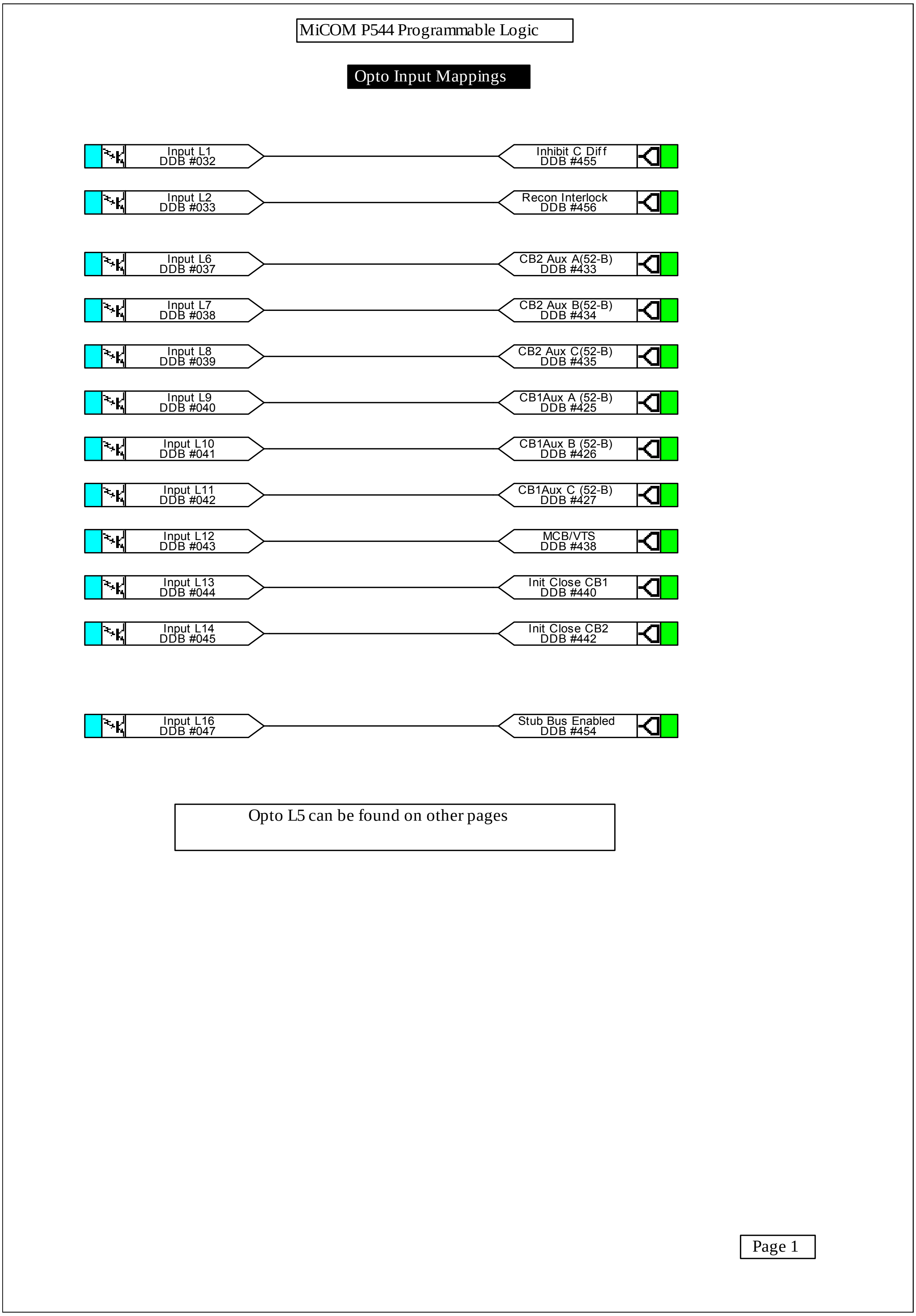
Check Sync & Auto-Reclose Function Mappings



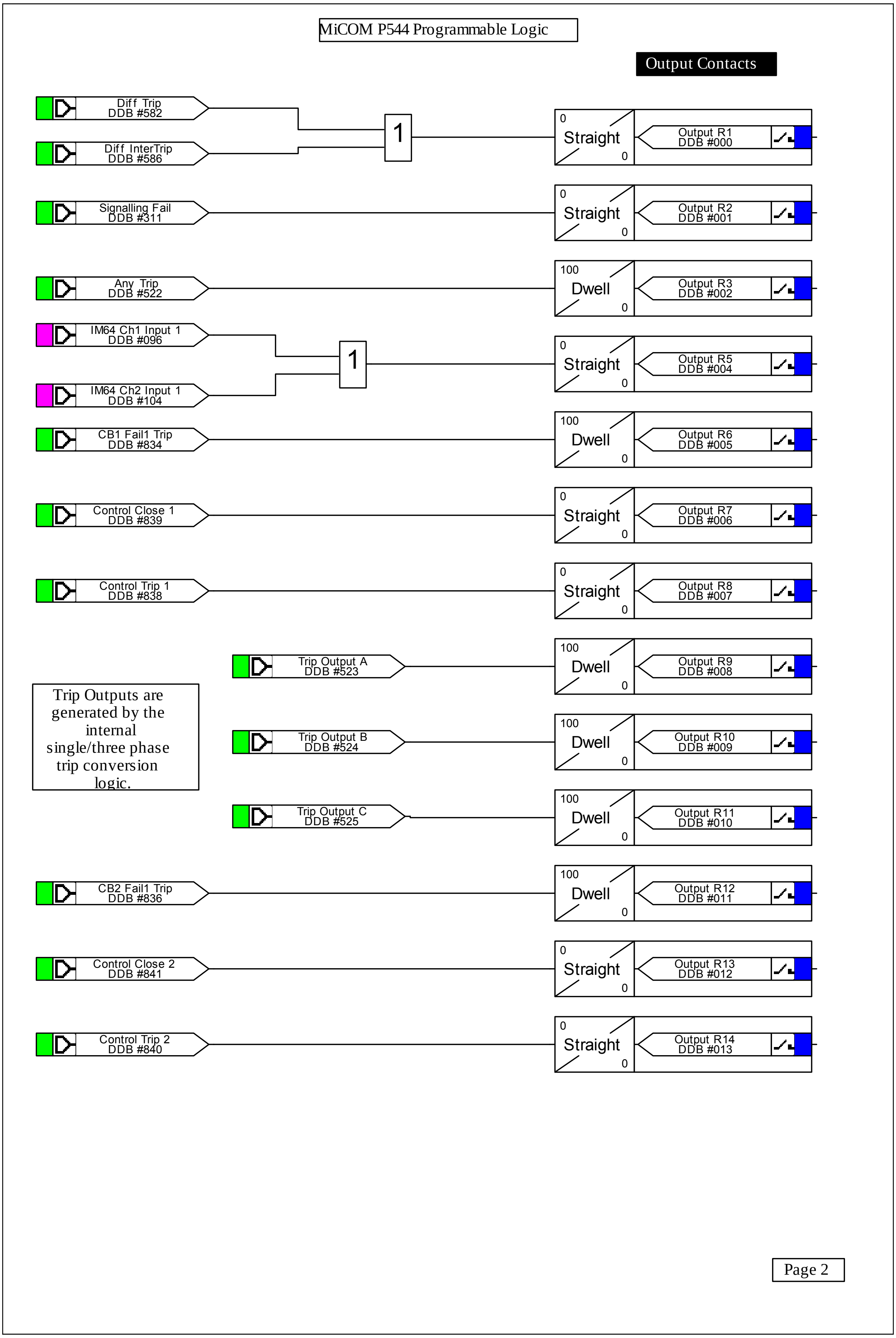
PL

MiCOM P544 WITH NO DISTANCE OPTION AND STANDARD CONTACTS PROGRAMMABLE SCHEME LOGIC

Opto Input Mappings

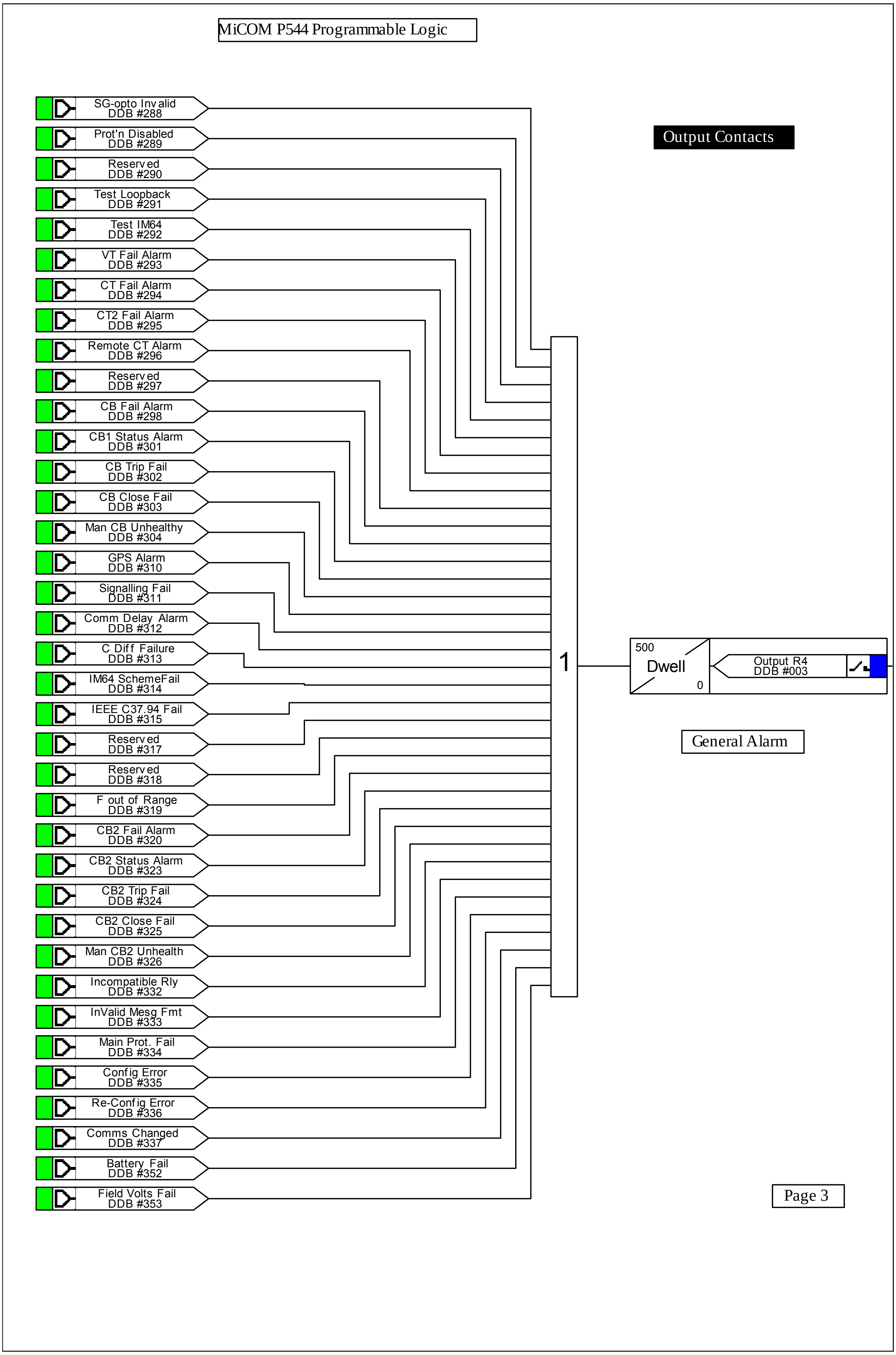


Output Relay Mappings



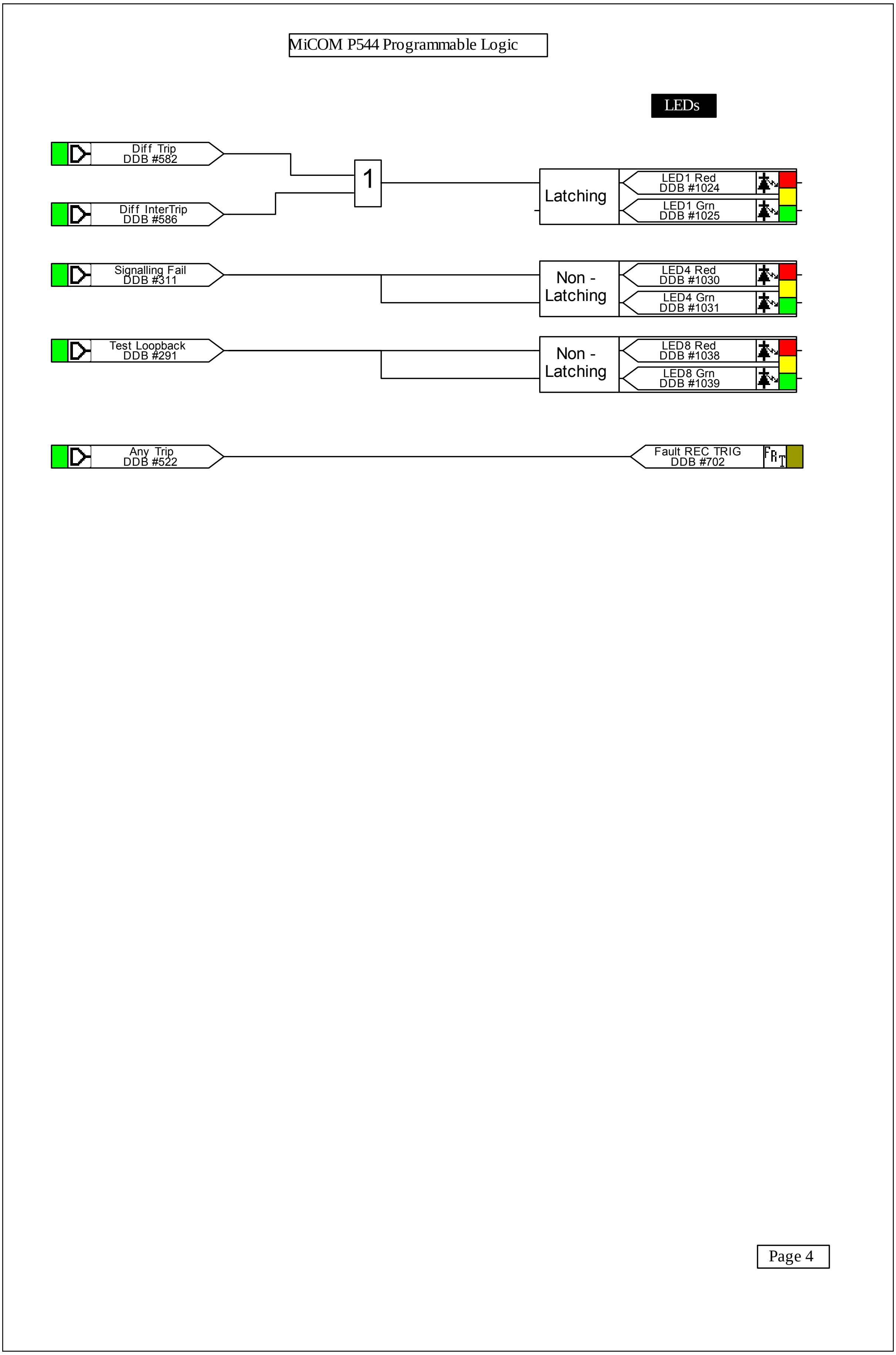
PL

Output Relay Mappings



PL

LED Mappings



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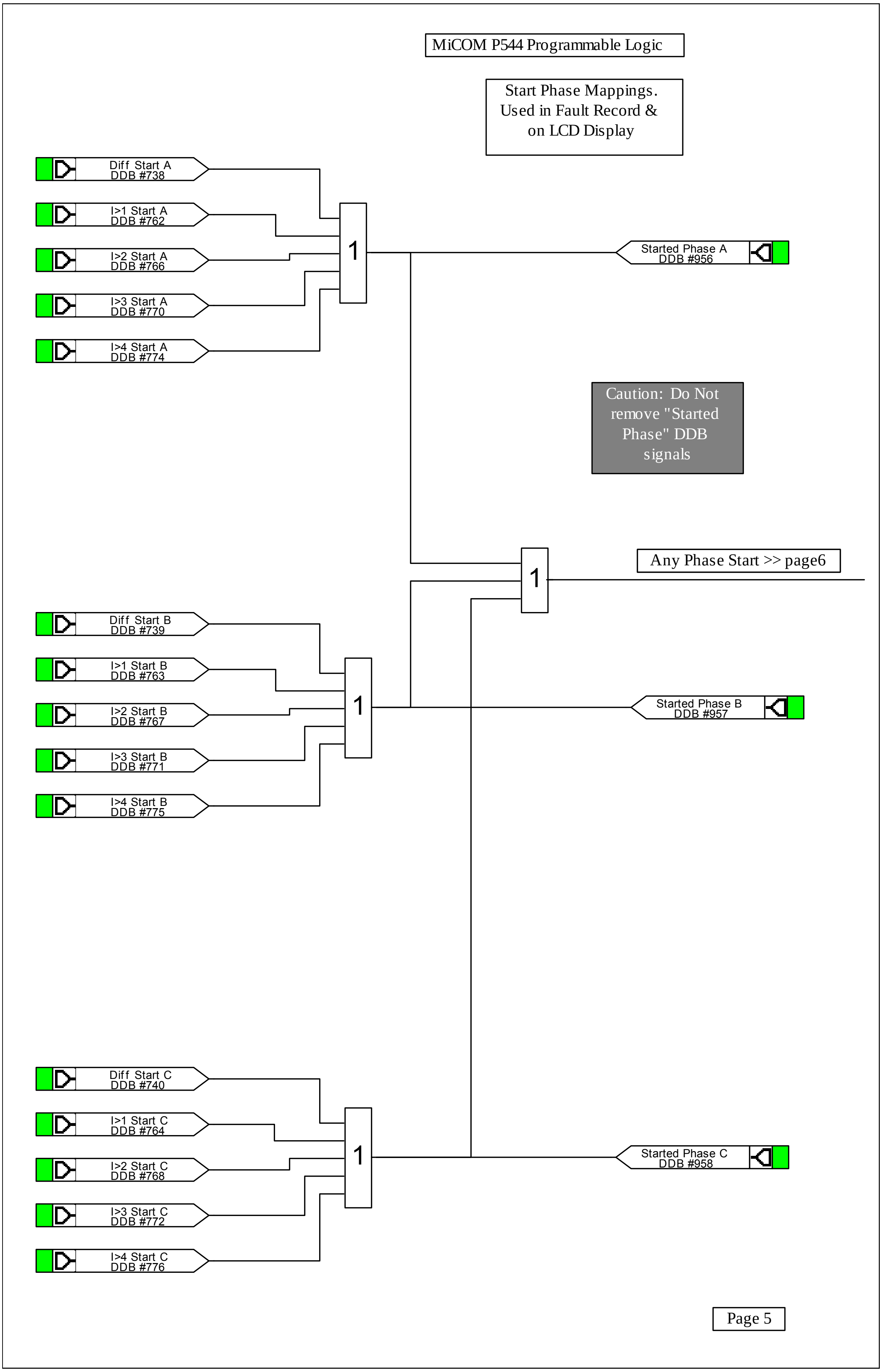
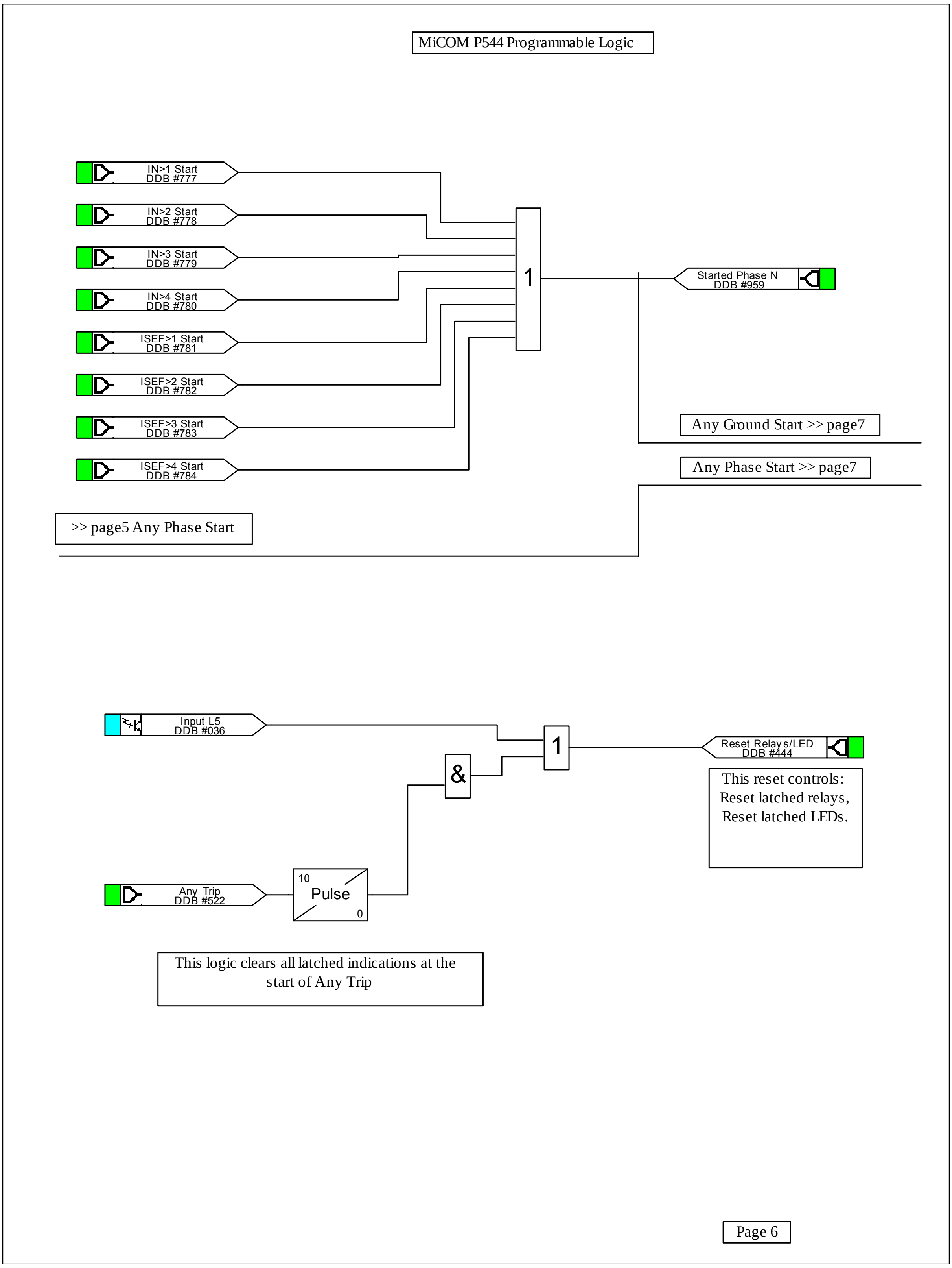
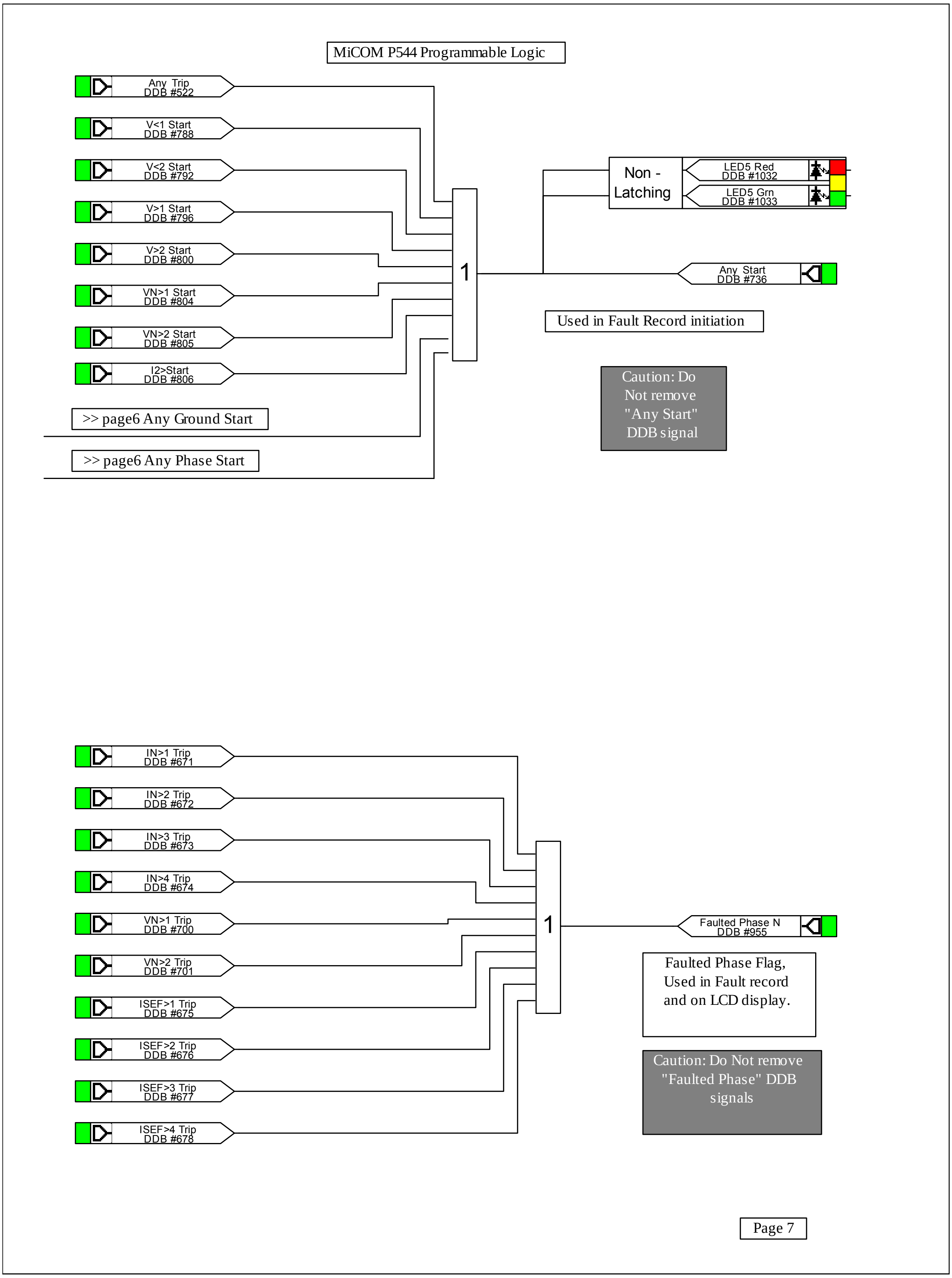
Start Mappings



Start Mappings



Faulted Phase Mappings



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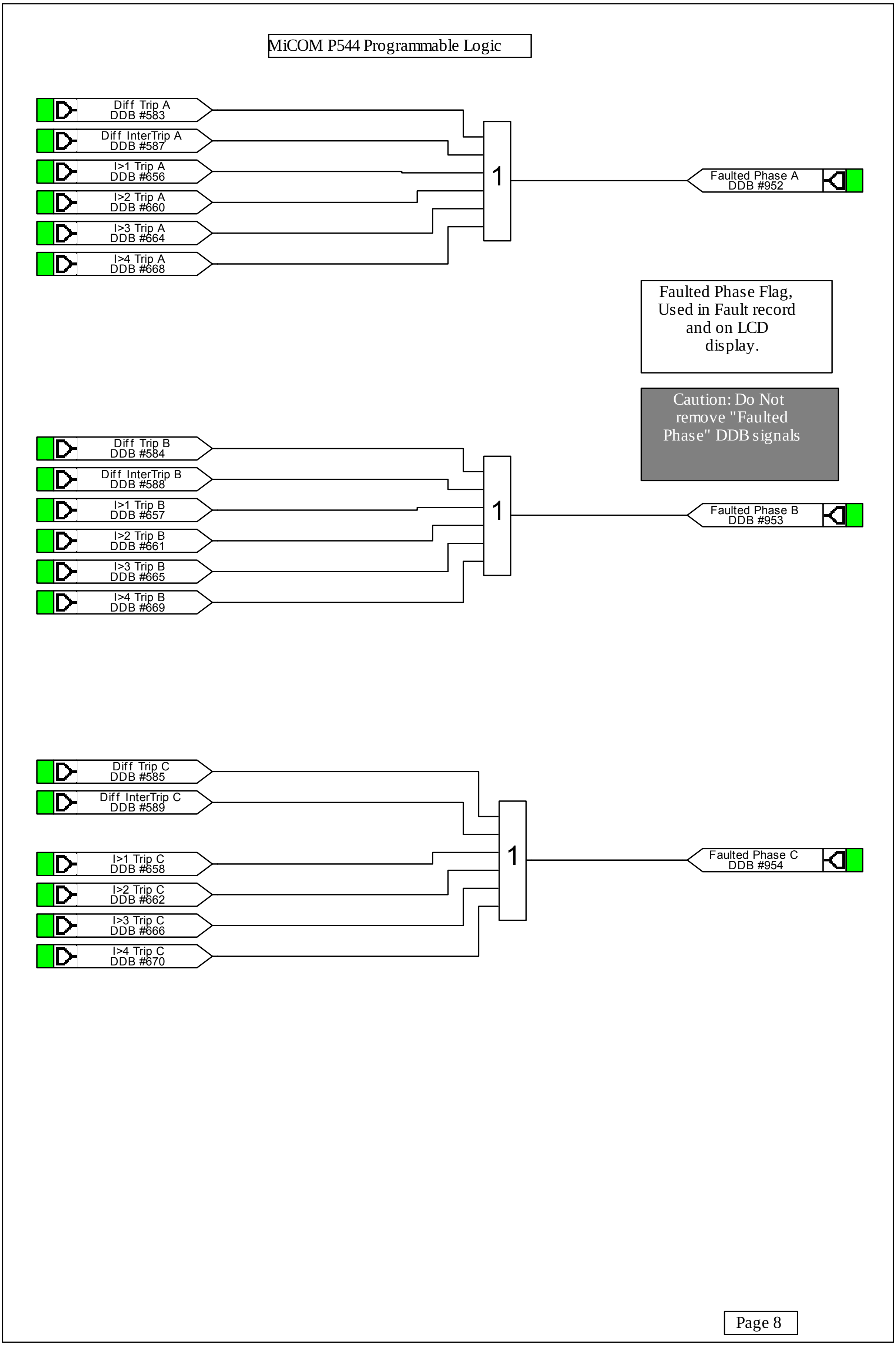
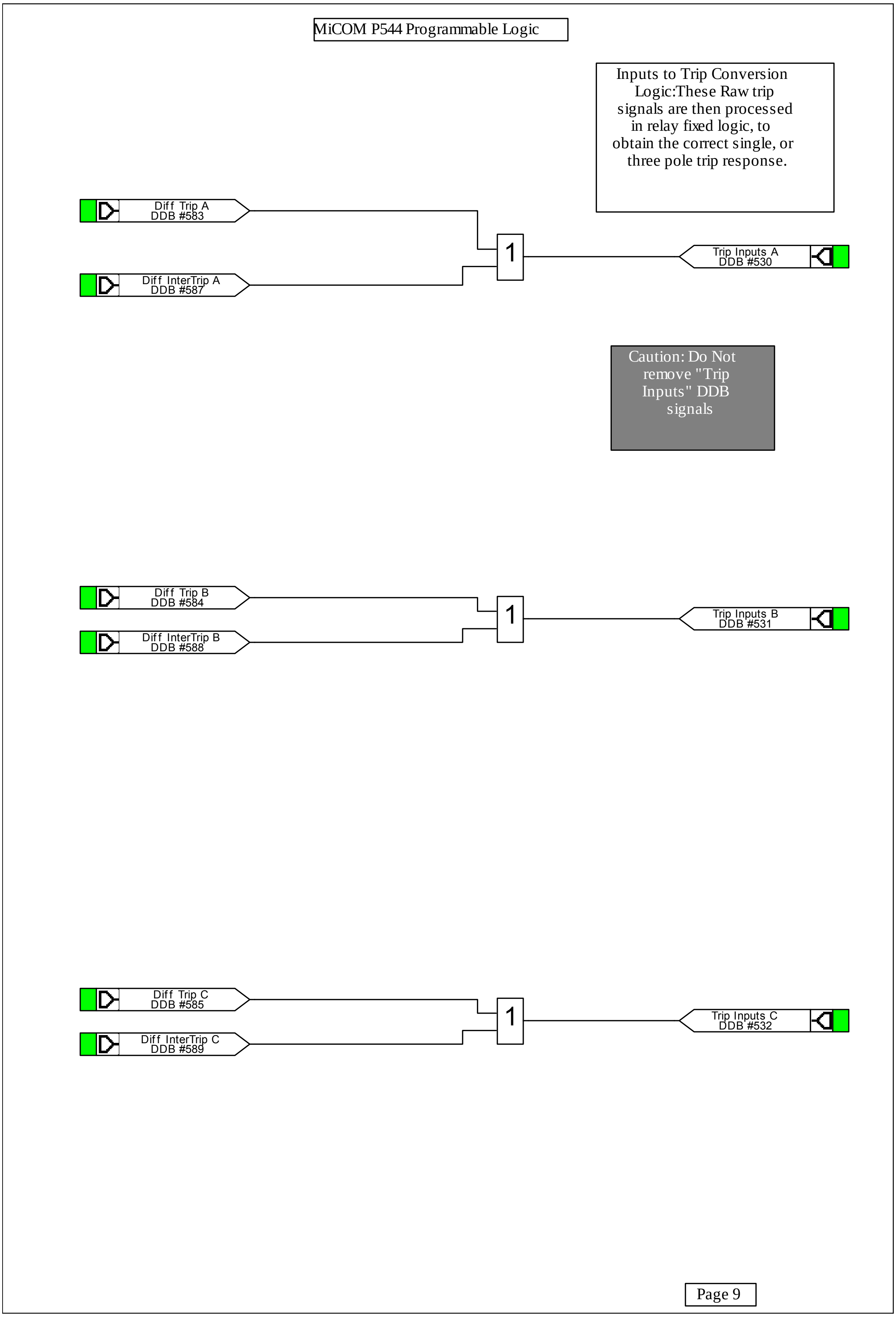
Faulted Phase Mappings

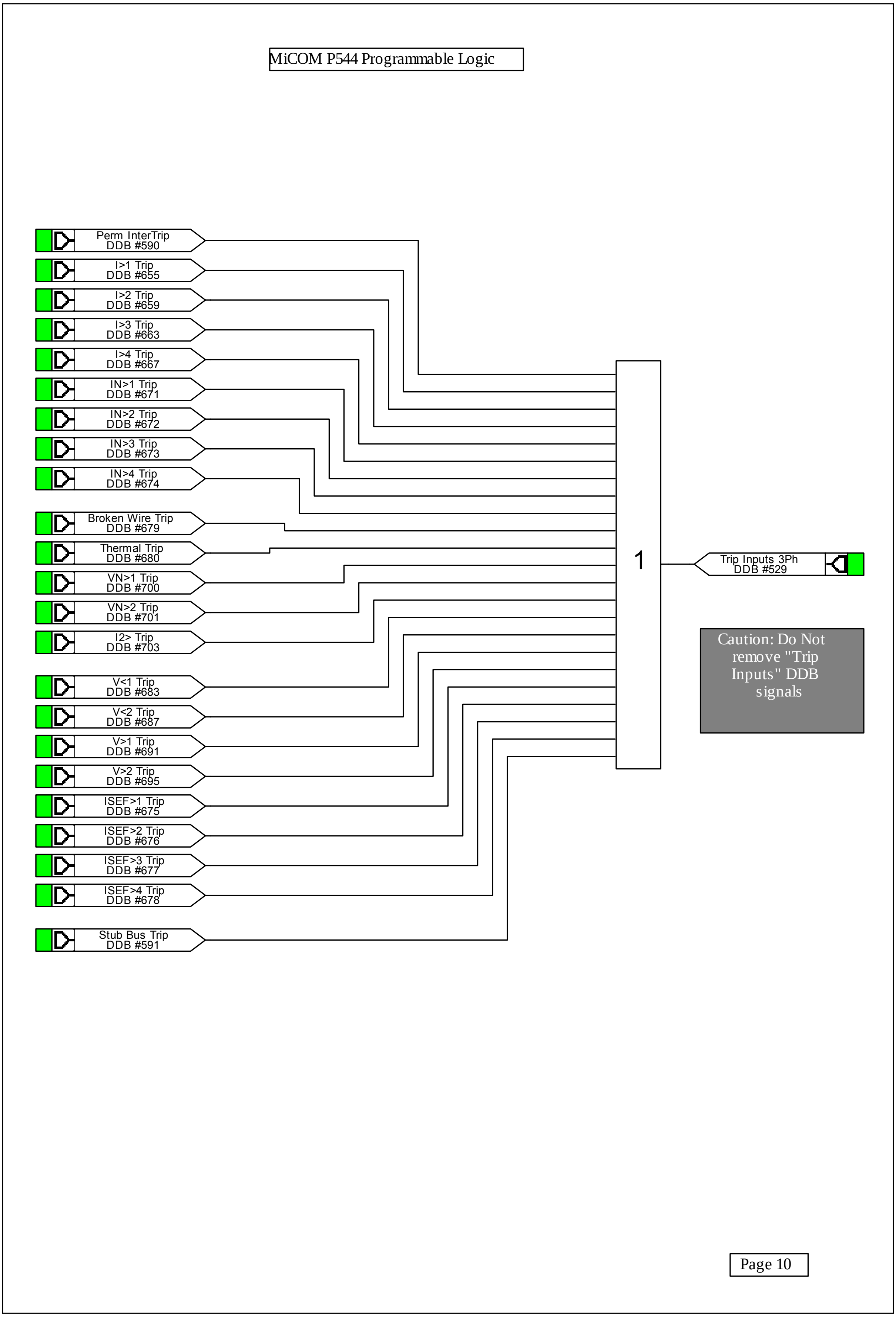


PL

Trip Inputs Mappings



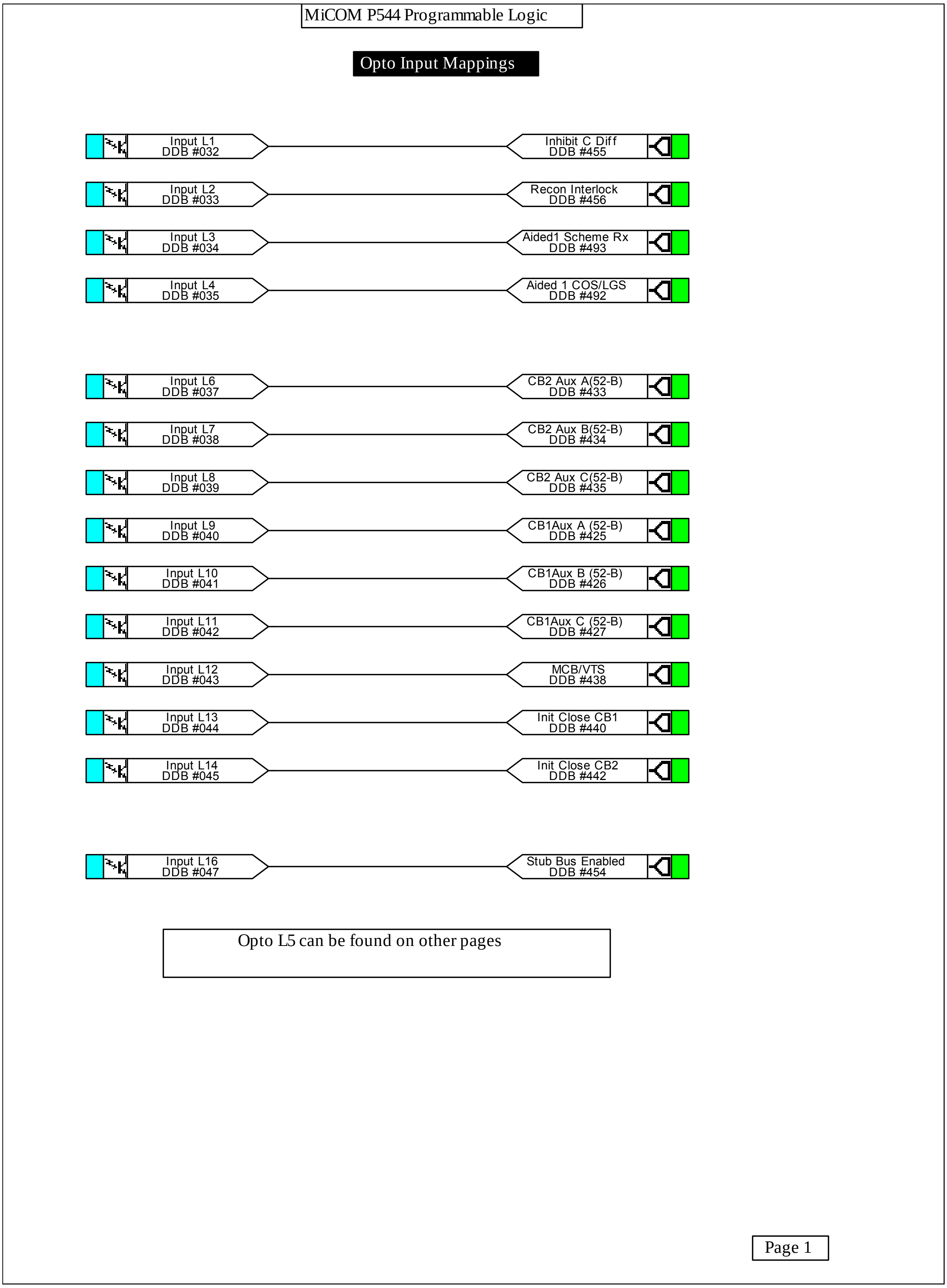
Trip Inputs Mappings



PL

MiCOM P544 WITH DISTANCE OPTION AND STANDARD CONTACTS PROGRAMMABLE SCHEME LOGIC

Opto Input Mappings



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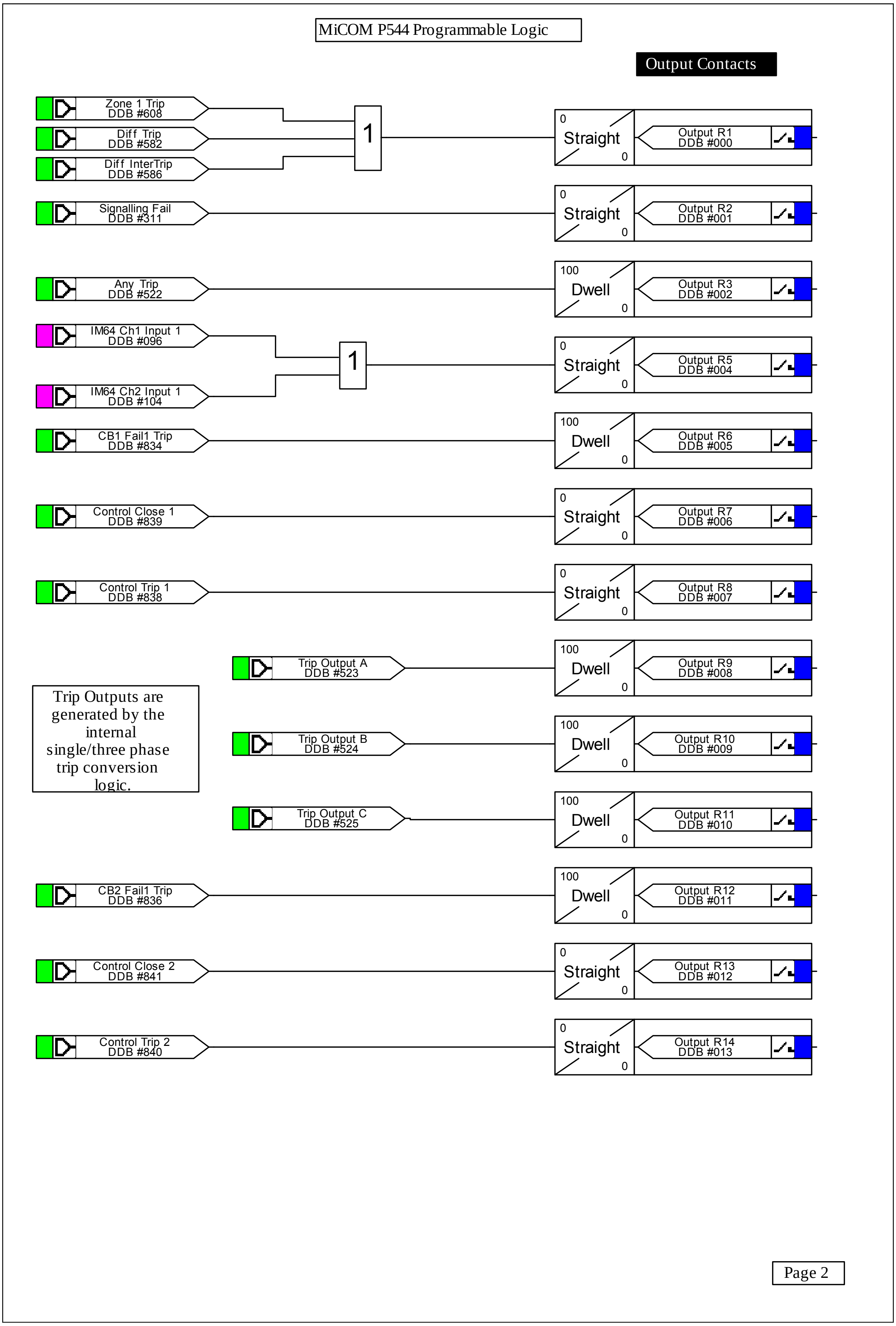
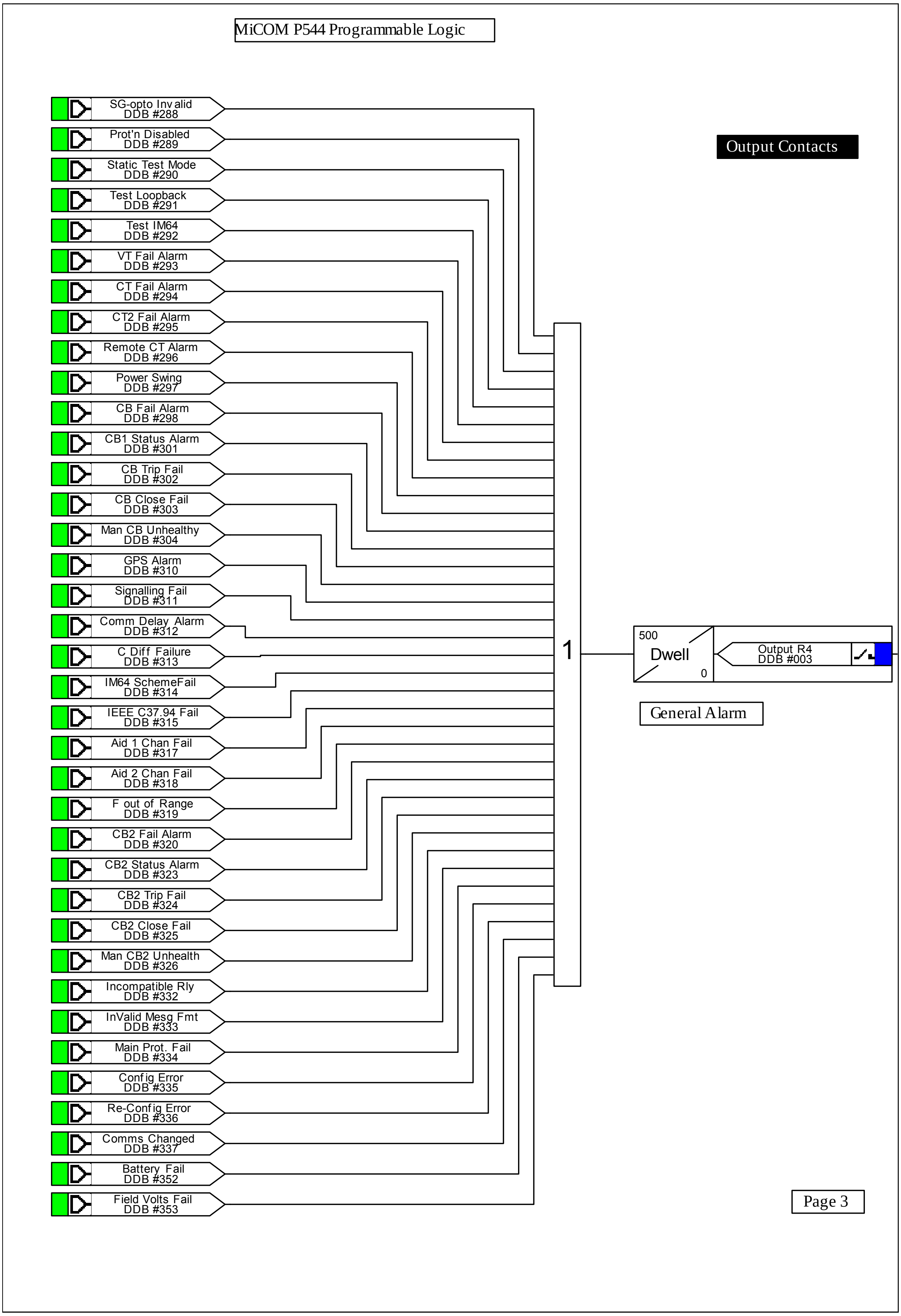
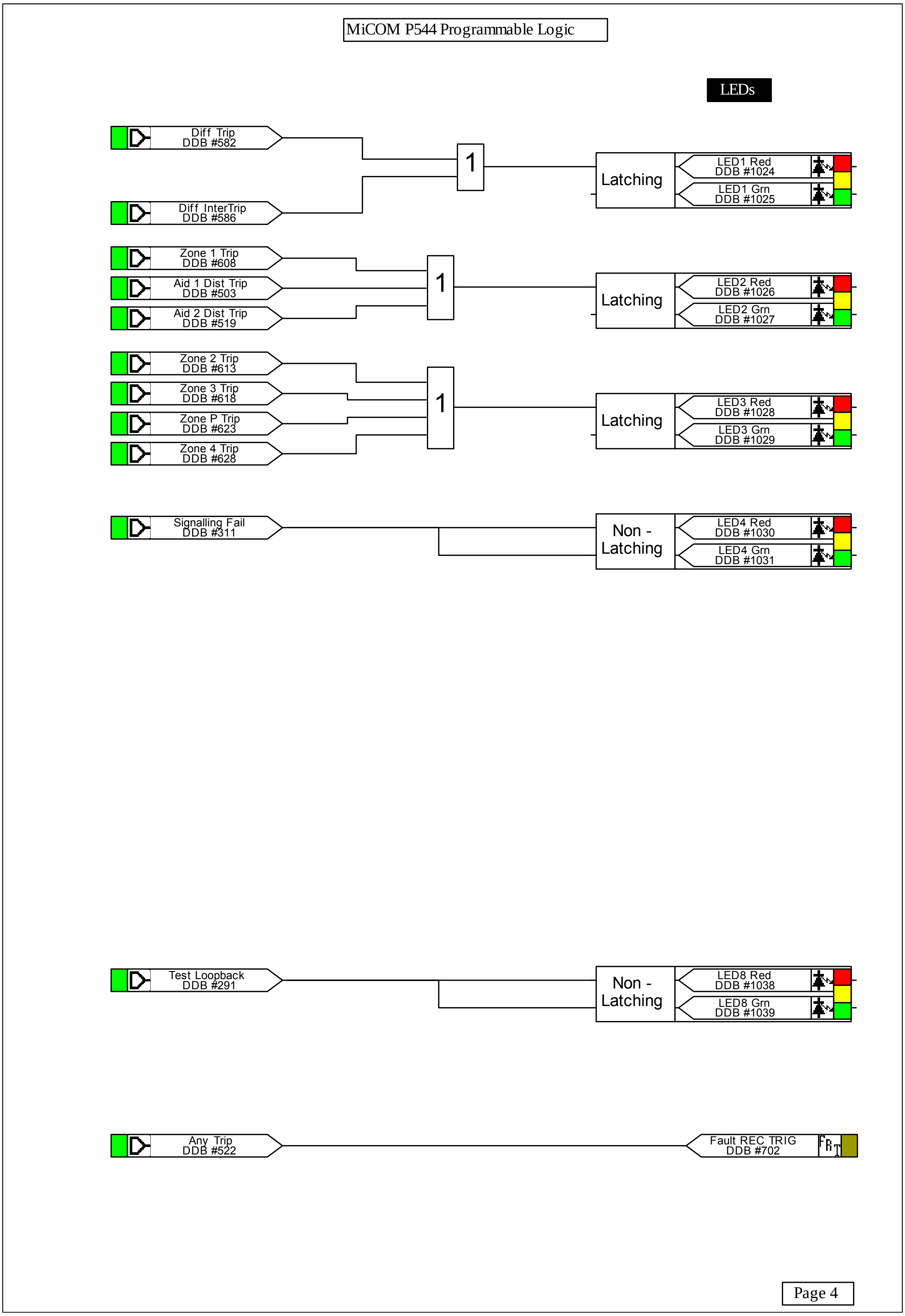
Outputs Relays Mapping



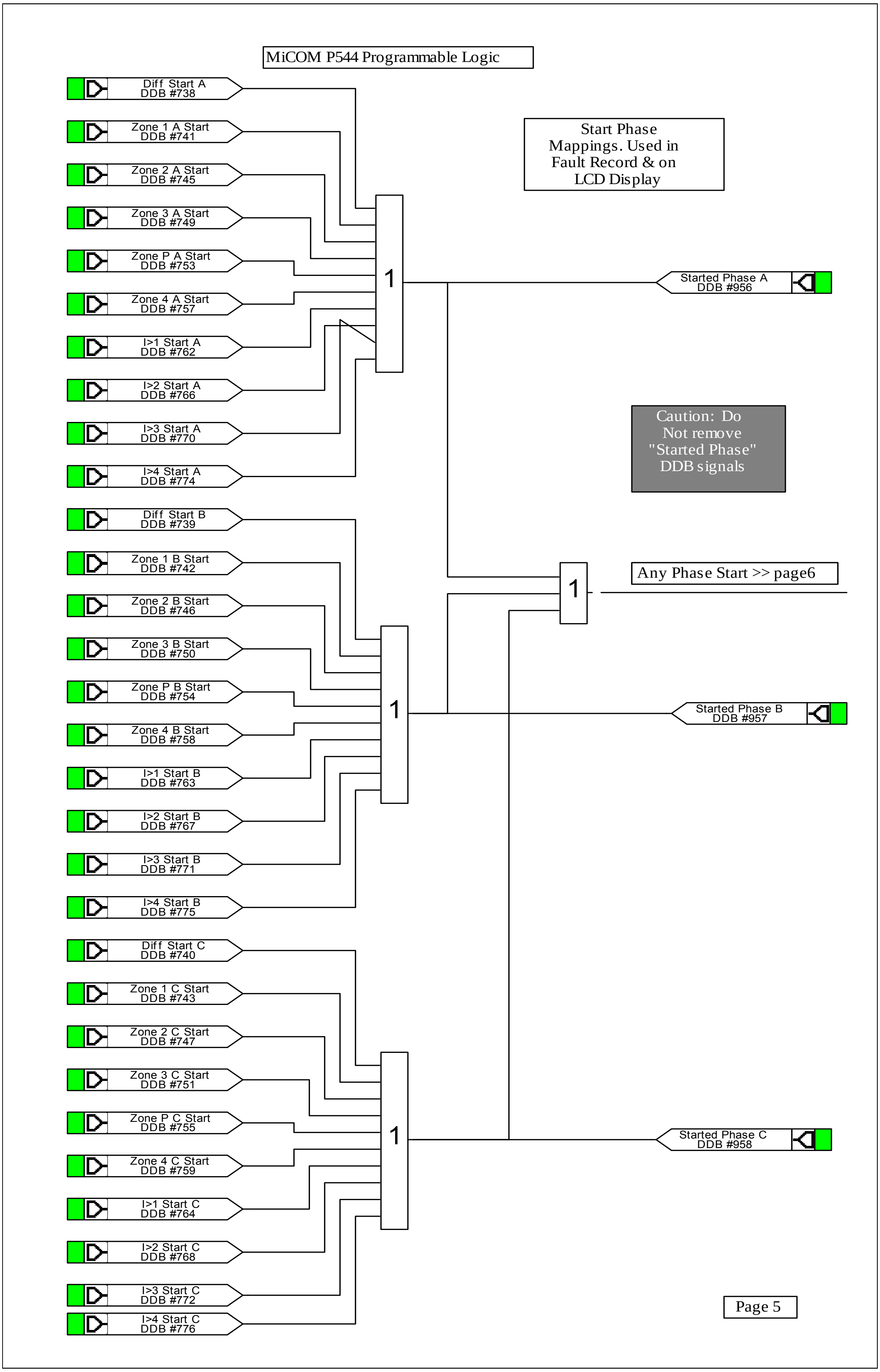
Outputs Relays Mapping



LED Mappings



Start Mappings



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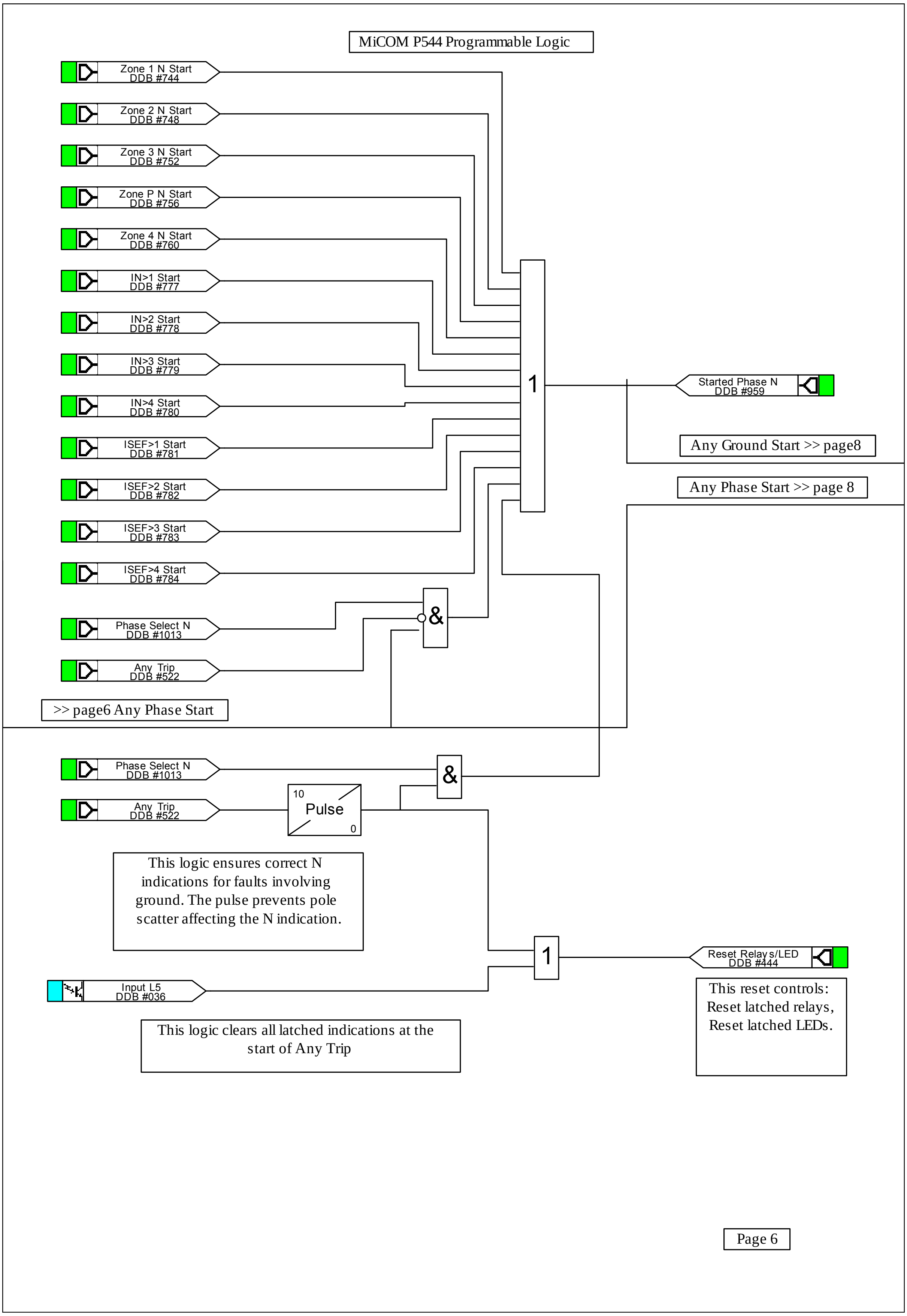
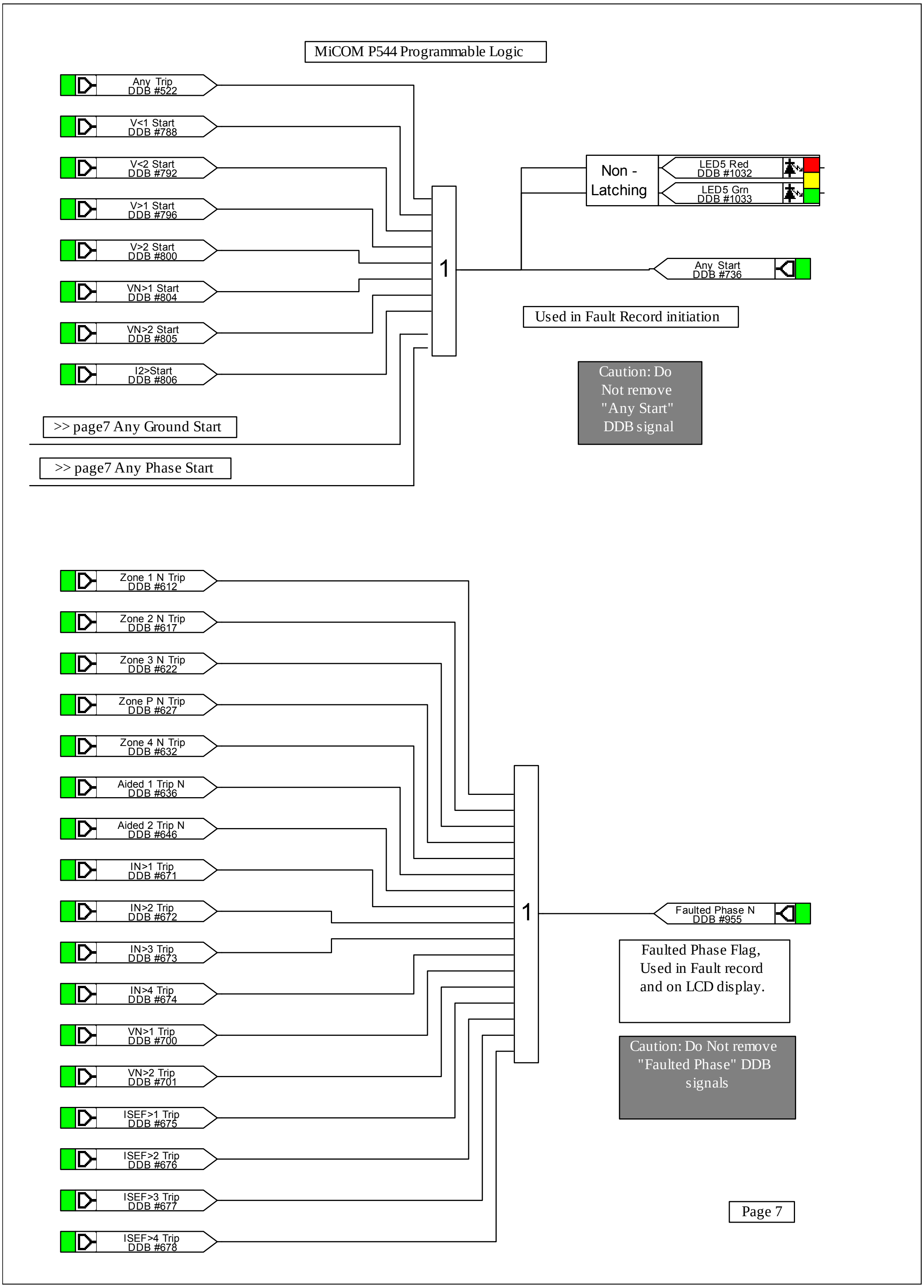
Start Mappings



Faulted Phase Mappings



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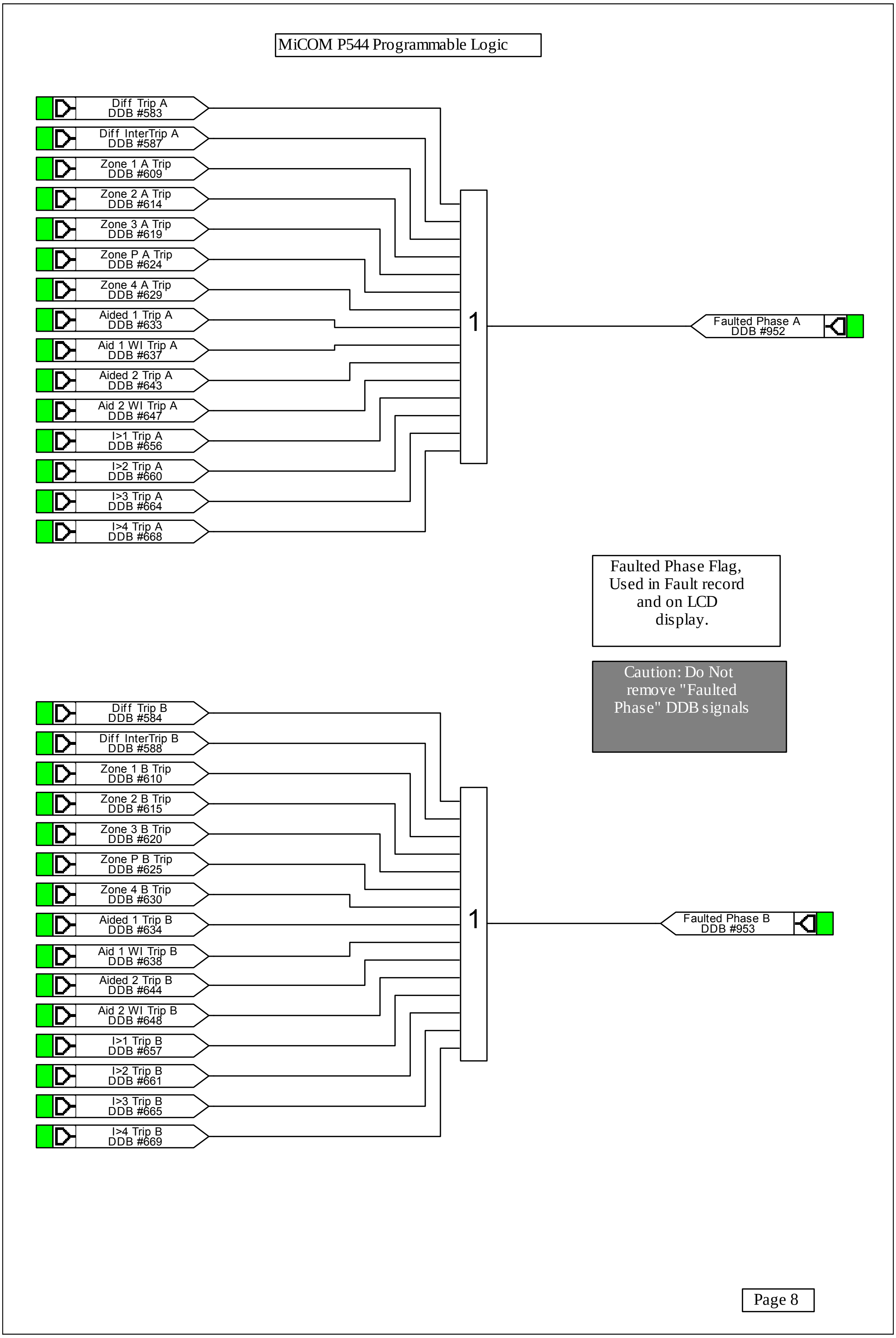
Faulted Phase Mappings



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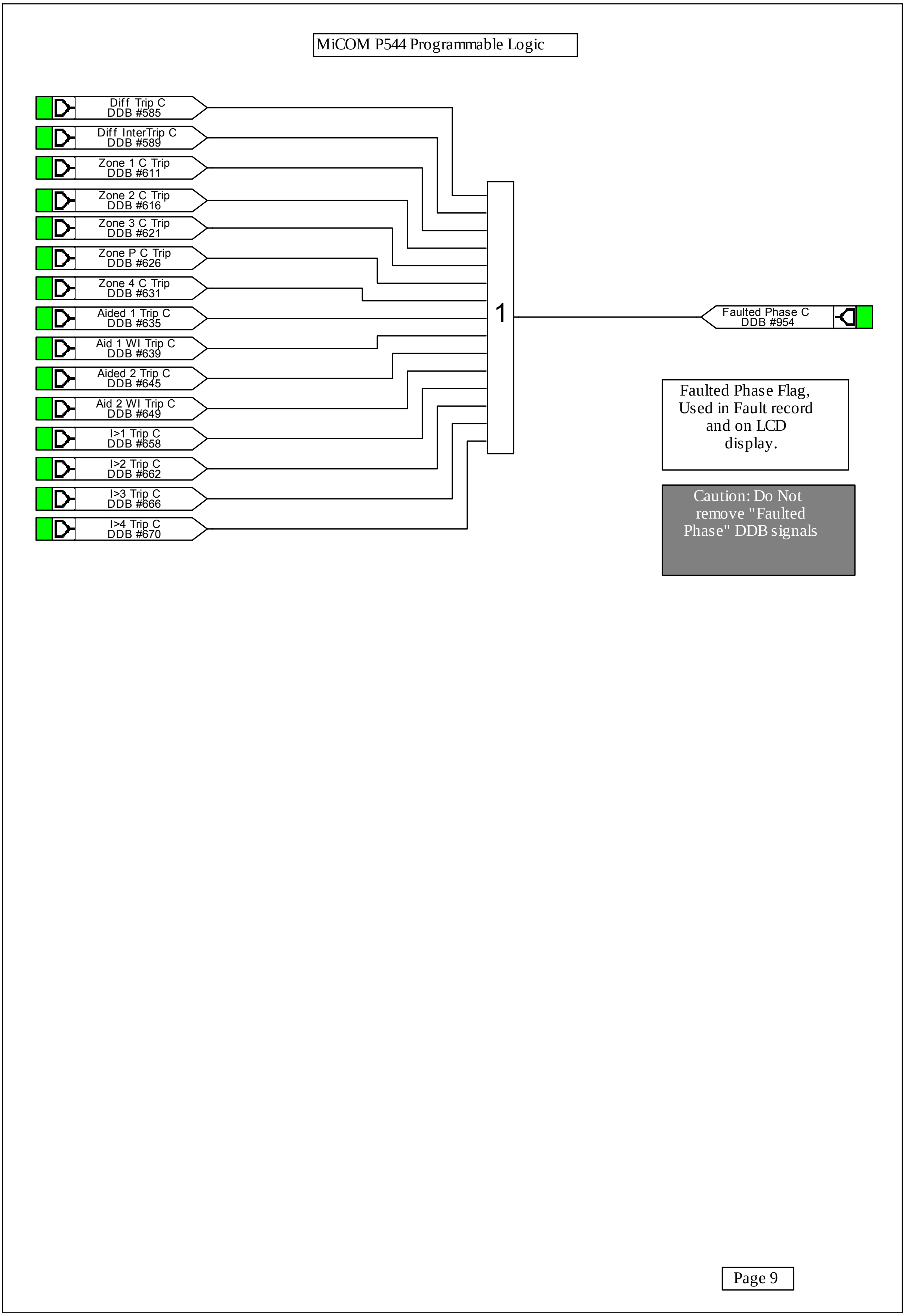
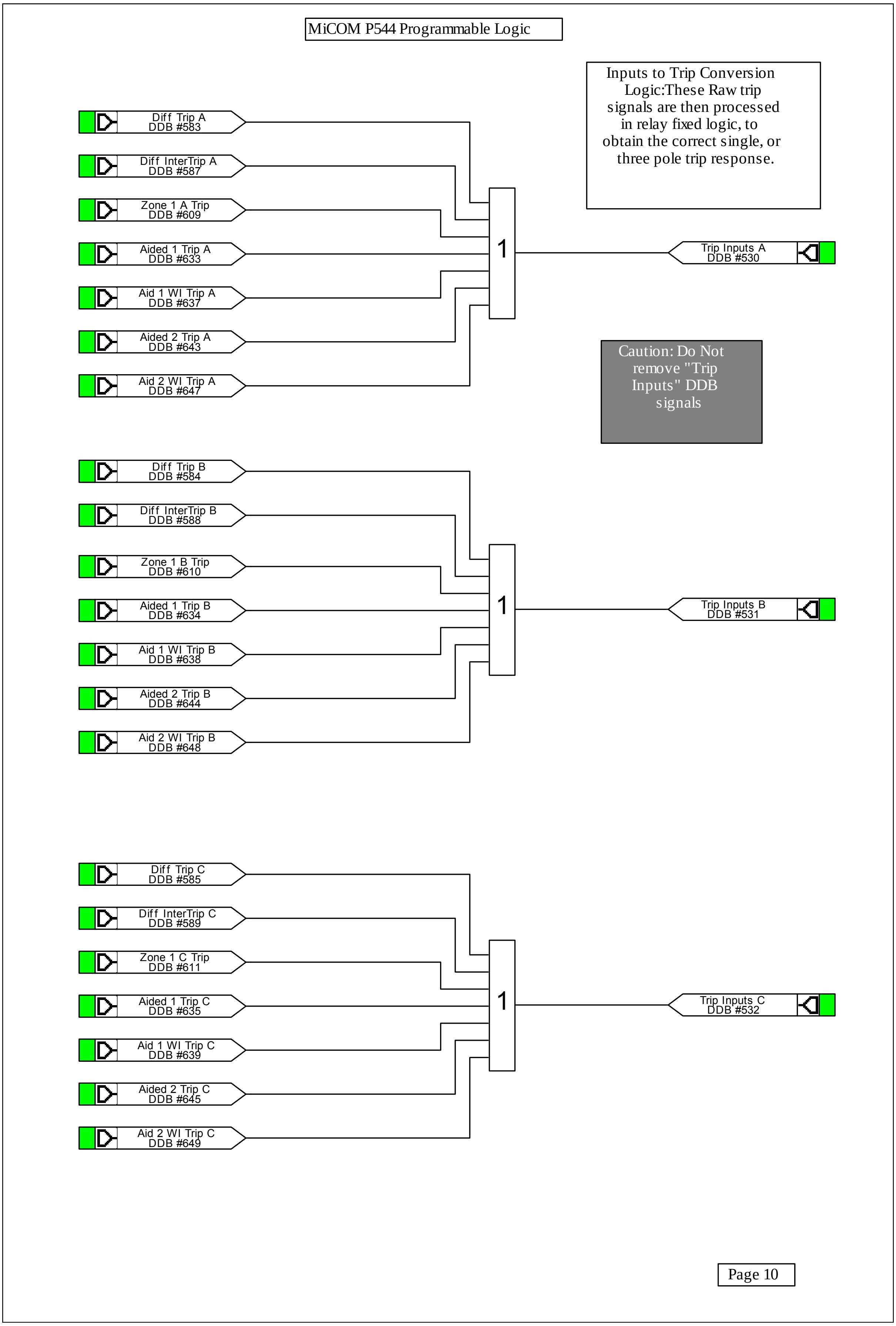
Faulted Phase Mappings



Trip Inputs Mappings



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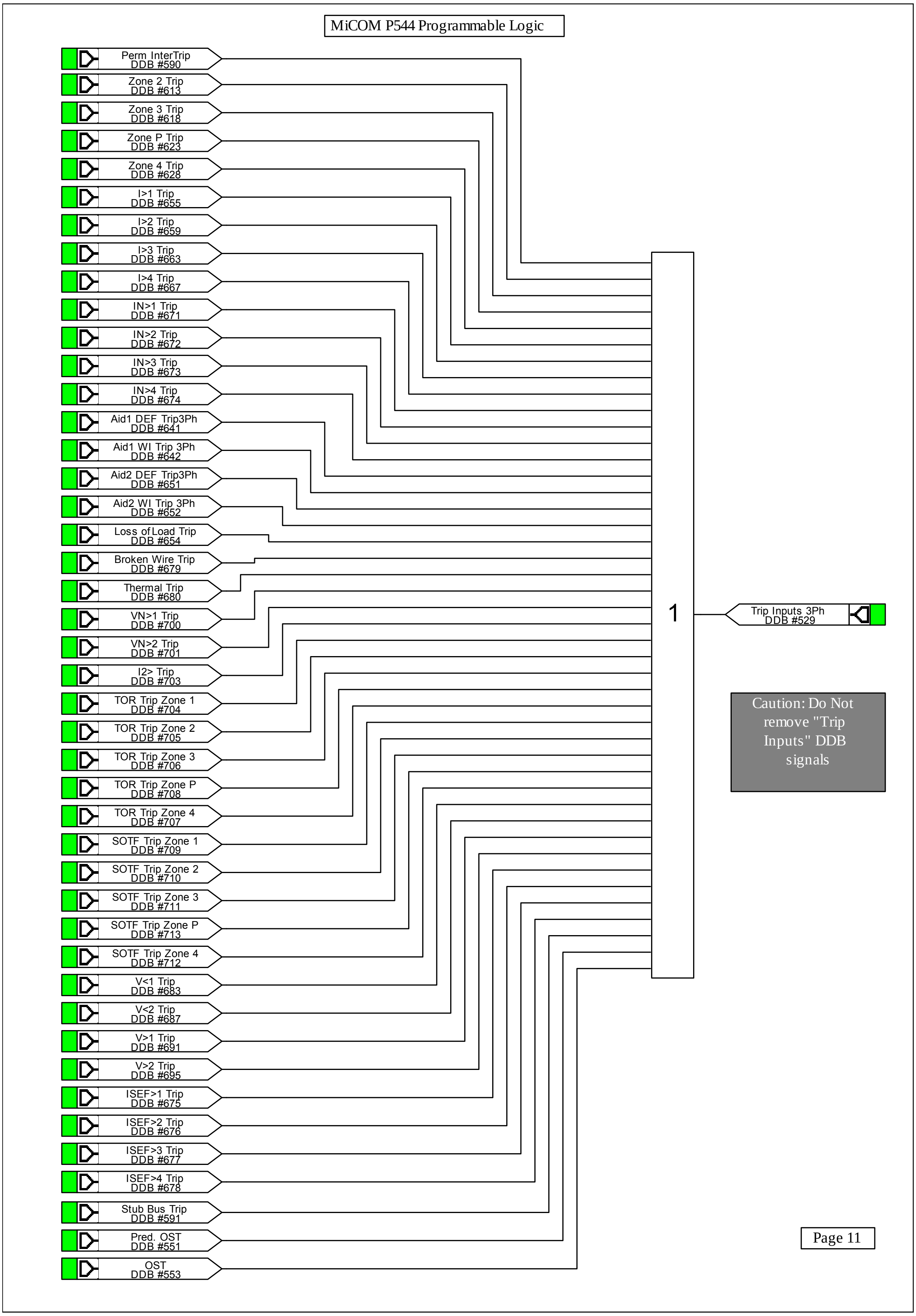
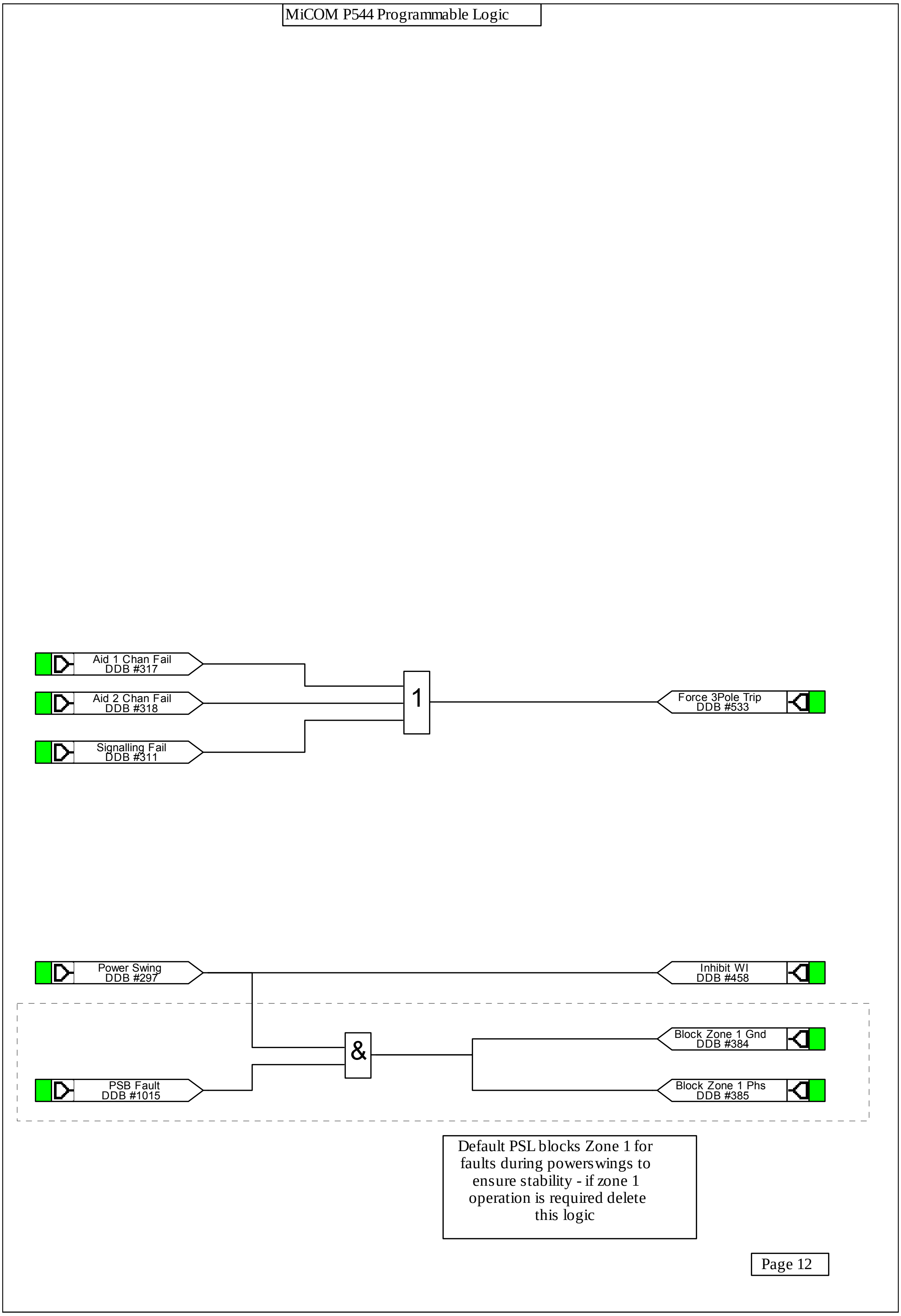
Trip Inputs Mappings



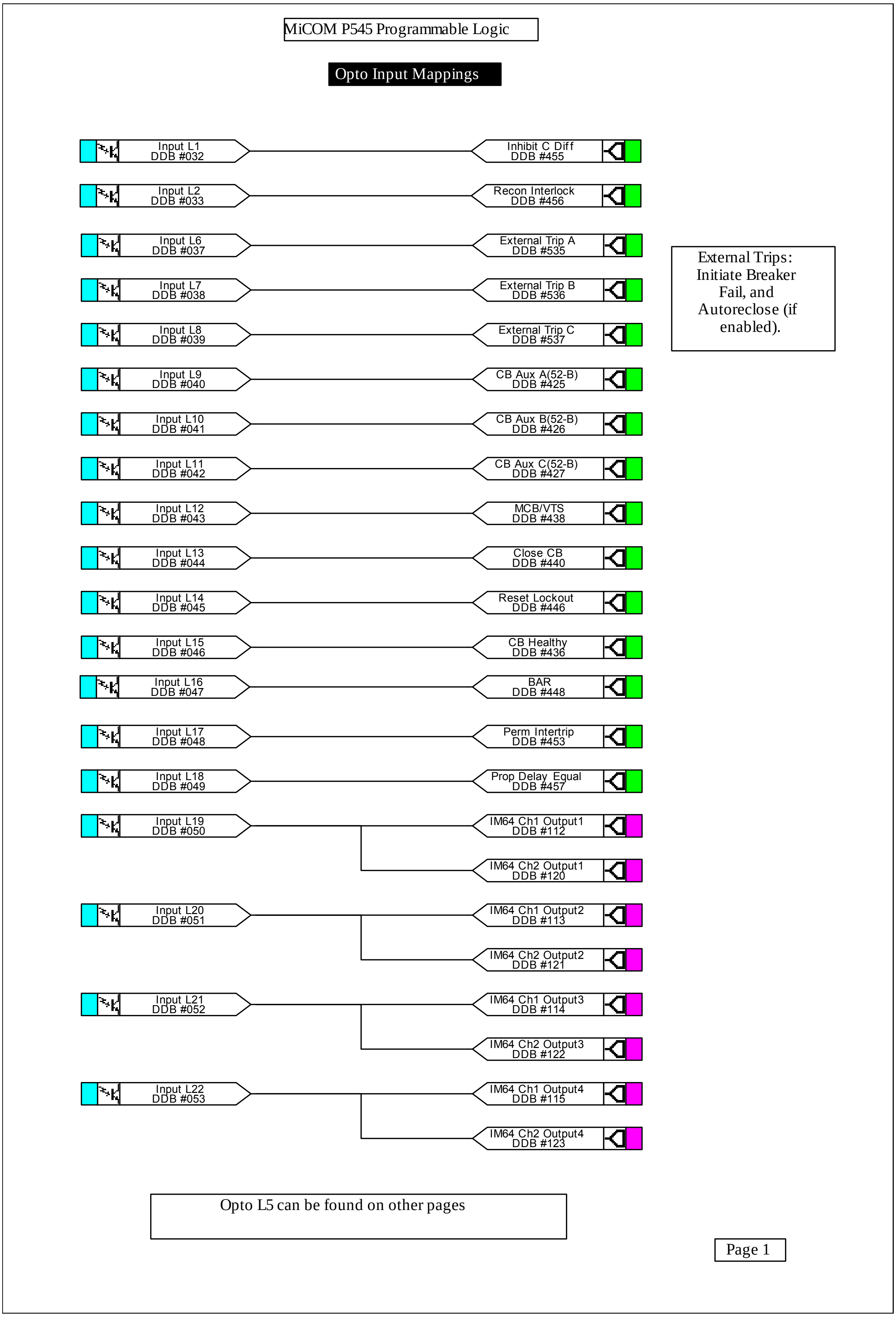
Force 3Pole Trip Mappings



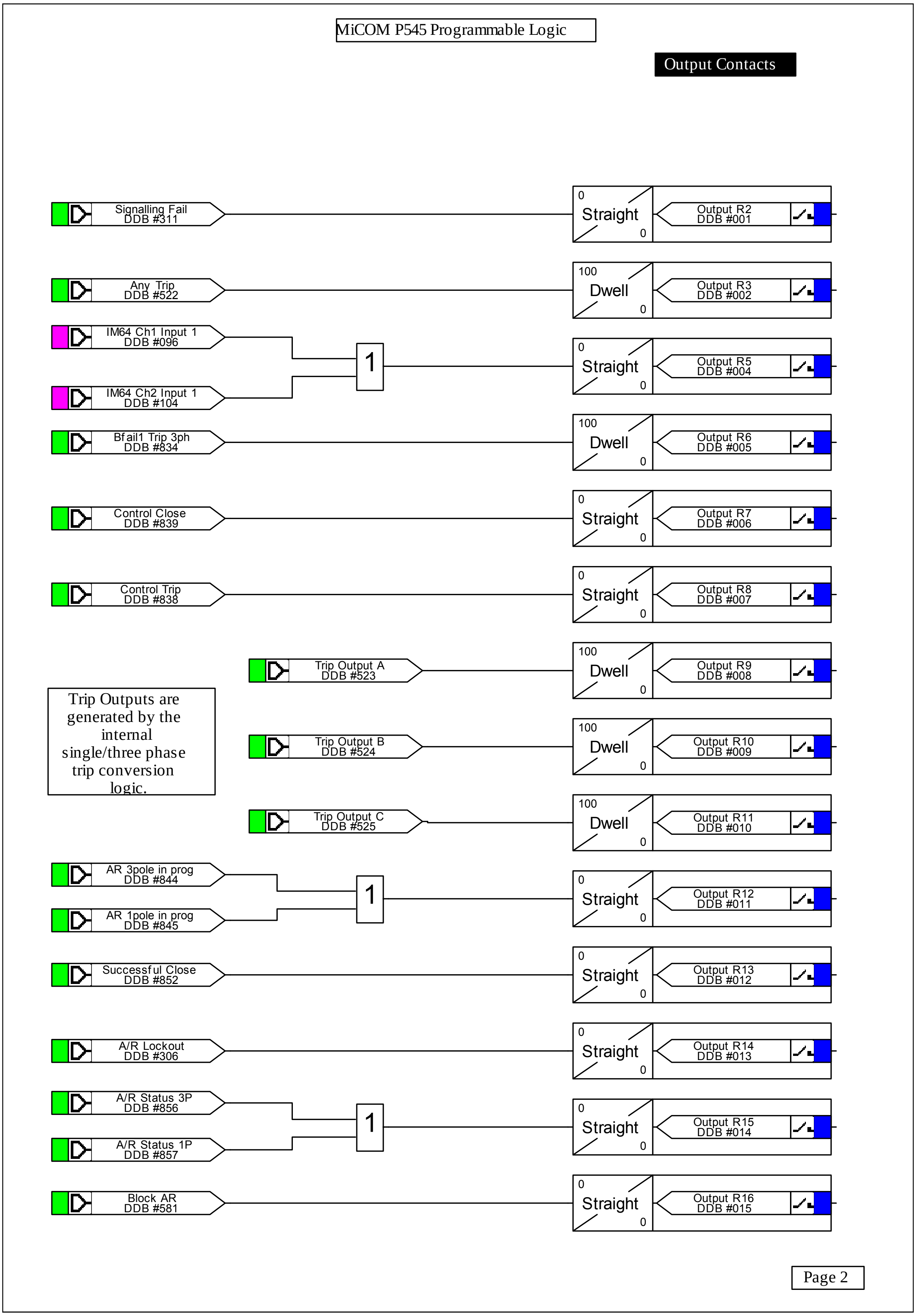
PL

MiCOM P545 WITH NO DISTANCE OPTION AND STANDARD CONTACTS OPTION PROGRAMMABLE SCHEME LOGIC

Opto Input Mappings



Outputs Relays Mappings



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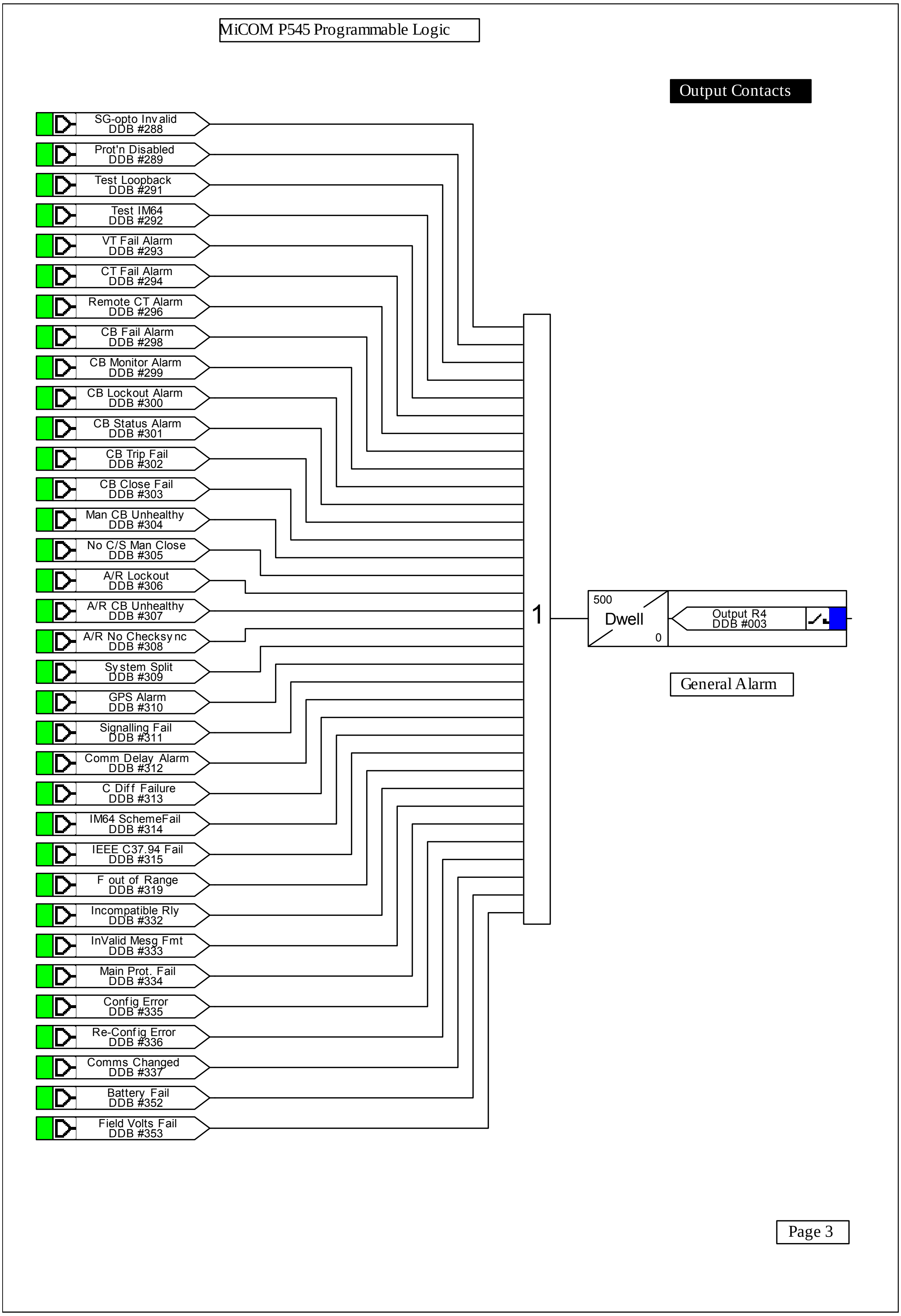
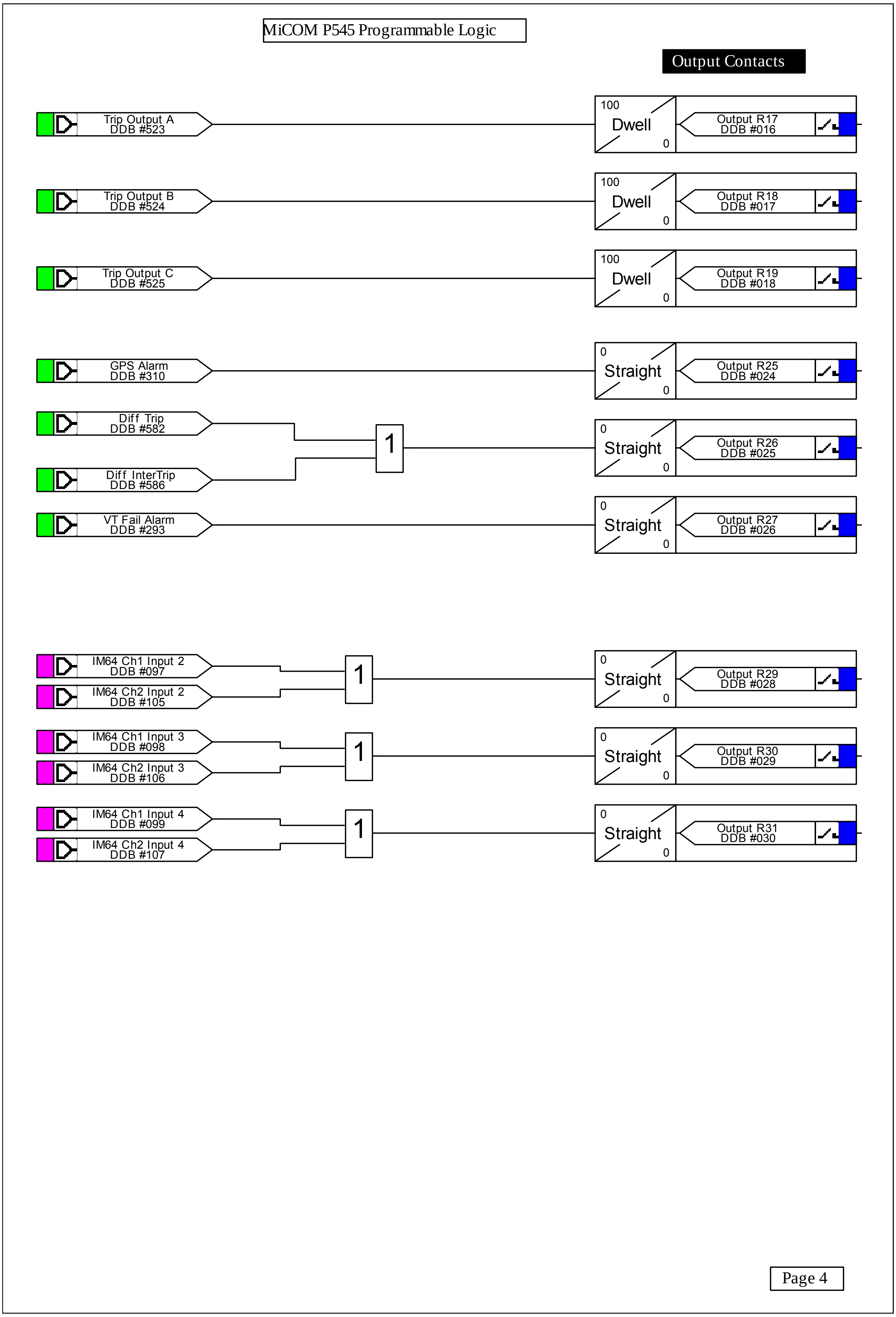
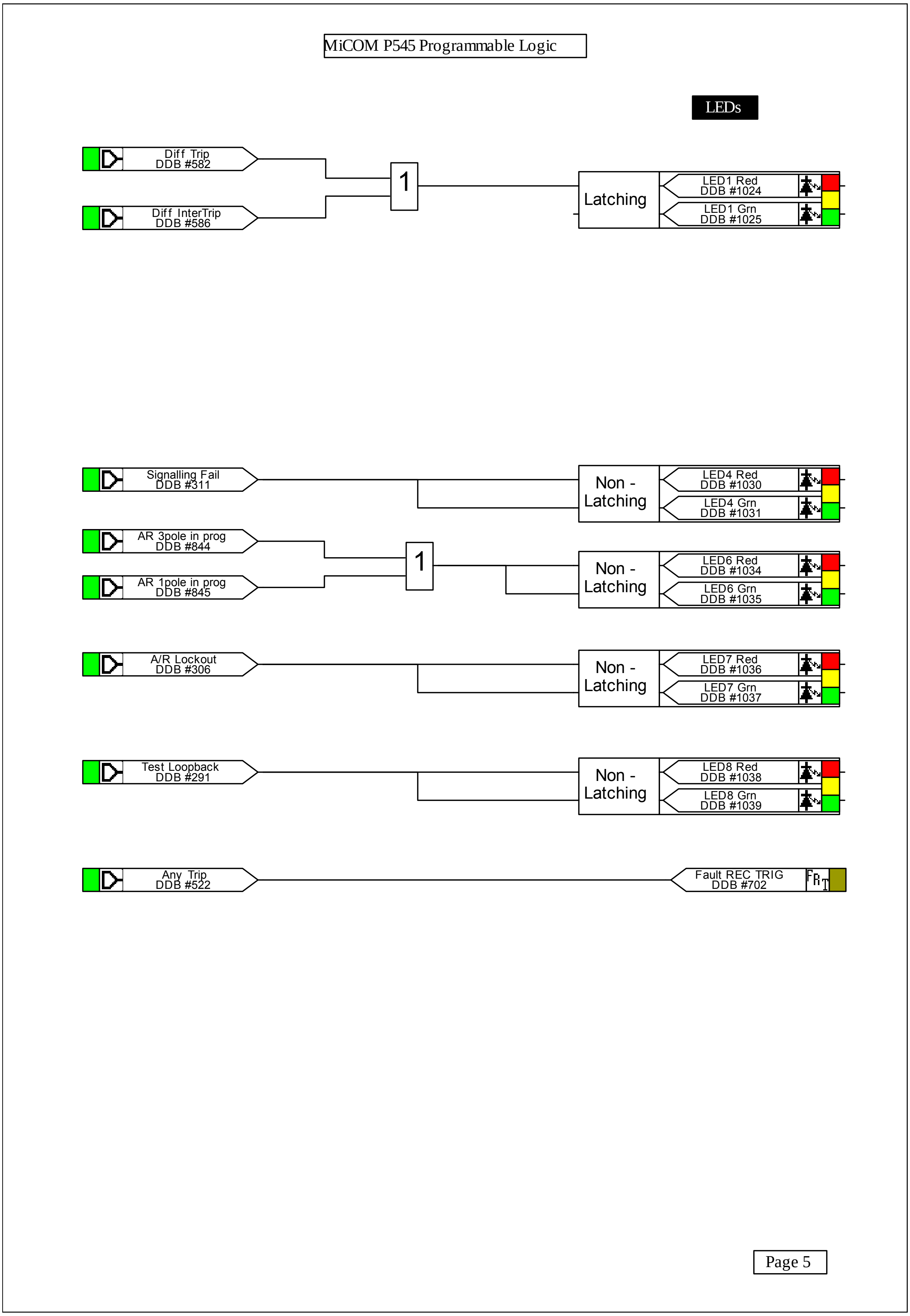
Outputs Relays Mappings



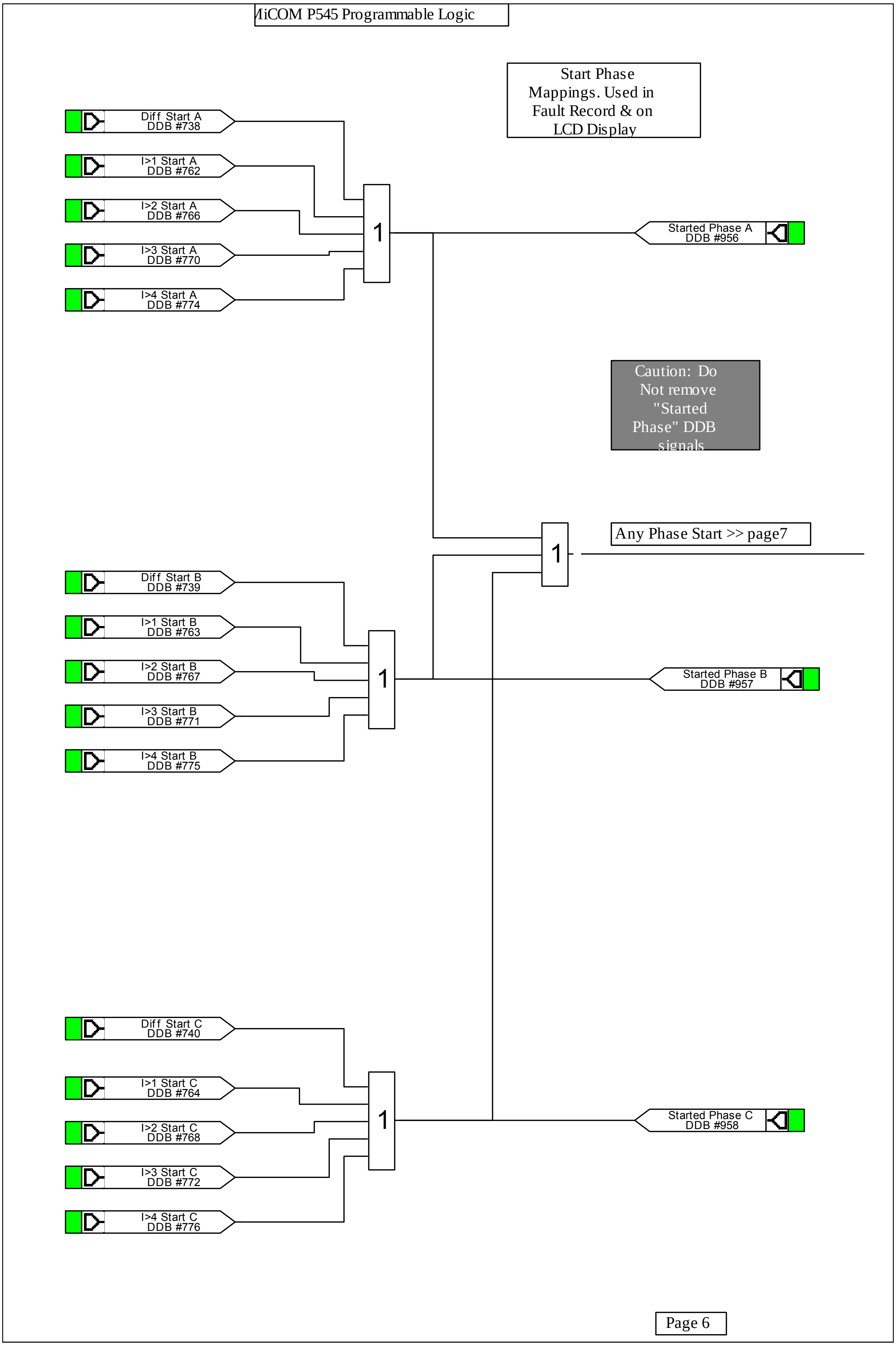
Outputs Relays Mappings



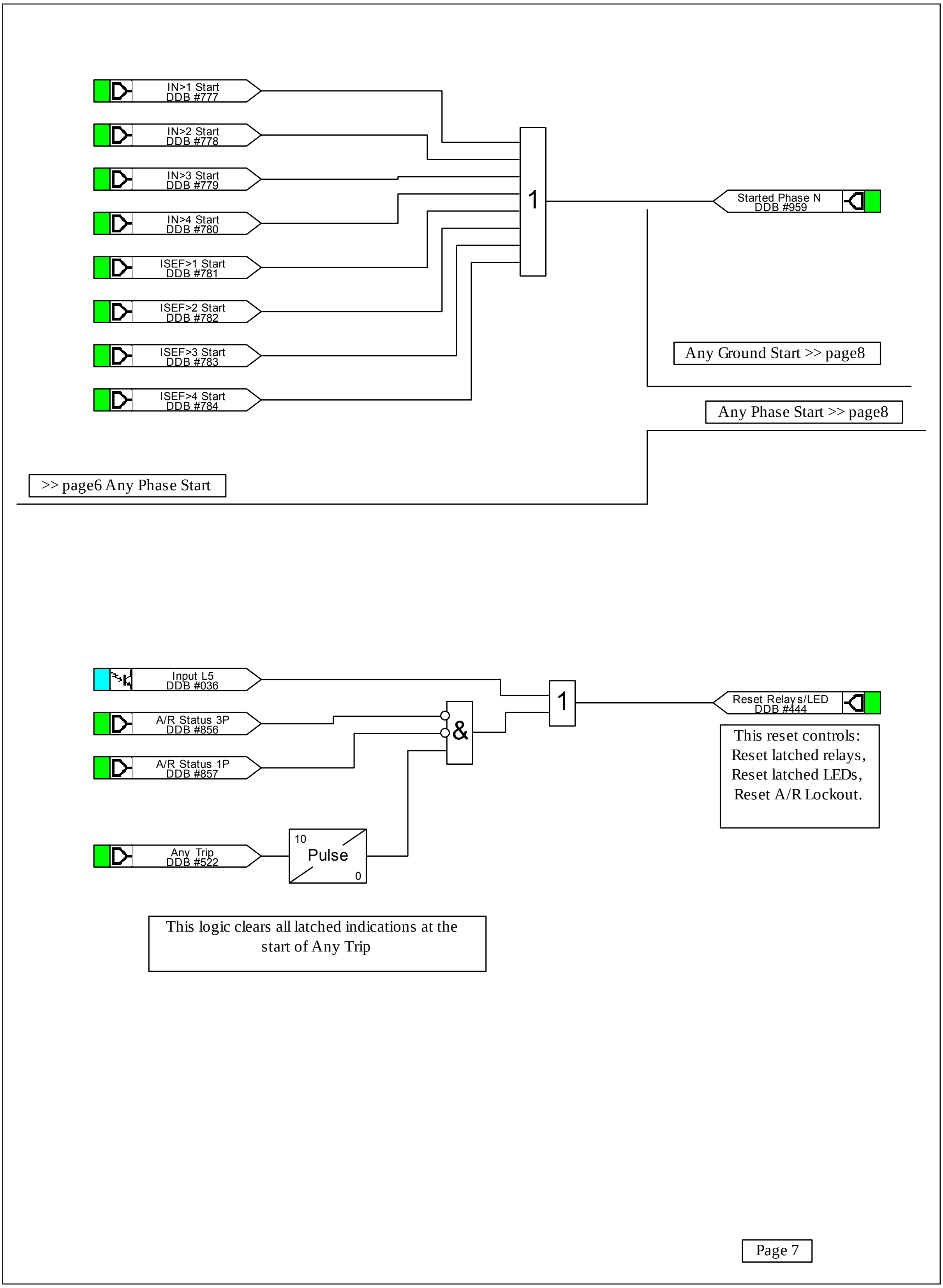
LED Mappings



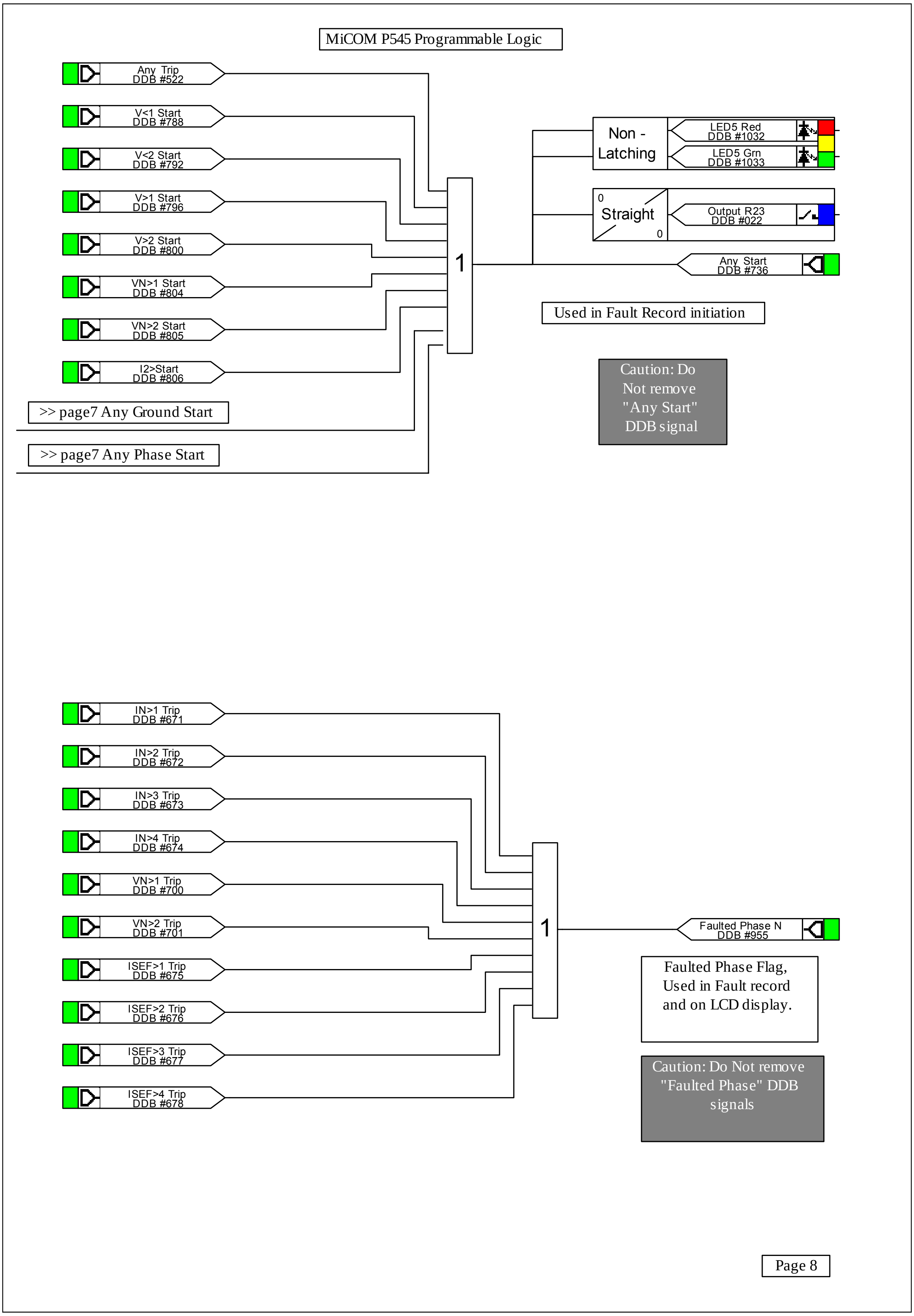
Start Mappings



Start Mappings



Faulted Phase Mappings



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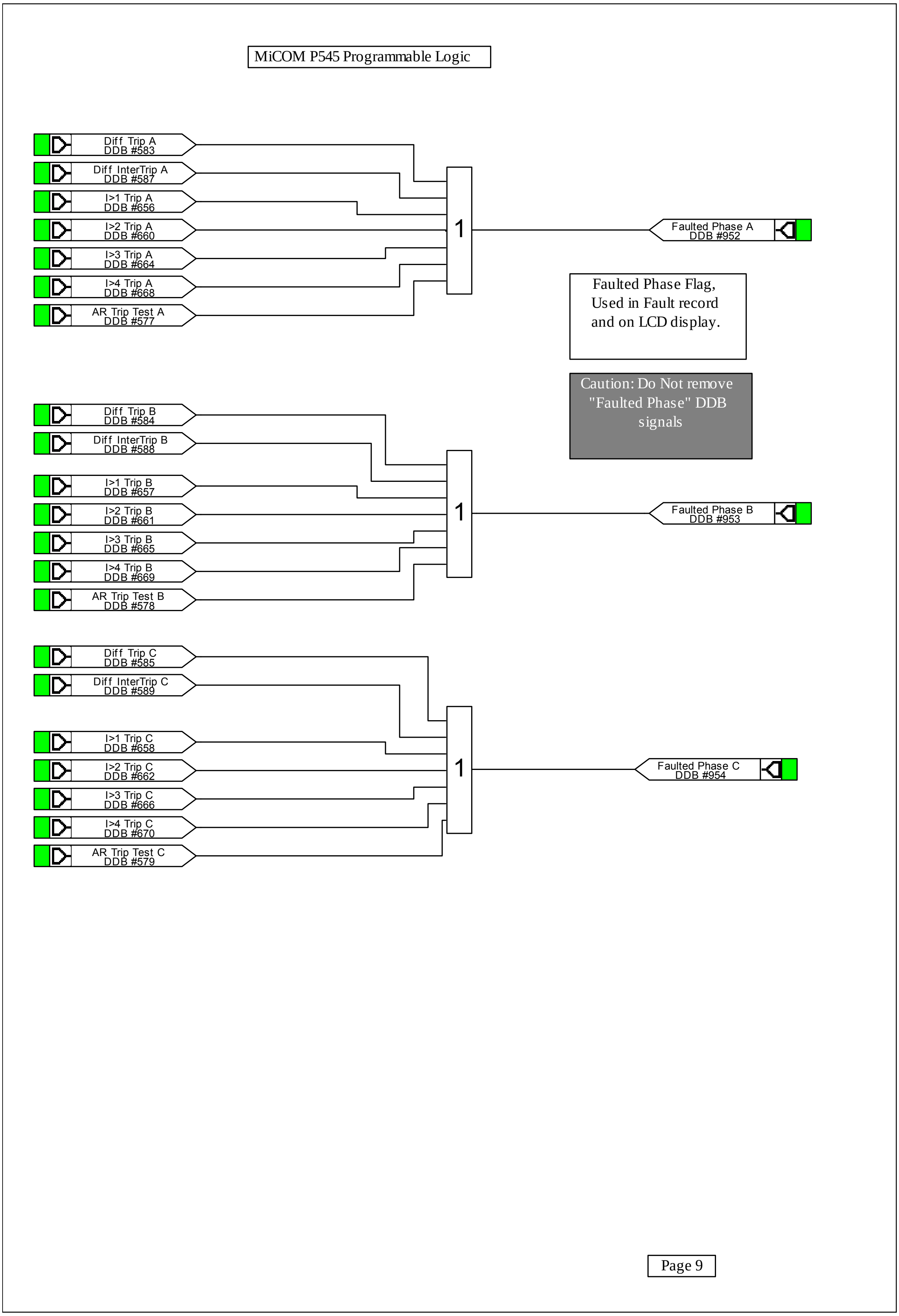
Faulted Phase Mappings



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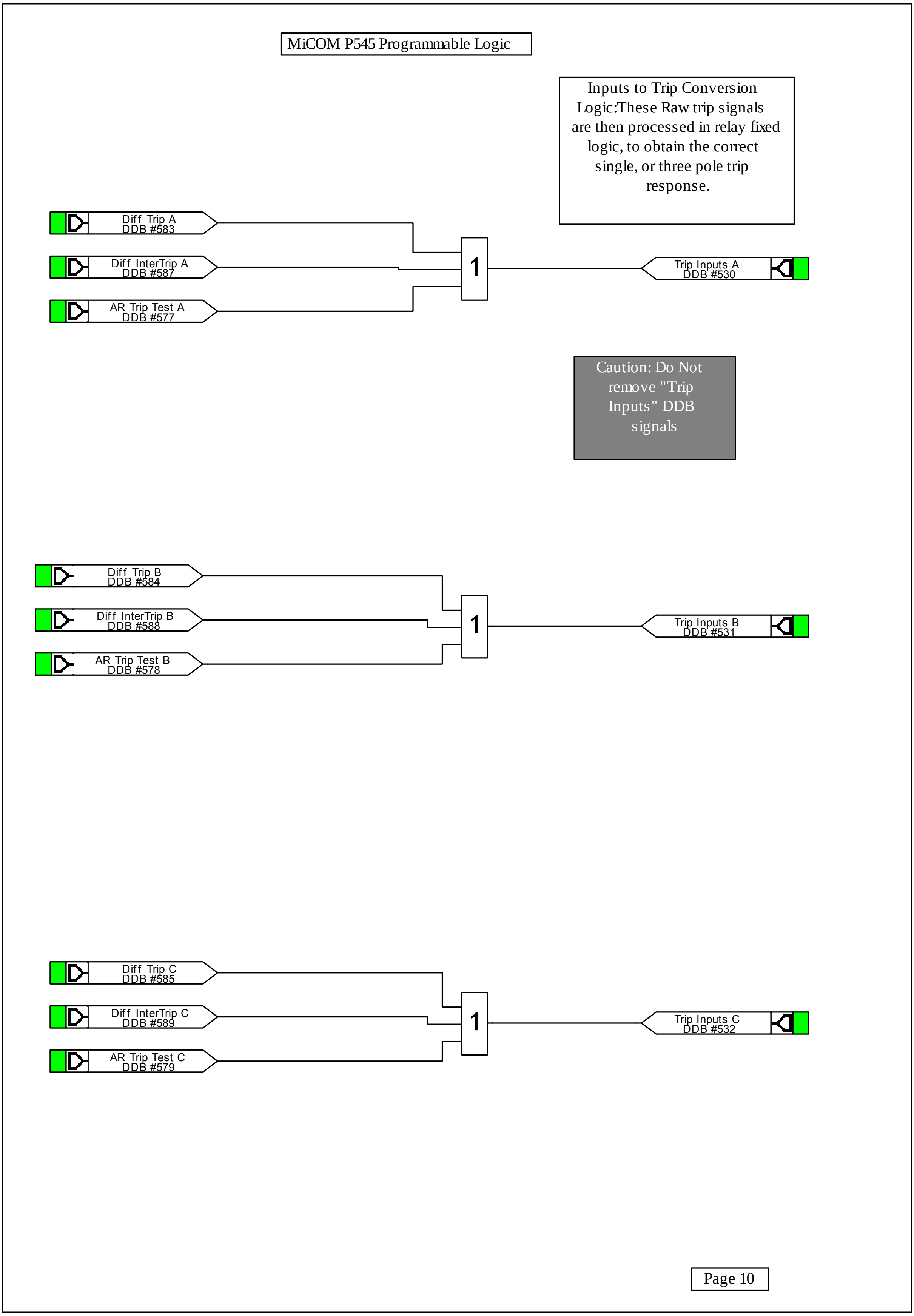
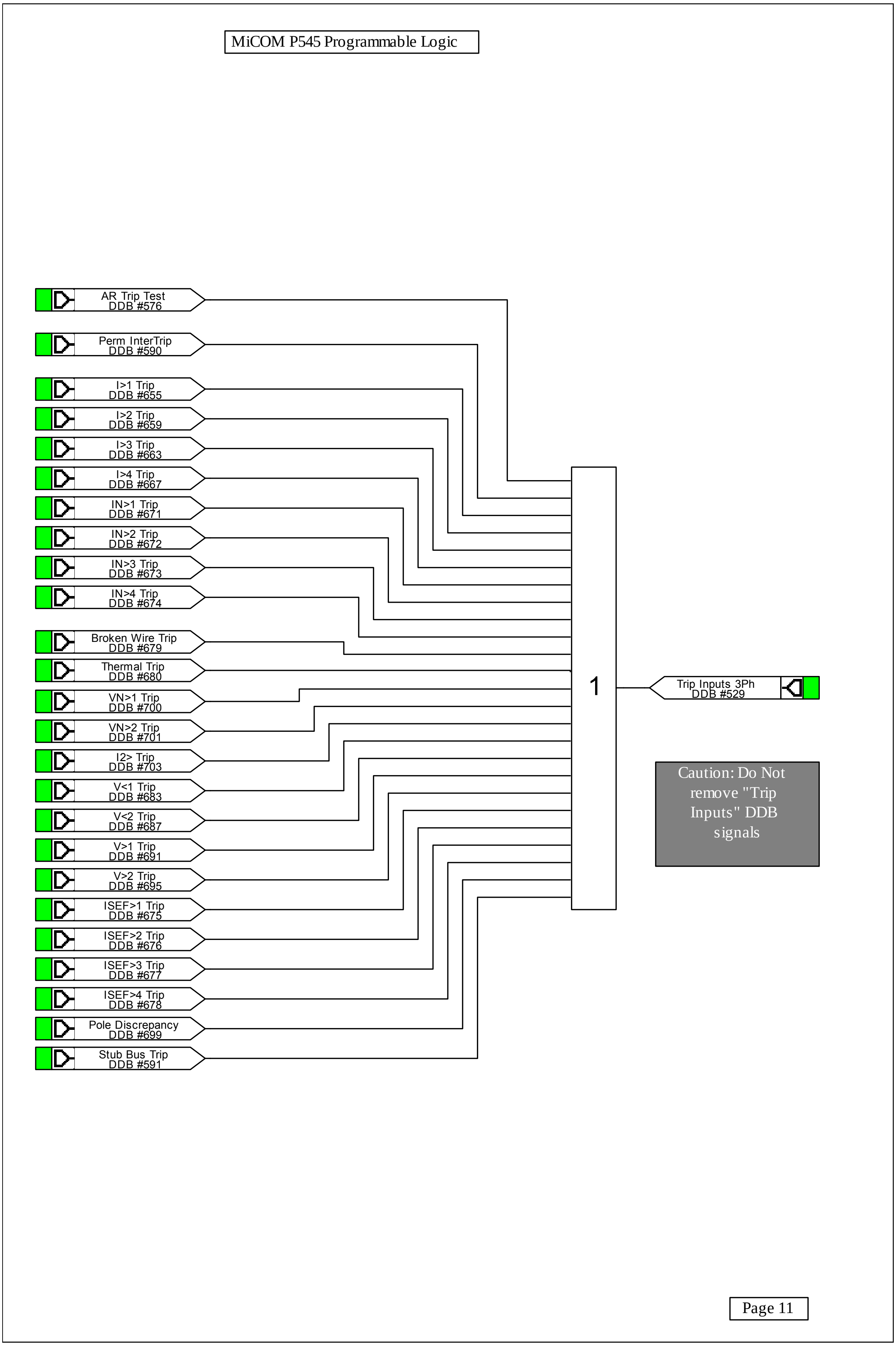
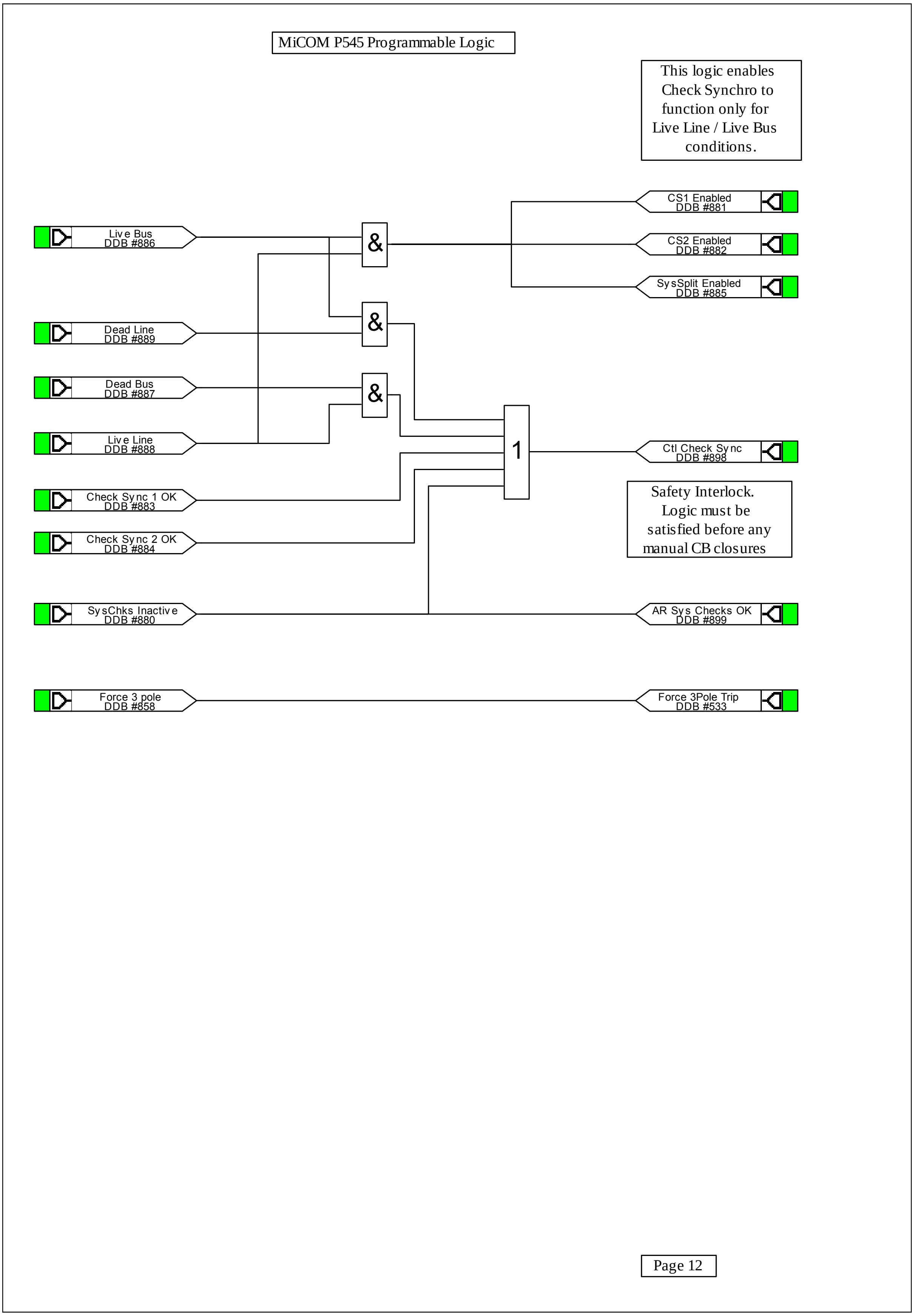
Trip Inputs Mappings



Trip Inputs Mappings

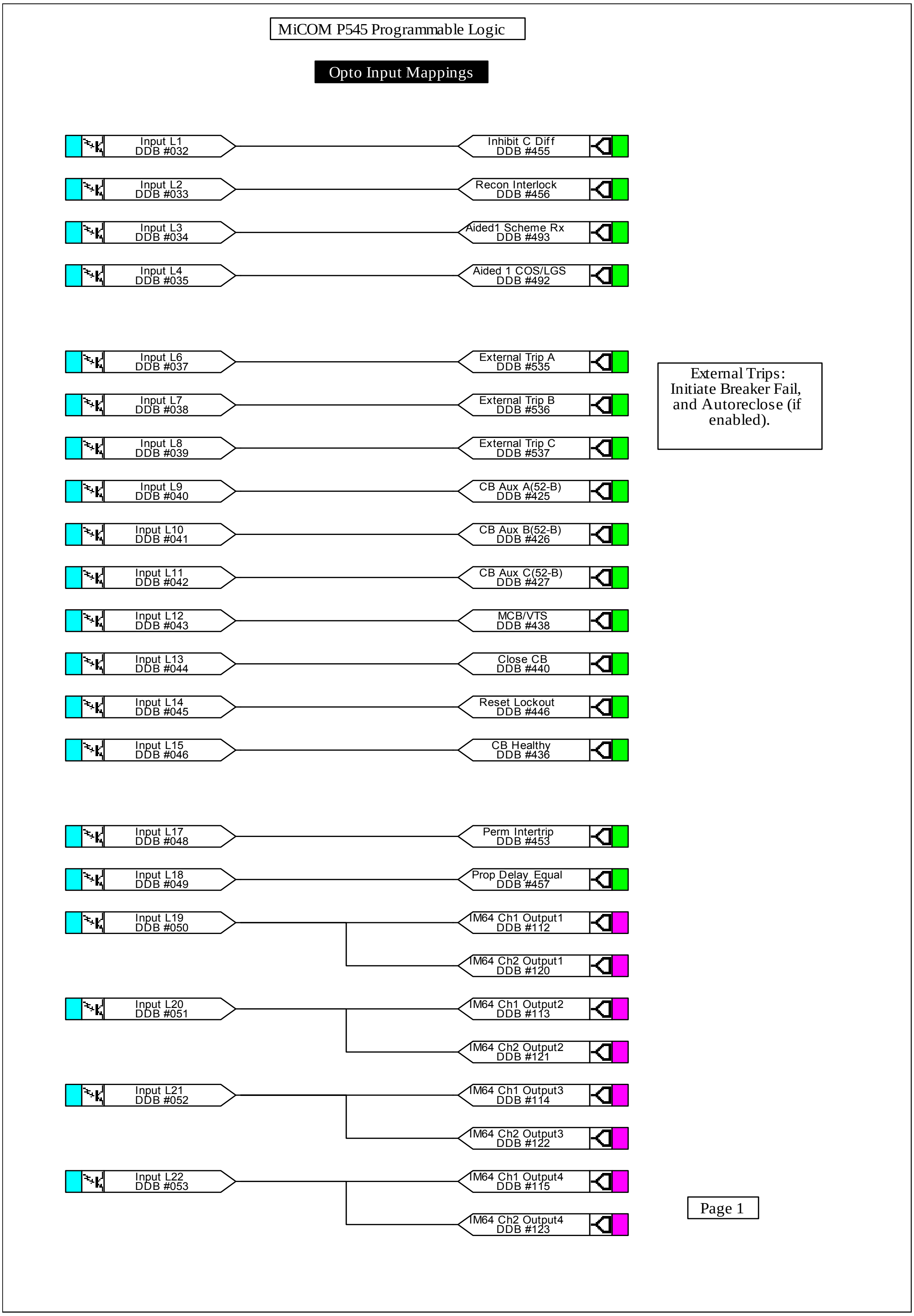


Auto-reclose & Check Sync. Mappings

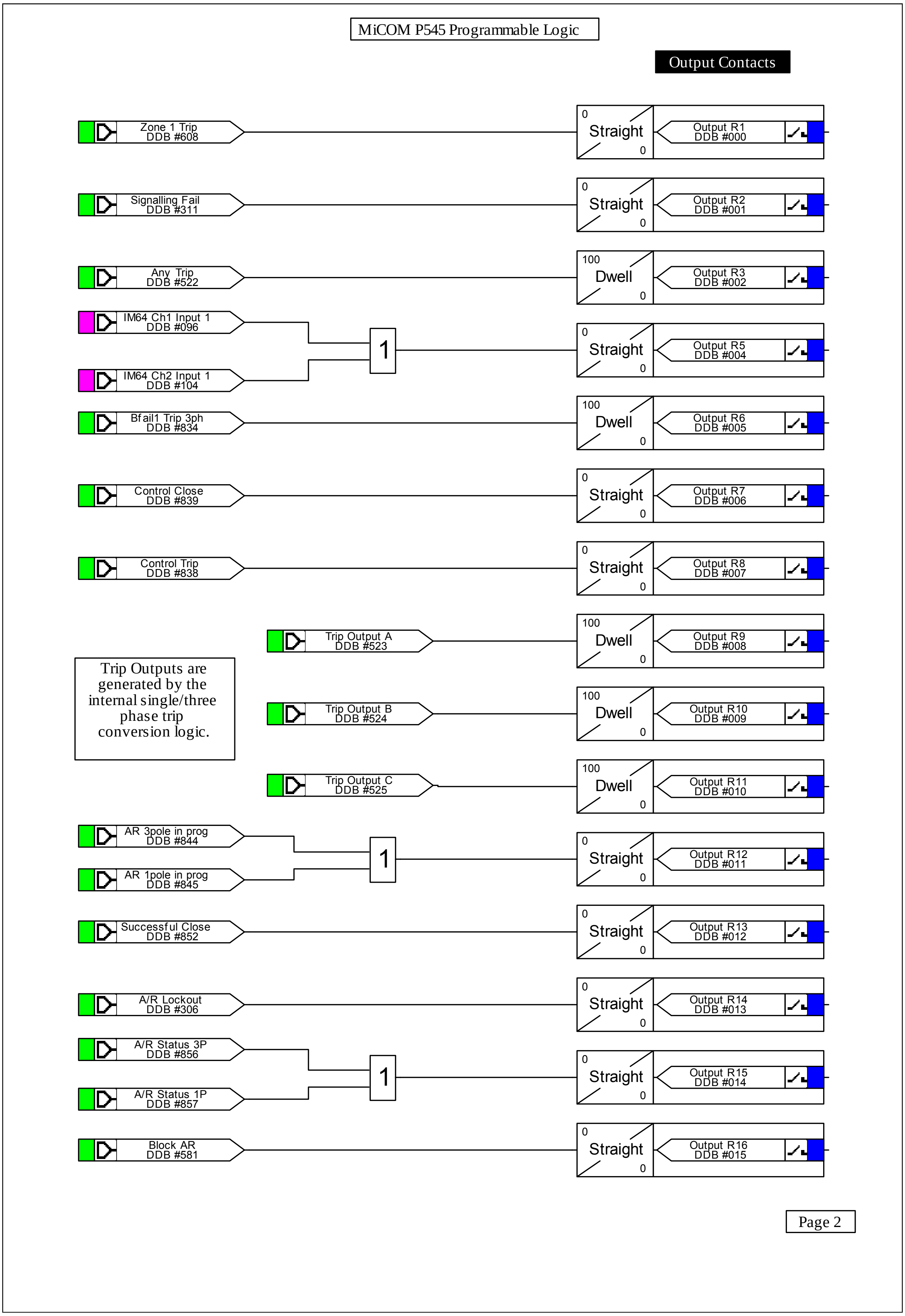


MiCOM P545 WITH DISTANCE OPTION AND STANDARD CONTACTS PROGRAMMABLE SCHEME LOGIC

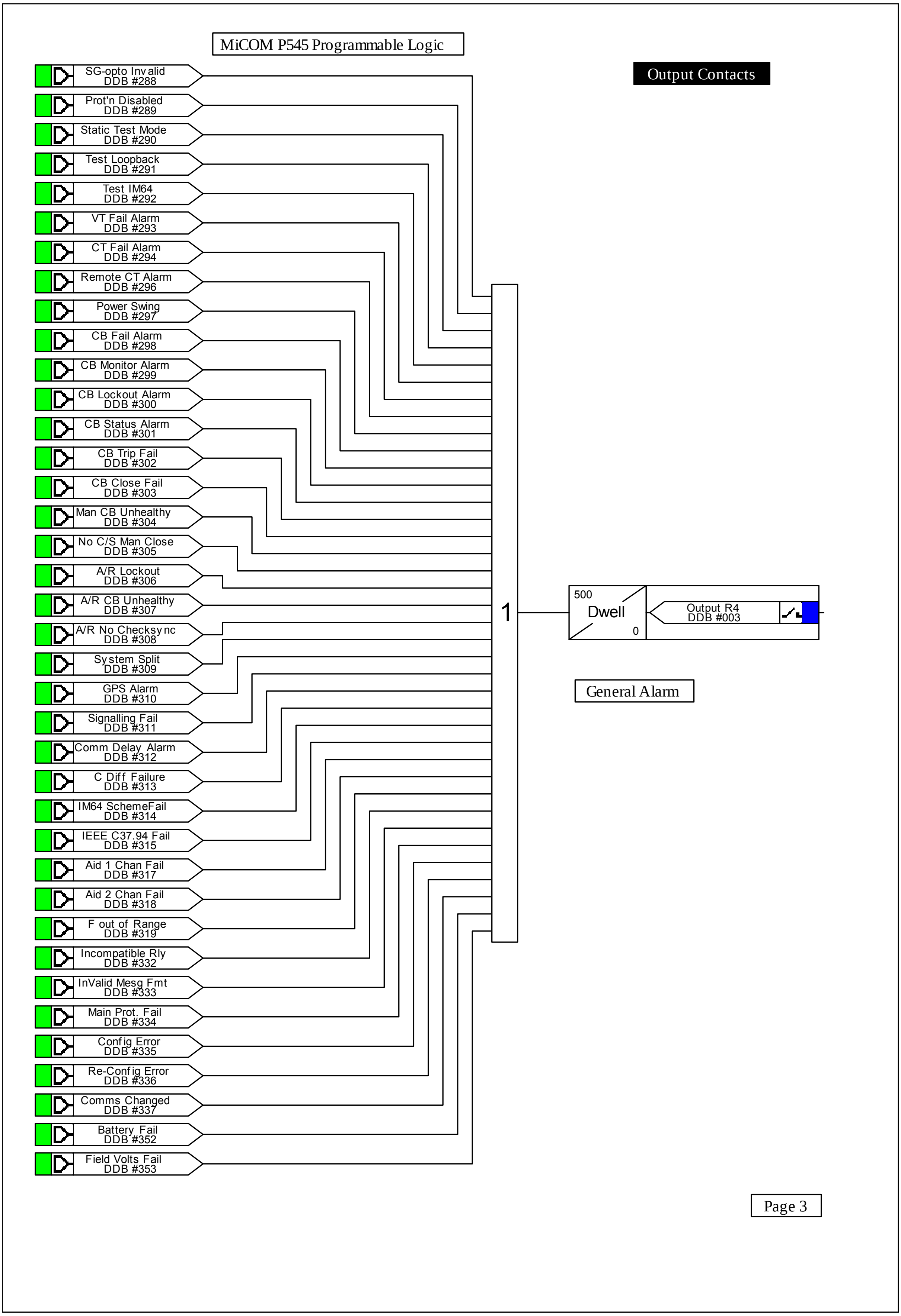
Opto Input Mappings



Output Relay Mappings

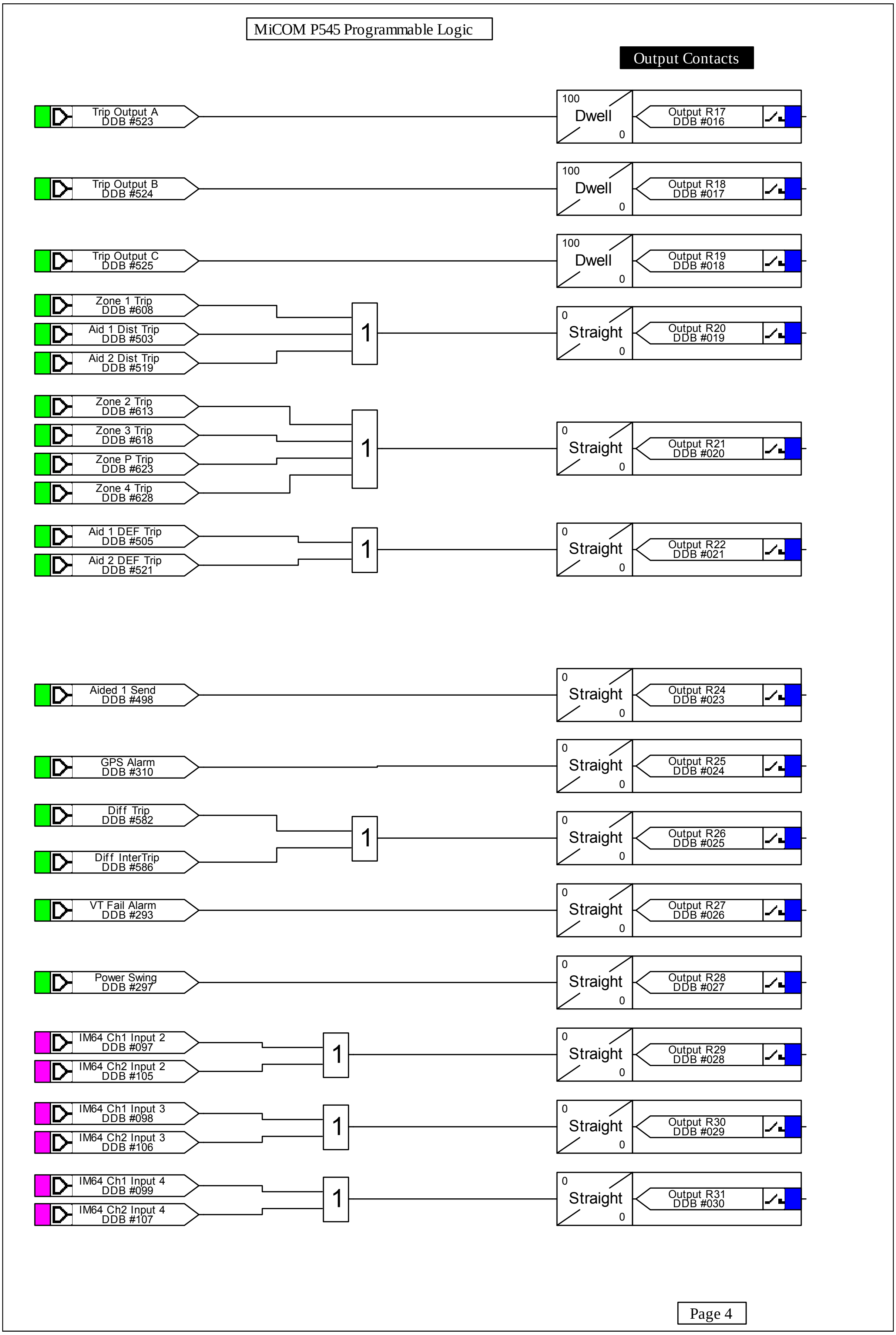


Output Relay Mappings

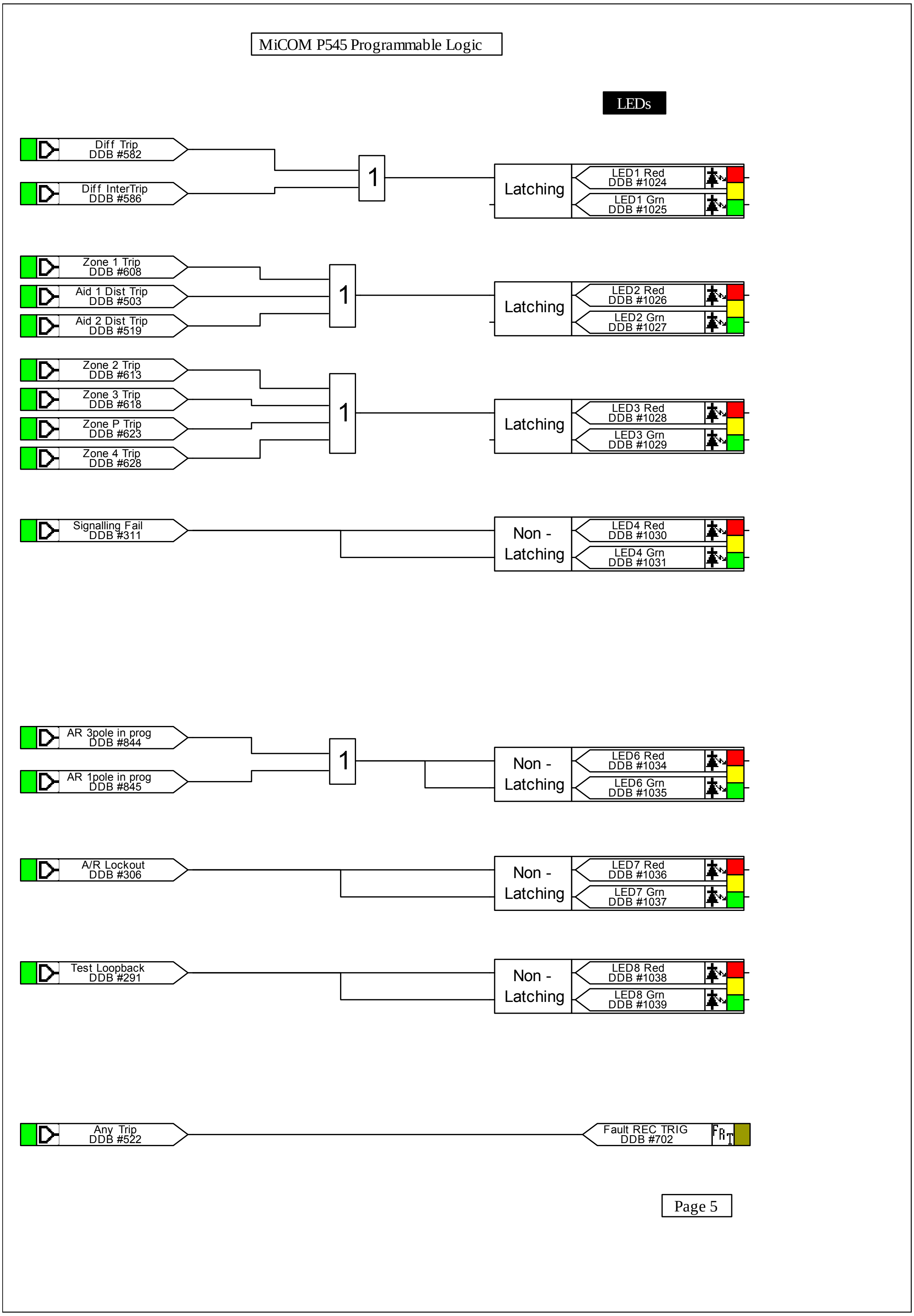


PL

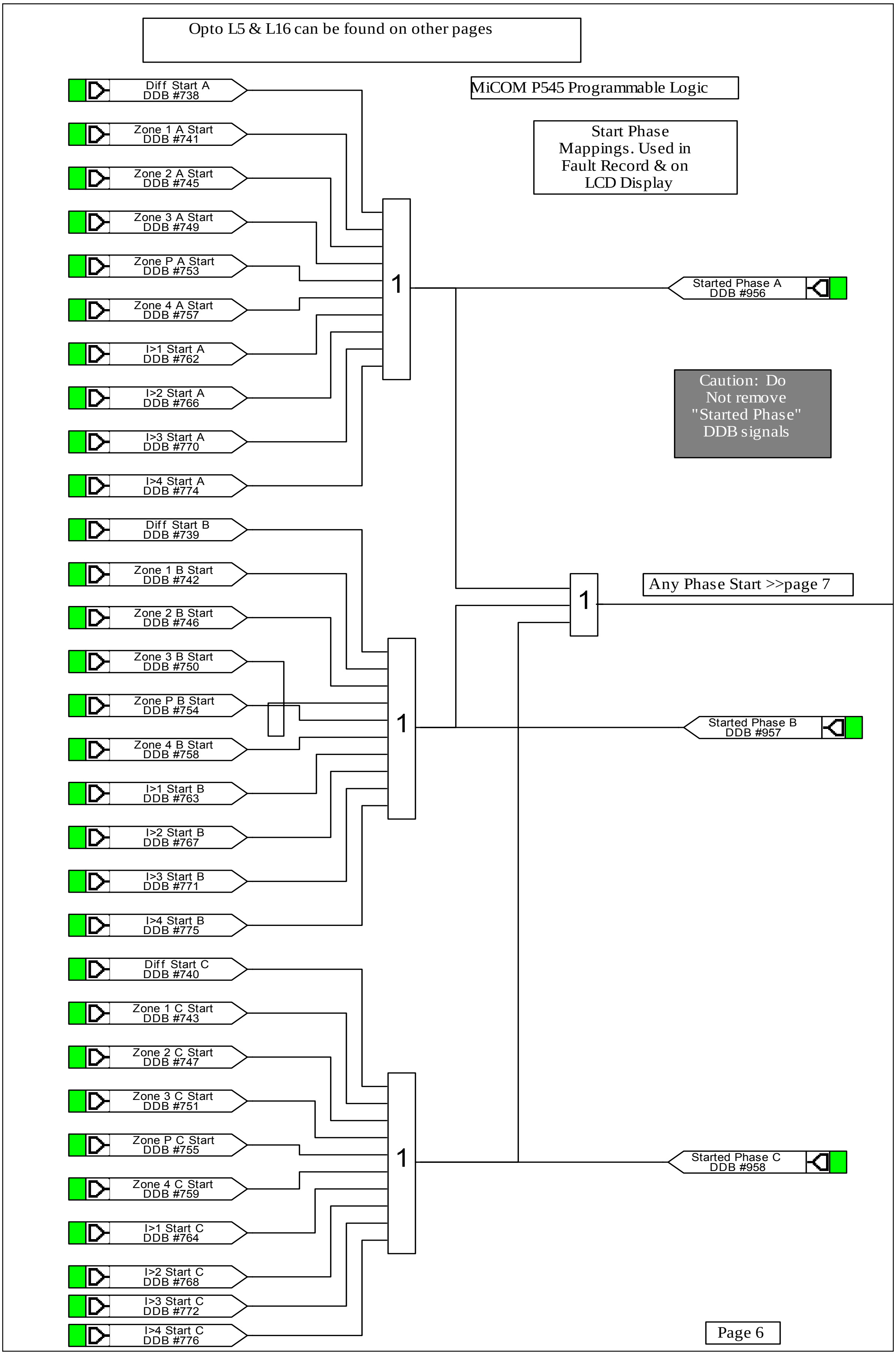
Output Relay Mappings



LED Mappings



Start Mappings



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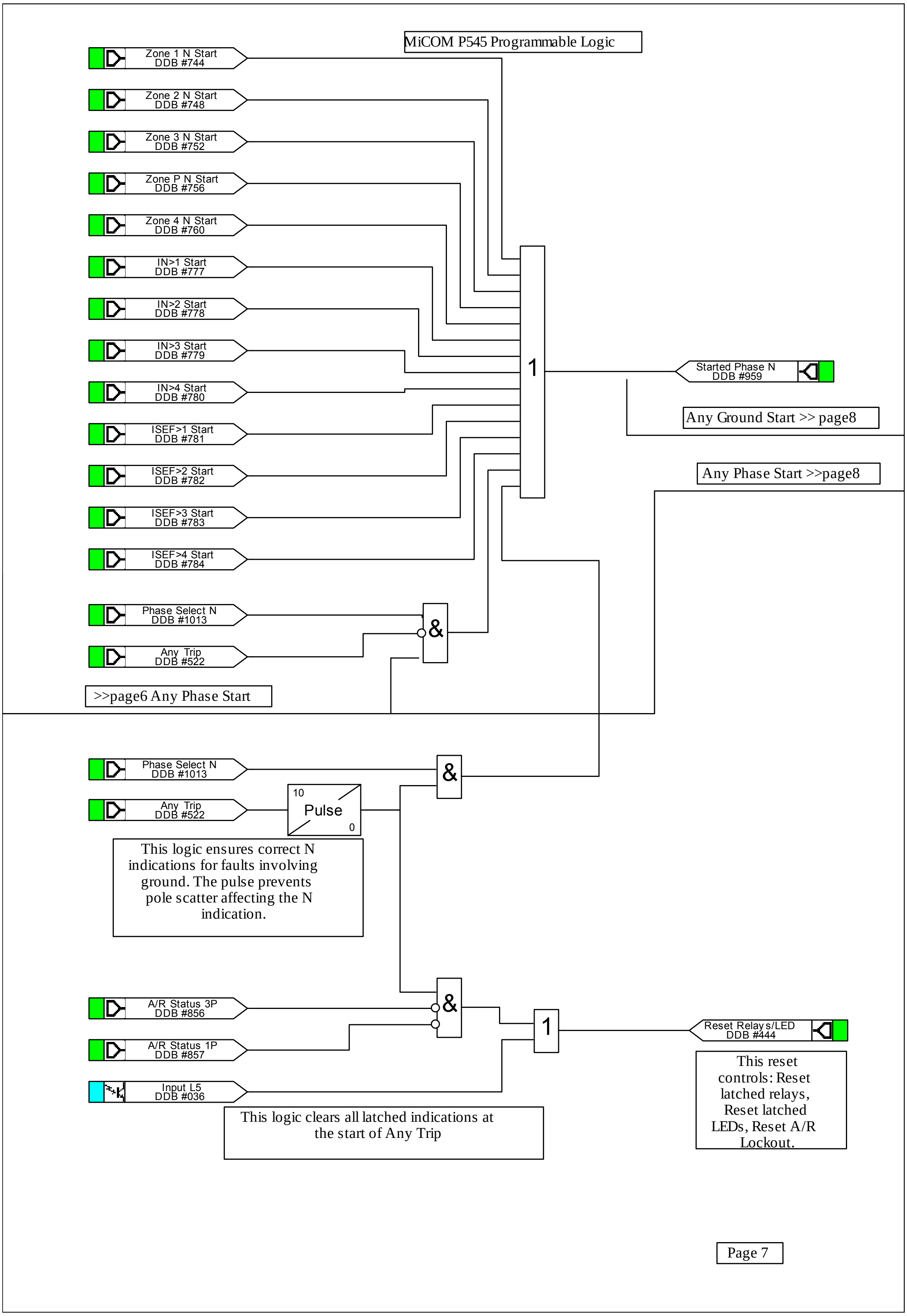
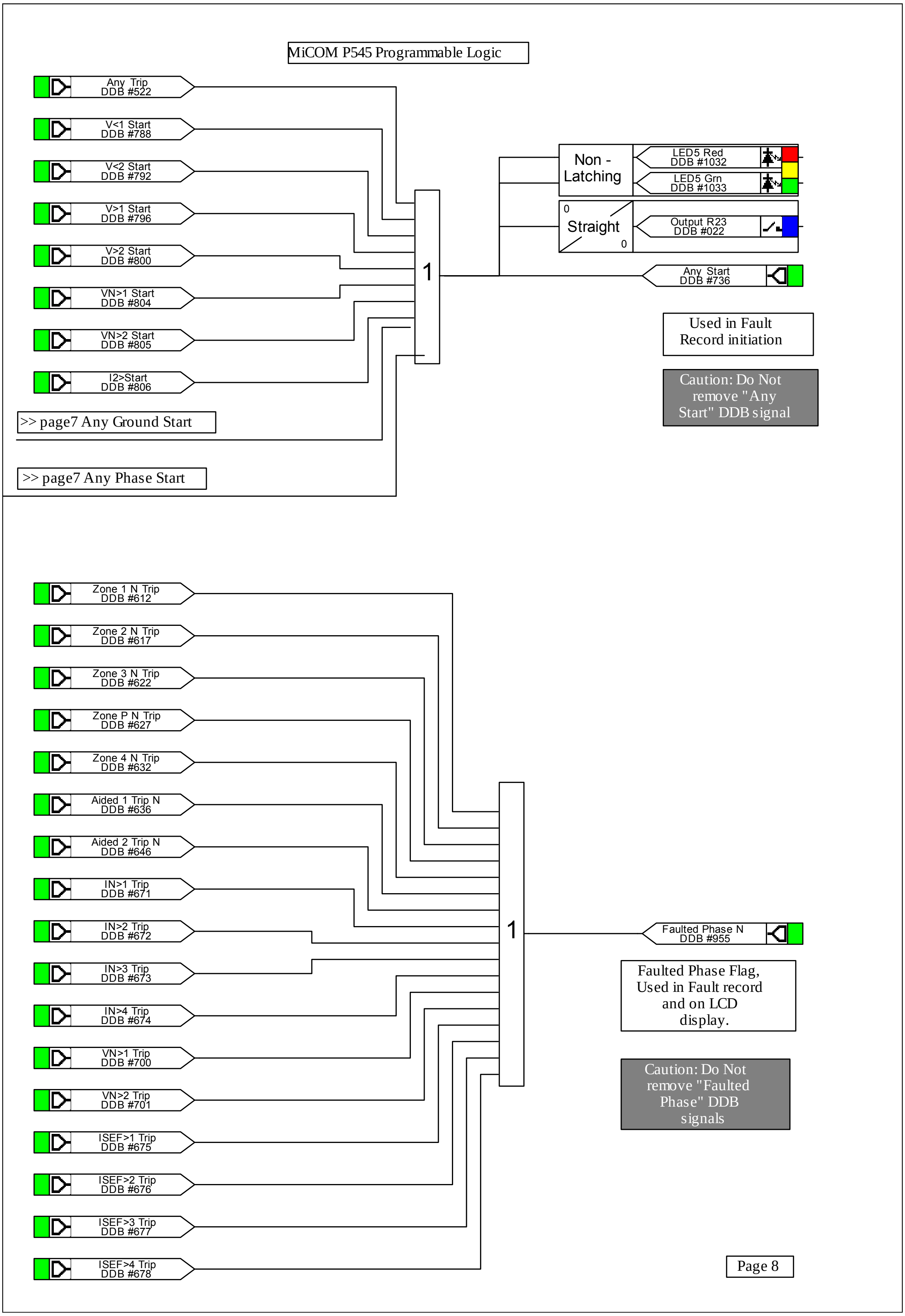
Start Mappings



PL

Faulted Phase Mappings



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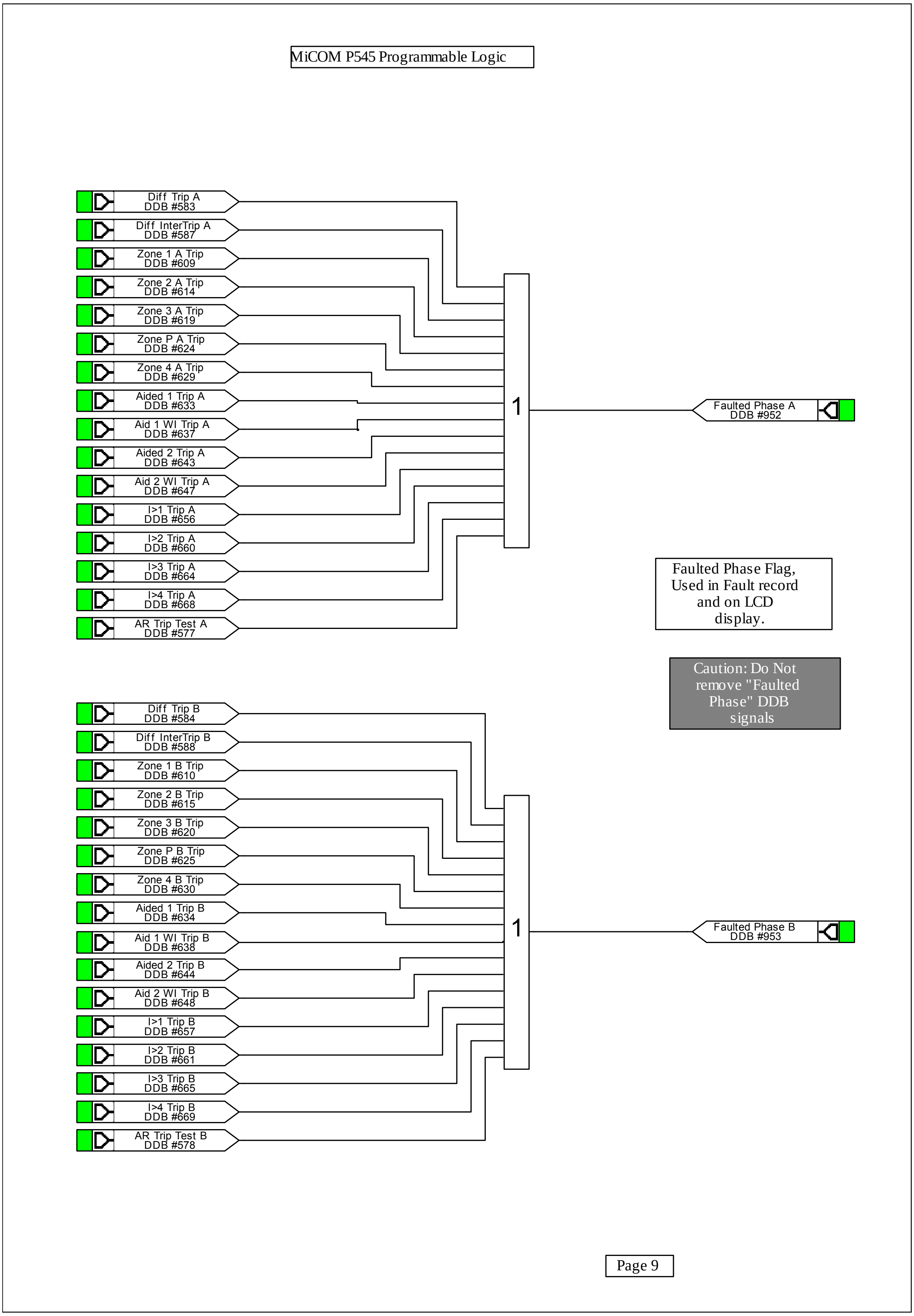
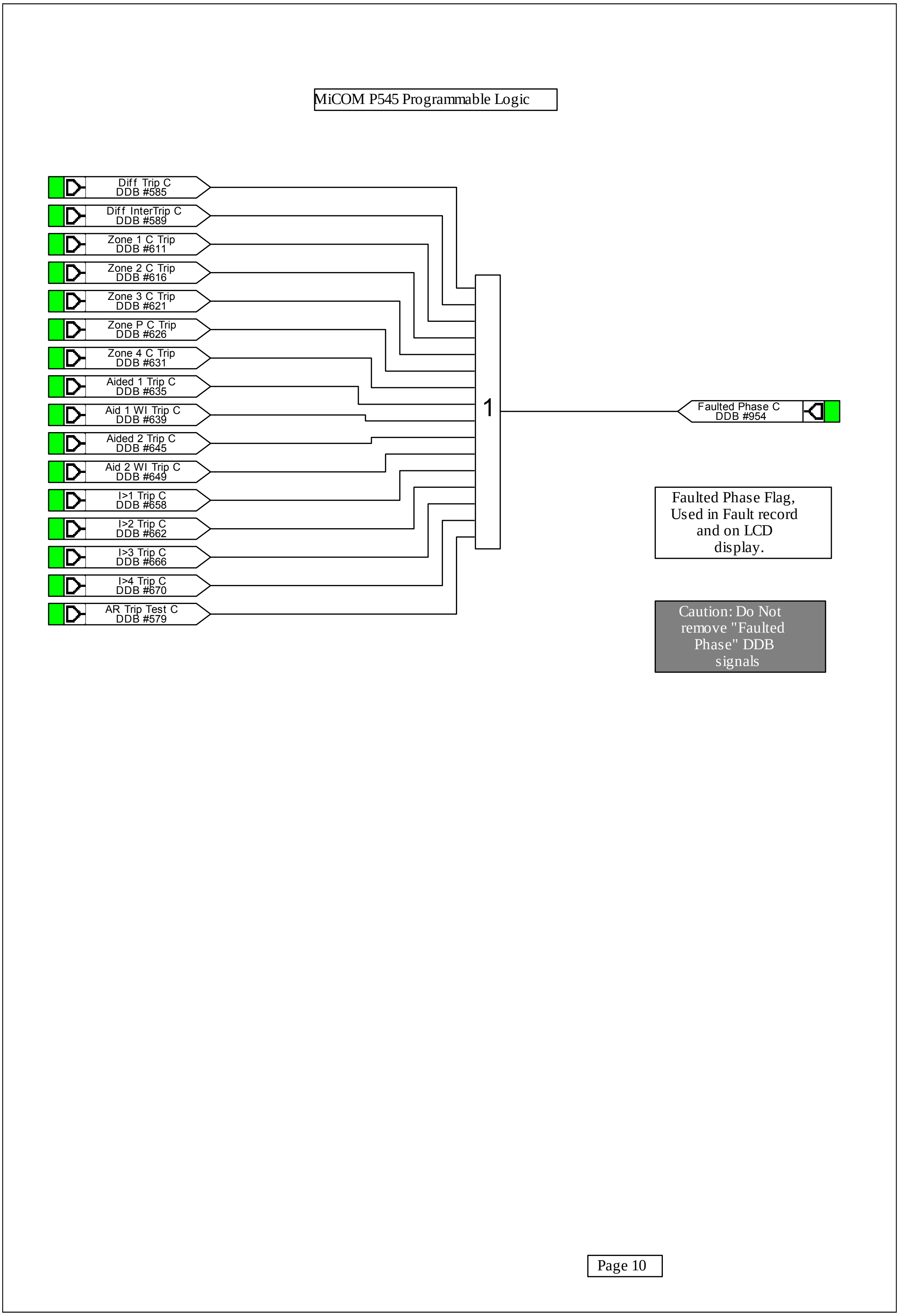
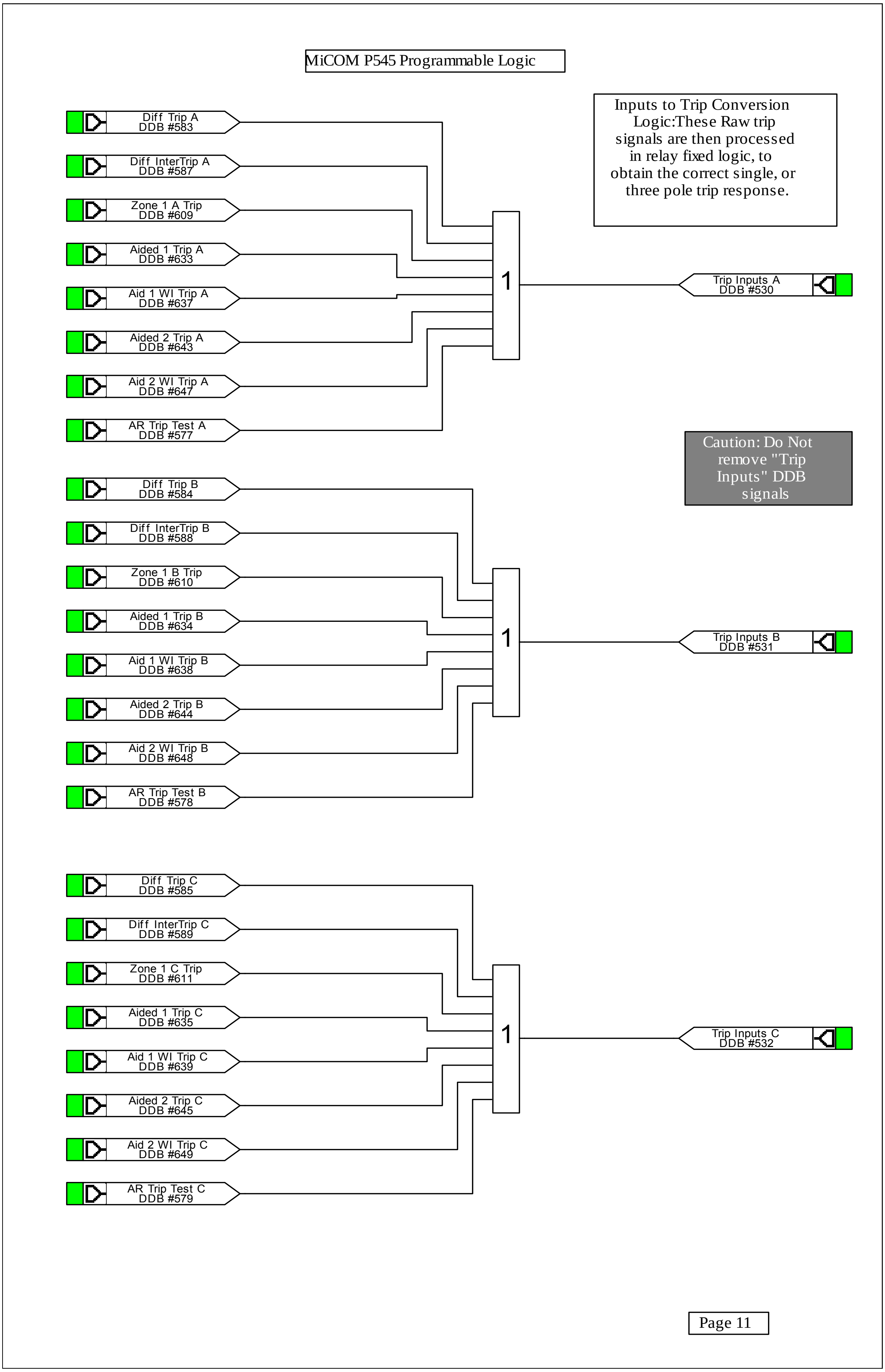
Faulted Phase Mappings



Faulted Phase Mappings



Trip Inputs Mappings



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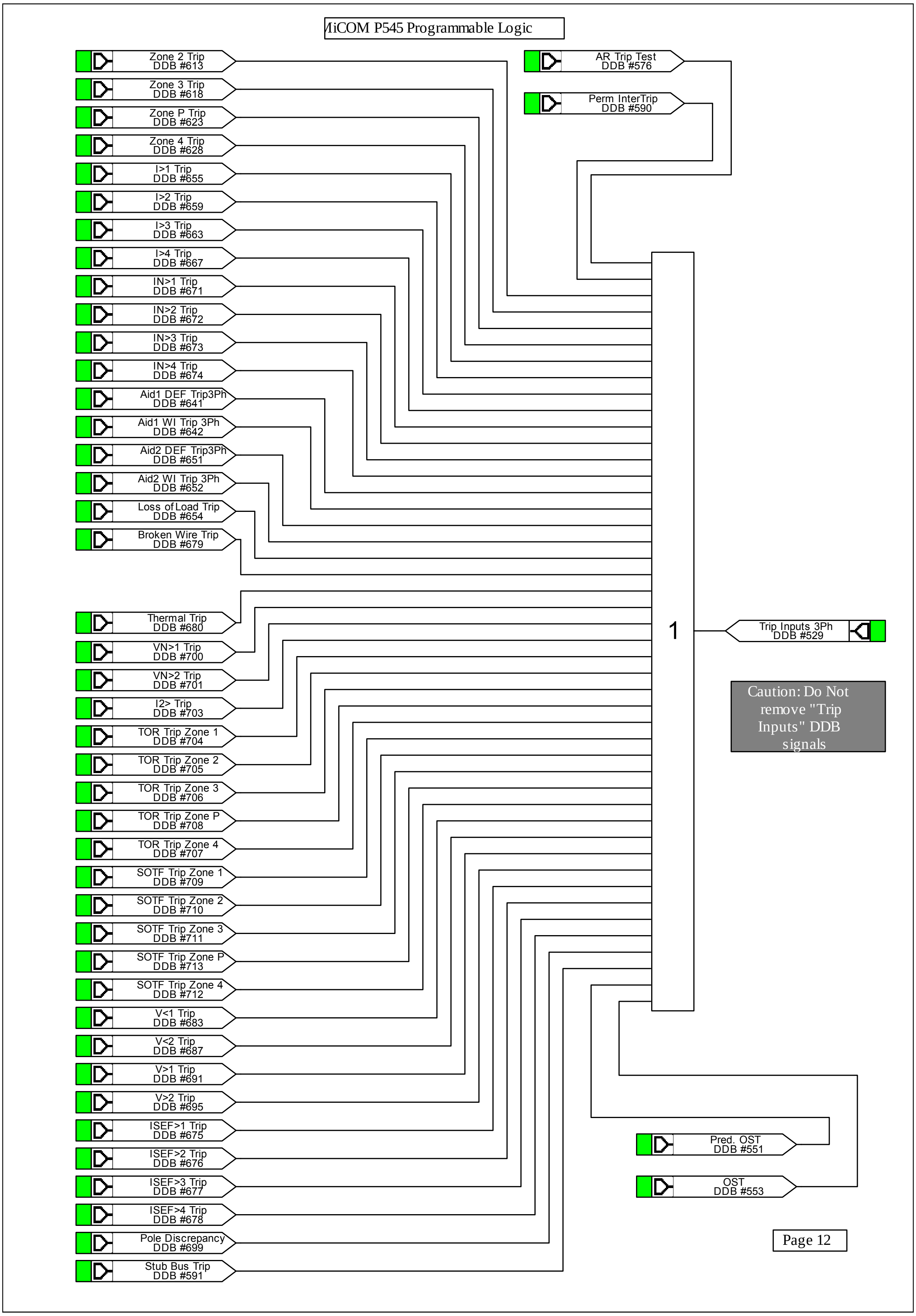
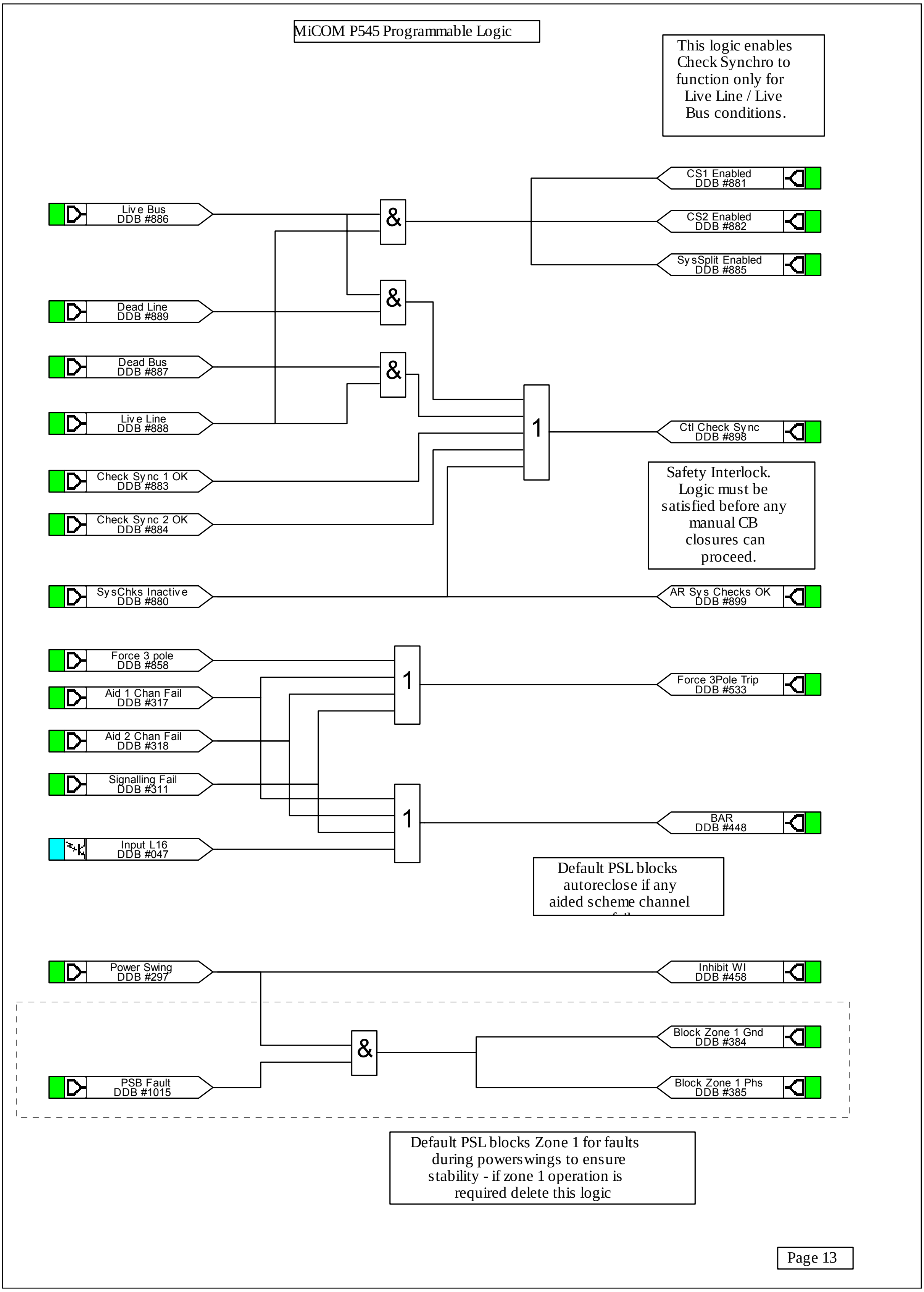
Trip Inputs Mappings

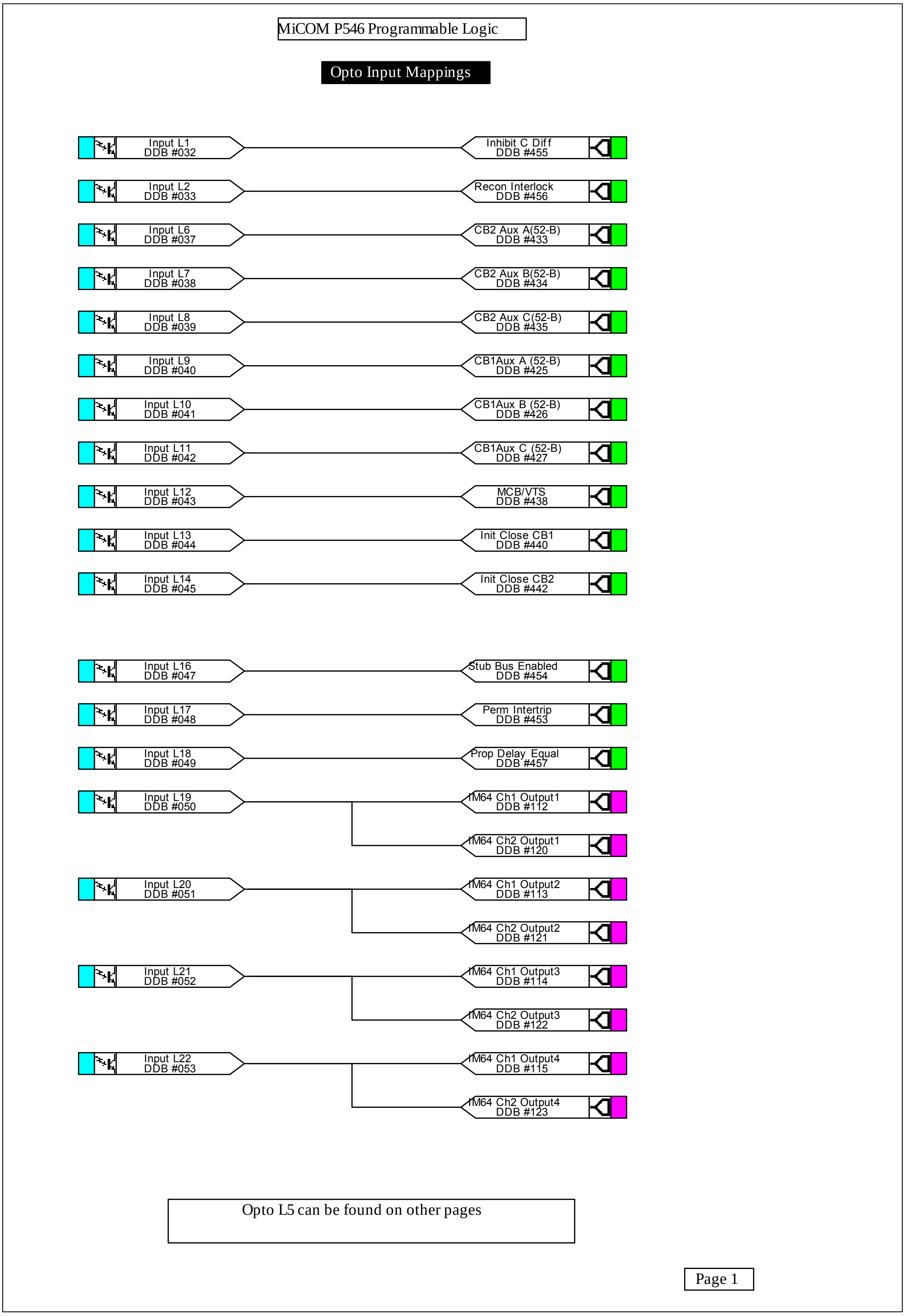


Auto-Reclose & Check Sync. Mappings

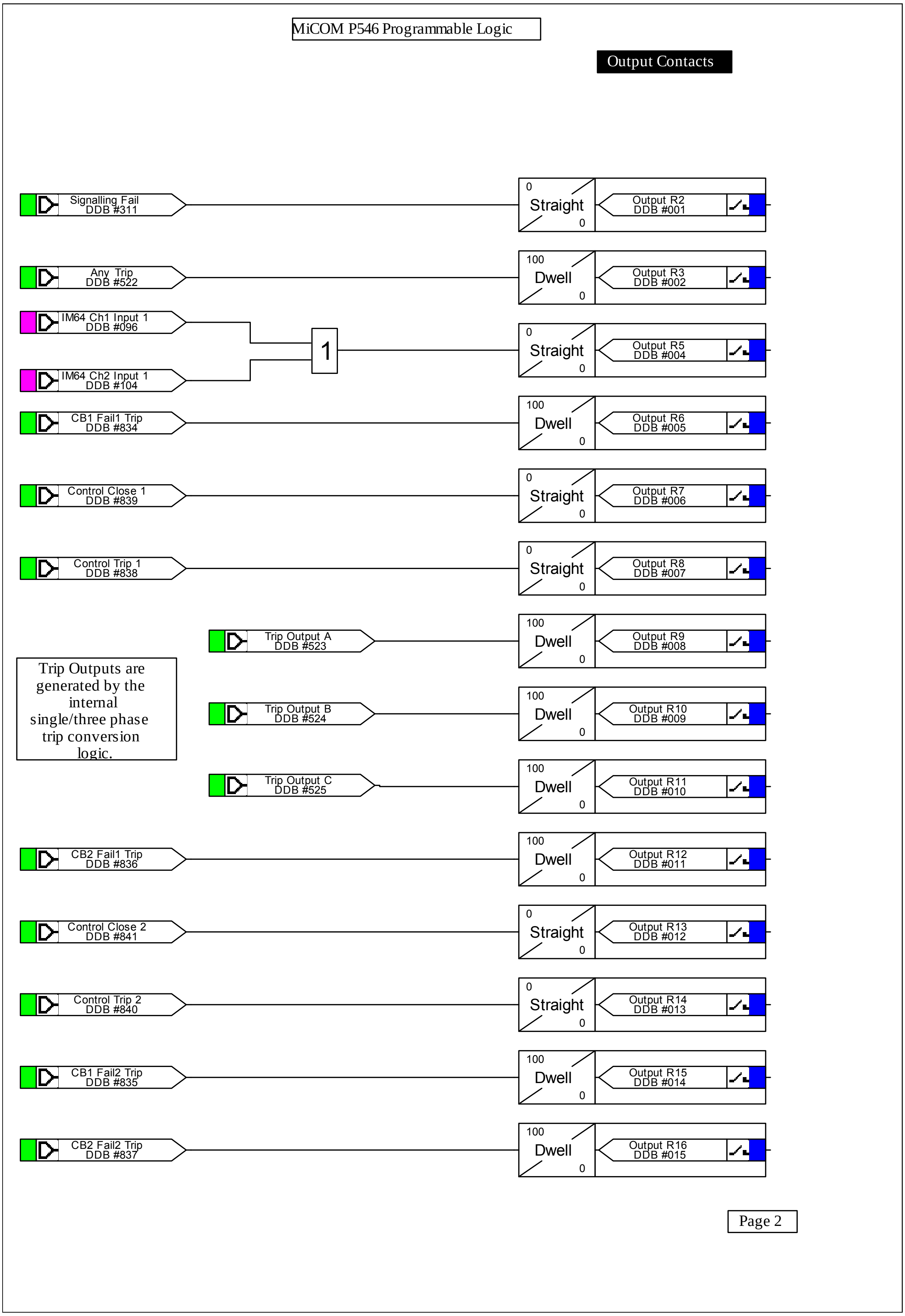


MiCOM P546 WITH NO DISTANCE OPTION AND STANDARD CONTACTS PROGRAMMABLE SCHEME LOGIC

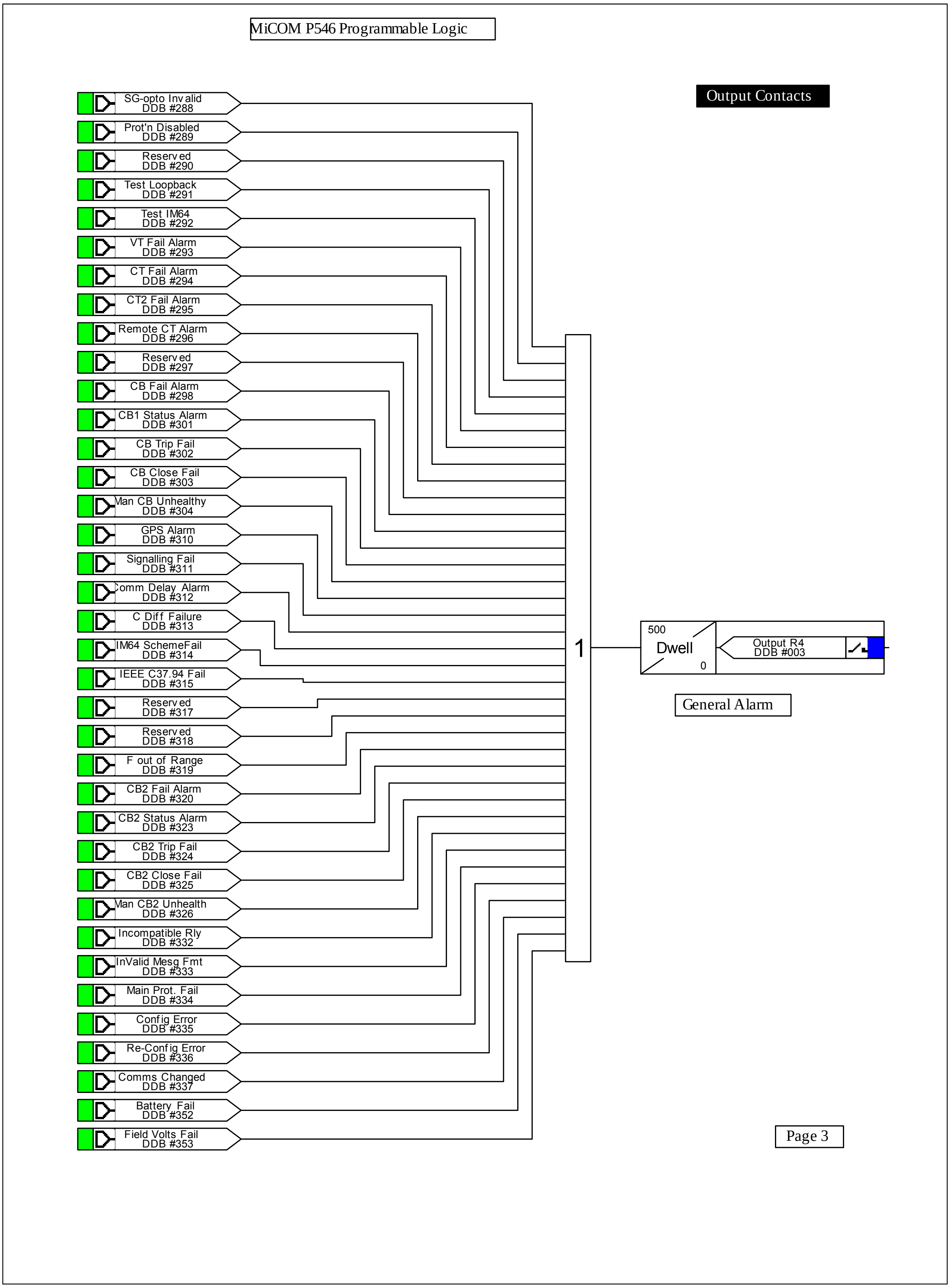
Opto Input Mappings



Output Relay Mappings



Output Relay Mappings



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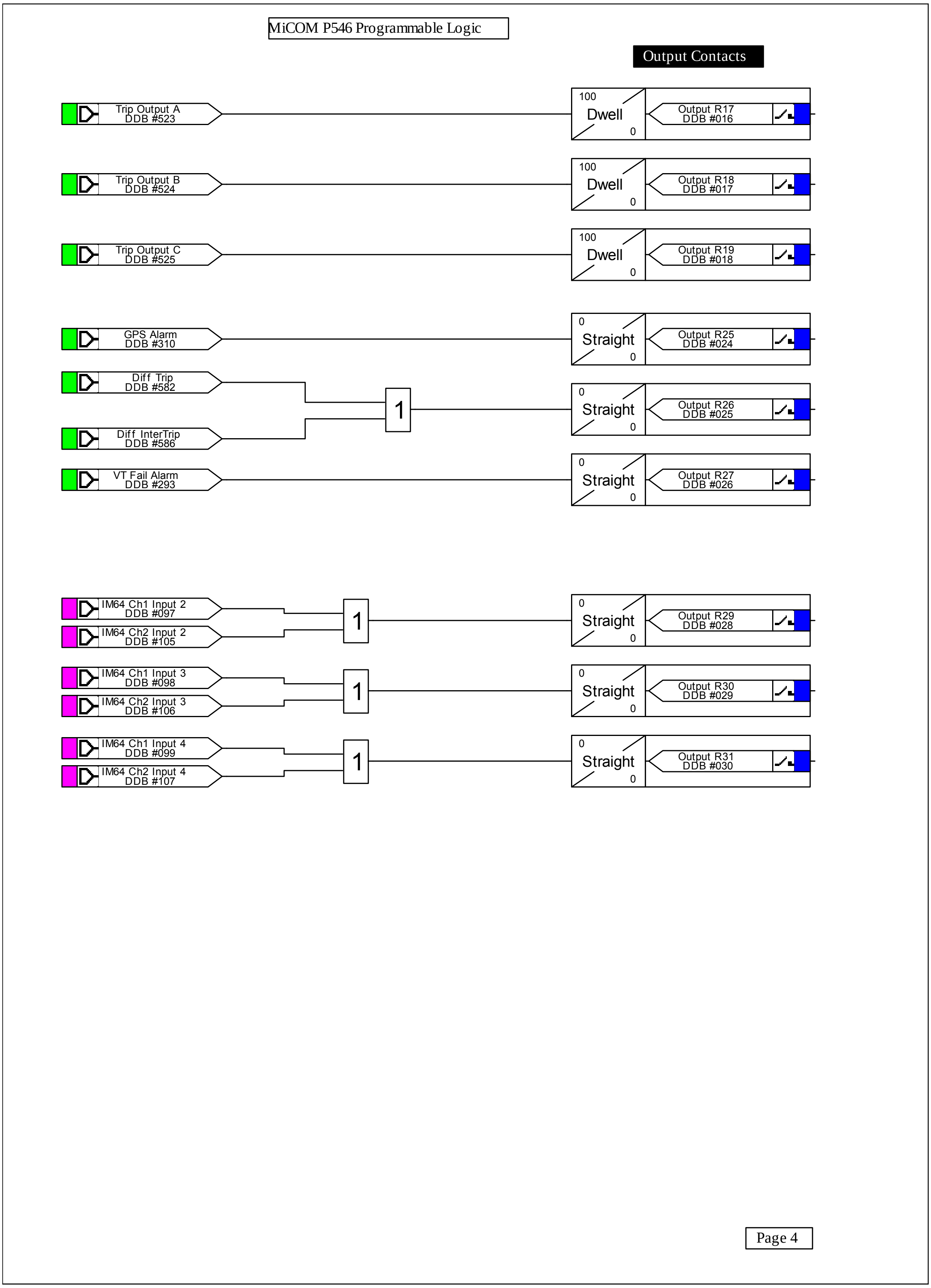
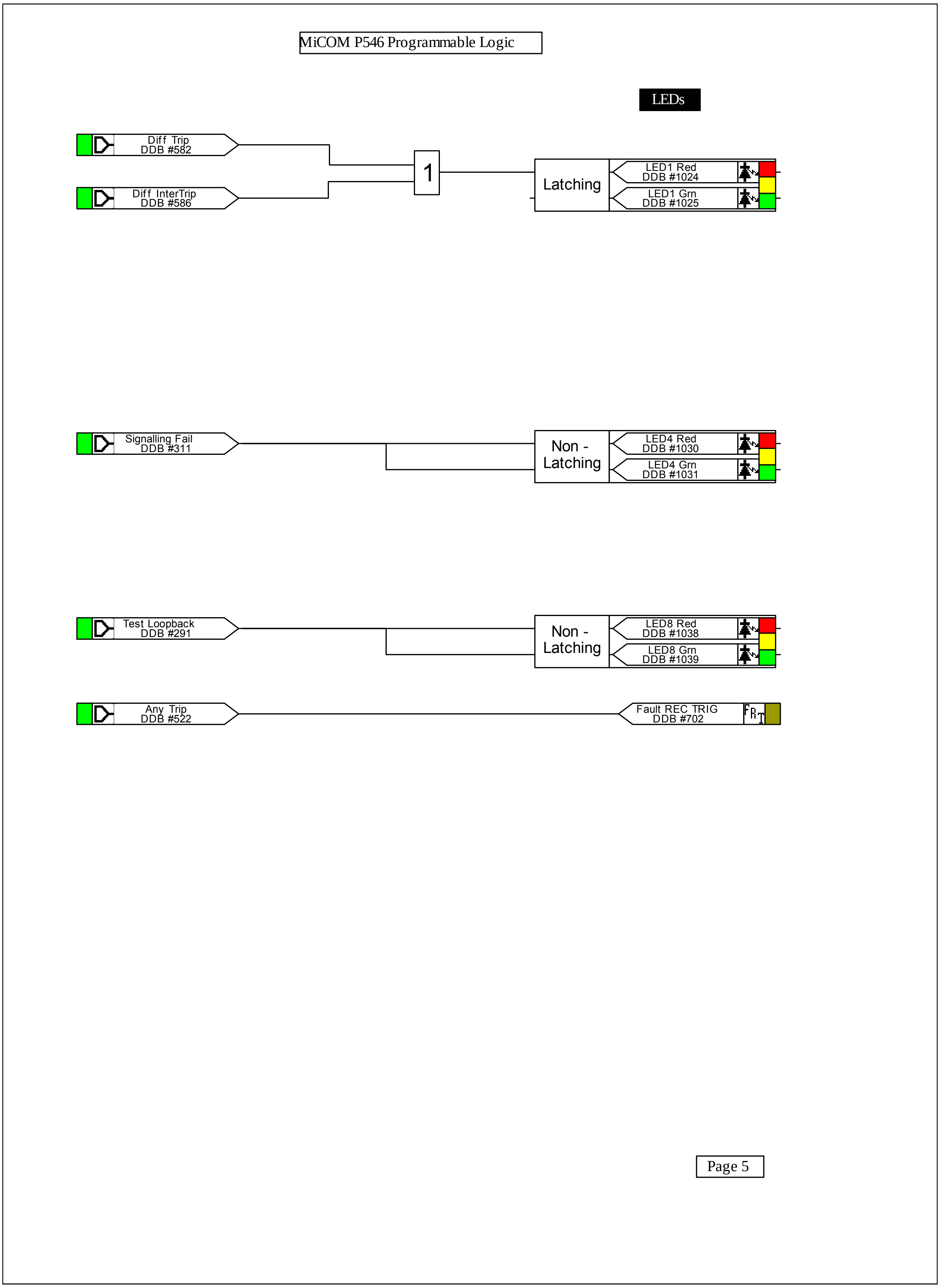
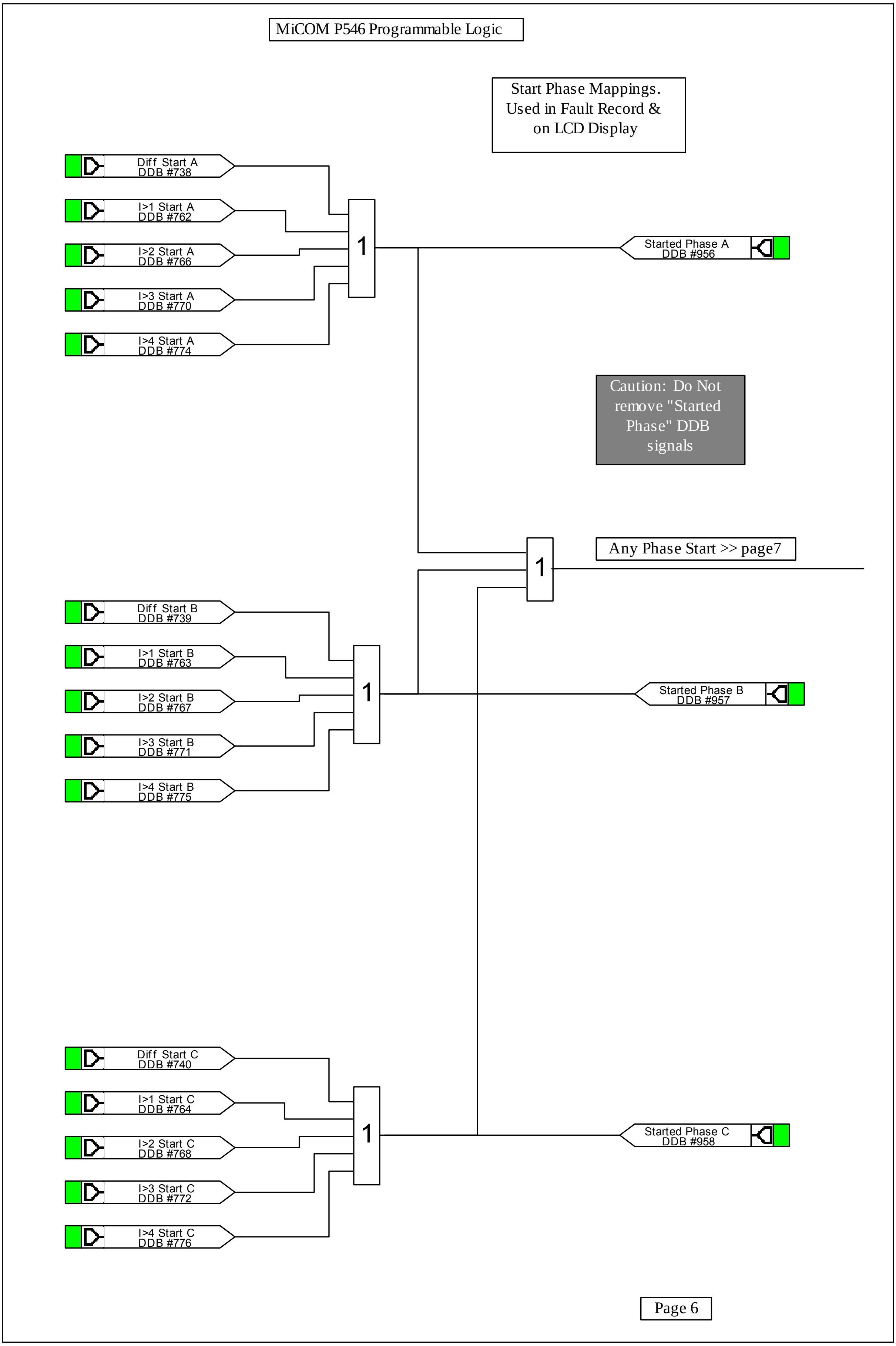
Output Relay Mappings



LED Mappings



Start Mappings



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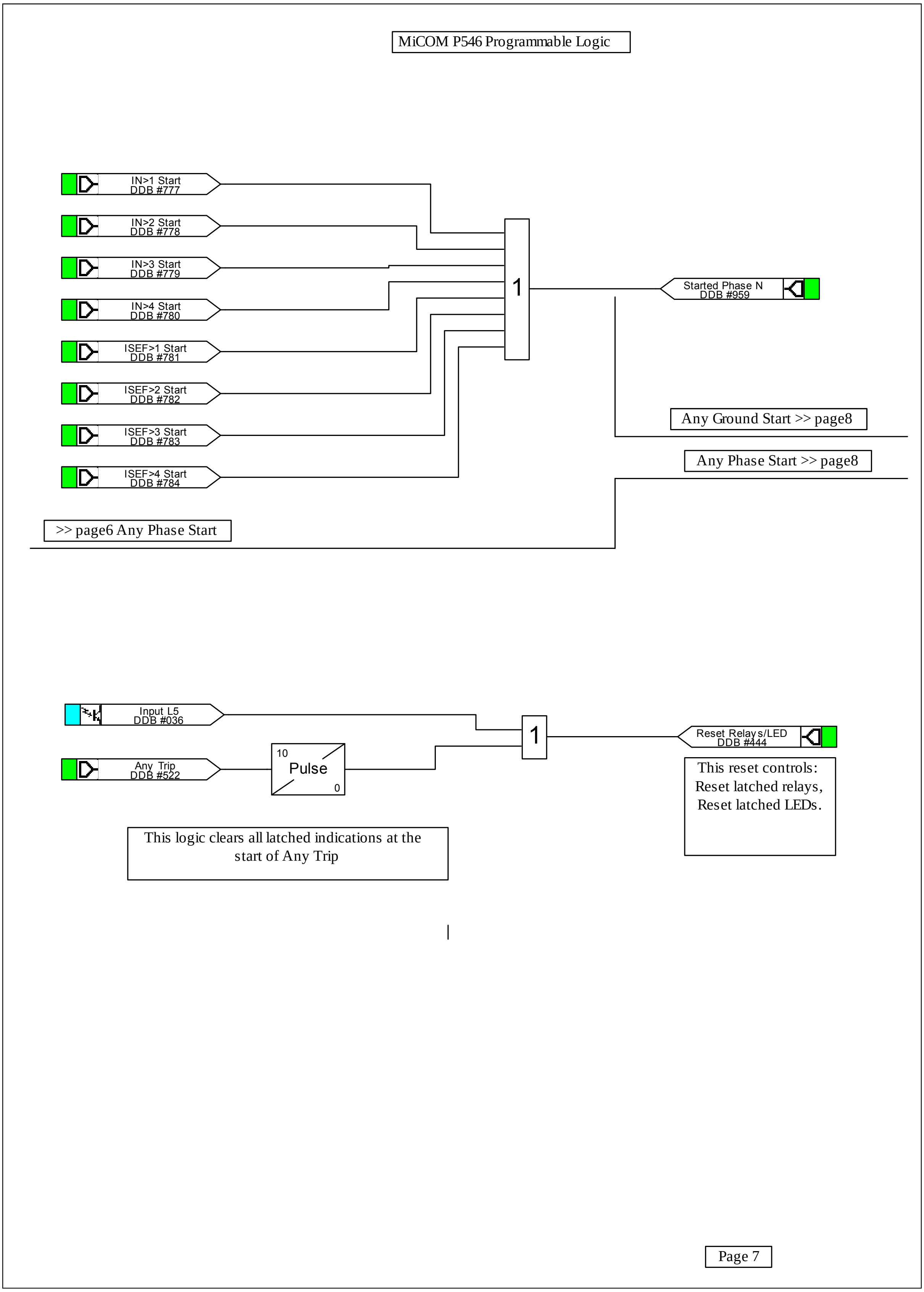
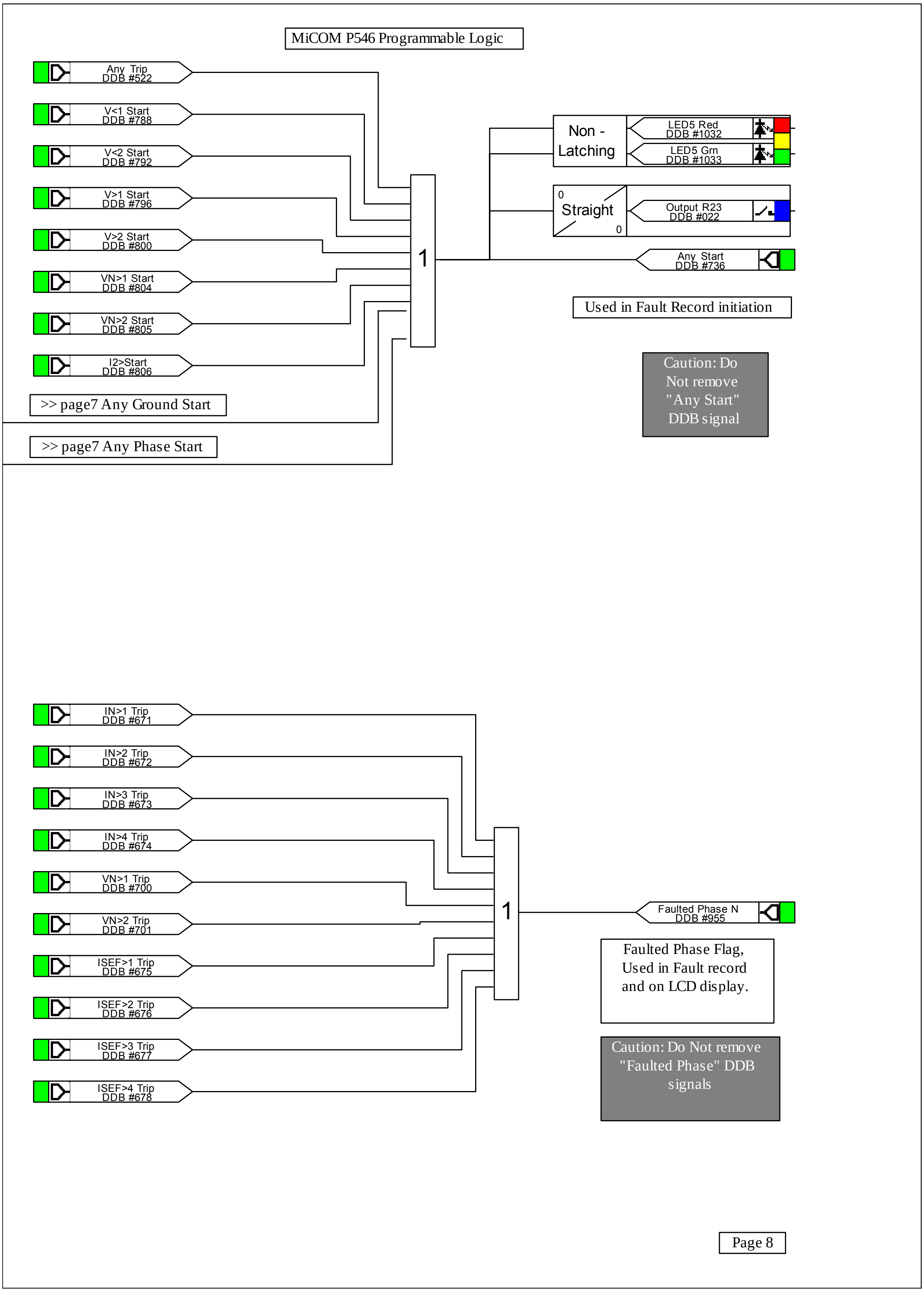
Start Mappings



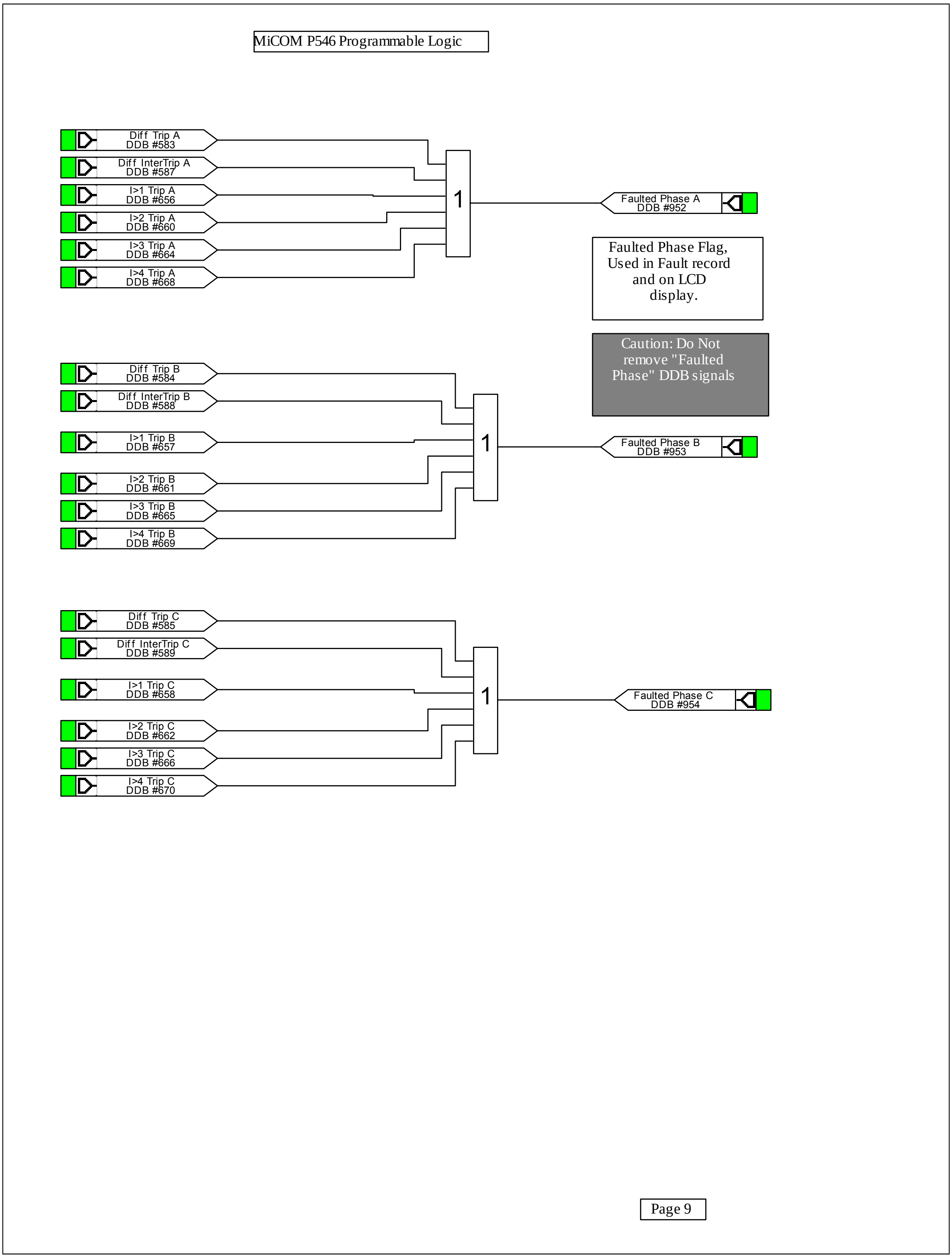
PL

Faulted Phase Mappings



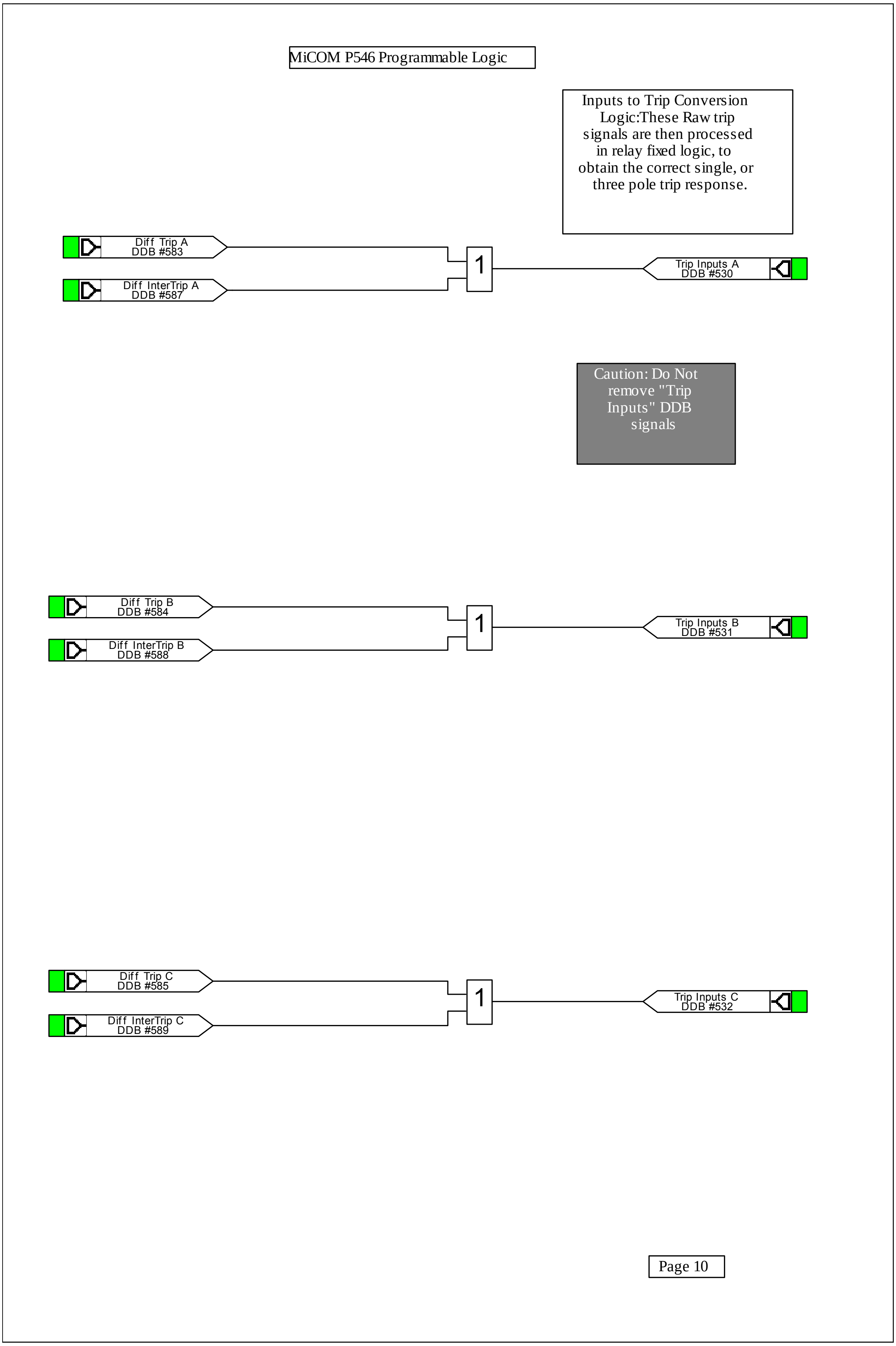
PL

Faulted Phase Mappings

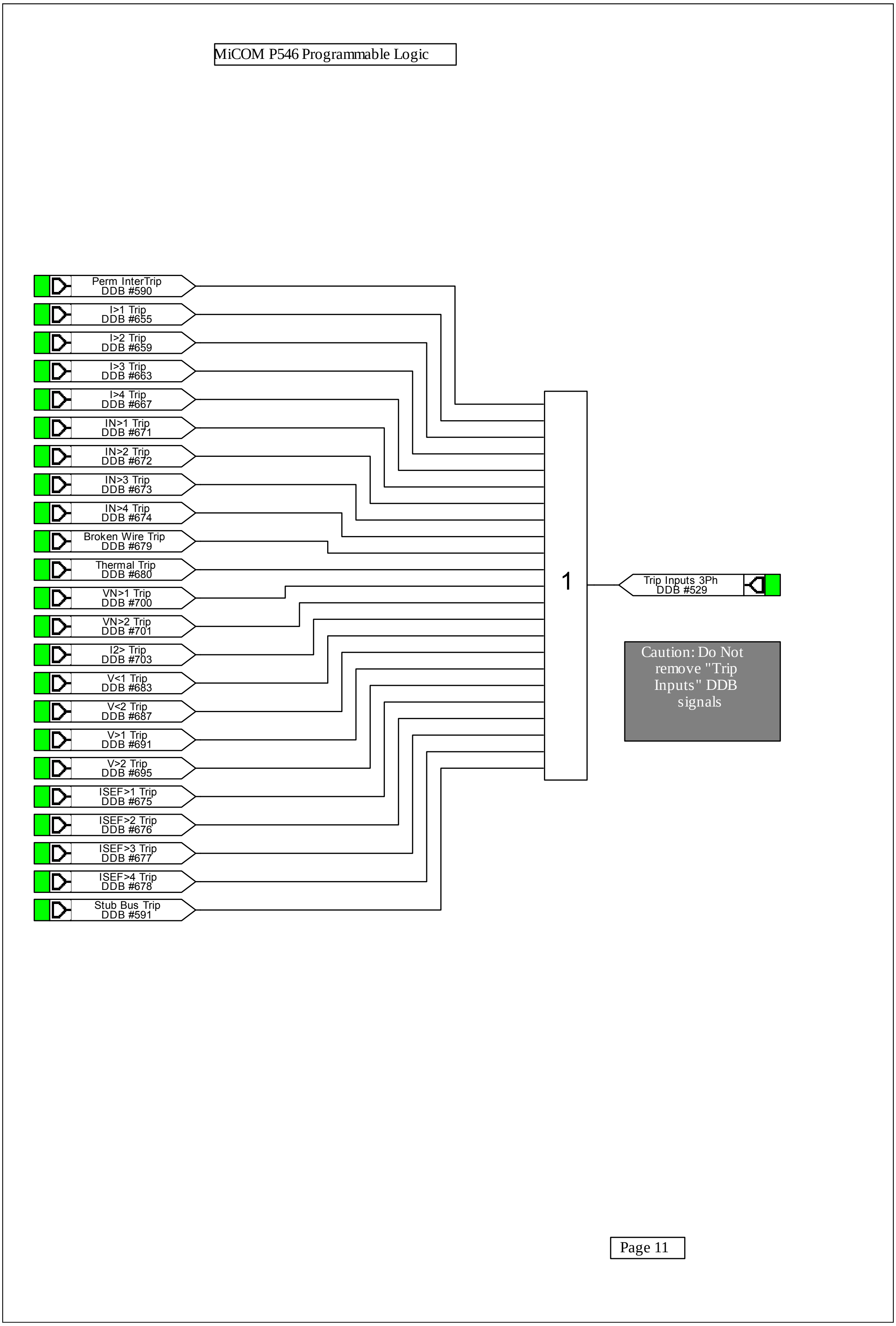


PL

Trip Inputs Mappings



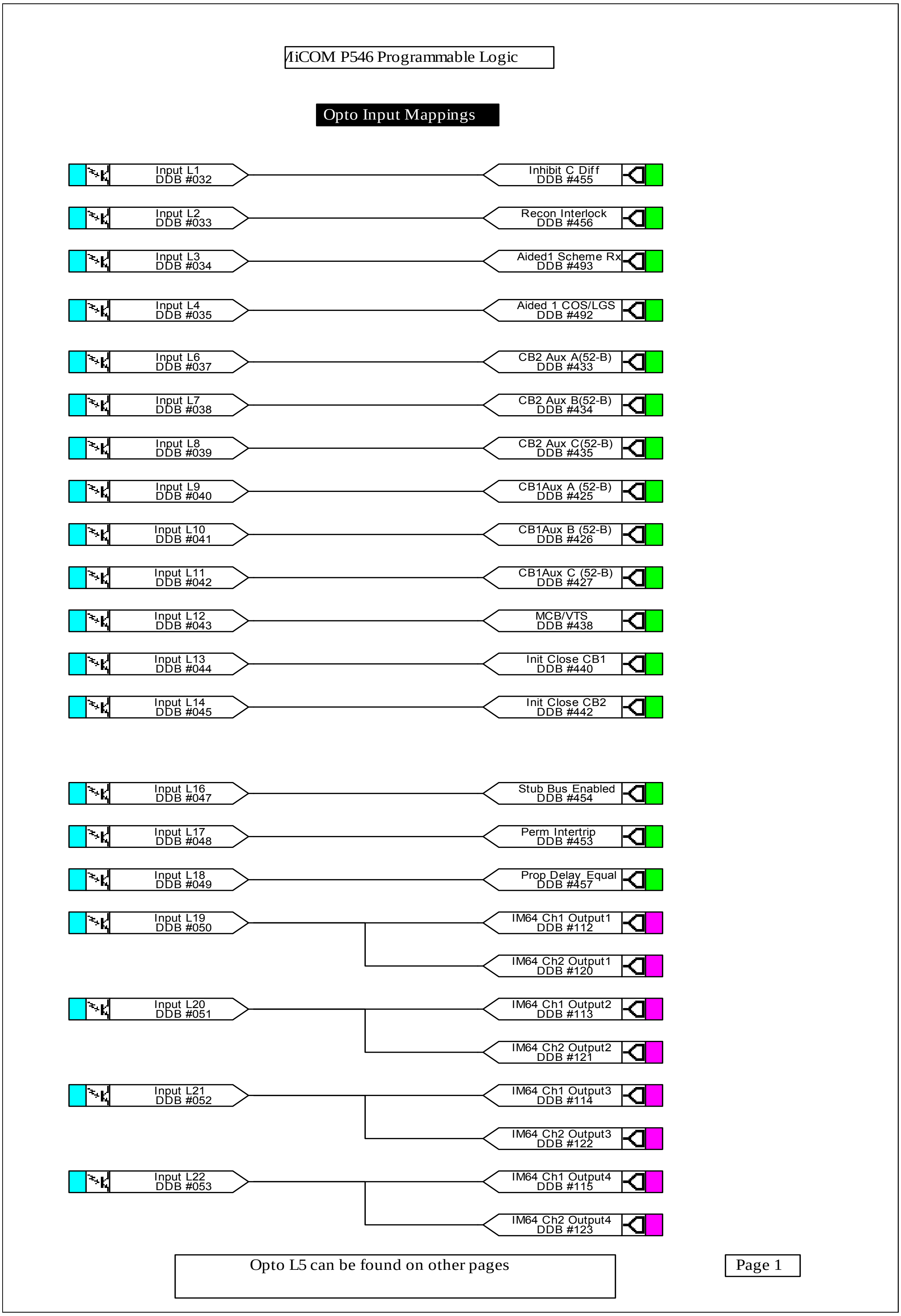
Trip Inputs Mappings



PL

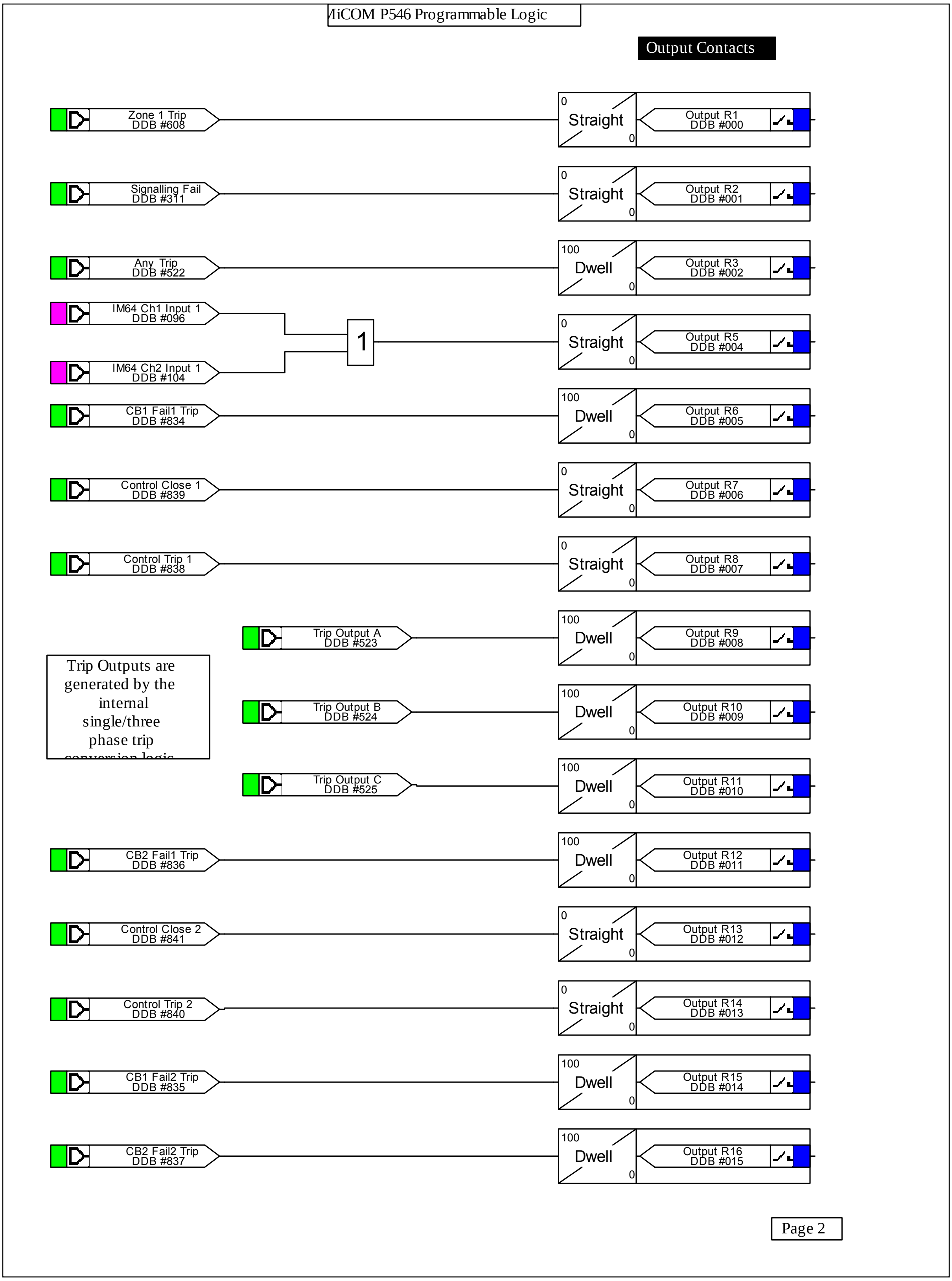
MiCOM P546 WITH DISTANCE OPTION AND STANDARD CONTACTS PROGRAMMABLE SCHEME LOGIC

Opto Input Mappings



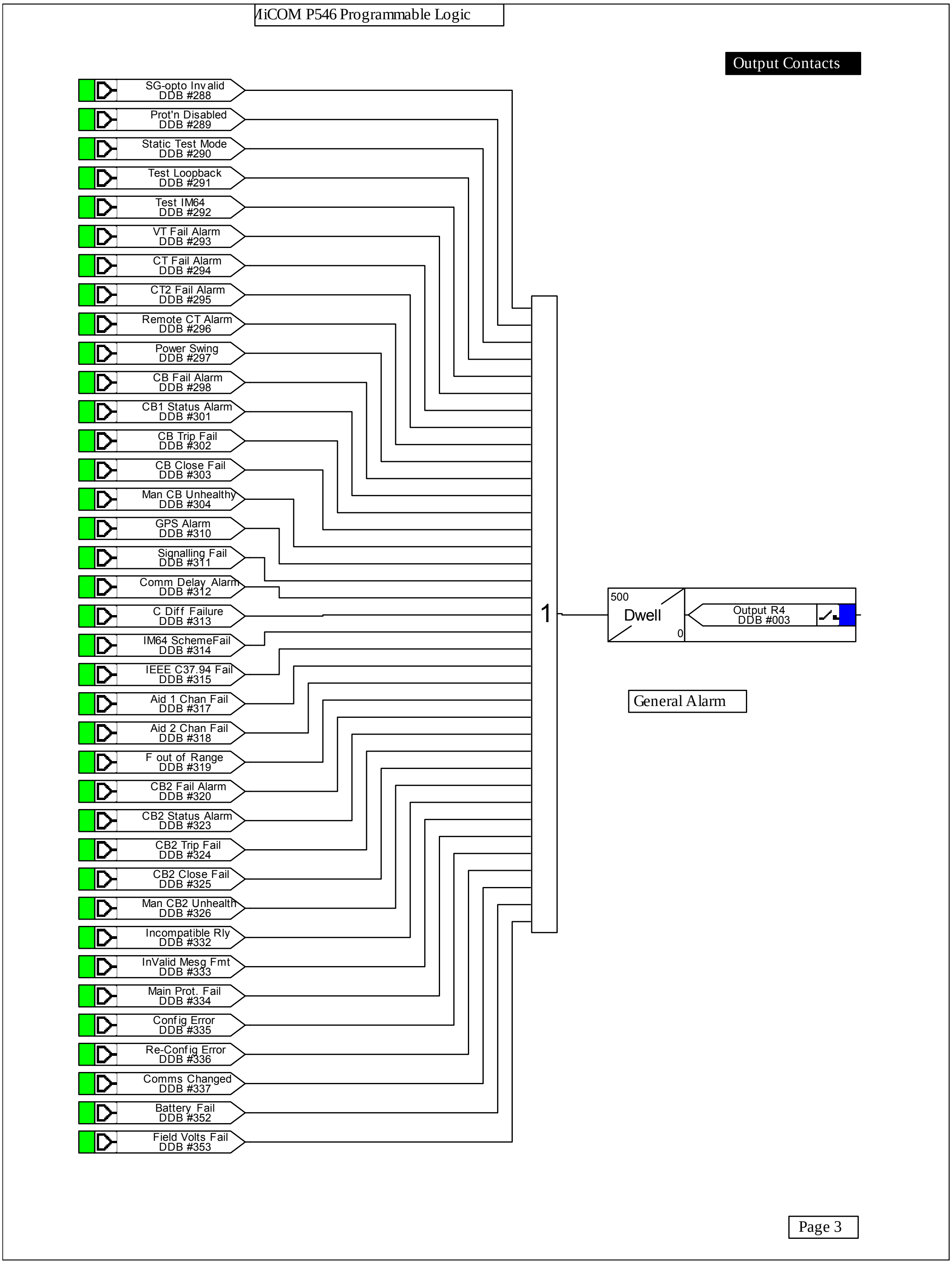
PL

Relay Outputs Mappings



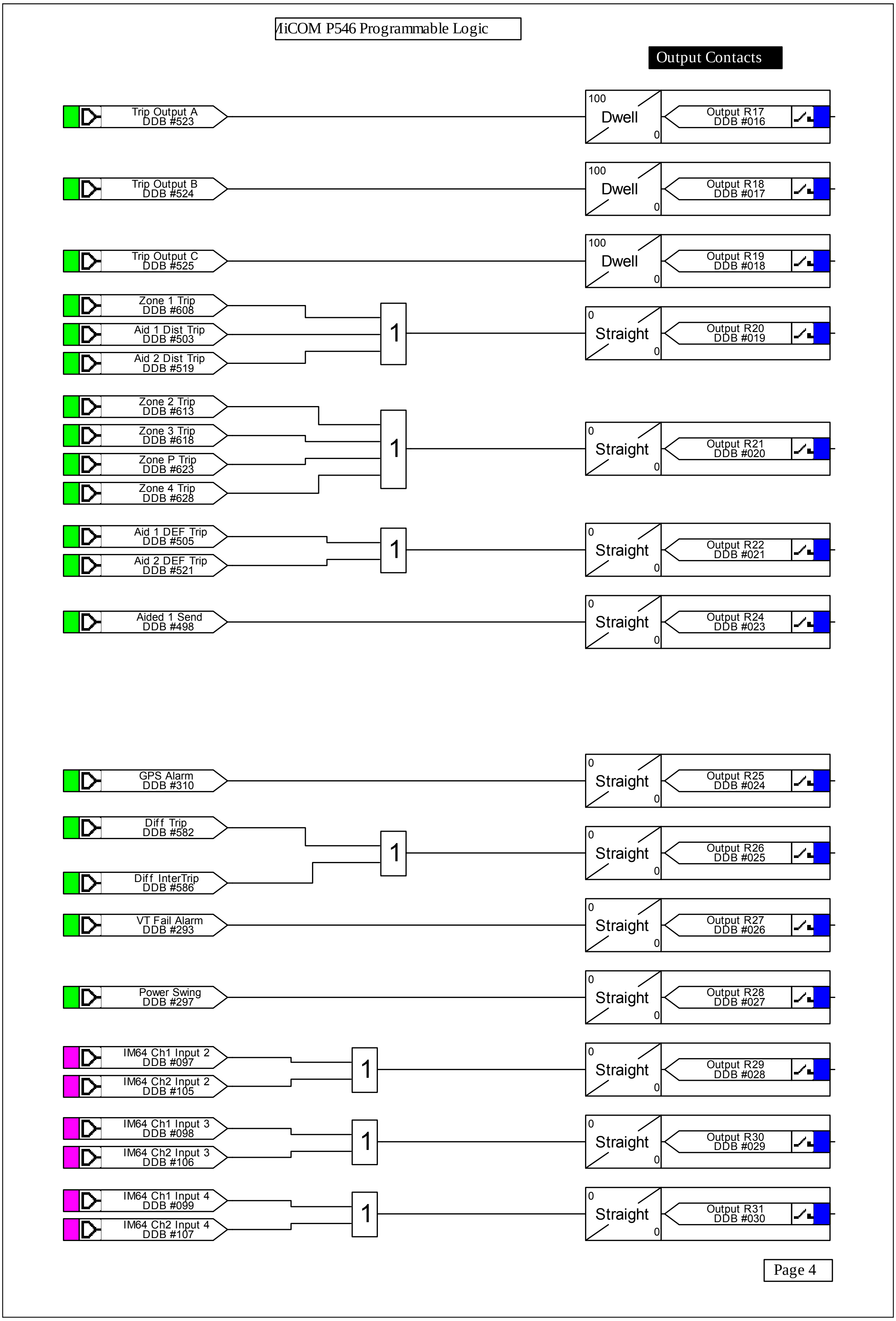
PL

Relay Outputs Mappings



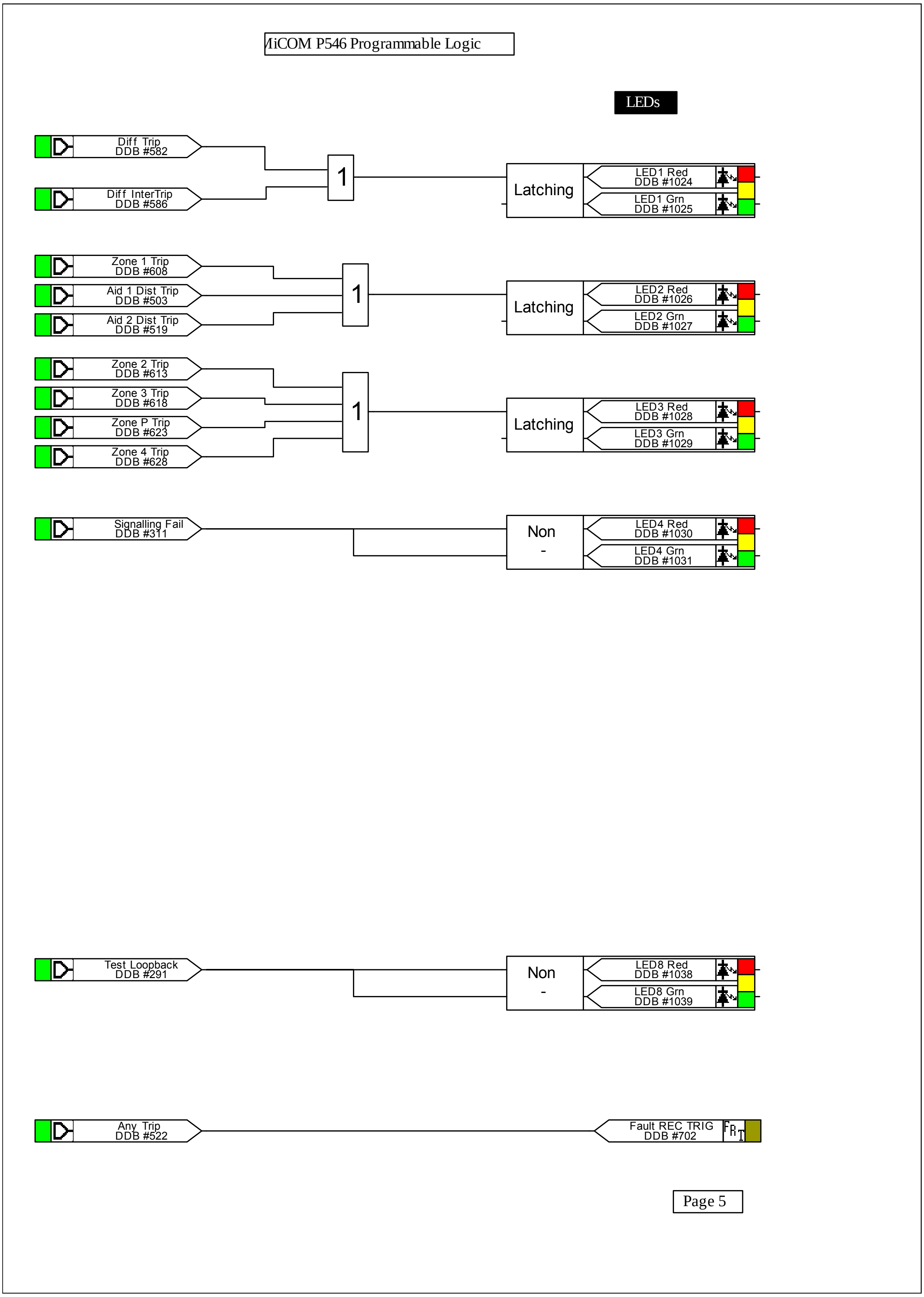
PL

Relay Outputs Mappings

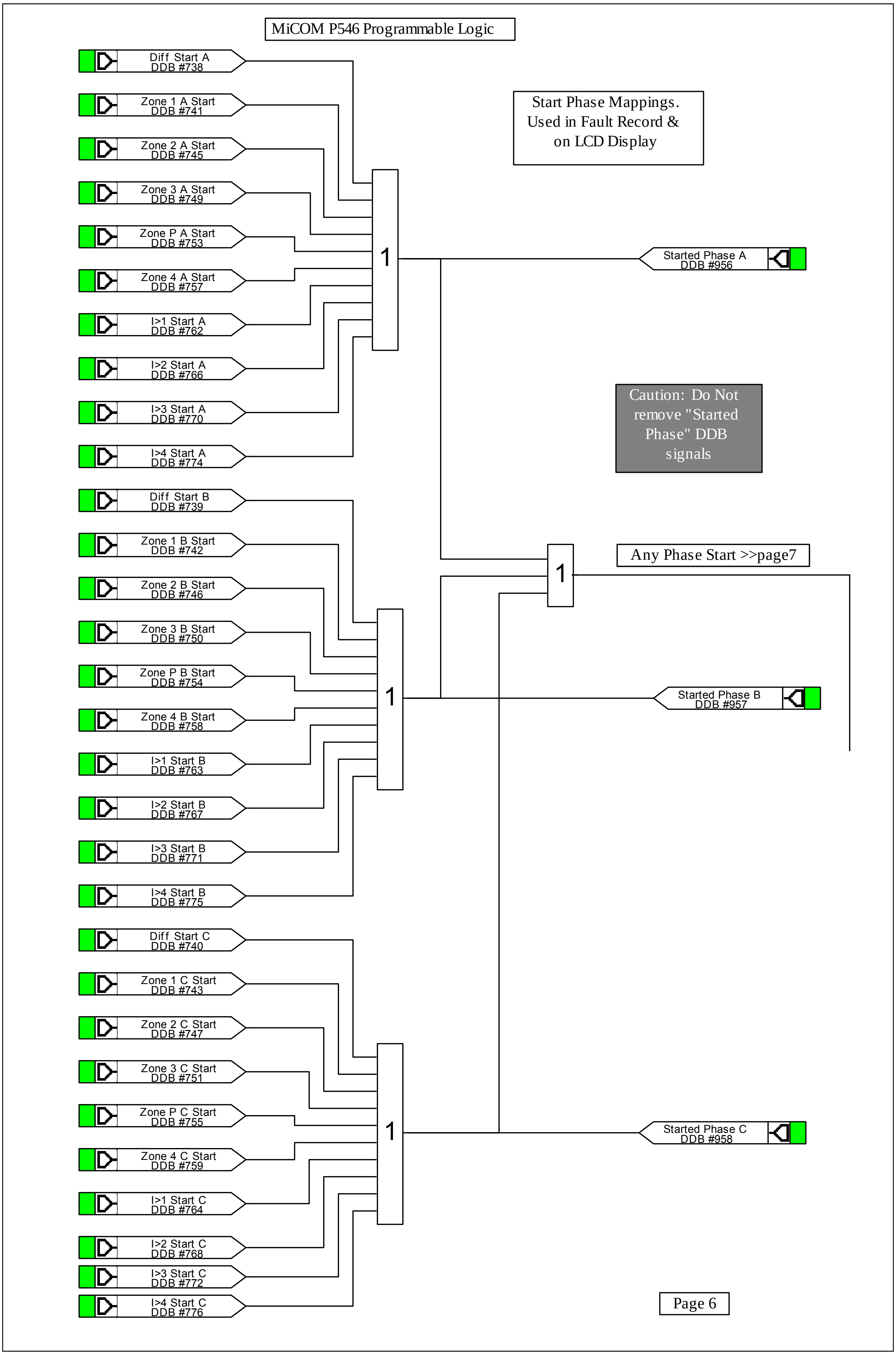


PL

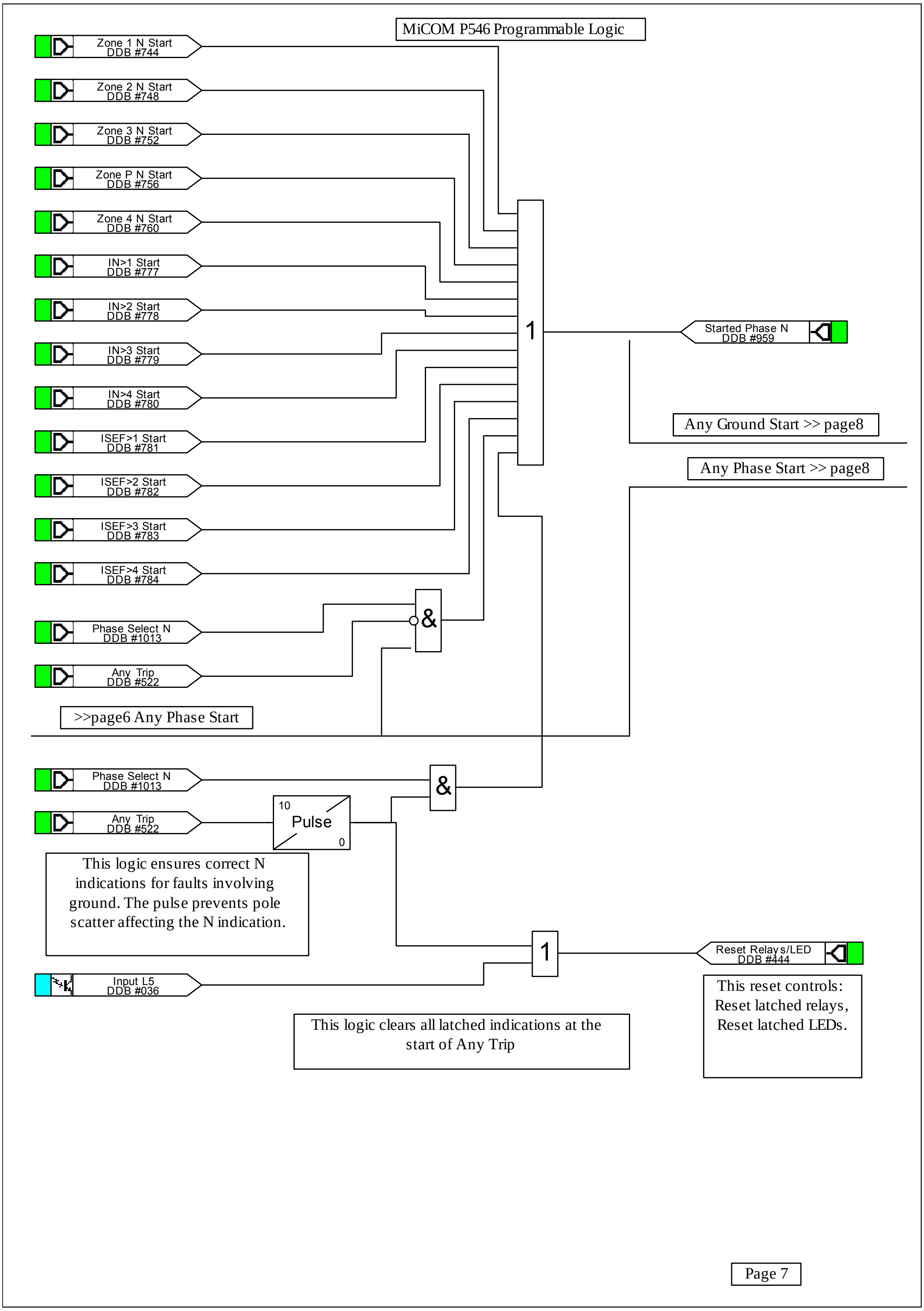
LED Mappings



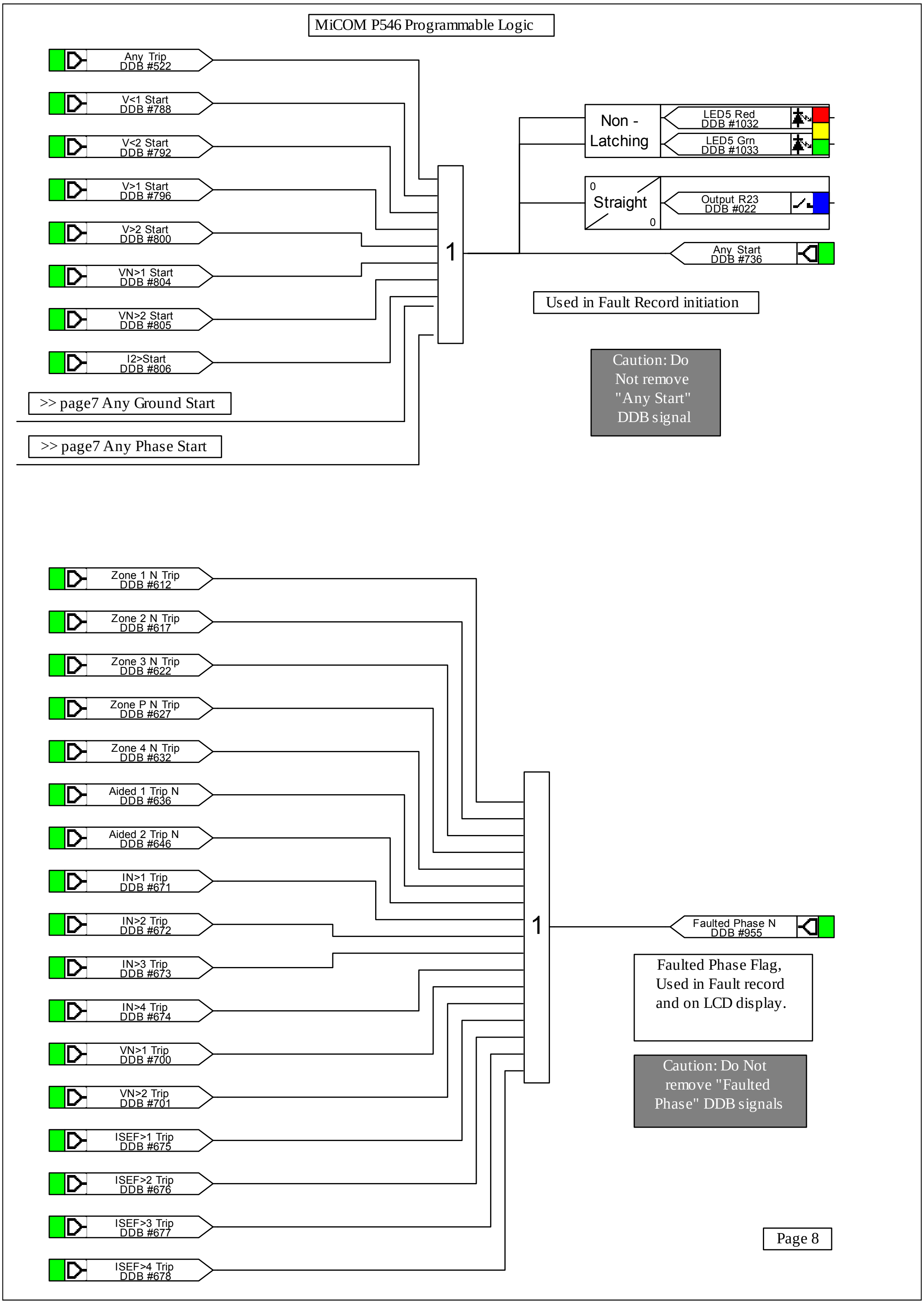
Start Mappings



Start Mappings



Faulted Phase Mappings



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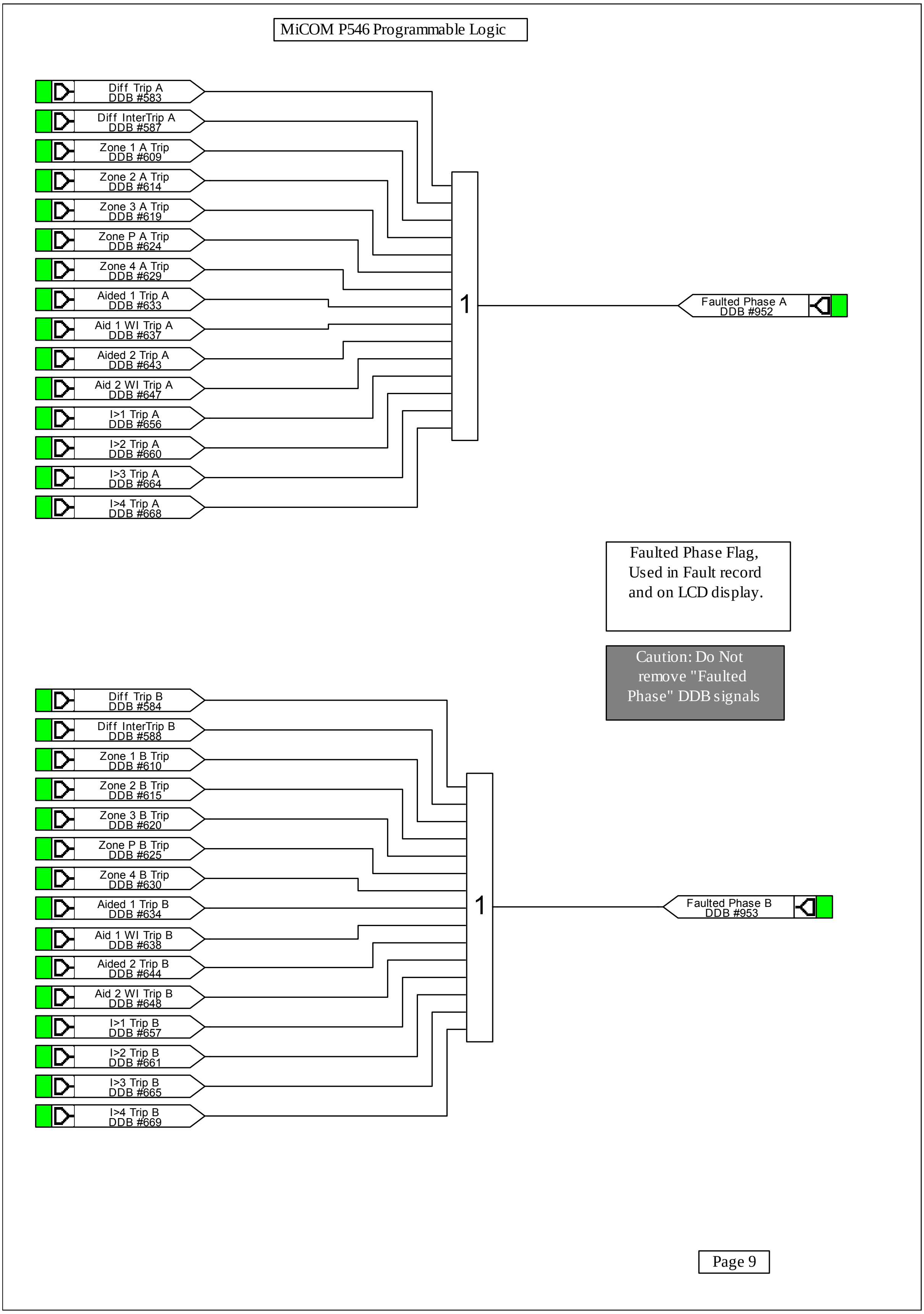
Faulted Phase Mappings



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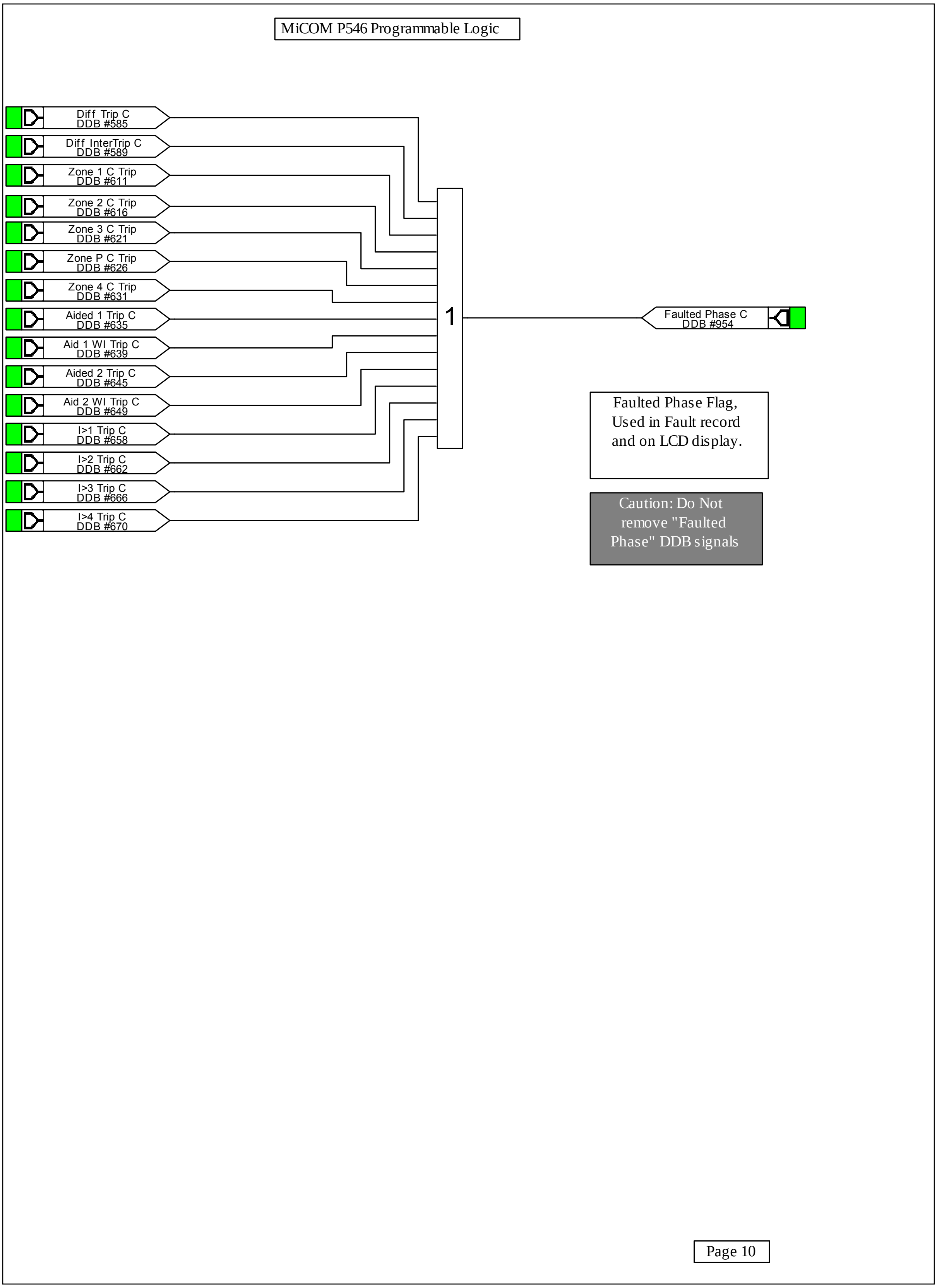
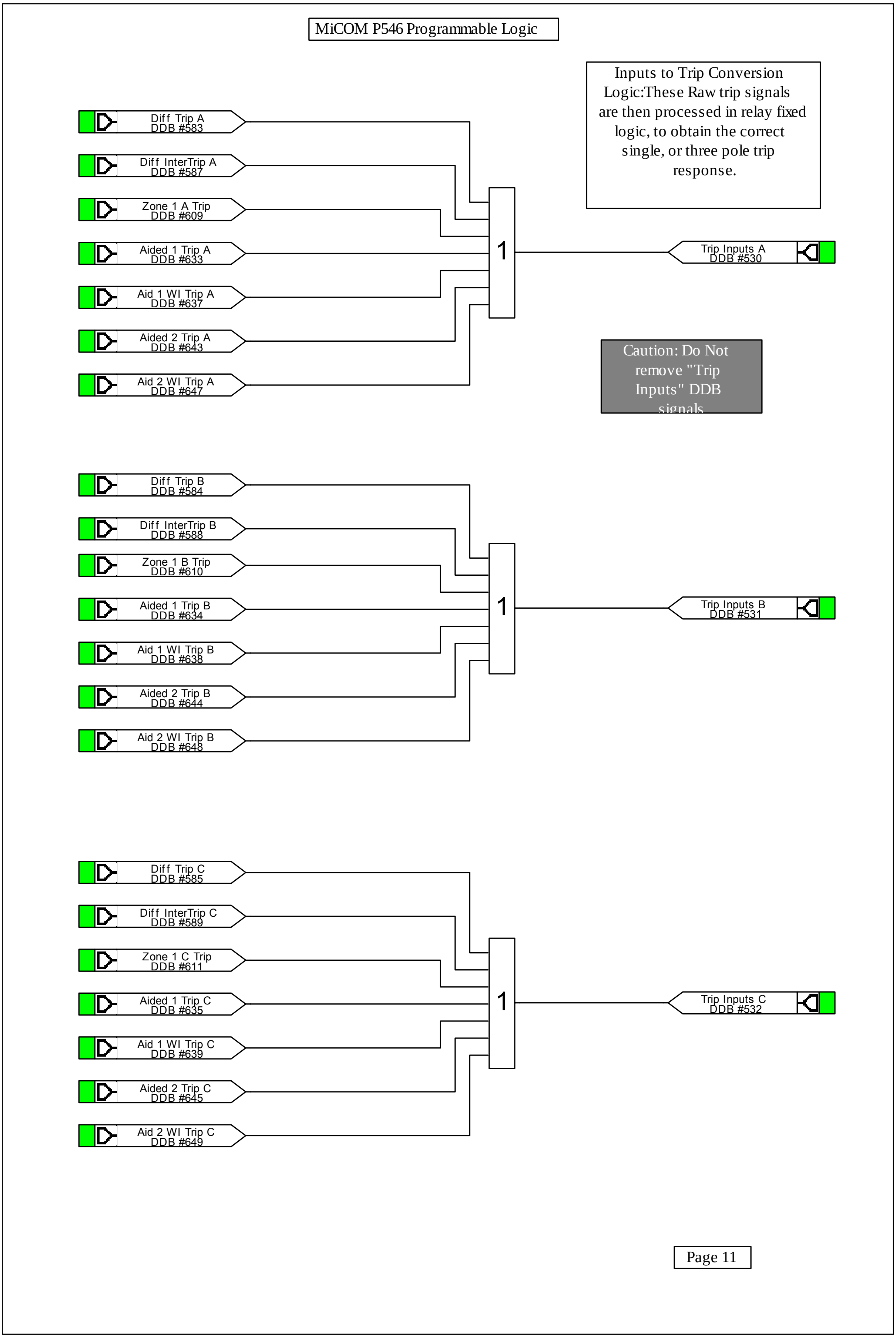
Faulted Phase Mappings

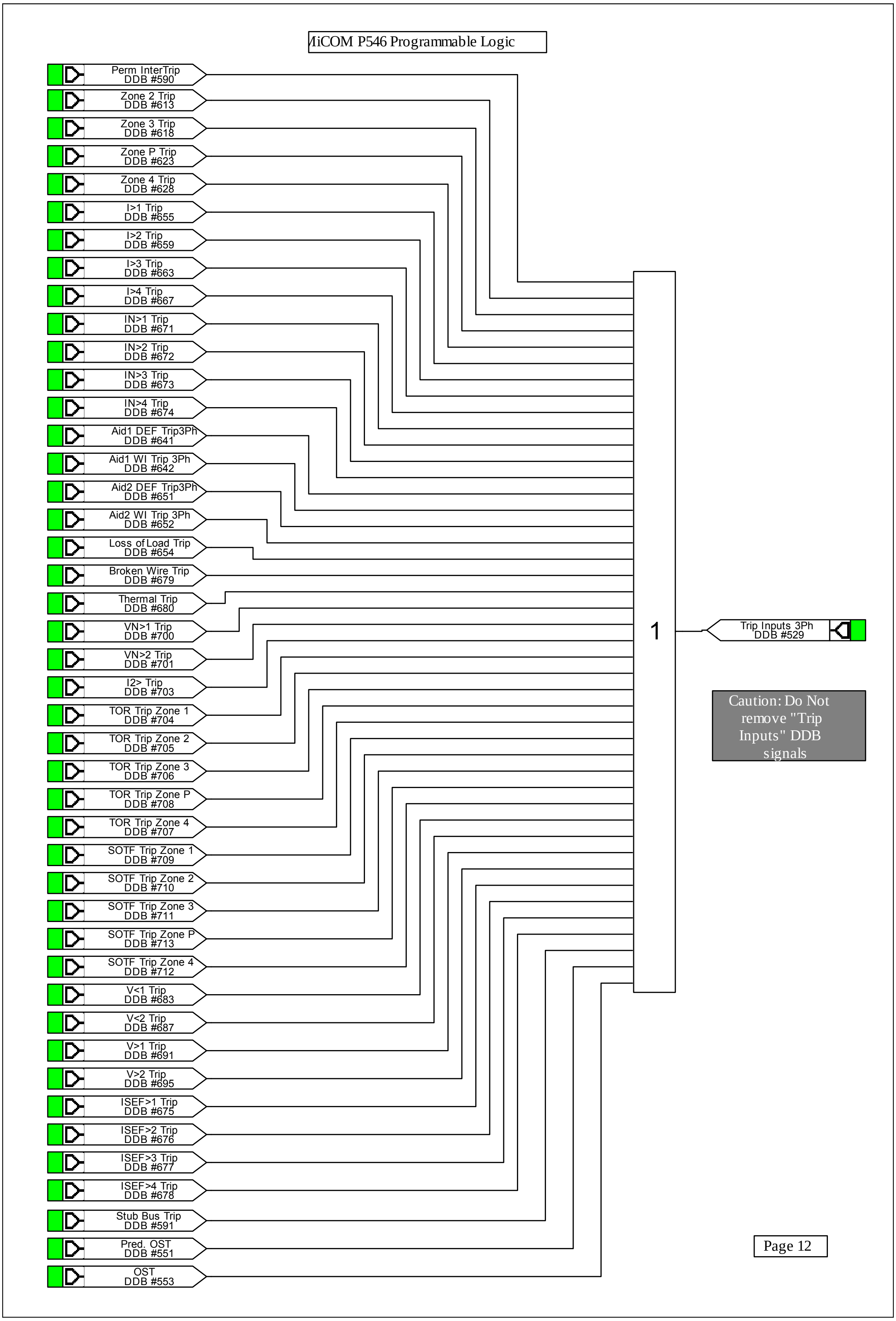


Trip Inputs Mappings

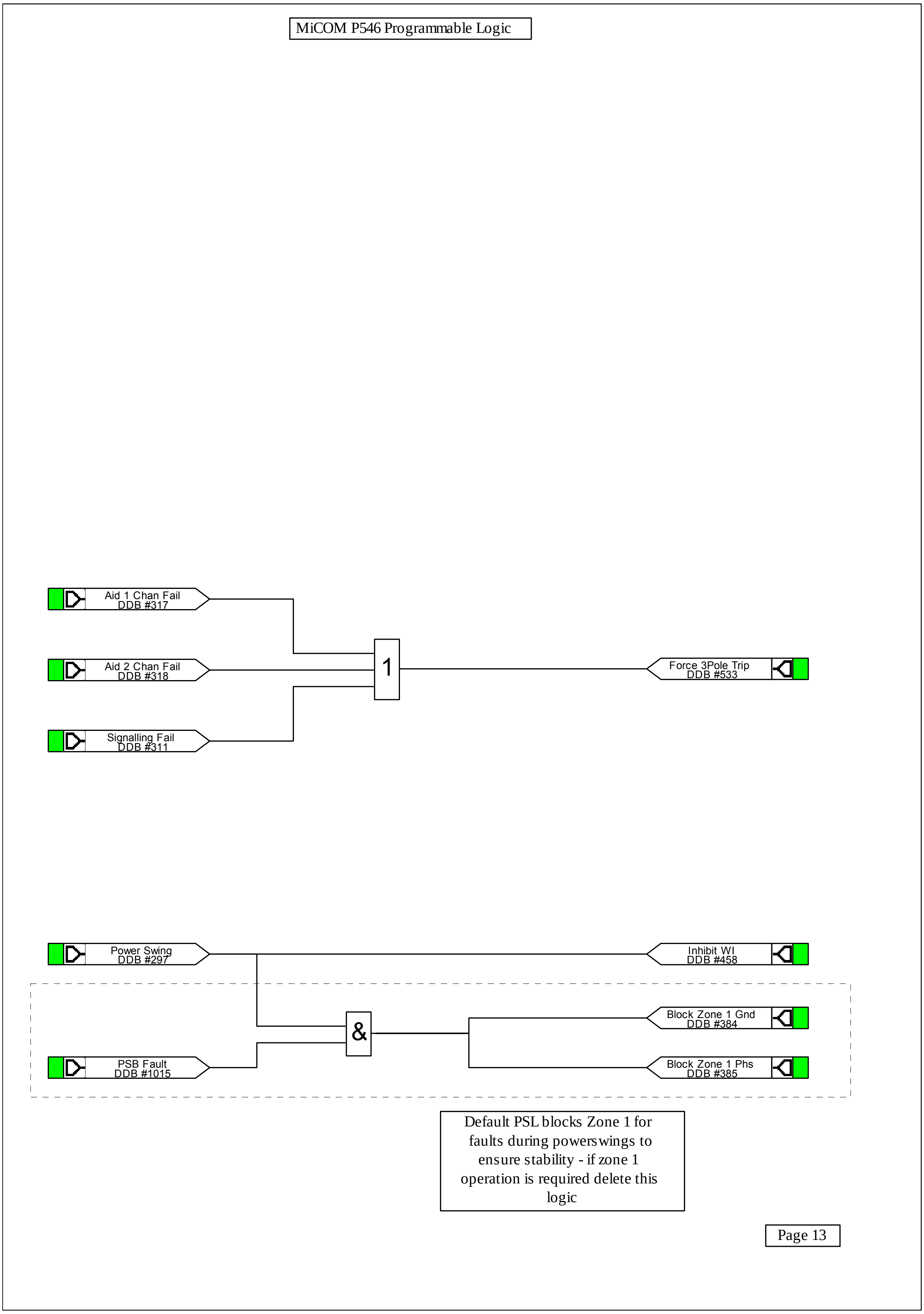


PL

Trip Inputs Mappings



Force 3Pole Trip



MEASUREMENTS AND RECORDING

MR

Date:	**7th August 2006**
Hardware Suffix:	**K**
Software Version:	**41 and 51**
Connection Diagrams:	**10P54302xx (xx = 01 to 02) & 10P54303xx (xx = 01 to 02)**
	10P54402xx (xx = 01 to 02) & 10P54403xx (xx = 01 to 02)
	10P54502xx (xx = 01 to 02) & 10P54503xx (xx = 01 to 02)
	10P54602xx (xx = 01 to 02) & 10P54603xx (xx = 01 to 02)

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CONTENTS

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1. MEASUREMENTS AND RECORDING

1.1 Introduction

The P54x is equipped with integral measurements, event, fault and disturbance recording facilities suitable for analysis of complex system disturbances.

The relay is flexible enough to allow for the programming of these facilities to specific user application requirements and are discussed below.

1.2 Event & fault records

The relay records and time tags up to 512 events and stores them in non-volatile (battery backed up) memory. This enables the system operator to establish the sequence of events that occurred within the relay following a particular power system condition, switching sequence etc. When the available space is exhausted, the oldest event is automatically overwritten by the new one.

The real time clock within the relay provides the time tag to each event, to a resolution of 1ms.

The event records are available for viewing either via the frontplate LCD or remotely, via the communications ports (courier versions only).

Local viewing on the LCD is achieved in the menu column entitled "VIEW RECORDS". This column allows viewing of event, fault and maintenance records and is shown in the following table:

VIEW RECORDS	
LCD Reference	**Description**
Select Event	Setting range from 0 to 511. This selects the required event record from the possible 512 that may be stored. A value of 0 corresponds to the latest event and so on.
Time & Date	Time & Date Stamp for the event given by the internal Real Time Clock.
Event Text	Up to 32 Character description of the Event refer to following sections).
Event Value	Up to 32 Bit Binary Flag or integer representative of the Event (refer to following sections).
Select Fault	Setting range from 0 to 4. This selects the required fault record from the possible 5 that may be stored. A value of 0 corresponds to the latest fault and so on.
	The following cells show all the fault flags, protection starts, protection trips, fault location, measurements etc. associated with the fault, i.e. the complete fault record.
Select Maint.	Setting range from 0 to 4. This selects the required maintenance report from the possible 5 that may be stored. A value of 0 corresponds to the latest report and so on.
Maint. Text	Up to 16 Character description of the occurrence (refer to following sections).
Maint. Type/Main Data	These cells are numbers representative of the occurrence. They form a specific error code which should be quoted in any related correspondence to Report Data.
Reset Indication	Either Yes or No. This serves to reset the trip LED indications provided that the relevant protection element has reset.

For extraction from a remote source via communications, refer to the SCADA Communications section (P54x/EN CT), where the procedure is fully explained.

1.2.1 Types of event

An event may be a change of state of a control input or output relay, an alarm condition, setting change etc. The following sections show the various items that constitute an event:

1.2.1.1 Change of state of opto-isolated inputs

If one or more of the opto (logic) inputs has changed state since the last time that the protection algorithm ran, the new status is logged as an event. When this event is selected to be viewed on the LCD, three applicable cells will become visible as shown below:

Time & date of event
“LOGIC INPUTS 1”
“Event Value 0101010101010101”

The Event Value is an 8, 12, 16 or 24-bit word showing the status of the opto inputs, where the least significant bit (extreme right) corresponds to opto input 1 etc. The same information is present if the event is extracted and viewed via PC.

1.2.1.2 Change of state of one or more output relay contacts

If one or more of the output relay contacts have changed state since the last time that the protection algorithm ran, then the new status is logged as an event. When this event is selected to be viewed on the LCD, three applicable cells will become visible as shown below:

Time & date of event
“OUTPUT CONTACTS 1”
“Event Value 010101010101010101010”

The Event Value is an 8, 12, 16, 24 or 32 bit word showing the status of the output contacts, where the least significant bit (extreme right) corresponds to output contact 1 etc. The same information is present if the event is extracted and viewed via PC.

1.2.1.3 Relay alarm conditions

Any alarm conditions generated by the relays will also be logged as individual events. The following table shows examples of some of the alarm conditions and how they appear in the event list:

Alarm Condition	Event Text	Event Value
Battery Fail	Battery Fail ON/OFF	Bit position 0 in 32 bit field
Field Voltage Fail	Field Volt Fail ON/OFF	Bit position 1 in 32 bit field
Setting Group via Opto Invalid	Setting Grp. Invalid ON/OFF	Bit position 2 in 32 bit field
Protection Disabled	Prot’n. Disabled ON/OFF	Bit position 3 in 32 bit field
Frequency out of Range	Freq. out of Range ON/OFF	Bit position 4 in 32 bit field
VTS Alarm	VT Fail Alarm ON/OFF	Bit position 5 in 32 bit field
CB Trip Fail Protection	CB Fail ON/OFF	Bit position 7 in 32 bit field

The previous table shows the abbreviated description that is given to the various alarm conditions and also a corresponding value between 0 and 31. This value is appended to each alarm event in a similar way as for the input and output events previously described. It is used by the event extraction software, such as MiCOM S1, to identify the alarm and is therefore invisible if the event is viewed on the LCD. Either ON or OFF is shown after the description to signify whether the particular condition has become operated or has reset.

1.2.1.4 Protection element starts and trips

Any operation of protection elements, (either a start or a trip condition) will be logged as an event record, consisting of a text string indicating the operated element and an event value. Again, this value is intended for use by the event extraction software, such as MiCOM S1, rather than for the user, and is therefore invisible when the event is viewed on the LCD.

1.2.1.5 General events

A number of events come under the heading of ‘General Events’ - an example is shown below:

Nature of Event	Displayed Text in Event Record	Displayed Value
Level 1 password modified, either from user interface, front or rear port.	PW1 modified UI, F, R or R2	0 UI=6, F=11, R=16, R2=38

A complete list of the ‘General Events’ is given in the Relay Menu Database (P54x/EN MD), which is a separate document, available for downloading from our website.

1.2.1.6 Fault records

Each time a fault record is generated, an event is also created. The event simply states that a fault record was generated, with a corresponding time stamp.

Note that viewing of the actual fault record is carried out in the "Select Fault’" cell further down the "VIEW RECORDS" column, which is selectable from up to 5 records. These records consist of fault flags, fault location, fault measurements etc. Also note that the time stamp given in the fault record itself will be more accurate than the corresponding stamp given in the event record as the event is logged some time after the actual fault record is generated.

The fault record is triggered from the ‘Fault REC. TRIG.’ signal assigned in the default programmable scheme logic to relay 3, protection trip. Note the fault measurements in the fault record are given at the time of the protection start. Also, the fault recorder does not stop recording until any start or relay 3 (protection trip) resets in order to record all the protection flags during the fault.

It is recommended that the triggering contact (relay 3 for example) be ‘self reset’ and not latching. If a latching contact were chosen the fault record would not be generated until the contact had fully reset.

1.2.1.7 Maintenance reports

Internal failures detected by the self-monitoring circuitry, such as watchdog failure, field voltage failure etc. are logged into a maintenance report. The maintenance report holds up to 5 such ‘events’ and is accessed from the "Select Report" cell at the bottom of the "VIEW RECORDS" column.

Each entry consists of a self explanatory text string and a ‘Type’ and ‘Data’ cell, which are explained in the menu extract at the beginning of this section.

Each time a Maintenance Report is generated, an event is also created. The event simply states that a report was generated, with a corresponding time stamp.

1.2.1.8 Setting changes

Changes to any setting within the relay are logged as an event. Two examples are shown in the following table:

Type of Setting Change	Displayed Text in Event Record	Displayed Value
Control/Support Setting	C & S Changed	22
Group # Change	Group # Changed	#

Where # = 1 to 4

Note: Control/Support settings are communications, measurement, CT/VT ratio settings etc, which are not duplicated within the four setting groups. When any of these settings are changed, the event record is created simultaneously. However, changes to protection or disturbance recorder settings will only generate an event once the settings have been confirmed at the 'setting trap'.

1.2.2 Resetting of event/fault records

If it is required to delete either the event, fault or maintenance reports, this may be done from within the "RECORD CONTROL" column.

1.2.3 Viewing event records via MiCOM S1 support software

When the event records are extracted and viewed on a PC they look slightly different than when viewed on the LCD. The following shows an example of how various events appear when displayed using MiCOM S1:

- Monday 03 January 2006 15:32:49 GMT I>1 Start ON

    MiCOM : MiCOM P54x

    Model Number: P543218A1M0500K

    Address: 001 Column: 00 Row: 23

    Event Type: Protection operation

- Monday 03 January 2006 15:32:52 GMT Fault Recorded

    MiCOM : MiCOM P54x

    Model Number: P543218A1M0500K

    Address: 001 Column: 01 Row: 00

    Event Type: Fault record

- Monday 03 January 2006 15:33:11 GMT Logic Inputs

    MiCOM : MiCOM P54x

    Model Number: P543218A1M0500K

    Address: 001 Column: 00 Row: 20

    Event Type: Logic input changed state

- Monday 03 January 2006 15:34:54 GMT Output Contacts

    MiCOM : MiCOM P54x

    Model Number: P543218A1M0500K

    Address: 001 Column: 00 Row: 21

    Event Type: Relay output changed state

- Monday 03 January 2006 15:35:55 GMT A/R Lockout ON

    MiCOM : MiCOM P54x

    Model Number: P543218A1M0500K

    Address: 001 Column: 00 Row: 22

    Event Type: Alarm event

- Tuesday 04 January 2006 20:18:22.988 GMT Zone 1 Trip ON

    MiCOM : MiCOM P54x

    Model Number: P543218A1M0500K

    Address: 001 Column: 0F Row: 30

    Event Type: Setting event

    As can be seen, the first line gives the description and time stamp for the event, whilst the additional information that is displayed below may be collapsed via the +/– symbol.

For further information regarding events and their specific meaning, refer to relay menu database document (P54x/EN MD). This is a standalone document not included in this manual.

1.2.4 Event filtering

It is possible to disable the reporting of events from all interfaces that supports setting changes. The settings that control the various types of events are in the record control column. The effect of setting each to disabled is as follows:

Menu Text	Default Setting	Available Settings
Clear Event	No	No or Yes
Selecting "Yes" will cause the existing event log to be cleared and an event will be generated indicating that the events have been erased.		
Clear Faults	No	No or Yes
Selecting "Yes" will cause the existing fault records to be erased from the relay.		
Clear Maint.	No	No or Yes
Selecting "Yes" will cause the existing maintenance records to be erased from the relay.		
Alarm Event	Enabled	Enabled or Disabled
Disabling this setting means that all the occurrences that produce an alarm will result in no event being generated.		
Relay O/P Event	Enabled	Enabled or Disabled
Disabling this setting means that no event will be generated for any change in logic input state.		
Opto Input Event	Enabled	Enabled or Disabled
Disabling this setting means that no event will be generated for any change in logic input state.		
General Event	Enabled	Enabled or Disabled
Disabling this setting means that no General Events will be generated.		
Fault Rec. Event	Enabled	Enabled or Disabled
Disabling this setting means that no event will be generated for any fault that produces a fault record.		

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Menu Text	Default Setting	Available Settings
Maint. Rec. Event	Enabled	Enabled or Disabled
Disabling this setting means that no event will be generated for any occurrence that produces a maintenance record.		
Protection Event	Enabled	Enabled or Disabled
Disabling this setting means that any operation of protection elements will not be logged as an event.		
DDB 31 - 0	11111111111111111111111111111111	
Displays the status of DDB signals 0 - 31.		
DDB 1407 - 1376	11111111111111111111111111111111	
Displays the status of DDB signals 1407 - 1376.		

Note that some occurrences will result in more than one type of event, e.g. a battery failure will produce an alarm event and a maintenance record event.

If the Protection Event setting is Enabled a further set of settings is revealed which allow the event generation by individual DDB signals to be enabled or disabled.

For further information regarding events and their specific meaning, refer to relay menu database document (P54x/EN MD).

1.3 Disturbance recorder

The integral disturbance recorder has an area of memory specifically set aside for record storage. The number of records that may be stored by the relay is dependent upon the selected recording duration. The relay can typically store a minimum of 20 records, each of 1.5 seconds duration. VDEW relays, however, have the same total record length but the VDEW protocol dictates that only 8 records (of 3 seconds duration) can be extracted via the rear port. Disturbance records continue to be recorded until the available memory is exhausted, at which time the oldest record(s) are overwritten to make space for the newest one.

The recorder stores actual samples that are taken at a rate of 48 samples per cycle.

Each disturbance record consists of eight analog data channels and thirty-two digital data channels. The relevant CT and VT ratios for the analog channels are also extracted to enable scaling to primary quantities. Note that if a CT ratio is set less than unity, the relay will choose a scaling factor of zero for the appropriate channel.

The "DISTURBANCE RECORDER" menu column is shown in the following table:

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
DISTURB. RECORDER				
Duration	1.5s	0.1s	10.5s	0.01s
This sets the overall recording time.				
Trigger Position	33.3%	0	100%	0.1%
This sets the trigger point as a percentage of the duration. For example, the default settings show that the overall recording time is set to 1.5s with the trigger point being at 33.3% of this, giving 0.5s pre-fault and 1s post fault recording times.				
Trigger Mode	Single	Single or Extended		
If set to single mode, if a further trigger occurs whilst a recording is taking place, the recorder will ignore the trigger. However, if this has been set to "Extended", the post trigger timer will be reset to zero, thereby extending the recording time.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Analog. Channel 1	VA	IA, IB, IC, IN, IN Sensitive, VA, VB, VC, IM, V Checksync (only for P543 and P545) and IA2, IB2, IC2 (only for P544 and P546)		
Selects any available analog input to be assigned to this channel (including derived IN residual current).				
Analog. Channel 2	VB	As above		
Analog. Channel 3	VC	As above		
Analog. Channel 4	IA	As above		
Analog. Channel 5	IB	As above		
Analog. Channel 6	IC	As above		
Analog. Channel 7	IN	As above		
Analog. Channel 8	IN Sensitive	As above		
Analog. Channel 9	V Checksync	As above		
Analog. Channel 10	IN	As above		
Analog. Channel 11	IN	As above		
Analog. Channel 12	IN	As above		
Digital Inputs 1 to 32	Relays 1 to 12 and Opto's 1 to 12	Any O/P Contact, Any Opto Inputs, or Internal Digital Signals		
The digital channels may monitor any of the opto isolated inputs or output contacts, in addition to a number of internal relay digital signals, such as protection starts, LEDs etc.				
Inputs 1 to 32 Trigger	No Trigger except Dedicated Trip Relay 3 operation which are set to Trigger L/H	No Trigger, Trigger L/H, Trigger H/L		
Any of the digital channels may be selected to trigger the disturbance recorder on either a low to high or a high to low transition.				

The pre and post fault recording times are set by a combination of the "Duration" and "Trigger Position" cells. "Duration" sets the overall recording time and the "Trigger Position" sets the trigger point as a percentage of the duration. For example, the default settings show that the overall recording time is set to 1.5s with the trigger point being at 33.3% of this, giving 0.5s pre-fault and 1s post fault recording times.

If a further trigger occurs whilst a recording is taking place, the recorder will ignore the trigger if the "Trigger Mode" has been set to "Single". However, if this has been set to "Extended", the post trigger timer will be reset to zero, thereby extending the recording time.

As can be seen from the menu, each of the analog channels is selectable from the available analog inputs to the relay. The digital channels may be mapped to any of the opto isolated inputs or output contacts, in addition to a number of internal relay digital signals, such as protection starts, LEDs etc. The complete list of these signals may be found by viewing the available settings in the relay menu or via a setting file in MiCOM S1. Any of the digital channels may be selected to trigger the disturbance recorder on either a low to high or a high to low transition, via the "Input Trigger" cell. The default trigger settings are that any dedicated trip output contacts (e.g. relay 3) will trigger the recorder.

It is not possible to view the disturbance records locally via the LCD; they must be extracted using suitable software such as MiCOM S1. This process is fully explained in the SCADA Communications section (P54x/EN SC).

1.4 Measurements

The relay produces a variety of both directly measured and calculated power system quantities. These measurement values are updated on a per second basis and can be viewed in the “Measurements” columns (up to three) of the relay or via MiCOM S1 Measurement viewer. The P54x relay is able to measure and display the following quantities as summarized.

- Phase Voltages
- Local and Remote Currents
- Differential and Bias Currents on a Per Phase Basis
- Sequence Voltages and Currents
- Slip Frequency
- Power and Energy Quantities
- Rms. Voltages and Currents
- Peak, Fixed and Rolling Demand Values

There are also measured values from the protection functions, which are also displayed under the measurement columns of the menu; these are described in the section on the relevant protection function.

1.4.1 Measured voltages and currents

The relay produces both phase to ground and phase to phase voltage and current values. They are produced directly from the DFT (Discrete Fourier Transform) used by the relay protection functions and present both magnitude and phase angle measurement.

Currents mentioned above can be seen on the Measurement 1 column. P54x also shows local and remote currents in Measurement 3 column. These currents have the same treatment as the currents used for differential protection purposes.

1.4.2 Sequence voltages and currents

Sequence quantities are produced by the relay from the measured Fourier values; these are displayed as magnitude and phase angle values.

1.4.3 Slip frequency

The relay produces a slip frequency measurement by measuring the rate of change of phase angle, between the bus and line voltages, over a one-cycle period. The slip frequency measurement assumes the bus voltage to be the reference phasor.

1.4.4 Power and energy quantities

Using the measured voltages and currents the relay calculates the apparent, real and reactive power quantities. These are produced on a phase by phase basis together with three-phase values based on the sum of the three individual phase values. The signing of the real and reactive power measurements can be controlled using the measurement mode setting. The four options are defined in the table below:

Measurement Mode	Parameter	Signing
0 (Default)	Export Power	+
	Import Power	–
	Lagging Vars	+
	Leading VArs	–
1	Export Power	–
	Import Power	+
	Lagging Vars	+
	Leading VArs	–
2	Export Power	+
	Import Power	–
	Lagging Vars	–
	Leading VArs	+
3	Export Power	–
	Import Power	+
	Lagging Vars	–
	Leading VArs	+

In addition to the measured power quantities the relay calculates the power factor on a phase by phase basis in addition to a three-phase power factor.

These power values are also used to increment the total real and reactive energy measurements. Separate energy measurements are maintained for the total exported and imported energy. The energy measurements are incremented up to maximum values of 1000GWhr or 1000GVARhr at which point they will reset to zero, it is also possible to reset these values using the menu or remote interfaces using the reset demand cell.

1.4.5 Rms. voltages and currents

Rms. phase voltage and current values are calculated by the relay using the sum of the samples squared over a cycle of sampled data.

1.4.6 Demand values

The relay produces fixed, rolling and peak demand values, using the reset demand menu cell it is possible to reset these quantities via the user interface or the remote communications.

Fixed demand values

The fixed demand value is the average value of a quantity over the specified interval; values are produced for each phase current and for three phase real and reactive power. The fixed demand values displayed by the relay are those for the previous interval, the values are updated at the end of the fixed demand period.

Rolling demand values

The rolling demand values are similar to the fixed demand values, the difference being that a sliding window is used. The rolling demand window consists of a number of smaller sub-periods. The resolution of the sliding window is the sub-period length, with the displayed values being updated at the end of each of the sub-periods.

Peak demand values

Peak demand values are produced for each phase current and the real and reactive power quantities. These display the maximum value of the measured quantity since the last reset of the demand values.

1.4.7 Settings

The following settings under the heading measurement set-up can be used to configure the relay measurement function.

Menu Text	Default Settings	Available settings
MEASUREMENT SETUP		
Default Display	Description	Description/Plant Reference/ Frequency/Access Level/3Ph + N Current/3Ph Voltage/Power/Date and Time
This setting can be used to select the default display from a range of options, note that it is also possible to view the other default displays whilst at the default level using the ◁ and ▷ keys. However once the 15 minute timeout elapses the default display will revert to that selected by this setting.		
Local Values	Primary	Primary/Secondary
This setting controls whether measured values via the front panel user interface and the front courier port are displayed as primary or secondary quantities.		
Remote Values	Primary	Primary/Secondary
This setting controls whether measured values via the rear communication port are displayed as primary or secondary quantities.		
Measurement Ref.	VA	VA/VB/VC/IA/IB/IC
Using this setting the phase reference for all angular measurements by the relay can be selected. This reference is for Measurements 1. Measurements 3 uses always IA local as a reference.		
Measurement Mode	0	0 to 3 step 1
This setting is used to control the signing of the real and reactive power quantities; the signing convention used is defined in the Measurements and Recording section (P54x/EN MR).		
Fix Dem. Period	30 minutes	1 to 99 minutes step 1 minute
This setting defines the length of the fixed demand window.		
Roll Sub Period	30 minutes	1 to 99 minutes step 1 minute
These two settings are used to set the length of the window used for the calculation of rolling demand quantities.		
Num. Sub Periods	1	1 to 15 step 1
This setting is used to set the resolution of the rolling sub window.		
Distance Unit*	km	km/miles
This setting is used to select the unit of distance for fault location purposes, note that the length of the line is preserved when converting from km to miles and vice versa.		

Menu Text	Default Settings	Available settings
MEASUREMENT SETUP		
Fault Location*	Distance	Distance/Ohms/% of Line
The calculated fault location can be displayed using one of several options selected using this setting.		
Remote2 Values	Primary	Primary or Secondary
The setting defines whether the values measured via the 2nd Rear Communication port are displayed in primary or secondary terms.		

1.4.8 Measurement display quantities

There are three “Measurement” columns available in the relay for viewing of measurement quantities. These can also be viewed with MiCOM S1 (see MiCOM Px40 - Monitoring section of the MiCOM S1 User Manual) and are shown below:

MEASUREMENTS 1	MEASUREMENTS 2	MEASUREMENTS 3	MEASUREMENTS 4
IA Magnitude 0 A	A Phase Watts 0 W	IA Local 0 A	Ch 1 Prop Delay
IA Phase Angle 0 deg	B Phase Watts 0 W	IA Angle Local 0 deg	Ch 2 Prop Delay
IB Magnitude 0 A	C Phase Watts 0 W	IB Local 0 A	Ch1 Rx Prop Delay
IB Phase Angle 0 deg	A Phase VArs 0 Var	IB Angle Local 0 deg	Ch1 Tx Prop Delay
IC Magnitude 0 A	B Phase VArs 0 Var	IC Local 0 A	Ch2 Rx Prop Delay
IC Phase Angle 0 deg	C Phase VArs 0 Var	IC Angle Local 0 deg	Ch2 Tx Prop Delay
IN Derived Mag. 0 A	A Phase VA 0 VA	IA remote 1 0 A	Channel 1 Status
IN Derived Angle 0 deg	B Phase VA 0 VA	IA Ang remote 1 0 deg	Channel 2 Status
ISEF Magnitude 0 A	C Phase VA 0 VA	IB remote 1 0 A	IM64 Rx Status
ISEF Angle 0 deg	3 Phase Watts 0 W	IB Ang remote 1 0 deg	STATISTICS
I1 Magnitude 0 A	3 Phase VArs 0 VAr	IC remote 1 0 A	Last Reset on
I2 Magnitude 0 A	3 Phase VA 0 VA	IC Ang remote 1 0 deg	Date/Time
I0 Magnitude 0 A	3Ph Power Factor 0	IA remote 2 0 A	Ch1 No.Vald Mess
IA RMS 0 A	APh Power Factor 0	IA Ang remote 2 0 deg	Ch1 No.Err Mess
IB RMS 0 A	BPh Power Factor 0	IB remote 2 0 A	Ch1 No.Errored s
IC RMS 0 A	CPh Power Factor 0	IB Ang remote 2 0 deg	Ch1 No.Sev Err s
IN RMS 0 A	3Ph WHours Fwd 0 Wh	IC remote 2 0 A	Ch1 No.Dgraded m
VAB Magnitude 0 V	3Ph WHours Rev 0 Wh	IC Ang remote 2 0 deg	Ch2 No.Vald Mess
VAB Phase Angle 0 deg	3Ph VArHours Fwd 0 VArh	IA Differential 0 A	Ch2 No.Err Mess
VBC Magnitude 0 V	3Ph VArHours Rev 0 VArh	IB Differential 0 A	Ch2 No.Errored s
VBC Phase Angle 0 deg	3Ph W Fix Demand 0 W	IC Differential 0 A	Ch2 No.Sev Err s
VCA Magnitude 0 V	3Ph VArs Fix Dem. 0 VAr	IA Bias 0 A	Ch2 No.Dgraded m
VCA Phase Angle 0 deg	IA Fixed Demand 0 A	IB Bias 0 A	Clear Statistics
VAN Magnitude 0 V	IB Fixed Demand 0 A	IC Bias 0 A	
VAN Phase Angle 0 deg	IC Fixed Demand 0 A		
VBN Magnitude 0 V	3 Ph W Roll Dem. 0 W		
VBN Phase Angle 0 deg	3Ph VArs Roll Dem. 0 VAr		
VCN Magnitude 0 V	IA Roll Demand 0 A		
VCN Phase Angle 0 deg	IB Roll Demand 0 A		
VN Derived Mag. 0 V	IC Roll Demand 0 A		
VN Derived Ang. 0 deg	3Ph W Peak Dem. 0 W		
V1 Magnitude 0 V	3Ph VAr Peak Dem. 0 VAr		
V2 Magnitude 0 V	IA Peak Demand 0 A		

MEASUREMENTS 1		MEASUREMENTS 2		MEASUREMENTS 3	MEASUREMENTS 4
V0 Magnitude	0 V	IB Peak Demand	0 A		
VAN RMS	0 V	IC Peak Demand	0 A		
VBN RMS	0 V	Reset Demand	No		
VCN RMS	0 V				
VAB RMS	0 V				
VBC RMS	0 V				
VCA RMS	0 V				
Frequency					
C/S Voltage Mag.	0 V				
C/S Voltage Ang.	0 deg				
C/S Bus-Line Ang.	0 deg				
Slip Frequency					
IM Magnitude	0 A				
IM Phase Angle	0 deg				
I1 Magnitude	0 A				
I1 Phase Angle	0 deg				
I2 Magnitude	0 A				
I2 Phase Angle	0 deg				
I0 Magnitude	0 A				
I0 Phase Angle	0 deg				
V1 Magnitude	0 V				
V1 Phase Angle	0 deg				
V2 Magnitude	0 V				
V2 Phase Angle	0 deg				
V0 Magnitude	0 V				
V0 Phase Angle	0 deg				

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MEASUREMENTS 4 Column:

Channel 1 and Channel 2 propagation times are displayed in seconds. These times are the ones calculated with asynchronous sampling (some times called “ping pong” method).

Ch1/Ch2 Rx Prop Delay Ch1 and Ch1/Ch2 Tx Prop Delay are displayed in seconds. These times are the ones calculated with synchronous sampling (by using GPS), therefore they are displayed only when GPS method is active (setting PROT COMMS - IM64/GPS Sync/Enabled)

‘Channel Status 1’ is a diagnostics flag associated with Channel 1 condition (Channel 2 is the same).

Bit “H/W B to J mode”	If a relay suffix K is communicating with a relay suffix B, G or J, this bit is "1"
Bit “Passthrough”	Ch1 data received via Ch2 in 3 ended configuration - self healing indication
Bit “Message Level”	Indicates poor Channel 1 quality
Bit “Timeout”	Indication that no valid message is received over Channel 1 during ‘Channel Timeout’ window
Bit “Mismatch Rxn”	Indication of mismatch between InterMiCOM64 Ch1 setting and Multiplexer
Bit “Path Yellow”	One way communication. Local relay that is sending over Ch1 indicates that remote end is not receiving

Bit “Signal Lost”	Mux indicates signal lost over Channel 1
Bit “Mux Clk F Error”	This is an alarm that appears if the Channel 1 baud rate is outside the limits 52Kbis/s or 70 Kbits/s
Bit “Remote GPS”	Indicates the status of the remote GPS on Channel 1
Bit “Local GPS”	Indicates the status of the local GPS on Channel 1
Bit “Tx”	Indication of transmission on Channel 1
Bit “Rx”	Indication of reception on Channel 1

‘IM64 Rx Status’ is a 16 bit word that displays the status of received commands as “1” or “0”.

‘Last Reset on’ displays the time and date of last statistics reset.

‘Ch1/Ch2 No. of valid messages’ displays the number of received valid messages over channel 1/2 since last statistics reset.

‘Ch1/Ch2 No. of Errored messages’ displays the number of invalid messages over channel 1/Ch 2 since last statistics reset.

The number of errored messages complies with ITU- G8.21 and is as follows:

‘Ch1/Ch2 No. Errored seconds’ displays the number of seconds containing 1 or more errored or lost messages

‘Ch1/Ch2 No. Severely Errored sconds‘ displays the number of seconds containing 31 or more errored or lost messages (1).

Note[1]: Any severely errored seconds are ignored when working out the minutes intervals

‘Ch1/Ch2 No. Degraded minutes’ displays the number of minutes containing 2 or more errored or lost messages.

The number of lost messages recorded is intended as an indicator for noises under normal communication conditions and not for recording long communication breaks. The lost message count is accumulated by incrementing a counter when a message is rejected by the Error code check, message length check and the sequential time tag check.

The error statistics are automatically cleared on power-up. They can also be cleared using the Clear Statistics setting in Measurements column of the menu.

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FIRMWARE DESIGN

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Date:	**7th August 2006**
Hardware Suffix:	**K**
Software Version:	**41 and 51**
Connection Diagrams:	**10P54302xx (xx = 01 to 02) & 10P54303xx (xx = 01 to 02)**
	10P54402xx (xx = 01 to 02) & 10P54403xx (xx = 01 to 02)
	10P54502xx (xx = 01 to 02) & 10P54503xx (xx = 01 to 02)
	10P54602xx (xx = 01 to 02) & 10P54603xx (xx = 01 to 02)

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CONTENTS

FIGURES

1. RELAY SYSTEM OVERVIEW

1.1 Hardware overview

The relay hardware is based on a modular design whereby the relay is made up of an assemblage of several modules which are drawn from a standard range. Some modules are essential while others are optional depending on the user's requirements.

The different modules that can be present in the relay are as follows:

1.1.1 Processor board

The processor board performs all calculations for the relay and controls the operation of all other modules within the relay. The processor board also contains and controls the user interfaces (LCD, LEDs, keypad, function keys and communication interfaces).

1.1.2 Co-processor board (optionally with interMiCOM^{64} fiber teleprotection)

Used to process the current differential protection algorithms and associated communication. It contains the optical fiber transmit and receive hardware and serial data communication controller for the differential protection signaling and InterMiCOM^{64} teleprotection.

1.1.3 Analog/digital input module

The input module converts the information contained in the analog and digital input signals into a format suitable for processing by the processor board. The standard input module consists of two boards: a transformer board to provide electrical isolation and a main input board which provides analog to digital conversion (with local storage of the calibration data) and the isolated digital ("opto") inputs.

1.1.4 Power supply module

The power supply module provides a power supply to all of the other modules in the relay, at three different voltage levels. The power supply board also provides the EIA(RS)485 electrical connection for the rear communication port. On a second board the power supply module contains the relays that provide the output contacts.

The power supply module also provides a 48V external field supply output to drive the opto isolated digital inputs (or the substation battery may be used to drive the optos).

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1.1.5 IRIG-B modulated or demodulated board (optional)

This board, can be used where an IRIG-B signal is available to provide an accurate time reference for the relay. There is also an option on this board to specify a fiber optic rear communication port, for use with IEC 60870 communications only.

1.1.6 Second rear comms and EIA(RS)232 interMiCOM^{64} board (optional)

The optional second rear port is designed typically for dial-up modem access by protection engineers/operators, when the main port is reserved for SCADA traffic. Communication is via one of three physical links: K-Bus, EIA(RS)485 or EIA(RS)232. The port supports full local or remote protection and control access by MiCOM S1 software. The second rear port is also available with an on board IRIG-B input.

1.1.7 Ethernet board

This is a mandatory board for IEC 61850 enabled relays. It provides network connectivity through either copper or fiber media at rates of 10Mb/s (copper only) or 100Mb/s. There is also an option on this board to specify IRIG-B port (modulated or un-modulated). This board, the IRIG-B board mentioned in section 1.1.5 and second rear comms board mentioned in section 1.1.6 are mutually exclusive as they all utilize slot A within the relay case.

All modules are connected by a parallel data and address bus which allows the processor board to send and receive information to and from the other modules as required. There is also a separate serial data bus for conveying sample data from the input module to the processor. Figure 1 shows the modules of the relay and the flow of information between them.

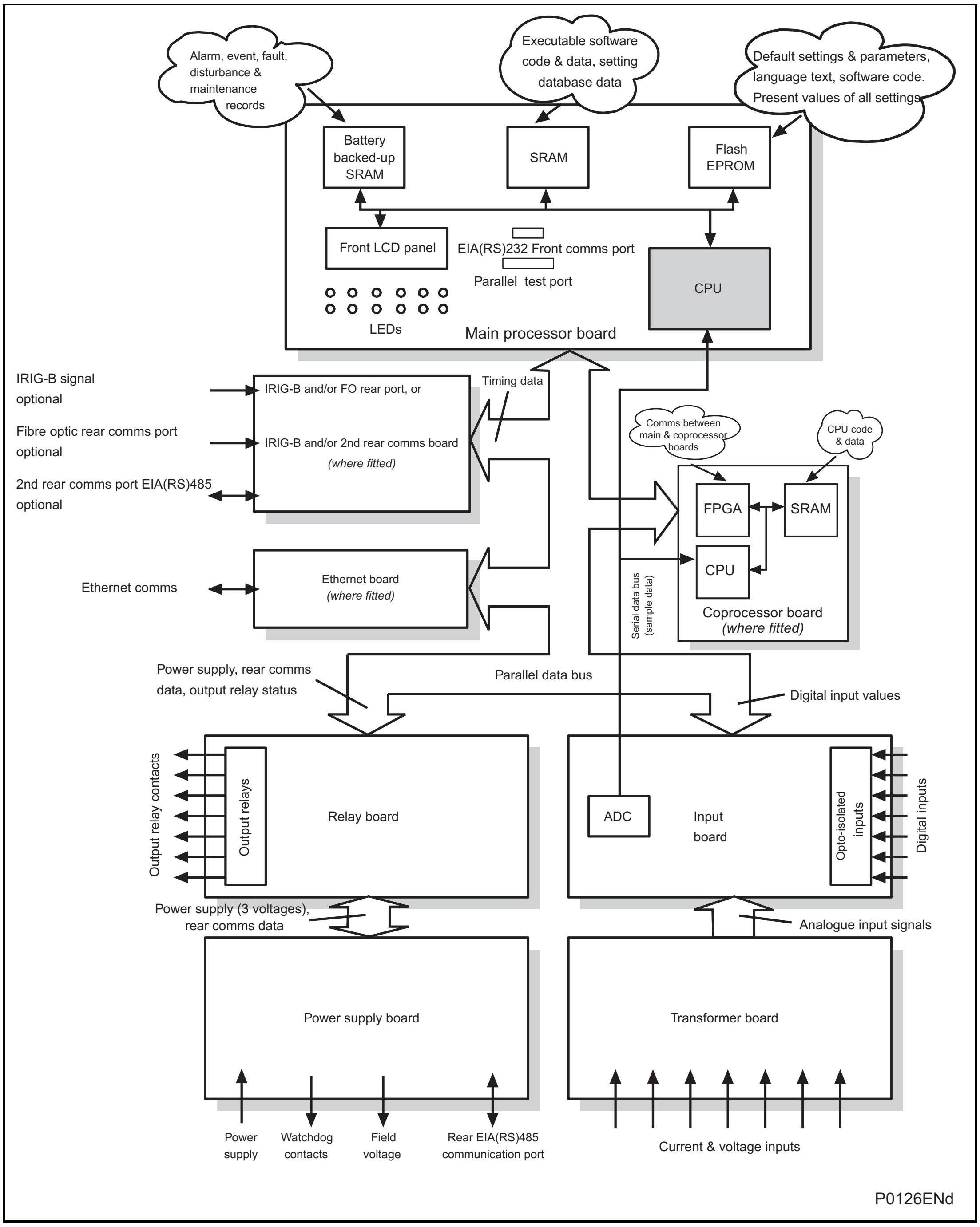

Figure 1: Relay modules and information flow

1.2 Software overview

The software for the relay can be conceptually split into four elements; the real-time operating system, the system services software, the platform software and the protection and control software. These four elements are not distinguishable to the user, and are all processed by the same processor board. The distinction between the four parts of the software is made purely for the purpose of explanation here.

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1.2.1 Real-time operating system

The real time operating system is used to provide a framework for the different parts of the relay's software to operate within. To this end the software is split into tasks.

The real-time operating system is responsible for scheduling the processing of these tasks such that they are carried out in the time available and in the desired order of priority. The operating system is also responsible for the exchange of information between tasks, in the form of messages.

1.2.2 System services software

The system services software provides the low-level control of the relay hardware. For example, the system services software controls the boot of the relay's software from the non-volatile flash EPROM memory at power-on, and provides driver software for the user interface via the LCD and keypad, and via the serial communication ports. The system services software provides an interface layer between the control of the relay's hardware and the rest of the relay software.

1.2.3 Platform software

The platform software deals with the management of the relay settings, the user interfaces and logging of event, alarm, fault and maintenance records. All of the relay settings are stored in a database within the relay which provides direct compatibility with Courier communications. For all other interfaces (i.e. the front panel keypad and LCD interface, IEC 60870-5-103, DNP3.0 and IEC 61850) the platform software converts the information from the database into the format required. The platform software notifies the protection & control software of all settings changes and logs data as specified by the protection & control software.

1.2.4 Protection & control software

The protection and control software performs the calculations for all of the protection algorithms of the relay. This includes digital signal processing, filtering, and ancillary tasks such as the measurements. The protection & control software interfaces with the platform software for settings changes and logging of records, and with the system services software for acquisition of sample data and access to output relays and digital opto-isolated inputs.

1.2.5 Disturbance recorder

The analog values and logic signals are routed from the protection and control software to the disturbance recorder software. The platform software interfaces to the disturbance recorder to allow extraction of the stored records.

2. HARDWARE MODULES

The relay is based on a modular hardware design where each module performs a separate function within the relay operation. This section describes the functional operation of the various hardware modules.

2.1 Processor board

The relay is based around a TMS320VC33-150MHz (peak speed), floating point, 32-bit digital signal processor (DSP) operating at a clock frequency of half this speed. This processor performs all of the calculations for the relay, including the protection functions, control of the data communication and user interfaces including the operation of the LCD, keypad and LEDs.

The processor board is located directly behind the relay's front panel which allows the LCD and LEDs to be mounted on the processor board along with the front panel communication ports. These comprise the 9-pin D-connector for EIA(RS)232 serial communications (e.g. using MiCOM S1 and Courier communications) and the 25-pin D-connector relay test port for parallel communication. All serial communication is handled using a field programmable gate array (FPGA).

The memory provided on the main processor board is split into two categories, volatile and non-volatile: the volatile memory is fast access SRAM which is used for the storage and execution of the processor software, and data storage as required during the processor's calculations. The non-volatile memory is sub-divided into 2 groups: 4MB of flash memory for non-volatile storage of software code, text and configuration data including the present setting values, and 2MB of battery backed-up SRAM for the storage of disturbance, event, fault and maintenance record data.

2.2 Co-processor board

A second processor board is used in the relay for the processing of the current differential and distance protection algorithms. The processor used on the second board is the same as that used on the main processor board. The second processor board has provision for fast access (zero wait state) SRAM for use with both program and data memory storage. This memory can be accessed by the main processor board via the parallel bus, and this route is used at power-on to download the software for the second processor from the flash memory on the main processor board. Further communication between the two processor boards is achieved via interrupts and the shared SRAM. The serial bus carrying the sample data is also connected to the co-processor board, using the processor's built-in serial port, as on the main processor board.

The co-processor board also handles all communication with the remote differential relay(s). This is achieved via BFOC 2.5 – ST optical fiber connections at the rear and hence the co-processor board holds the optical modules to transmit and receive data over the fiber links. One or two channels will be provided, each comprising a Rx (receive) and a Tx (transmit) fiber as a pair. The channels, when fitted according to an ordering option, are labeled Ch1 and Ch2.

2.3 Internal communication buses

The relay has two internal buses for the communication of data between different modules. The main bus is a parallel link that is part of a 64-way ribbon cable. The ribbon cable carries the data and address bus signals in addition to control signals and all power supply lines. Operation of the bus is driven by the main processor board that operates as a master while all other modules within the relay are slaves.

The second bus is a serial link that is used exclusively for communicating the digital sample values from the input module to the main processor board. The DSP processor has a built-in serial port that is used to read the sample data from the serial bus. The serial bus is also carried on the 64-way ribbon cable.

2.4 Input module

The input module provides the interface between the relay processor board and the analog and digital signals coming into the relay. The input module consists of two PCBs; the main input board and a transformer board. The P543 and P545 relays provides four voltage inputs and five current inputs. The P544 and P546 relays provides three voltage inputs and eight current inputs.

2.4.1 Transformer board

The current inputs will accept either 1A or 5A nominal current (observe menu and wiring options) and the nominal voltage input is 100/110/115/120V.

The transformers are used both to step-down the currents and voltages to levels appropriate to the relay's electronic circuitry and to provide effective isolation between the relay and the power system. The connection arrangements of both the current and voltage transformer secondaries provide differential input signals to the main input board to reduce noise.

2.4.2 Input board

The main input board is shown as a block diagram in Figure 2. It provides the circuitry for the digital input signals and the analog-to-digital conversion for the analog signals. Hence it takes the differential analog signals from the CTs and VTs on the transformer board(s), converts these to digital samples and transmits the samples to the processor board via the serial data bus. On the input board the analog signals are passed through an anti-alias filter before being multiplexed into a single analog to digital converter chip. The A - D converter provides 16-bit resolution and a serial data stream output. The digital input signals are opto isolated on this board to prevent excessive voltages on these inputs causing damage to the relay's internal circuitry.

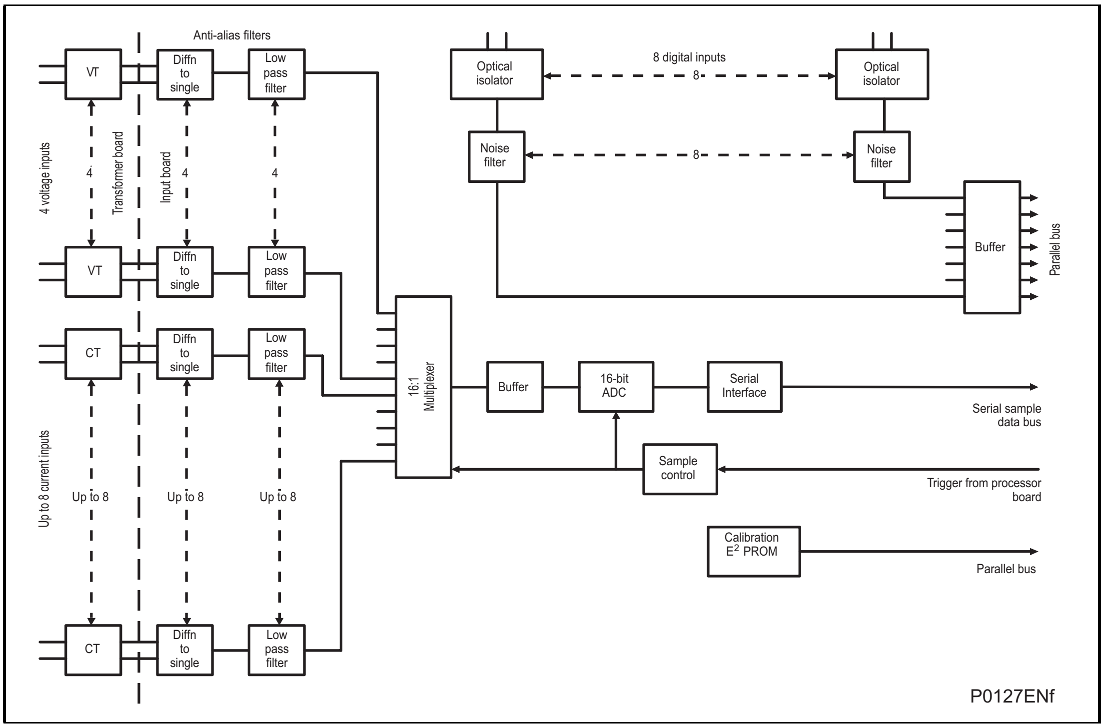

Figure 2: Main input board

Three spare channels are used to sample three different reference voltages for the purpose of continually checking the operation of the multiplexer and the accuracy of the A-D converter. The sample rate is maintained at 48 samples per cycle of the power waveform by a logic control circuit which is driven by the frequency tracking function on the main processor board.

The calibration non-volatile memory holds the calibration coefficients which are used by the processor board to correct for any amplitude or phase errors introduced by the transformers and analog circuitry.

The other function of the input board is to read the state of the signals present on the digital inputs and present this to the parallel data bus for processing. The input board holds 8 optical isolators for the connection of up to eight digital input signals. The opto-isolators are used with the digital signals for the same reason as the transformers with the analog signals; to isolate the relay's electronics from the power system environment. The input board provides some hardware filtering of the digital signals to remove unwanted noise before buffering the signals for reading on the parallel data bus. Depending on the relay model, more than 8 digital input signals can be accepted by the relay. This is achieved by the use of an additional opto-board which contains the same provision for 8 isolated digital inputs as the main input board, but does not contain any of the circuits for analogue signals which are provided on the main input board.

2.4.3 Universal opto isolated logic inputs

The P54x is fitted with universal opto isolated logic inputs that can be programmed for the nominal battery voltage of the circuit of which they are a part i.e. thereby allowing different voltages for different circuits e.g. signaling, tripping. They can also be programmed as Standard 60% - 80% or 50% - 70% to satisfy different operating constraints.

Threshold levels are as follows:

Nominal Battery Voltage (Vdc)	**Standard 60% - 80%**		**50% - 70%**	
	No Operation (logic 0) Vdc	**Operation (logic 1) Vdc**	**No Operation (logic 0) Vdc**	**Operation (logic 1) Vdc**
24/27	<16.2	>19.2	<12.0	>16.8
30/34	<20.4	>24.0	<15.0	>21.0
48/54	<32.4	>38.4	<24.0	>33.6
110/125	<75.0	>88.0	<55.0	>77.0
220/250	<150.0	>176.0	<110	>154

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This lower value eliminates fleeting pickups that may occur during a battery earth fault, when stray capacitance may present up to 50% of battery voltage across an input.

Each input also has selectable filtering which can be utilized. This allows use of a pre-set filter of ½ cycle which renders the input immune to induced noise on the wiring: although this method is secure it can be slow, particularly for intertripping. This can be improved by switching off the ½ cycle filter in which case one of the following methods to reduce ac noise should be considered. The first method is to use double pole switching on the input, the second is to use screened twisted cable on the input circuit.

- The P543 has 16 opto inputs
- The P544 has 16 opto inputs
- The P545 has 24 opto inputs
- The P546 has 24 opto inputs

2.5 Power supply module (including output relays)

The power supply module contains two PCBs, one for the power supply unit itself and the other for the output relays. The power supply board also contains the input and output hardware for the rear communication port which provides an EIA(RS)485 communication interface.

2.5.1 Power supply board (including EIA(RS)485 communication interface)

One of three different configurations of the power supply board can be fitted to the relay. This will be specified at the time of order and depends on the nature of the supply voltage that will be connected to the relay. The three options are shown in the table below:

Nominal dc Range	Nominal ac Range
24/54 V	DC only
48/125 V	30/100 Vrms
110/250 V	100/240 Vrms

The output from all versions of the power supply module are used to provide isolated power supply rails to all of the other modules within the relay. Three voltage levels are used within the relay, 5.1V for all of the digital circuits, ±16V for the analogue electronics, e.g. on the input board, and 22V for driving the output relay coils. All power supply voltages including the 0V earth line are distributed around the relay via the 64-way ribbon cable. One further voltage level is provided by the power supply board which is the field voltage of 48V. This is brought out to terminals on the back of the relay so that it can be used to drive the optically isolated digital inputs.

The two other functions provided by the power supply board are the EIA(RS)485 communications interface and the watchdog contacts for the relay. The EIA(RS)485 interface is used with the relay’s rear communication port to provide communication using one of either Courier, IEC 60870-5-103 or DNP3.0 protocols. The EIA(RS)485 hardware supports half-duplex communication and provides optical isolation of the serial data being transmitted and received. All internal communication of data from the power supply board is conducted via the output relay board which is connected to the parallel bus.

The watchdog facility provides two output relay contacts, one normally open and one normally closed which are driven by the processor board. These are provided to give an indication that the relay is in a healthy state.

The power supply board incorporates inrush current limiting. This limits the peak inrush current, during energization, to approximately 10A.

2.5.2 Output relay board

The output relay board holds seven relays, three with normally open contacts and four with changeover contacts. The relays are driven from the 22V power supply line. The relays’ state is written to or read from using the parallel data bus. Depending on the relay model seven additional output contacts may be provided, through the use of up to three extra relay boards.

2.5.3 High break relay board

One ‘high break’ output relay board consisting of four normally open output contacts is available as an option as follows:

- If High break option is selected in P543 or P544, these relays will contain one ‘high break’ output relay board, having a total of 7 standard relay outputs and 4 ‘high break’ relay outputs
- If High break option is selected in P545 or P546, these relays will contain two ‘high break’ output relay boards, having a total of 16 standard relay outputs and 8 ‘high break’ relay outputs

This board contains a hybrid of MOSFET solid state devices (SSD) in parallel with high capacity relay output contacts. The MOSFET has a varistor across it to provide protection which is required when switching off inductive loads as the stored energy in the inductor causes a reverse high voltage which could damage the MOSFET.

When there is a control input command to operate an output contact the miniature relay is operated at the same time as the SSD. The miniature relay contact closes in nominally 3.5mS and is used to carry the continuous load current; the SSD operates in <0.2ms and is switched off after 7.5mS. When the control input resets to open the contacts, the SSD is again turned on for 7.5mS. The miniature relay resets in nominally 3.5ms before the SSD and so the SSD is used to break the load. The SSD absorbs the energy when breaking inductive loads and so limits the resulting voltage surge. This contact arrangement is for switching dc circuits only. As the SSD comes on very fast (<0.2ms) then these high break output contacts have the added advantage of being very fast operating.

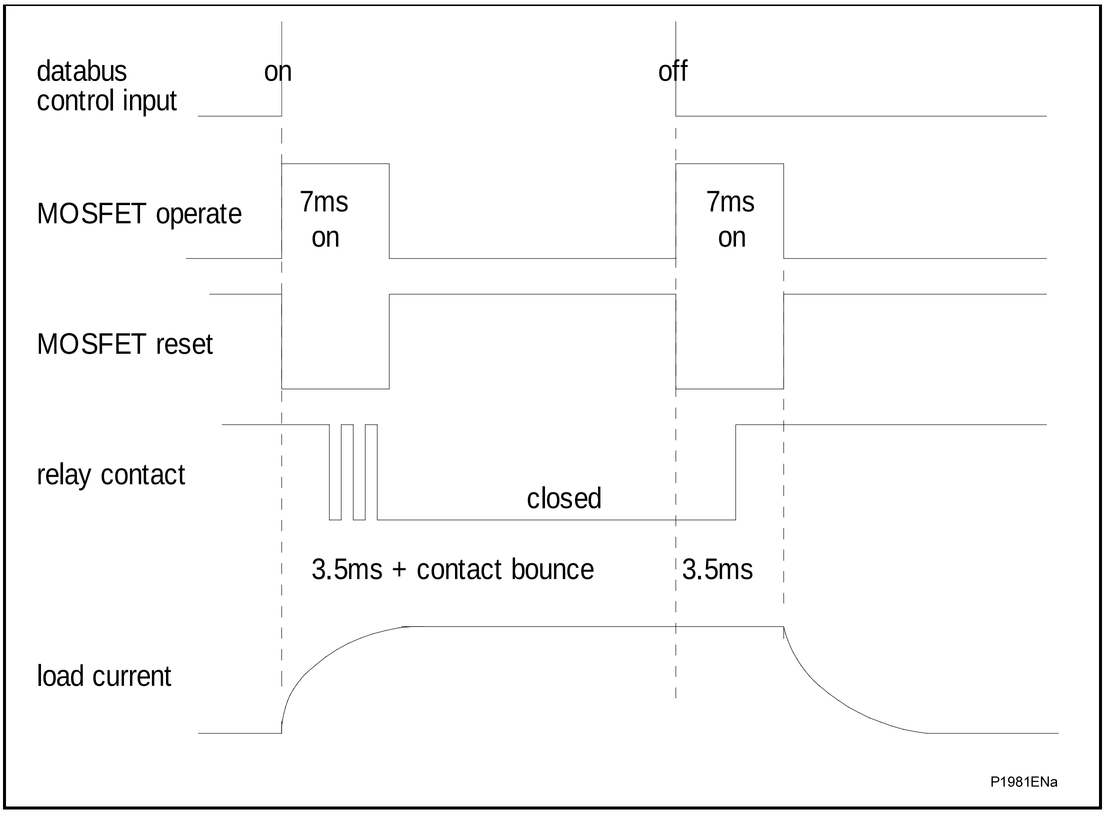

Figure 3: High break contact operation

2.5.3.1 High break contact applications

1) Efficient scheme engineering

In traditional hardwired scheme designs, high break capability could only be achieved using external electromechanical trip relays. External MVAJ tripping relays can be used or the new high break contacts inside MiCOM relays can be used - reducing panel space.

2) Accessibility of CB auxiliary contacts

Common practice is to use circuit breaker 52a (CB Closed) auxiliary contacts to break the trip coil current on breaker opening, thus easing the duty on the protection contacts. In cases such as operation of disconnectors, or retrofitting, it may be that 52a contacts are either unavailable or unreliable. High break contacts can be used to break the trip coil current in these applications.

3) Breaker fail

The technique to use 52a contacts in trip circuits was described above. However, in the event of failure of the local circuit breaker (stuck breaker), or defective auxiliary contacts (stuck contacts), the 52a contact action is incorrect. The interrupting duty at the local breaker then falls on the relay output contacts which may not be rated to perform this duty. MiCOM high break contacts will avoid the risk of burnt relay contacts.

4) Initiation of teleprotection

The MiCOM high break contacts also offer fast making. This can provide faster tripping: additionally, fast keying of teleprotection is a benefit. Fast keying bypasses the usual contact operation time, such that permissive, blocking and intertrip commands can be routed faster.

2.6 IRIG-B board (optional)

The IRIG-B board is an order option which can be fitted to provide an accurate timing reference for the relay. The IRIG-B signal is connected to the board via a BNC connector on the back of the relay. The timing information is used to synchronize the relay's internal real-time clock to an accuracy of 1ms. The internal clock is then used for the time tagging of the event, fault maintenance and disturbance records.

The IRIG-B board can also be specified with a fiber optic transmitter/receiver which can be used for the rear communication port instead of the EIA(RS)485 electrical connection (IEC 60870 protocol only).

2.7 Second rear communications board

For relays with Courier, Modbus, IEC60870-5-103 or DNP3 protocol on the first rear communications port there is the hardware option of a second rear communications port, which will run the Courier language. This can be used over one of three physical links: twisted pair K-Bus (non polarity sensitive), twisted pair EIA(RS)485 (connection polarity sensitive) or EIA(RS)232.

The second rear comms board and IRIG-B board are mutually exclusive since they use the same hardware slot. For this reason two versions of second rear comms board are available; one with an IRIG-B input and one without. The physical layout of the second rear comms board is shown in Figure 4.

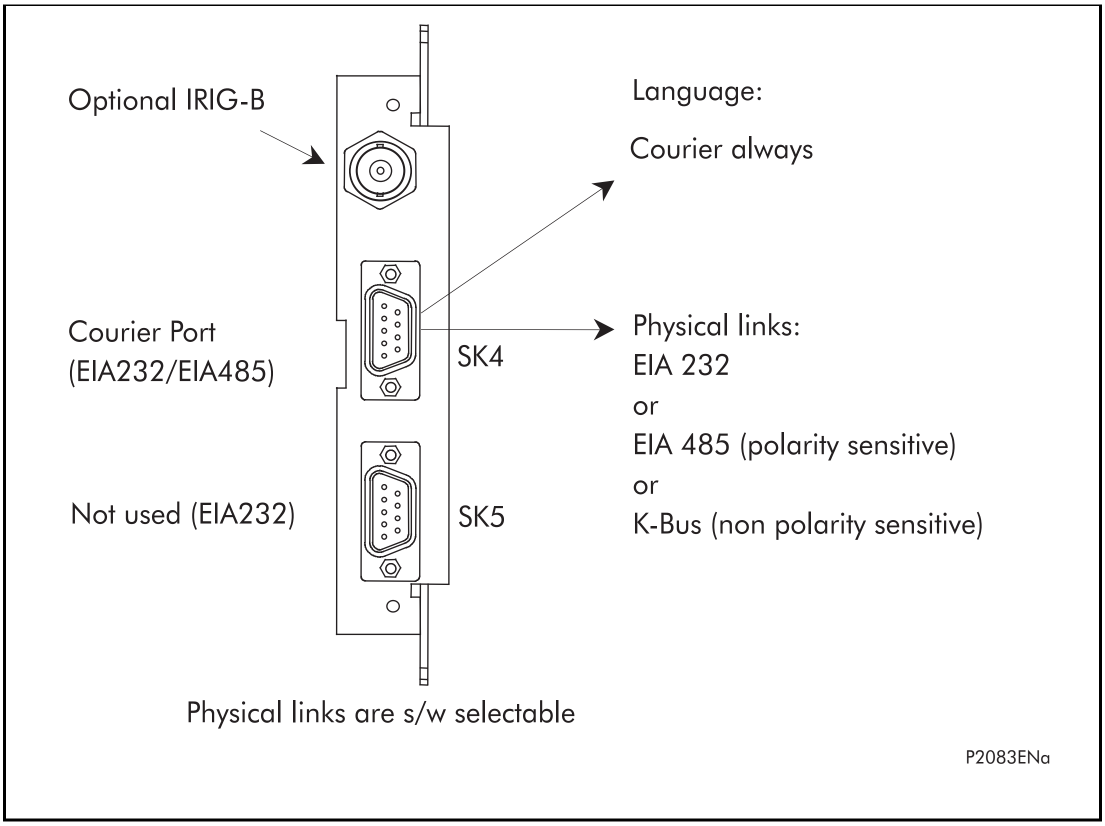

Figure 4: Second rear comms board (optional)

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2.8 Ethernet board

The optional Ethernet board (ZN0049) has 3 variants which support the IEC 61850 implementation:

- 100 Mbits/s Fiber Optic + 10/100 Mbits/s Copper
- 100 Mbits/s Fiber Optic + 10/100 Mbits/s Copper + modulated IRIG-B
- 100 Mbits/s Fiber Optic + 10/100 Mbits/s Copper + un-modulated IRIG-B

This card is fitted into Slot A of the relay, which is the optional communications slot. Each Ethernet card has a unique MAC address used for Ethernet communications. This is printed on the rear of the card, alongside the Ethernet sockets.

The 100 Mbits/s Fiber Optic ports use ST® type connectors and are suitable for 1300nm multi-mode fiber type.

Copper ports use RJ45 type connectors. When using copper Ethernet, it is important to use Shielded Twisted Pair (STP) or Foil Twisted Pair (FTP) cables, to shield the IEC 61850 communications against electromagnetic interference. The RJ45 connector at each end of the cable must be shielded, and the cable shield must be connected to this RJ45 connector shield, so that the shield is grounded to the relay case. Both the cable and the RJ45 connector at each end of the cable must be Category 5 minimum, as specified by the IEC 61850 standard. It is recommended that each copper Ethernet cable is limited to a maximum length of 3 meters and confined within one bay/cubicle.

When using IEC 61850 communications through the Ethernet card, the rear EIA(RS)485 and front EIA(RS)232 ports are also available for simultaneous use, both using the Courier protocol.

The physical layout of the Ethernet board is shown in Figure 5.

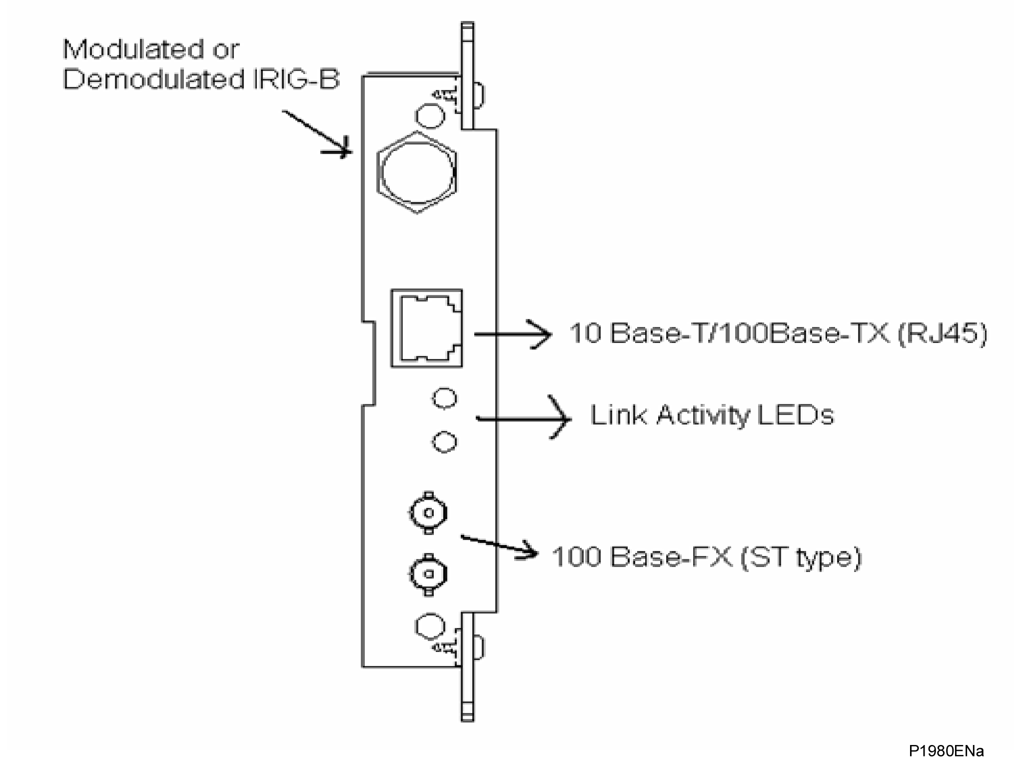

Figure 5: Ethernet board (optional)

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2.9 Mechanical layout

The case materials of the relay are constructed from pre-finished steel that has a conductive covering of aluminum and zinc. This provides good earthing at all joints giving a low impedance path to earth that is essential for performance in the presence of external noise. The boards and modules use a multi-point earthing strategy to improve the immunity to external noise and minimize the effect of circuit noise. Ground planes are used on boards to reduce impedance paths and spring clips are used to ground the module metalwork.

Heavy duty terminal blocks are used at the rear of the relay for the current and voltage signal connections. Medium duty terminal blocks are used for the digital logic input signals, the output relay contacts, the power supply and the rear communication port. A BNC connector is used for the optional IRIG-B signal. 9-pin and 25-pin female D-connectors are used at the front of the relay for data communication.

Inside the relay the PCBs plug into the connector blocks at the rear, and can be removed from the front of the relay only. The connector blocks to the relay’s CT inputs are provided with internal shorting links inside the relay which will automatically short the current transformer circuits before they are broken when the board is removed.

The front panel consists of a membrane keypad with tactile dome keys, an LCD and 12 LEDs mounted on an aluminum backing plate.

3. RELAY SOFTWARE

The software can be considered to be made up of four sections:

- The real-time operating system
- The system services software
- The platform software
- The protection & control software

This section describes in detail the latter two of these, the platform software and the protection & control software, which between them control the functional behavior of the relay. Figure 6 shows the structure of the relay software.

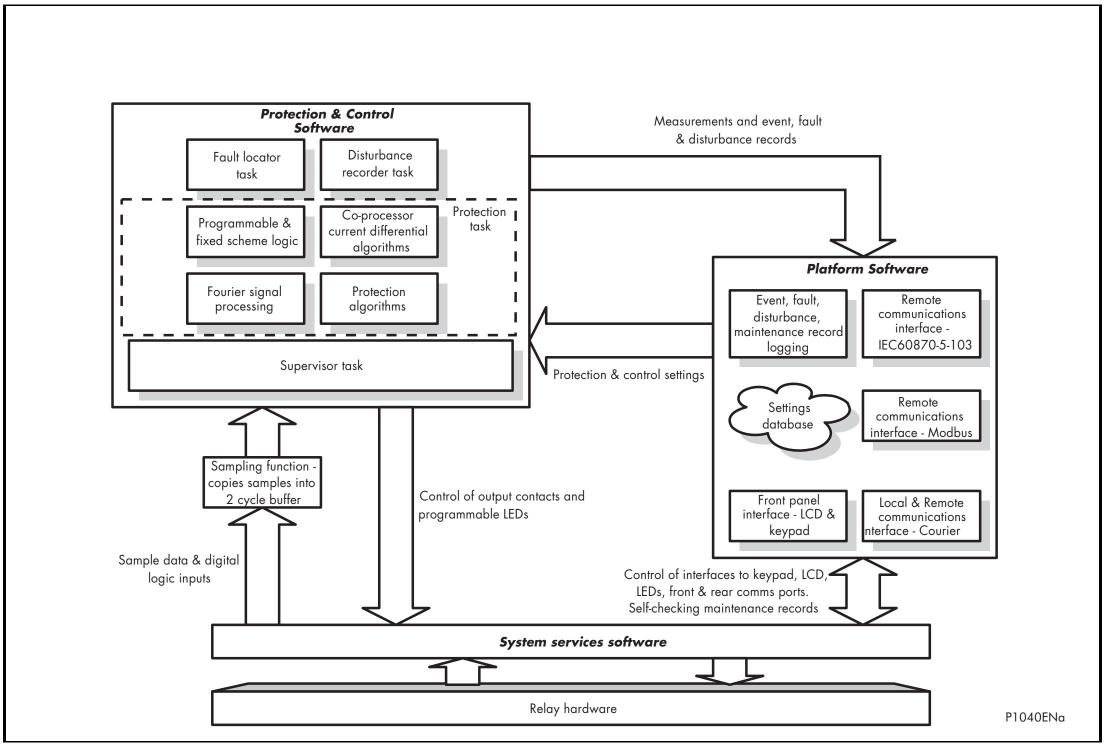

Figure 6: Relay software structure

3.1 Real-time operating system

The software is split into tasks; the real-time operating system is used to schedule the processing of the tasks to ensure that they are processed in the time available and in the desired order of priority. The operating system is also responsible in part for controlling the communication between the software tasks through the use of operating system messages.

3.2 System services software

As shown in Figure 5, the system services software provides the interface between the relay's hardware and the higher-level functionality of the platform software and the protection & control software. For example, the system services software provides drivers for items such as the LCD display, the keypad and the remote communication ports, and controls the boot of the processor and downloading of the processor code into SRAM from flash EPROM at power up.

3.3 Platform software

The platform software has three main functions:

- To control the logging of records that are generated by the protection software, including alarms and event, fault, and maintenance records
- To store and maintain a database of all of the relay's settings in non-volatile memory
- To provide the internal interface between the settings database and each of the relay's user interfaces, i.e. the front panel interface and the front and rear communication ports, using whichever communication protocol has been specified (Courier, IEC 60870-5-103, DNP 3.0)

3.3.1 Record logging

The logging function is provided to store all alarms, events, faults and maintenance records. The records for all of these incidents are logged in battery backed-up SRAM in order to provide a non-volatile log of what has happened. The relay maintains four logs: one each for up to 96 alarms, 500 event records, 5 fault records and 5 maintenance records. The logs are maintained such that the oldest record is overwritten with the newest record. The logging function can be initiated from the protection software or the platform software is responsible for logging of a maintenance record in the event of a relay failure. This includes errors that have been detected by the platform software itself or error that are detected by either the system services or the protection software function. See also the section on supervision and diagnostics later in this chapter.

3.3.2 Settings database

The settings database contains all of the settings and data for the relay, including the protection, disturbance recorder and control & support settings. The settings are maintained in non-volatile memory. The platform software's management of the settings database includes the responsibility of ensuring that only one user interface modifies the settings of the database at any one time. This feature is employed to avoid conflict between different parts of the software during a setting change. For changes to protection settings and disturbance recorder settings, the platform software operates a 'scratchpad' in SRAM memory. This allows a number of setting changes to be applied to the protection elements, disturbance recorder and saved in the database in non-volatile memory. If a setting change affects the protection & control task, the database advises it of the new values.

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3.3.3 Database interface

The other function of the platform software is to implement the relay's internal interface between the database and each of the relay's user interfaces. The database of settings and measurements must be accessible from all of the relay's user interfaces to allow read and modify operations. The platform software presents the data in the appropriate format for each user interface.

3.4 Protection and control software

The protection and control software task is responsible for processing all of the protection elements and measurement functions of the relay. To achieve this it has to communicate with both the system services software and the platform software as well as organize its own operations. The protection software has the highest priority of any of the software tasks in the relay in order to provide the fastest possible protection response. The protection & control software has a supervisor task that controls the start-up of the task and deals with the exchange of messages between the task and the platform software.

3.4.1 Overview - protection and control scheduling

After initialization at start-up, the protection and control task on the main processor board is suspended until the co-processor board re-starts via an interrupt. In the case where the co-processor board has failed, the protection task will automatically start after six analog samples have been received. In normal operation the task will be re-started by the co-processor 16 times per cycle. The acquisition of samples on the main processor board is controlled by a ‘sampling function’ which is called by the system services software and takes each set of new samples from the input module and stores them in a two-cycle buffer, these samples are also stored concurrently by the co-processor.

3.4.2 Signal processing

The sampling function provides filtering of the digital input signals from the opto-isolators and frequency tracking of the analog signals.

The frequency tracking of the analog input signals is achieved by a recursive Fourier algorithm which is applied to one of the input signals, and works by detecting a change in the measured signal’s phase angle. The calculated value of the frequency is used to modify the sample rate being used by the input module so as to achieve a constant sample rate of 48 samples per cycle of the power waveform. The value of the frequency is also stored for use by the protection and control task.

When the protection and control task is re-started by the sampling function, it calculates the Fourier components for the analogue signals. The Fourier components are calculated using a one-cycle, 48 sample Discrete Fourier Transform (DFT). The DFT is always calculated using the last cycle of samples from the 2-cycle buffer, i.e. the most recent data is used. The DFT used in this way extracts the power frequency fundamental component from the signal and produces the magnitude and phase angle of the fundamental in rectangular component format. The DFT provides an accurate measurement of the fundamental frequency component, and effective filtering of harmonic frequencies and noise. This performance is achieved in conjunction with the relay input module which provides hardware anti-alias filtering to attenuate frequencies above the half sample rate, and frequency tracking to maintain a sample rate of 48 samples per cycle. The Fourier components of the input current and voltage signals are stored in memory so that they can be accessed by all of the protection elements’ algorithms. The samples from the input module are also used in an unprocessed form by the disturbance recorder for waveform recording and to calculate true rms values of current, voltage and power for metering purposes.

3.4.3 Main protection digital filtering

All of the processing for the differential and distance protection algorithms is performed on the co-processor board.

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3.4.3.1 Differential protection

The differential protection is based on the relays at the line ends exchanging data messages four times per cycle. To achieve this the co-processor takes the frequency-tracked samples at 48 samples per cycle from the input board and converts these to 8 samples per cycle based on the nominal frequency (i.e. not frequency tracked). The co-processor calculates the Fourier transform of the fixed rate samples after every sample, using a one-cycle window. This generates current measurements eight times per cycle which are used for the differential protection algorithm and transmitted to the remote relay(s) using the HDLC (high-level data link control) communication protocol.

The co-processor is also responsible for managing intertripping commands via the communication link, and re-configuration instigated from the remote relay(s). Data exchange between the co-processor board and the main processor board is achieved through the use of shared memory on the co-processor board. When the main processor accesses this memory, the co-processor is temporarily halted. After the co-processor code has been copied onto the board at initialization, the main traffic between the two boards consists of setting change information, commands from the main processor, differential protection measurements and output data.

3.4.3.2 Distance protection

The current and voltage inputs are filtered, using finite impulse response (FIR) digital filters to reduce the effects of non-power frequency components in the input signals, such as DC offsets in current waveforms, and capacitor voltage transformer (CVT) transients in the voltages. The P54x uses a combination of a 1/4 cycle filter using 12 coefficients, a 1/2 cycle filter using 24 coefficients, and a one cycle filter using 48 coefficients. The relay automatically performs intelligent switching in the application of the filters, to select the best balance of removal of transients with fast response. Note that the protection elements themselves then perform additional filtering, for example implemented by the trip count strategy.

Figure 7 shows the frequency response of the 12, 24 and 48 coefficient filters, noting that all have a gain of unity at the fundamental:

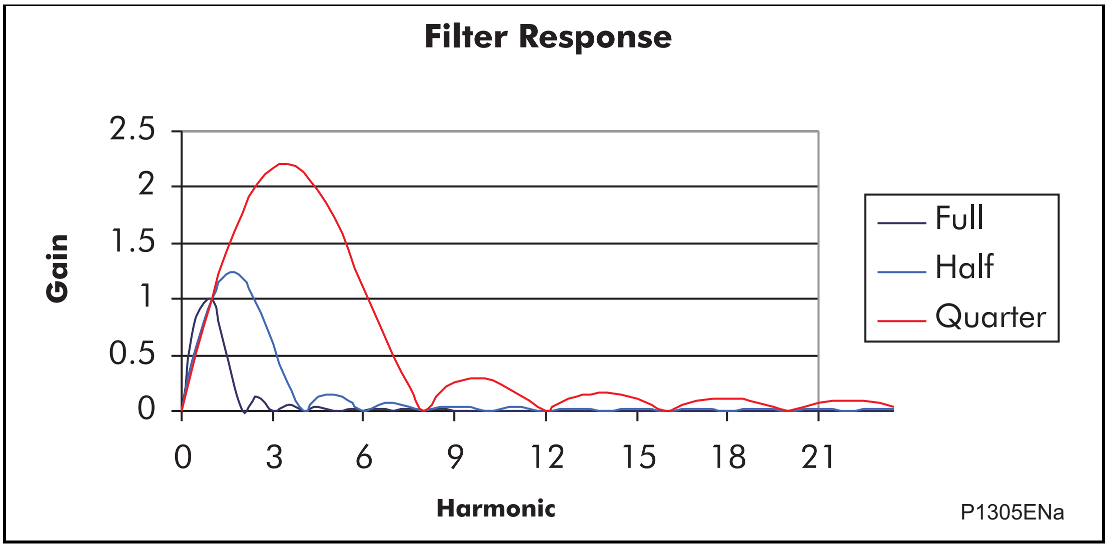

Figure 7: Frequency response of filters

3.4.3.3 Fourier filtering

All backup protection and measurement functions use one cycle fourier digital filtering to extract the power frequency component. This filtering is performed on the main processor board.

3.4.4 Programmable scheme logic

The purpose of the programmable scheme logic (PSL) is to allow the relay user to configure an individual protection scheme to suit their own particular application. This is achieved through the use of programmable logic gates and delay timers. To allow greater flexibility the PSL is part of the relay protection setting group.

The input to the PSL is any combination of the status of the digital input signals from the opto-isolators on the input board, the outputs of the protection elements, e.g. protection starts and trips, and the outputs of the fixed protection scheme logic. The fixed scheme logic provides the relay's standard protection schemes. The PSL itself consists of software logic gates and timers. The logic gates can be programmed to perform a range of different logic functions and can accept any number of inputs. The timers are used either to create a programmable delay, and/or to condition the logic outputs, e.g. to create a pulse of fixed duration on the output regardless of the length of the pulse on the input. The outputs of the PSL are the LEDs on the front panel of the relay and the output contacts at the rear.

The execution of the PSL logic is event driven; the logic is processed whenever any of its inputs change, for example as a result of a change in one of the digital input signals or a trip output from a protection element. Also, only the part of the PSL logic that is affected by the particular input change that has occurred is processed. This reduces the amount of processing time that is used by the PSL. The protection and control software updates the logic delay timers and checks for a change in the PSL input signals every time it runs.

This system provides flexibility for the user to create their own scheme logic design. However, it also means that the PSL can be configured into a very complex system, and because of this setting of the PSL is implemented through the PC support package MiCOM S1

3.4.4.1 PSL data - attaching a text identifier for version traceability

In the PSL editor in MiCOM S1 when a PSL file is downloaded to the relay the user can specify the group to download the file and a 32 character PSL reference description. This PSL reference is shown in the ‘Grp1/2/3/4 PSL Ref’ cell in the ‘PSL DATA’ menu in the relay. The download date and time and file checksum for each groups PSL file is also shown in the ‘PSL DATA’ menu in cells ‘Date/Time’ and ‘Grp 1/2/3/4 PSL ID’. The PSL data can be used to indicate if a PSL has been changed and thus be useful in providing information for version control of PSL files.

The default PSL Reference description is “Default PSL” followed by the model number e.g. “Default PSL P54x??????0yy0?” refers to the software version e.g. 40. This is the same for all protection setting groups (since the default PSL is the same for all groups). Since the LCD display (bottom line) only has space for 16 characters the display must be scrolled to see all 32 characters of the PSL Reference description.

The default date and time is the date and time when the defaults were loaded from flash into EEPROM.

Note: The PSL DATA column information is visible via the relay front panel interface or over the Courier communications protocol.

3.4.5 Event recording

A change in any digital input signal or protection element output signal causes an event record to be created. These events are generated by the relay protection software and immediately time stamped before being buffered in a fast area of memory to avoid compromising the protection function of the relay. They are then transferred to battery backed up SRAM for non-volatile storage. It is possible for the fast buffer to overflow under avalanche conditions, if this occurs then a maintenance record is generated to indicate this loss of information.

3.4.6 Disturbance recorder

The disturbance recorder operates as a separate task from the protection and control task. It can record the waveforms for up to 12 calibrated analog channels and the values of up to 32 digital signals. The recording time is user selectable up to a maximum of 10 seconds. The disturbance recorder is supplied with data by the protection and control task once per cycle. The disturbance recorder collates the data that it receives into the required length disturbance record. The disturbance records can be extracted by MiCOM S1 which can also store the data in COMTRADE format, thus allowing the use of other packages to view the recorded data.

3.4.7 Fault locator

The fault locator locator uses a 12-cycle buffer of the analog input signals and returns the calculated location of the fault to the protection and control task which includes it in the fault record for the fault. The prefault and fault voltages and currents are calculated by the fault locator, there are also presented within the fault record. When the fault record is complete (i.e. includes the fault location), the protection and control task can send a message to the supervisor task to log the fault record.

4. SELF TESTING & DIAGNOSTICS

The relay includes a number of self-monitoring functions to check the operation of its hardware and software when it is in service. These are included so that if an error or fault occurs within the relay's hardware or software, the relay is able to detect and report the problem and attempt to resolve it by performing a re-boot. This involves the relay being out of service for a short period of time which is indicated by the 'Healthy' LED on the front of the relay being extinguished and the watchdog contact at the rear operating. If the restart fails to resolve the problem, then the relay will take itself permanently out of service. Again this will be indicated by the LED and watchdog contact.

If a problem is detected by the self-monitoring functions, the relay attempts to store a maintenance record in battery backed-up SRAM to allow the nature of the problem to be notified to the user.

The self-monitoring is implemented in two stages: firstly a thorough diagnostic check which is performed when the relay is booted-up, e.g. at power-on, and secondly a continuous self-checking operation which checks the operation of the relay's critical functions whilst it is in service.

4.1 Start-up self-testing

The self-testing which is carried out when the relay is started takes a few seconds to complete, during which time the relay's protection is unavailable. This is signaled by the 'Healthy' LED on the front of the relay which will illuminate when the relay has passed all of the tests and entered operation. If the testing detects a problem, the relay will remain out of service until it is manually restored to working order.

The operations that are performed at start-up are as follows:

4.1.1 System boot

The integrity of the flash EPROM memory is verified using a checksum before the program code and data stored in it is copied into SRAM to be used for execution by the processor. When the copy has been completed the data then held in SRAM is compared to that in the flash EPROM to ensure that the two are the same and that no errors have occurred in the transfer of data from flash EPROM to SRAM. The entry point of the software code in SRAM is then called which is the relay initialization code.

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4.1.2 Initialization software

The initialization process includes the operations of initializing the processor registers and interrupts, starting the watchdog timers (used by the hardware to determine whether the software is still running), starting the real-time operating system and creating and starting the supervisor task. In the course of the initialization process the relay checks:

- The status of the battery
- The integrity of the battery backed-up SRAM that is used to store event, fault and disturbance records
- The voltage level of the field voltage supply which is used to drive the opto-isolated inputs
- The operation of the LCD controller
- The watchdog operation
- At the conclusion of the initialization software the supervisor task begins the process of starting the platform software. The checking that is made in the process of starting the co-processor board is as follows:
- A check is made for the presence of, and a valid response from, the co-processor board
- The SRAM on the co-processor board is checked with a test bit pattern before the co-processor code is transferred from the flash EPROM

Any of these checks which produces an error results in the co-processor board being left out of service and the relay relying on the other protection functions which are provided by the main processor board.

4.1.3 Platform software initialization & monitoring

In starting the platform software, the relay checks the integrity of the data held in non-volatile memory with a checksum, the operation of the real-time clock, and the IRIG-B board if fitted. The final test that is made concerns the input and output of data; the presence and healthy condition of the input board is checked and the analog data acquisition system is checked through sampling the reference voltage.

At the successful conclusion of all of these tests the relay is entered into service and the protection started-up.

4.2 Continuous self-testing

When the relay is in service, it continually checks the operation of the critical parts of its hardware and software. The checking is carried out by the system services software (see section on relay software earlier in this chapter) and the results reported to the platform software. The functions that are checked are as follows:

- The flash EPROM containing all program code and language text is verified by a checksum
- The code and constant data held in SRAM is checked against the corresponding data in flash EPROM to check for data corruption
- The SRAM containing all data other than the code and constant data is verified with a checksum
- The battery status
- The level of the 48V field voltage
- The integrity of the digital signal I/O data from the opto-isolated inputs and the relay contacts is checked by the data acquisition function every time it is executed. The operation of the analogue data acquisition system is continuously checked by the acquisition function every time it is executed, by means of sampling the reference voltages
- The operation of the IRIG-B board is checked, where it is fitted, by the software that reads the time and date from the board
- The operation of the Ethernet board is checked, where it is fitted, by the software on the main processor card. If the Ethernet board fails to respond an alarm is raised and the card is reset in an attempt to resolve the problem

In the unlikely event that one of the checks detects an error within the relay’s subsystems, the platform software is notified and it will attempt to log a maintenance record in battery backed-up SRAM. If the problem is with the battery status or the IRIG-B board, the relay will continue in operation. However, for problems detected in any other area the relay will initiate a shutdown and re-boot. This will result in a period of up to 5 seconds when the protection is unavailable, but the complete restart of the relay including all initializations should clear most problems that could occur. As described above, an integral part of the start-up procedure is a thorough diagnostic self-check. If this detects the same problem that caused the relay to restart, i.e. the restart has not cleared the problem, then the relay will take itself permanently out of service. This is indicated by the ‘Healthy’ LED on the front of the relay, which will extinguish, and the watchdog contact which will operate.

COMMISSIONING

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Date:	**7th August 2006**
Hardware Suffix:	**K**
Software Version:	**41 and 51**
Connection Diagrams:	**10P54302xx (xx = 01 to 02) & 10P54303xx (xx = 01 to 02)**
	10P54402xx (xx = 01 to 02) & 10P54403xx (xx = 01 to 02)
	10P54502xx (xx = 01 to 02) & 10P54503xx (xx = 01 to 02)
	10P54602xx (xx = 01 to 02) & 10P54603xx (xx = 01 to 02)

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FIGURES

1. INTRODUCTION

The P54x employs a high degree of self-checking and, in the unlikely event of a failure, will give an alarm. As a result of this, the commissioning tests do not need to be as extensive as with non-numeric electronic or electro-mechanical relays.

To commission numeric relays, it is only necessary to verify that the hardware is functioning correctly and the application-specific software settings have been applied to the relay. It is considered unnecessary to test every function of the relay if the settings have been verified by one of the following methods:

- Extracting the settings applied to the relay using appropriate setting software (preferred method)
- Via the operator interface

Unless previously agreed to the contrary, the customer will be responsible for determining the application-specific settings to be applied to the relay and for testing of any scheme logic applied by external wiring and/or configuration of the relay's internal programmable scheme logic.

Blank commissioning test and setting records are provided at the end of this chapter for completion as required.

As the relay's menu language is user-selectable, it is acceptable for the Commissioning Engineer to change it to allow accurate testing as long as the menu is restored to the customer's preferred language on completion.

To simplify the specifying of menu cell locations in these Commissioning Instructions, they will be given in the form [courier reference: COLUMN HEADING, Cell Text]. For example, the cell for selecting the menu language (first cell under the column heading) is located in the System Data column (column 00) so it would be given as [0001: SYSTEM DATA, Language].

Before carrying out any work on the equipment, the user should be familiar with the contents of the Safety Guide (SFTY/4L M/C11) or later issue, or the Safety and Technical Data sections of this Technical Manual and also the ratings on the equipment's rating label.

The MiCOM P54x relay must not be disassembled in any way during commissioning.

2. COMMISSIONING TESTS - RELAY FACILITIES

To help minimize the time required to test MiCOM relays the relay provides several test facilities under the 'COMMISSION TESTS' menu heading. There are menu cells which allow the status of the opto-isolated inputs, output relay contacts, internal digital data bus (DDB) signals and user-programmable LEDs to be monitored. Additionally there are cells to test the operation of the output contacts, user-programmable LEDs and, where available, the auto-reclose cycles.

The following table shows the relay menu of commissioning tests, including the available setting ranges and factory defaults:

Menu text	Default setting	DDB	Settings
COMMISSION TESTS			
Opto I/P Status			
Relay O/P Status			
Test Port Status			
LED Status			
Monitor Bit 1	1060: LED_CON_R1		0 to 1407 See Courier Database (P54x/EN GC) for details of digital data bus signals
Monitor Bit 2	1062: LED_CON_R2		
Monitor Bit 3	1064: LED_CON_R3		
Monitor Bit 4	1066: LED_CON_R4		
Monitor Bit 5	1068: LED_CON_R5		
Monitor Bit 6	1070 :LED_CON_R6		
Monitor Bit 7	1072: LED_CON_R7		
Monitor Bit 8	1074: LED_CON_R8		
Test Mode	Disabled		Disabled Test Mode Contacts Blocked
Test Pattern	All bits set to 0		0 = Not Operated 1 = Operated
Contact Test	No Operation		No Operation Apply Test Remove Test
Test LEDs	No Operation		No Operation Apply Test
Test Auto-reclose	No Operation		No Operation 3 Pole Test Pole A Test Pole B Test Pole C Test
Static Test	Disabled		Enabled, Disabled
Loopback Mode	Disabled		Disabled, Internal, External
IM64 TestPattern	All bits set to 0		0 = Not Operated 1 = Operated
IM64 Test Mode	Disabled		Disabled or Enabled

2.1 Opto I/P status

This menu cell displays the status of the relay's opto-isolated inputs as a binary string, a '1' indicating an energized opto-isolated input and a '0' a de-energized one. If the cursor is moved along the binary numbers the corresponding label text will be displayed for each logic input.

It can be used during commissioning or routine testing to monitor the status of the opto-isolated inputs whilst they are sequentially energized with a suitable dc voltage.

2.2 Relay O/P status

This menu cell displays the status of the digital data bus (DDB) signals that result in energization of the output relays as a binary string, a '1' indicating an operated state and '0' a non-operated state. If the cursor is moved along the binary numbers the corresponding label text will be displayed for each relay output.

The information displayed can be used during commissioning or routine testing to indicate the status of the output relays when the relay is 'in service'. Additionally fault finding for output relay damage can be performed by comparing the status of the output contact under investigation with its associated bit.

Note: When the 'Test Mode' cell is set to 'Contacts Blocked' this cell will continue to indicate which contacts would operate if the relay was in-service, it does not show the actual status of the output relays.

2.3 Test port status

This menu cell displays the status of the eight digital data bus (DDB) signals that have been allocated in the 'Monitor Bit' cells. If the cursor is moved along the binary numbers the corresponding DDB signal text string will be displayed for each monitor bit.

By using this cell with suitable monitor bit settings, the state of the DDB signals can be displayed as various operating conditions or sequences are applied to the relay. Thus the programmable scheme logic can be tested.

2.4 LED status

The 'LED Status' cell is an eight bit binary string that indicates which of the user-programmable LEDs on the relay are illuminated when accessing the relay from a remote location, a '1' indicating a particular LED is lit and a '0' not lit.

2.5 Monitor bits 1 to 8

The eight 'Monitor Bit' cells allow the user to select the status of which digital data bus signals can be observed in the 'Test Port Status' cell or via the monitor/download port. Each 'Monitor Bit' is set by entering the required digital data bus (DDB) signal number (0 – 1407) from the list of available DDB signals in the Courier Database (P54x/EN GC). The pins of the monitor/download port used for monitor bits are given in the table overleaf. The signal ground is available on pins 18, 19, 22 and 25.

Monitor Bit	1	2	3	4	5	6	7	8
Monitor/Download Port Pin	11	12	15	13	20	21	23	24

THE MONITOR/DOWNLOAD PORT DOES NOT HAVE ELECTRICAL ISOLATED AGAINST INDUCED VOLTAGES ON THE COMMUNICATIONS CHANNEL. IT SHOULD THEREFORE ONLY BE USED FOR LOCAL COMMUNICATIONS.

2.6 Test mode

This menu cell is to allow secondary injection testing to be performed on the relay. It also enables a facility to directly test the output contacts by applying menu controlled test signals. To select test mode the option 'Test Mode' should be selected. This takes the relay out of service causing an alarm condition to be recorded and the yellow 'Out of Service' LED to illuminate. This also freezes any information stored in the CB CONDITION column and in

IEC60870-5-103 builds changes the Cause of Transmission, COT, to Test Mode. However the output contacts are still active in this mode. To disable the output contacts in addition to the above select ‘Blocked’. Once testing is complete the cell must be set back to ‘Disabled’ to restore the relay back to service. Test mode can also be selected by energizing an opto mapped to the Test Mode signal.

WHEN THE ‘TEST MODE’ CELL IS SET TO ‘BLOCKED’ THE RELAY SCHEME LOGIC DOES NOT DRIVE THE OUTPUT RELAYS AND HENCE THE PROTECTION WILL NOT TRIP THE ASSOCIATED CIRCUIT BREAKER IF A FAULT OCCURS.

2.7 Test pattern

The ‘Test Pattern’ cell is used to select the output relay contacts that will be tested when the ‘Contact Test’ cell is set to ‘Apply Test’. The cell has a binary string with one bit for each user-configurable output contact which can be set to ‘1’ to operate the output under test conditions and ‘0’ to not operate it.

2.8 Contact test

When the ‘Apply Test’ command in this cell is issued the contacts set for operation (set to ‘1’) in the ‘Test Pattern’ cell change state. After the test has been applied the command text on the LCD will change to ‘No Operation’ and the contacts will remain in the Test State until reset issuing the ‘Remove Test’ command. The command text on the LCD will again revert to ‘No Operation’ after the ‘Remove Test’ command has been issued.

Note: When the ‘Test Mode’ cell is set to ‘Contacts Blocked’ the ‘Relay O/P Status’ cell does not show the current status of the output relays and hence can not be used to confirm operation of the output relays. Therefore it will be necessary to monitor the state of each contact in turn.

2.9 Test LEDs

When the ‘Apply Test’ command in this cell is issued the eight user-programmable LEDs will illuminate for approximately 2 seconds before they extinguish and the command text on the LCD reverts to ‘No Operation’.

2.10 Test auto-reclose

Where the relay provides an auto-reclose function, this cell will be available for testing the sequence of circuit breaker trip and auto-reclose cycles with the settings applied.

Issuing the command ‘3 Pole Trip’ will cause the relay to perform the first three phase trip/reclose cycle so that associated output contacts can be checked for operation at the correct times during the cycle. Once the trip output has operated the command text will revert to ‘No Operation’ whilst the rest of the auto-reclose cycle is performed. To test subsequent three phase auto-reclose cycles repeat the ‘3 Pole Trip’ command.

Similarly, where single pole auto-reclosing is available, the cycles for each single pole can be checked by sequentially issuing the ‘Pole A Test’, ‘Pole B Test’ or ‘Pole C Test’, as appropriate.

Note: The factory settings for the relay’s programmable scheme logic has the ‘AR Trip Test’ signal mapped to relay 3. If the programmable scheme logic has been changed, it is essential that this signal remains mapped to relay 3 for the ‘Test Auto-reclose’ facility to work.

2.11 Static test mode

Modern dynamic secondary injection test sets are able to accurately mimic real power system faults. The test sets mimic an instantaneous fault “shot”, with the real rate of rise of current, and any decaying DC exponential component, according to the point on (voltage) wave of fault inception. Injections for all three phases provide a six signal set of analog inputs: Va, Vb, Vc, Ia, Ib, Ic. Such injection test sets can be used with the P54x, with <u>no</u> special testing limitations.

- Conversely, older test sets may not properly simulate:
- A healthy prefault voltage memory
- A real fault shot (instead a gradually varying current or voltage may be used)
- The rate of rise of current and DC components
- A six signal set of analog inputs (instead, these may offer for example: Va, Vb, Ia, Ib only, to test for an A-B injection)

Such injection sets may be referred to as *"Static"* simulators.

As the P54x relies on voltage memories and delta step changes as would happen on a real power system, certain functions within the relay must be disabled or bypassed to allow injection testing. Selecting the "**Static Mode**" test option serves to bypass the delta phase selectors, and power swing detection.

For the tests, the delta directional line is also replaced by a conventional distance directional line, and the digital filtering slows to use a fixed one cycle window. Memory polarizing is replaced by cross-polarizing from unfaulted phases.

The Static Test mode allows older injection test sets to be retained, and used to commission and test the P54x.

Note: Trip times may be up to ½ cycle longer when tested in the static mode, due to the nature of the test voltage and current, and the slower filtering. This is normal, and perfectly acceptable.

2.12 Loopback mode

If the P54x relay is used as a current differential relay, i.e. [090F Phase Diff] within [09 CONFIGURATION] is enabled, the loopback test facilities provide to the user with the ability to check the current differential protection. On the other hand, if the P54x relay is not used as a current differential relay, i.e. [090F Phase Diff] is disabled and [0941 InterMiCOM^{64} Fiber] is enabled within [09 CONFIGURATION], the loopback test facilities, provide to the user with the ability to check the InterMiCOM^{64} signaling.

Note that by selecting the [0F13 Loopback Mode] to "Internal", only the internal software of the relay is checked whereas "External" will check both the software and hardware.

When relay is switched into either 'Loopback Mode', the relay will automatically use generic addresses (address 0-0) and will respond as if it is connected to a remote relay with the current at the remote end equal to and in phase with the current injected at the local end. The signals sent and received (IM64) continue to be from and to the signals defined in the programmable logic.

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2.13 IM64 test pattern

The 'IM64Test Pattern' cell is used to set the DDB signals (included in the User Defined Inter-Relay Commands) that will be tested when the 'IM64 Test Mode' cell is set to 'Enable'. The cell has a binary string with one bit for each User Defined Inter-Relay Commands which can be set to '1' to operate the IM64 output under test conditions and '0' to not operate it.

2.14 IM64 test mode

When the 'Enable" command in this cell is issued the DDB set for operation (set to '1') in the 'Test Pattern' cell change state.

2.15 Using a monitor/download port test box

A monitor/download port test box containing 8 LED's and a switchable audible indicator is available. It is housed in a small plastic box with a 25-pin male D-connector that plugs directly into the relay's monitor/download port. There is also a 25-pin female D-connector which allows other connections to be made to the monitor/download port whilst the monitor/download port test box is in place.

Each LED corresponds to one of the monitor bit pins on the monitor/download port with ‘Monitor Bit 1’ being on the left hand side when viewing from the front of the relay. The audible indicator can either be selected to sound if a voltage appears any of the eight monitor pins or remain silent so that indication of state is by LED alone.

3. SETTING FAMILIARIZATION

When commissioning a relay P54x for the first time, sufficient time should be allowed to become familiar with the method by which the settings are applied.

The Introduction (P54x/EN GS) contains a detailed description of the menu structure of P54x relays.

With the secondary front cover in place all keys except the ↵ key are accessible. All menu cells can be read. LEDs and alarms can be reset. However, no protection or configuration settings can be changed, or fault and event records cleared.

Removing the secondary front cover allows access to all keys so that settings can be changed, LEDs and alarms reset, and fault and event records cleared. However, menu cells that have access levels higher than the default level will require the appropriate password to be entered before changes can be made.

Alternatively, if a portable PC is available together with suitable setting software (such as MiCOM S1), the menu can be viewed a page at a time to display a full column of data and text. This PC software also allows settings to be entered more easily, saved to a file on disk for future reference or printed to produce a setting record. Refer to the PC software user manual for details. If the software is being used for the first time, allow sufficient time to become familiar with its operation.

4. EQUIPMENT REQUIRED FOR COMMISSIONING

4.1 Minimum equipment required

Multifunctional dynamic current and voltage injection test set.

Multimeter with suitable ac current range, and ac and dc voltage ranges of 0 - 440V and 0 - 250V respectively.

Continuity tester (if not included in multimeter).

Phase angle meter.

Phase rotation meter.

Note: Modern test equipment may contain many of the above features in one unit.

4.2 Optional equipment

Multi-finger test plug type P992 (if test block type P991 installed) or MMLB (if using MMLG blocks).

An electronic or brushless insulation tester with a dc output not exceeding 500V (for insulation resistance testing when required).

A portable PC, with appropriate software (this enables the rear communications port to be tested, if this is to be used, and will also save considerable time during commissioning).

KITZ K-Bus to EIA(RS)232 protocol converter (if EIA(RS)485 K-Bus port is being tested and one is not already installed).

EIA(RS)485 to EIA(RS)232 converter (if EIA(RS)485 MODBUS port is being tested).

A printer (for printing a setting record from the portable PC).

5. PRODUCT CHECKS

These product checks cover all aspects of the relay which should be checked to ensure that it has not been physically damaged prior to commissioning, is functioning correctly and all input quantity measurements are within the stated tolerances.

If the application-specific settings have been applied to the relay prior to commissioning, it is advisable to make a copy of the settings so as to allow their restoration later. This could be done by:

– Obtaining a setting file on a diskette from the customer (this requires a portable PC with appropriate setting software for transferring the settings from the PC to the relay)

– Extracting the settings from the relay itself (this again requires a portable PC with appropriate setting software)

– Manually creating a setting record. This could be done using a copy of the setting record located at the end of this chapter to record the settings as the relay's menu is sequentially stepped through via the front panel user interface

If password protection is enabled and the customer has changed password 2 that prevents unauthorized changes to some of the settings, either the revised password 2 should be provided, or the customer should restore the original password prior to commencement of testing.

Note: In the event that the password has been lost, a recovery password can be obtained from Schneider Electric by quoting the serial number of the relay. The recovery password is unique to that relay and is unlikely to work on any other relay.

5.1 With the relay de-energized

The following group of tests should be carried out without the auxiliary supply being applied to the relay and with the trip circuit isolated.

The current and voltage transformer connections must be isolated from the relay for these checks. If a P991 test block is provided, the required isolation can easily be achieved by inserting test plug type P992 that effectively open-circuits all wiring routed through the test block.

Before inserting the test plug, reference should be made to the scheme (wiring) diagram to ensure that this will not potentially cause damage or a safety hazard. For example, the test block may be associated with protection current transformer circuits. It is essential that the sockets in the test plug, which correspond to the current transformer secondary windings, are linked before the test plug is inserted into the test block.

DANGER: Never open circuit the secondary circuit of a current transformer since the high voltage produced may be lethal and could damage insulation.

If a test block is not provided, the voltage transformer supply to the relay should be isolated by means of the panel links or connecting blocks. The line current transformers should be short-circuited and disconnected from the relay terminals. Where means of isolating the auxiliary supply and trip circuit (e.g. isolation links, fuses, MCB, etc.) are provided, these should be used. If this is not possible, the wiring to these circuits will have to be disconnected and the exposed ends suitably terminated to prevent them from being a safety hazard.

5.1.1 Visual inspection

The rating information given under the top access cover on the front of the relay should be checked. Check that the relay being tested is correct for the protected line/circuit. Ensure that the circuit reference and system details are entered onto the setting record sheet. Double-check the CT secondary current rating, and be sure to record the actual CT tap which is in use.

Carefully examine the relay to see that no physical damage has occurred since installation.

Ensure that the case earthing connections, bottom left-hand corner at the rear of the relay case, are used to connect the relay to a local earth bar using an adequate conductor.

5.1.2 Current transformer shorting contacts (optional check)

If required, the current transformer shorting contacts can be checked to ensure that they close when the heavy duty terminal block (block reference C in Figure 1) is disconnected from the current input PCB.

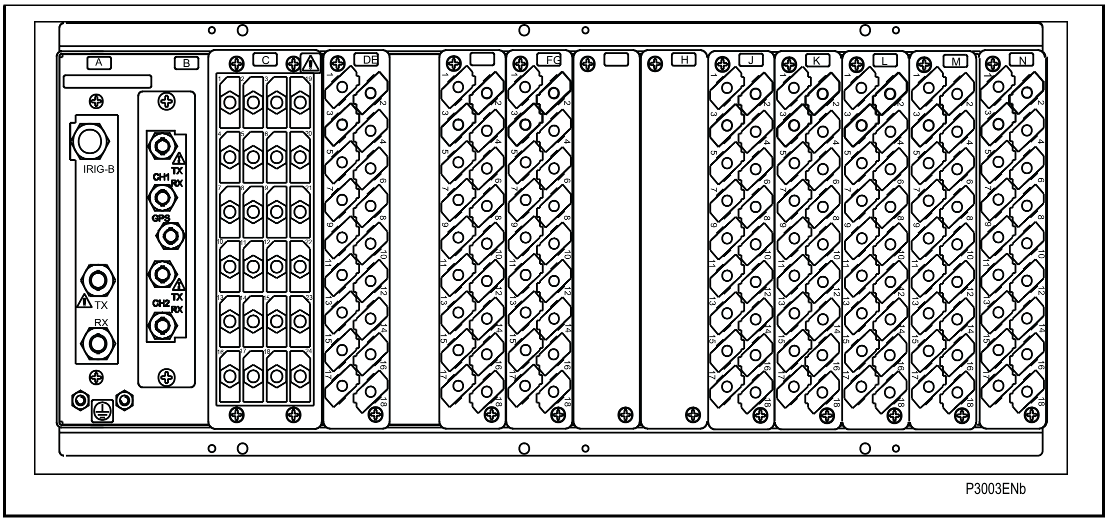

Figure 1: Rear terminal blocks on size 80TE case

The heavy duty terminal block is fastened to the rear panel using four crosshead screws. These are located top and bottom between the first and second, and third and fourth, columns of terminals (see Figure 2).

Note: The use of a magnetic bladed screwdriver is recommended to minimize the risk of the screws being left in the terminal block or lost.

Pull the terminal block away from the rear of the case and check with a continuity tester that all the shorting switches being used are closed. The table shows the terminals between which shorting contacts are fitted.

Current Input	Shorting Contact Between Terminals			
	P543	P544	P545	P546
	1A - Common - 5A			
IA	C3 - C2 - C1	C3 - C2 – C1	D3 - D2 - D1	D3 - D2 - D1
IB	C6 - C5 - C4	C6 - C5 - C4	D6 - D5 - D4	D6 - D5 - D4
IC	C9 - C8 - C7	C9 - C8 - C7	D9 - D8 - D7	D9 - D8 - D7
IA (CT2)	Not applicable	E3 - E2 - E1	Not applicable	F3 - F2 - F1
IB (CT2)	Not applicable	E6 - E5 - E4	Not applicable	F6 - F5 - F4
IC (CT2)	Not applicable	E9 - E8 - E7	Not applicable	F9 - F8 - F7
ISEF	C15 - C14 - C13	C15 - C14 - C13	D15 - D14 - D13	D15 - D14 - D13
IM	C12 - C11 - C10	C12 - C11 - C10	D12 - D11 - D10	D12 - D11 - D10

Table 1: Current transformer shorting contact locations

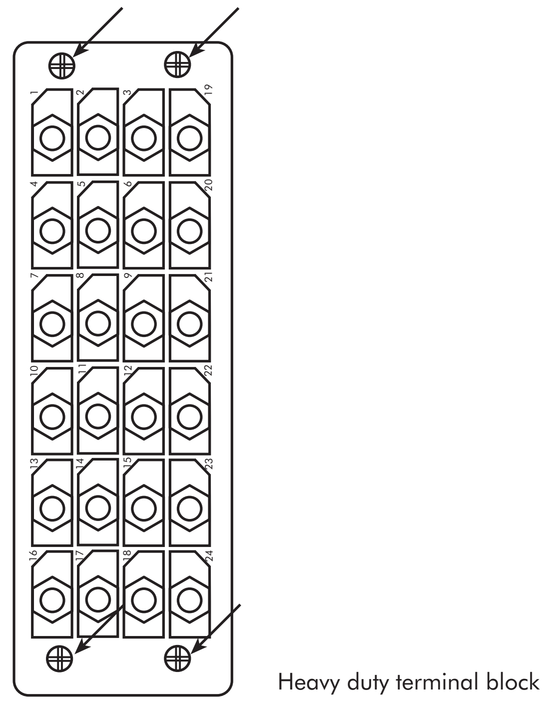

Figure 2: Location of securing screws for heavy duty terminal blocks

5.1.3 Insulation

Insulation resistance tests are only necessary during commissioning if it is required for them to be done and they have not been performed during installation.

Isolate all wiring from the earth and test the insulation with an electronic or brushless insulation tester at a dc voltage not exceeding 500V. Terminals of the same circuits should be temporarily connected together.

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The main groups of relay terminals are:

a) Voltage transformer circuits

b) Current transformer circuits

c) Auxiliary voltage supply

d) Field voltage output and opto-isolated control inputs

e) Relay contacts

f) EIA(RS)485 communication port

g) Case earth

The insulation resistance should be greater than 100MΩ at 500V.

On completion of the insulation resistance tests, ensure all external wiring is correctly reconnected to the relay.

5.1.4 External wiring

Check that the external wiring is correct to the relevant relay diagram and scheme diagram. Ensure as far as practical that phasing/phase rotation appears to be as expected. The relay diagram number appears on the rating label under the top access cover on the front of the relay.

If a P991 test block is provided, the connections should be checked against the scheme (wiring) diagram. It is recommended that the supply connections are to the live side of the test block colored orange with the odd numbered terminals (1, 3, 5, 7 etc.). The auxiliary supply is normally routed via terminals 13 (supply positive) and 15 (supply negative), with terminals 14 and 16 connected to the relay's positive and negative auxiliary supply terminals respectively. However, check the wiring against the schematic diagram for the installation to ensure compliance with the customer's normal practice.

5.1.5 Watchdog contacts

Using a continuity tester, check that the watchdog contacts are in the states given in the table below for a de-energized relay.

Terminals		Contact State	
		Relay De-energized	Relay Energized
J11 - J12	(P543 & P544)	Closed	Open
J13 - J14	(P543 & P544)	Open	Closed
M11 - M12	(P545 & P546)	Closed	Open
M13 - M14	(P545 & P546)	Open	Closed

Table 2: Watchdog contact status

5.1.6 Auxiliary supply

The relay can be operated from either a dc only or AC/DC auxiliary supply depending on the relay's nominal supply rating. The incoming voltage must be within the operating range specified in the table below.

Without energizing the relay measure the auxiliary supply to ensure it is within the operating range.

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Nominal Supply Rating DC [AC rms]		DC Operating Range	AC Operating Range
24 - 48V	[-]	19 to 65V	-
48 - 110V	[30 - 100V]	37 to 150V	24 - 110V
125 - 250V	[100 - 240V]	87 to 300V	80 to 265V

Table 3: Operational range of auxiliary supply Vx

It should be noted that the relay can withstand an ac ripple of up to 12% of the upper rated voltage on the dc auxiliary supply.

Do not energize the relay or interface unit using the battery charger with the battery disconnected as this can irreparably damage the relay's power supply circuitry.

Energize the relay only if the auxiliary supply is within the specified operating ranges. If a test block is provided, it may be necessary to link across the front of the test plug to connect the auxiliary supply to the relay.

5.2 With the relay energized

The following group of tests verifies that the relay hardware and software is functioning correctly and should be carried out with the auxiliary supply applied to the relay.

The current and voltage transformer connections must remain isolated from the relay for these checks. The trip circuit should also remain isolated to prevent accidental operation of the associated circuit breaker. The InterMiCOM^{64} communication channel (where fitted) should be disconnected to prevent the remote end relay being affected during the tests.

5.2.1 Watchdog contacts

Using a continuity tester, check the watchdog contacts are in the states given in Table 2 for an energized relay.

5.2.2 LCD front panel display

The liquid crystal display is designed to operate in a wide range of substation ambient temperatures. For this purpose, the Px40 relays have an "*LCD Contrast*" setting. This allows the user to adjust how light or dark the characters displayed will be. The contrast is factory pre-set to account for a standard room temperature, however it may be necessary to adjust the contrast to give the best in-service display. To change the contrast, cell [09FF: LCD Contrast] at the bottom of the CONFIGURATION column can be incremented (darker) or de-cremented (lighter), as required.

<u>Care</u>: Before applying a contrast setting, ensure that it will not render the display too light or dark such that menu text becomes unreadable. Should such a mistake be made, it is possible to restore a visible display by downloading a MiCOM S1 setting file, with the LCD Contrast set within the typical range of 7 - 11.

5.2.3 Date and time

Before setting the date and time, ensure that the factory-fitted battery isolation strip, that prevents battery drain during transportation and storage, has been removed. With the lower access cover open, presence of the battery isolation strip can be checked by a red tab protruding from the positive side of the battery compartment. Whilst lightly pressing the battery, to prevent it from falling out of the battery compartment, pull the red tab to remove the isolation strip.

The date and time should now be set to the correct values. The method of setting will depend on whether accuracy is being maintained via the optional Inter-Range Instrumentation Group standard B (IRIG-B) port on the rear of the relay.

5.2.3.1 With an IRIG-B signal

If a satellite time clock signal conforming to IRIG-B is provided and the relay has the optional IRIG-B port fitted, the satellite clock equipment should be energized.

To allow the relay's time and date to be maintained from an external IRIG-B source cell [0804: DATE and TIME, IRIG-B Sync.] must be set to 'Enabled'.

Ensure the relay is receiving the IRIG-B signal by checking that cell [0805: DATE and TIME, IRIG-B Status] reads 'Active'.

Once the IRIG-B signal is active, adjust the time offset of the universal co-coordinated time (satellite clock time) on the satellite clock equipment so that local time is displayed.

Check the time, date and month are correct in cell [0801: DATE and TIME, Date/Time]. The IRIG-B signal does not contain the current year so it will need to be set manually in this cell.

In the event of the auxiliary supply failing, with a battery fitted in the compartment behind the bottom access cover, the time and date will be maintained. Therefore, when the auxiliary supply is restored, the time and date will be correct and not need to be set again.

To test this, remove the IRIG-B signal, and then remove the auxiliary supply from the relay. Leave the relay de-energized for approximately 30 seconds. On re-energization, the time in cell [0801: DATE and TIME, Date/Time] should be correct.

Reconnect the IRIG-B signal.

5.2.3.2 Without an IRIG-B signal

If the time and date is not being maintained by an IRIG-B signal, ensure that cell [0804: DATE and TIME, IRIG-B Sync.] is set to 'Disabled'.

Set the date and time to the correct local time and date using cell [0801: DATE and TIME, Date/Time].

In the event of the auxiliary supply failing, with a battery fitted in the compartment behind the bottom access cover, the time and date will be maintained. Therefore when the auxiliary supply is restored the time and date will be correct and not need to be set again.

To test this, remove the auxiliary supply from the relay for approximately 30 seconds. On re-energization, the time in cell [0801: DATE and TIME, Date/Time] should be correct.

5.2.4 Light emitting diodes (LEDs)

On power up the green LED should have illuminated and stayed on indicating that the relay is healthy. The relay has non-volatile memory which remembers the state (on or off) of the alarm, trip and, if configured to latch, user-programmable LED indicators when the relay was last energized from an auxiliary supply. Therefore these indicators may also illuminate when the auxiliary supply is applied.

If any of these LEDs are on then they should be reset before proceeding with further testing. If the LEDs successfully reset (the LED goes out), there is no testing required for that LED because it is known to be operational.

Note: It is likely that alarms related to the communications channels will not reset at this stage.

5.2.4.1 Testing the alarm and out of service LEDs

The alarm and out of service LEDs can be tested using the COMMISSION TESTS menu column. Set cell [0F0D: COMMISSION TESTS, Test Mode] to 'Contacts Blocked'. Check that the out of service LED illuminates continuously and the alarm LED flashes.

It is not necessary to return cell [0F0D: COMMISSION TESTS, Test Mode] to 'Disabled' at this stage because the test mode will be required for later tests.

5.2.4.2 Testing the trip LED

The trip LED can be tested by initiating a manual circuit breaker trip from the relay. However, the trip LED will operate during the setting checks performed later. Therefore no further testing of the trip LED is required at this stage.

5.2.4.3 Testing the user-programmable LEDs

To test the user-programmable LEDs set cell [0F10: COMMISSION TESTS, Test LEDs] to ‘Apply Test’. Check that all 8 LED’s on the right-hand side of the relay illuminate.

5.2.5 Field voltage supply

The relay generates a field voltage of nominally 48V that can be used to energize the opto-isolated inputs (alternatively the substation battery may be used).

Measure the field voltage voltage across the terminals 7 and 9 on the terminal block given in the table below. Check that the field voltage is within the range 40V to 60V when no load is connected and that the polarity is correct.

Repeat for terminals 8 and 10.

Supply Rail	Terminals
	P54x
+ve	J7 & 8 - (P543 & P544)
–ve	J9 & J10 - (P543 & P544)
+ve	M7 & 8 - (P543 & P544)
–ve	M9 & M10 - (P543 & P544)

Table 4: Field voltage terminals

5.2.6 Input opto-isolators

This test checks that all the opto-isolated inputs on the relay are functioning correctly.

– P543 and P544 have 16 opto inputs

– P545 and P546 have 24 opto inputs

The opto-isolated inputs should be energized one at a time, see external connection diagrams (P54x/EN IN) for terminal numbers. Ensuring correct polarity, connect the field supply voltage to the appropriate terminals for the input being tested.

Note: The opto-isolated inputs may be energized from an eternal dc auxiliary supply (e.g. the station battery) in some installations. Check that this is not the case before connecting the field voltage otherwise damage to the relay may result.

The status of each opto-isolated input can be viewed using either cell [0020: SYSTEM DATA, Opto I/P Status] or [0F01: COMMISSION TESTS, Opto I/P Status], a ‘1’ indicating an energized input and a ‘0’ indicating a de-energized input. When each opto-isolated input is energized one of the characters on the bottom line of the display will change to indicate the new state of the inputs.

5.2.7 Output relays

This test checks that all the output relays are functioning correctly.

– P543 and P544 have 14 relay outputs

– P545 and P546 have 32 relay outputs

Ensure that the relay is still in test mode by viewing cell [0F0D: COMMISSION TESTS, Test Mode] to ensure that it is set to ‘Blocked’.

The output relays should be energized one at a time. To select output relay 1 for testing, set cell [0F0E: COMMISSION TESTS, Test Pattern] as appropriate.

Connect a continuity tester across the terminals corresponding to output relay 1 as given in external connection diagram (P54x/EN IN).

To operate the output relay set cell [0F0F: COMMISSION TESTS, Contact Test] to 'Apply Test'. Operation will be confirmed by the continuity tester operating for a normally open contact and ceasing to operate for a normally closed contact. Measure the resistance of the contacts in the closed state.

Reset the output relay by setting cell [0F0F: COMMISSION TESTS, Contact Test] to 'Remove Test'.

Note: It should be ensured that thermal ratings of anything connected to the output relays during the contact test procedure are not exceeded by the associated output relay being operated for too long. It is therefore advised that the time between application and removal of the contact test is kept to the minimum.

Repeat the test for the remaining relays.

Return the relay to service by setting cell [0F0D: COMMISSION TESTS, Test Mode] to 'Disabled'.

5.2.8 Rear communications port

This test should only be performed where the relay is to be accessed from a remote location and will vary depending on the communications standard being adopted.

It is not the intention of the test to verify the operation of the complete system from the relay to the remote location, just the relay's rear communications port and any protocol converter necessary.

5.2.8.1 Courier communications

If a K-Bus to EIA(RS)232 KITZ protocol converter is installed, connect a portable PC running the appropriate software to the incoming (remote from relay) side of the protocol converter. The terminal numbers for the relay's K-Bus port are given in the table below.

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Connection		**Terminal**
K-Bus	IEC60870-5-103 or DNP3.0	P54x
Screen	Screen	N16 - (P545, P546)
1	+ve	N17 - (P545, P546)
2	–ve	N18 - (P545, P546)
Screen	Screen	J16 - (P543, P544)
1	+ve	J17 - (P543, P544)
2	–ve	J18 - (P543, P544)
Screen	Screen	F16 - (P543, P544)

Table 5: EIA(RS)485 terminals

Ensure that the communications baud rate and parity settings in the application software are set the same as those on the protocol converter (usually a KITZ but could be a SCADA RTU). The relays courier address in cell [0E02: COMMUNICATIONS, Remote Access] must be set to a value between 1 and 254.

Check that communications can be established with this relay using the portable PC.

5.2.8.2 IEC60870-5-103 (VDEW) communications

If the relay has the optional fiber optic communications port fitted, the port to be used should be selected by setting cell [0E07: COMMUNICATIONS, Physical Link] to 'Fiber Optic'.

IEC60870-5-103/VDEW communication systems are designed to have a local Master Station and this should be used to verify that the relay's fiber optic or EIA(RS)485 port, as appropriate, is working.

Ensure that the relay address and baud rate settings in the application software are set the same as those in cell [0E04: COMMUNICATIONS, Baud Rate] of the relay.

Check that, using the Master Station, communications with the relay can be established.

5.2.8.3 DNP3.0 interface

Connect a portable PC running the appropriate DNP3.0 software to the relay's EIA(RS)485 port via an EIA(RS)232 interface converter. The terminal numbers for the relay's EIA(RS)485 port are given in Table 5. Ensure that the relay address, baud rate and parity are set the same as those in cells [0E04: COMMUNICATIONS, Baud Rate] and [0E05: COMMUNICATIONS, Parity] of the relay.

Check that communications with this relay can be established.

5.2.9 Second rear communications port

This test should only be performed where the relay is to be accessed from a remote location and will vary depending on the communications standard being adopted.

It is not the intention of the test to verify the operation of the complete system from the relay to the remote location, just the relays rear communications port and any protocol converter necessary.

5.2.9.1 K-Bus configuration

If a K-Bus to EIA(RS)232 KITZ protocol converter is installed, connect a portable PC running the appropriate software (e.g. MiCOM S1 or PAS&T) to the incoming (remote from relay) side of the protocol converter.

If a KITZ protocol converter is not installed, it may not be possible to connect the PC to the relay installed. In this case a KITZ protocol converter and portable PC running appropriate software should be temporarily connected to the relays second rear communications port configured for K-Bus. The terminal numbers for the relays K-Bus port are given in Table 6. However, as the installed protocol converter is not being used in the test, only the correct operation of the relays K-Bus port will be confirmed.

Pin*	Connection
4	EIA(RS)485 - 1 (+ ve)
7	EIA(RS)485 - 2 (- ve)

Table 6: 2nd rear communications port K-Bus terminals

* - All other pins unconnected.

Ensure that the communications baud rate and parity settings in the application software are set the same as those on the protocol converter (usually a KITZ but could be a SCADA RTU). The relays courier address in cell [0E90: COMMUNICATIONS, RP2 Address] must be set to a value between 1 and 254. The second rear communications port configuration [0E88: COMMUNICATIONS RP2 Port Config.] must be set to K-Bus.

Check that communications can be established with this relay using the portable PC.

5.2.9.2 EIA(RS)485 configuration

If an EIA(RS)485 to EIA(RS)232 converter (Schneider Electric CK222) is installed, connect a portable PC running the appropriate software (e.g. MiCOM S1) to the EIA(RS)232 side of the converter and the second rear communications port of the relay to the EIA(RS)485 side of the converter.

The terminal numbers for the relays EIA(RS)485 port are given in Table 6.

Ensure that the communications baud rate and parity settings in the application software are set the same as those in the relay. The relays courier address in cell [0E90: COMMUNICATIONS, RP2 Address] must be set to a value between 1 and 254. The second rear communications port configuration [0E88: COMMUNICATIONS RP2 Port Config.] must be set to EIA(RS)485.

Check that communications can be established with this relay using the portable PC.

5.2.9.3 EIA(RS)232 configuration

Connect a portable PC running the appropriate software (e.g. MiCOM S1) to the rear EIA(RS)232[1] port of the relay.

The second rear communications port connects via the 9-way female D-type connector (SK4). The connection is compliant to EIA(RS)574.

Pin	Connection
1	No Connection
2	RxD
3	TxD
4	DTR#
5	Ground
6	No Connection
7	RTS#
8	CTS#
9	No Connection

Table 7: Second rear communications port EIA(RS)232 terminals

- These pins are control lines for use with a modem.

Connections to the second rear port configured for EIA(RS)232 operation can be made using a screened multi-core communication cable up to 15m long, or a total capacitance of 2500pF. The cable should be terminated at the relay end with a 9-way, metal shelled, D-type male plug. The terminal numbers for the relays EIA(RS)232 port are given in Table 7.

Ensure that the communications baud rate and parity settings in the application software are set the same as those in the relay. The relays courier address in cell [0E90: COMMUNICATIONS, RP2 Address] must be set to a value between 1 and 254. The second rear communications port configuration [0E88: COMMUNICATIONS RP2 Port Config.] must be set to EIA(RS)232.

Check that communications can be established with this relay using the portable PC.

[1] This port is actually compliant to EIA(RS)574; the 9-pin version of EIA(RS)232, see www.tiaonline.org.

5.2.10 Current inputs

This verifies that the accuracy of current measurement is within the acceptable tolerances.

All relays will leave the factory set for operation at a system frequency of 50Hz. If operation at 60Hz is required then this must be set in cell [0009: SYSTEM DATA, Frequency].

Apply current equal to the line current transformer secondary winding rating to each current transformer input of the corresponding rating in turn, see Table 1 or external connection diagram (P54x/EN IN) for appropriate terminal numbers, checking its magnitude using a multimeter/test set readout. The corresponding reading can then be checked in the relay's MEASUREMENTS 1 column and value displayed recorded.

The measured current values displayed on the relay LCD or a portable PC connected to the front communication port will either be in primary or secondary Amperes. If cell [0D02: MEASURE'T SETUP, Local Values] is set to 'Primary', the values displayed should be equal to the applied current multiplied by the corresponding current transformer ratio set in the 'CT and VT RATIOS' menu column (see Table 8). If cell [0D02: MEASURE'T SETUP, Local Values] is set to 'Secondary', the value displayed should be equal to the applied current.

Note: If a PC connected to the relay via the rear communications port is being used to display the measured current, the process will be similar. However, the setting of cell [0D03: MEASURE'T SETUP, Remote Values] will determine whether the displayed values are in primary or secondary Amperes. The measurement accuracy of the relay is ±1%. However, an additional allowance must be made for the accuracy of the test equipment being used.

Current Input	**Shorting Contact Between Terminals**			
	P543	**P544**	**P545**	**P546**
	1A - Common - 5A			
I_A	C3 - C2 - C1	C3 - C2 - C1	D3 - D2 - D1	D3 - D2 - D1
I_B	C6 - C5 - C4	C6 - C5 - C4	D6 - D5 - D4	D6 - D5 - D4
I_C	C9 - C8 - C7	C9 - C8 - C7	D9 - D8 - D7	D9 - D8 - D7
I_A (CT2)	Not applicable	E3 - E2 - E1	Not applicable	F3 - F2 - F1
I_B (CT2)	Not applicable	E6 - E5 - E4	Not applicable	F6 - F5 - F4
I_C (CT2)	Not applicable	E9 - E8 - E7	Not applicable	F9 - F8 - F7
I_{SEF}	C15 - C14 - C13	C15 - C14 - C13	D15 - D14 - D13	D15 - D14 - D13
I_M	C12 - C11 - C10	C12 - C11 - C10	D12 - D11 - D10	D12 - D11 - D10

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Cell in MEASUREMENTS 1 Column (02)	**Corresponding CT Ratio (in 'CT and VT RATIOS' Column(0A) of Menu)**
[0201: IA Magnitude] [0203: IB Magnitude [0205: IC Magnitude]	$\frac{\text{[0A07 : Phase CT Primary]}}{\text{[0A08 : Phase CT Secondary]}}$
[0232: IM Magnitude]	$\frac{\text{[0A0D : MC amp CT Primary]}}{\text{[0A0E : MC amp CT Secondary]}}$
[020B: ISEF Magnitude]	$\frac{\text{[0A0B : SEF amp CT Primary]}}{\text{[0A0C : SEF amp CT Secondary]}}$

Table 8: CT ratio settings

5.2.11 Voltage inputs

This test verifies that the accuracy of voltage measurement is within the acceptable tolerances.

Apply rated voltage to each voltage transformer input in turn, checking its magnitude using a multimeter/test set readout. Refer to the table below for the corresponding reading in the relay's MEASUREMENTS 1 column and record the value displayed.

	Voltage Applied to P543 & P544	**Voltage Applied to P545 & P546**
Cell in MEASUREMENTS 1 column		
[021A: VAN Magnitude]	C19 - C22	D19 - D22
[021C: VBN Magnitude]	C20 - C22	D20 - D22
[021E: VCN Magnitude]	C21 - C22	D21 - D22
[022E: C/S Voltage Mag]	C23 - C24	D23 - D24

Table 9: Voltage input terminals

The measured voltage values on the relay LCD or a portable PC connected to the front communication port will either be in primary or secondary volts. If cell [0D02: MEASURE'T SETUP, Local Values] is set to 'Primary', the values displayed should be equal to the applied voltage multiplied by the corresponding voltage transformer ratio set in the 'VT and CT RATIOS' menu column (see Table 10). If cell [0D02: MEASURE'T SETUP, Local Values] is set to 'Secondary', the value displayed should be equal to the applied voltage.

Note: If a PC connected to the relay via the rear communications port is being used to display the measured voltage, the process will be similar. However, the setting of cell [0D03: MEASURE'T SETUP, Remote Values] will determine whether the displayed values are in primary or secondary Volts.

The measurement accuracy of the relay is ±1%. However, an additional allowance must be made for the accuracy of the test equipment being used.

Cell in MEASUREMENTS 1 Column (02)	**Corresponding CT Ratio (in 'CT and VT RATIOS' Column (0A) of Menu)**
[021A: VAN Magnitude] [021C: VBN Magnitude] [021E: VCN Magnitude]	$\frac{\text{[0A01 : Main VT Primary]}}{\text{[0A02 : Main VT Secondary]}}$
[022E: C/S Voltage Mag]	$\frac{\text{[0A03 : C/S VT Primary]}}{\text{[0A04 : C/S VT Secondary]}}$

Table 10: Voltage ratio settings

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5.3 Fiber communications

This test verifies that the relay's current differential (or Fiber InterMiCOM^{64}) fiber optic communications ports and, if installed, P590 interface units, used for communications between the P54x current differential relays at each end of the feeder being protected, are operating correctly.

A P590 unit will be situated near the multiplexer in applications where communications between P54x relays is via multiplexed communication channels and the PCM multiplexer is installed remote from the relay room. This unit provides bi-directional optical to electrical signal conversion between the cross-site optical fiber from the relay and the electrical interface of the multiplexer.

The method of testing is similar whether communications between relays is via dedicated optical fibers or using a P590 unit to interface the relay's fiber optic communications channel to a multiplexer. However, where P590 interface units are being used, there are a number of extra tests on the P590 units that need to be performed before testing of the communications can begin.

When connecting or disconnecting optical fibers care should be taken not to look directly into the transmit port or end of the optical fiber.

5.3.1 Direct fiber optic communications

Set cell [0F13 Test Loopback] to 'External'.

Using a length of fiber optic cable, refer to the Installation chapter (P54x/EN IN/XXX), terminated with a ST connector at each end, connect the Channel 1 transmit (Tx) and Channel 1 receive (Rx) ports on the rear of the relay together. If Channel 2 is being used (Three terminal or dual redundant application) connect the Channel 2 transmit and receive ports on the rear of the relay together. The relay will now respond as if it is connected to a remote relay with the current at the remote end equal to and in phase with the current injected at the local end (without currents in the case of fiber InterMiCOM^{64}). Reset any alarm indications and check that no further communications failure alarms are raised. The relay will indicate a loopback alarm which can only be cleared by setting the loopback to disabled.

Set cell [0F15 IM64 Test Mode] to 'Enabled', cell [0F14 IM64 TestPattern] to 'Enabled' and set any Test pattern. To verify the correct operation of loopback test, check in [MEASUREMENTS 4] column that cell 'IM64 Rx Status' matches with the Test Pattern. The communication statistics will indicate the number of valid and any errored messages received, note that the propagation delay measurement will not be valid in this mode of operation.

Alternatively use the internal loopback feature by setting cell [0F13 Test Loopback] to 'Internal Loop' and repeat the above test. In this mode it is not necessary to change the fiber.

Note in loopback mode the signals sent and received via the InterMiCOM^{64} interface continue to be from and to the signals defined in the programmable logic.

Note that a test pattern can be also sent to the remote end in order to test the whole InterMiCOM^{64} communication path by enabling [OF15 IM64 Test Mode] and connecting two ends. If such a test is performed, special care has to be taken as the test pattern will be executed via PSL at the remote end.

Alternatively use the internal loopback feature by setting cell [0F13 Test Loopback] to 'Internal'. In this mode it is not necessary to change the fiber.

5.3.2 Communications using P591 interface units

The P591 converts the optical output of the P54x relay to an electrical signal for a PCM multiplexer with G.703 interfaces. The unit is housed in a size 20TE case and should be located near to the multiplexer.

Before loopback testing can begin, some other checks must be completed.

5.3.2.1 Visual inspection

Carefully examine the unit to see that no physical damage has occurred since installation.

The rating information given under the top access cover on the front of the unit should be checked to ensure it is correct for the particular installation.

Ensure that the case earthing connection, top left-hand corner at the rear of the case, is used to connect the unit to a local earth bar using an adequate conductor.

5.3.2.2 Insulation

Insulation resistance tests are only necessary during commissioning if it is required for them to be done and they haven't been performed during installation.

Isolate all wiring from the earth and test the insulation with an electronic or brushless insulation tester at a dc voltage not exceeding 500V. The auxiliary dc supply terminals should be temporarily connected together.

The insulation resistance should be greater than 100MΩ at 500V.

On completion of the insulation resistance tests, ensure all external wiring is correctly reconnected to the P591.

5.3.2.3 External wiring

Check that the external wiring is correct to the relevant connection diagram or scheme diagram. The connection diagram number appears on the rating label under the top access cover on the front of the P591. The corresponding connection diagram will have been supplied with the Schneider Electric order acknowledgement for the P591.

It is especially important that the dc supplies are wired with the correct polarity.

5.3.2.4 Auxiliary supply

P591 units operate from a dc only auxiliary supply within the operative range of 19V to 65V for a 24 - 48V version and 87.5V to 300V for a 110 - 250V version.

Without energizing the P591 units measure the auxiliary supply to ensure it is within the operating range.

It should be noted that the P591 interface unit is designed to withstand an ac ripple component of up to 12% of the normal dc auxiliary supply. However, in all cases the peak value of the dc supply must not exceed the maximum specified operating limit.

Do not energize the P591 using the battery charger with the battery disconnected as this can irreparably damage the unit's power supply circuitry.

Energize the P591 only if the auxiliary supply is within the specified operating ranges. If a P991 test block is provided, it may be necessary to link across the front of the test plug to connect the auxiliary supply to the P591.

5.3.2.5 Light emitting diodes (LED's)

On power up the green 'SUPPLY HEALTHY' LED should have illuminated and stayed on, thus indicating that the P591 is healthy.

5.3.2.6 Loopback test

Remove any external wiring from terminals 3, 4, 7 and 8 at the rear of each P591 unit. Loopback the G.703 signals on each unit by connecting a wire link between terminals 3 and 7, and a second wire between terminals 4 and 8.

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Measure and record the optical signal strength received by the P591 by disconnecting the optical fiber from the receive port on the rear of the unit and connecting it to an optical power meter. The mean level should be in the range -16.8dBm to -25.4dBm. If the mean level is outside of this range check the size and type of fiber being used.

Measure and record the optical output power of the transmit port of the P591 using the optical power meter and length of 50/125µm optical fiber. The mean value should be in the range -16.8dBm to -22.8dBm.

Ensure that the transmit (Tx) and receive (Rx) optical fibers between the P54x relay and P591 units are connected.

Return to the P54x relay and set cell [0F13 Test Loopback] to 'External'. The relay will then respond as if it is connected to a remote relay with the current at the remote end equal to and in phase with the current injected at the local end (no currents in case of fiber InterMiCOM^{64}). Reset alarm indications. The relay will indicate a loopback alarm which can only be cleared by setting the loopback to disabled. Channel status, propagation delays and communication statistics should be checked in [MEASUREMENTS 4] column.

Set cell [0F15 IM64 Test Mode] to 'Enabled', cell [0F14 IM64 TestPattern] to 'Enabled' and set any Test pattern. To verify the correct operation of loopback test, check in [MEASUREMENTS 4] column that cell 'IM64 Rx Status' matches with the Test Pattern. The communication statistics will indicate the number of valid and any errored messages received, note that the propagation delay measurement will not be valid in this mode of operation.

Alternatively use the internal loopback feature by setting cell [0F13 Test Loopback] to 'Internal Loop' and repeat the above test. In this mode it is not necessary to change the fiber.

Note in loopback mode the signals sent and received via the InterMiCOM^{64} interface continue to be from and to the signals defined in the programmable logic.

Note that a test pattern can be also sent to the remote end in order to test the whole InterMiCOM^{64} communication path by enabling [OF15 IM64 Test Mode] and connecting two ends. If such a test is performed, special care has to be taken as the test pattern will be executed via PSL at the remote end.

5.3.3 Communications using P592 interface units

The P592 converts the optical output of the P54x relay to an electrical signal for a PCM multiplexer with V.35 interfaces. The unit is housed in a size 20TE case and should be located near to the multiplexer.

Before loopback testing can begin, some other checks must be completed.

5.3.3.1 Visual inspection

Carefully examine the unit to see that no physical damage has occurred since installation.

The rating information given under the top access cover on the front of the unit should be checked to ensure it is correct for the particular installation.

Ensure that the case earthing connection, top left-hand corner at the rear of the case, is used to connect the unit to a local earth bar using an adequate conductor.

5.3.3.2 Insulation

Insulation resistance tests are only necessary during commissioning if it is required for them to be done and they haven't been performed during installation.

Isolate all wiring from the earth and test the insulation with an electronic or brushless insulation tester at a dc voltage not exceeding 500V. The auxiliary dc supply terminals should be temporarily connected together.

The V.35 circuits of the P592 are isolated from all other circuits but are electrically connected to the outer case. The circuits must not therefore be insulation or impulse tested to the case.

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The insulation resistance should be greater than 100MΩ at 500V.

On completion of the insulation resistance tests, ensure all external wiring is correctly reconnected to the P592.

5.3.3.3 External wiring

Check that the external wiring is correct to the relevant connection diagram or scheme diagram. The connection diagram number appears on the rating label under the top access cover on the front of the P592. The corresponding connection diagram will have been supplied with the Schneider Electric order acknowledgement for the P592.

It is especially important that the dc supplies are wired with the correct polarity.

5.3.3.4 Auxiliary supply

P592 units operate from a dc only auxiliary supply within the operative range of 19V to 300V.

Without energizing the P592 units measure the auxiliary supply to ensure it is within the operating range.

It should be noted that the P592 interface unit is designed to withstand an ac ripple component of up to 12% of the normal dc auxiliary supply. However, in all cases the peak value of the dc supply must not exceed the maximum specified operating limit.

Do not energize the P592 using the battery charger with the battery disconnected as this can irreparably damage the unit's power supply circuitry.

Energize the P592 only if the auxiliary supply is within the specified operating ranges. If a P991 test block is provided, it may be necessary to link across the front of the test plug to connect the auxiliary supply to the P592.

5.3.3.5 Light emitting diodes (LED's)

On power up the green 'SUPPLY HEALTHY' LED should have illuminated and stayed on indicating that the P592 is healthy.

The four red LED's can be tested by appropriate setting of the DIL switches on the unit's front plate. Set the data rate switch according to the communication channel bandwidth available. Set all other switches to 0. To illuminate the 'DSR OFF' and 'CTS OFF' LED's, disconnect the V.35 connector from the rear of the P592 and set the 'DSR' and 'CTS' switches to '0'. The 'OPTO LOOPBACK' and 'V.35 LOOPBACK' LED's can be illuminated by setting their corresponding switches to '1'.

Once operation of the LED's has been established set all DIL switches, except for the 'OPTO LOOPBACK' switch, to '0' and reconnect the V.35 connector.

5.3.3.6 Loopback test

With the 'OPTO LOOPBACK' switch in the '1' position the receive and transmit optical ports are electrically connected together. This allows the optical fiber communications between the P54x relay and the P592 to be tested, but not the internal circuitry of the P592 itself.

Measure and record the optical signal strength received by the P592 by disconnecting the optical fiber from the receive port on the rear of the unit and connecting it to an optical power meter. The mean level should be in the range -16.8dBm to -25.4dBm. If the mean level is outside of this range check the size and type of fiber being used.

Measure and record the optical output power of the transmit port of the P592 using the optical power meter and length of 50/125μm optical fiber. The mean value should be in the range -16.8dBm to -22.8dBm.

Ensure that the transmit (Tx) and receive (Rx) optical fibers between the P54x relay and P592 units are connected.

Return to the P54x relay and set cell [0F13 Test Loopback] to 'External'. The relay will then respond as if it is connected to a remote relay with the current at the remote end equal to and in phase with the current injected at the local end (no currents in case of fiber InterMiCOM^{64}). Reset alarm indications. The relay will indicate a loopback alarm which can only be cleared by setting the loopback to disabled. Channel status, propagation delays and communication statistics should be checked in [MEASUREMENTS 4] column.

Set cell [0F15 IM64 Test Mode] to 'Enabled', cell [0F14 IM64 TestPattern] to 'Enabled' and set any Test pattern. To verify the correct operation of loopback test, check in [MEASUREMENTS 4] column that cell 'IM64 Rx Status' matches with the Test Pattern. The communication statistics will indicate the number of valid and any errored messages received, note that the propagation delay measurement will not be valid in this mode of operation.

Alternatively use the internal loopback feature by setting cell [0F13 Test Loopback] to 'Internal Loop' and repeat the above test. In this mode it is not necessary to change the fiber.

Note in loopback mode the signals sent and received via the InterMiCOM^{64} interface continue to be from and to the signals defined in the programmable logic.

Note that a test pattern can be also sent to the remote end in order to test the whole InterMiCOM^{64} communication path by enabling [OF15 IM64 Test Mode] and connecting two ends. If such a test is performed, special care has to be taken as the test pattern will be executed via PSL at the remote end.

5.3.4 Communications using P593 interface units

The P593 converts the optical output of the P54x relay to an electrical signal for a PCM multiplexer with X.21 interfaces. The unit is housed in a size 20TE case and should be located near to the multiplexer.

Before loopback testing can begin, some other checks must be completed.

5.3.4.1 Visual inspection

WARNING: Electrostatic Discharge (ESD) precautions must be applied while the secondary cover is removed from the unit.

If applicable replace the secondary front cover from the unit. Carefully examine the unit to see that no physical damage has occurred since installation.

The rating information given under the top access cover on the front of the unit should be checked to ensure it is correct for the particular installation.

Ensure that the case earthing connection, top left-hand corner at the rear of the case, is used to connect the unit to a local earth bar using an adequate conductor.

5.3.4.2 Insulation

Insulation resistance tests are only necessary during commissioning if it is required for them to be done and they have not been performed during installation.

Isolate all wiring from the earth and test the insulation with an electronic or brushless insulation tester at a dc voltage not exceeding 500V. The auxiliary dc supply terminals should be temporarily connected together.

The X.21 circuits of the P593 are isolated from all other circuits but are electrically connected to the outer case. The circuits must not therefore be insulation or impulse tested to the case.

The insulation resistance should be greater than 100MΩ at 500V.

On completion of the insulation resistance tests, ensure all external wiring is correctly reconnected to the P593.

5.3.4.3 External wiring

Check that the external wiring is correct to the relevant connection diagram or scheme diagram. The connection diagram number appears on the rating label under the top access cover on the front of the P593. The corresponding connection diagram will have been supplied with the Schneider Electric order acknowledgement for the P593.

It is especially important that the dc supplies are wired with the correct polarity.

5.3.4.4 Auxiliary supply

P593 units operate from a dc only auxiliary supply within the operative range of 19.5V to 300V.

Without energizing the P593 units measure the auxiliary supply to ensure it is within the operating range.

It should be noted that the P593 interface unit is designed to withstand an ac ripple component of up to 12% of the normal dc auxiliary supply. However, in all cases the peak value of the dc supply must not exceed the maximum specified operating limit.

Do not energize the P593 using the battery charger with the battery disconnected as this can irreparably damage the unit's power supply circuitry.

Energize the P593 only if the auxiliary supply is within the specified operating ranges. If a P991 test block is provided, it may be necessary to link across the front of the test plug to connect the auxiliary supply to the P593.

5.3.4.5 Light emitting diodes (LED's)

On power up the green 'SUPPLY' LED should have illuminated and stayed on indicating that the P593 is healthy.

Set the 'X.21 LOOPBACK' switch to 'ON'. The green 'CLOCK' and red 'X.21 LOOPBACK' LED's should illuminate. Reset the 'X.21 LOOPBACK' switch to the 'OFF' position.

Set the 'OPTO LOOPBACK' switch to 'ON'. The red 'OPTO LOOPBACK' LED should illuminate. Do not reset the "OPTO LOOPBACK' switch as it is required in this position for the next test.

5.3.4.6 Loopback test

With the 'OPTO LOOPBACK' switch in the 'ON' position the receive and transmit optical ports are electrically connected together. This allows the optical fiber communications between the P54x relay and the P593 to be tested, but not the internal circuitry of the P593 itself.

Measure and record the optical signal strength received by the P593 by disconnecting the optical fiber from the receive port on the rear of the unit and connecting it to an optical power meter. The mean level should in the range -16.8dBm to -25.4dBm. If the mean level is outside of this range check the size and type of fiber being used.

Measure and record the optical output power of the transmit port of the P593 using the optical power meter and length of 50/125μm optical fiber. The mean value should be in the range -16.8dBm to -22.8dBm

Ensure that the transmit (Tx) and receive (Rx) optical fibers between the P54x relay and P593 units are connected.

Set the 'OPTO LOOPBACK' switch to 'OFF' and 'X.21 LOOPBACK' switch to 'ON' respectively. With the 'X.21 LOOPBACK' switch in this position the 'Receive Data' and 'Transmit Data' lines of the X.21 communication interface are connected together. This allows the optical fiber communications between the P54x relay and the P593, and the internal circuitry of the P593 itself to be tested.

Return to the P54x relay and set cell [0F13 Test Loopback] to 'External'. The relay will then respond as if it is connected to a remote relay with the current at the remote end equal to and in phase with the current injected at the local end (no currents in case of fiber InterMiCOM^{64}). Reset alarm indications. The relay will indicate a loopback alarm which can only be cleared by setting the loopback to disabled. Channel status, propagation delays and communication statistics should be checked in [MEASUREMENTS 4] column.

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Set cell [0F15 IM64 Test Mode] to 'Enabled', cell [0F14 IM64 TestPattern] to 'Enabled' and set any Test pattern. To verify the correct operation of loopback test, check in [MEASUREMENTS 4] column that cell 'IM64 Rx Status' matches with the Test Pattern. The communication statistics will indicate the number of valid and any errored messages received, note that the propagation delay measurement will not be valid in this mode of operation.

Alternatively use the internal loopback feature by setting cell [0F13 Test Loopback] to 'Internal Loop' and repeat the above test. In this mode it is not necessary to change the fiber.

Note in loopback mode the signals sent and received via the InterMiCOM^{64} interface continue to be from and to the signals defined in the programmable logic.

Note that a test pattern can be also sent to the remote end in order to test the whole InterMiCOM^{64} communication path by enabling [OF15 IM64 Test Mode] and connecting two ends. If such a test is performed, special care has to be taken as the test pattern will be executed via PSL at the remote end.

5.3.5 IEEE C37.94 compatible multiplexers

See section 5.3.1 for loopback tests which are also appropriate for the IEEE C37.94 interface.

5.4 GPS synchronization using the P594 interface units

The P594 provides one pulse per second for synchronizing purposes. The unit is housed in a 20TE case and can be located up to 1 km away from the relay.

5.4.1 Visual inspection

Carefully examine the unit to see that no physical damage has occurred since installation.

The rating information, given under the top access cover on the front of the unit, should be checked to ensure that it is the correct model for the particular installation.

Ensure that the case earthing connection, top left hand corner at the rear of the case is used to connect the unit to a local earthing bar using an adequate conductor.

5.4.2 Insulation

Insulation resistance tests are only necessary during commissioning if it is required for them to be done and they have not been performed during installation.

Isolate all wiring from the earth and test the insulation with an electronic or brushless insulation tester at a dc voltage not exceeding 500V. The auxiliary dc supply terminals should be temporarily connected together.

The insulation resistance should be greater than 100MΩ at 500V.

On completion of the insulation resistance tests, ensure that all external wiring is correctly reconnected to the P594.

5.4.3 External wiring

Check that the external wiring is correct to the relevant connection diagram or scheme diagram. The connection diagram number appears on the rating label under the top access cover on the front of the P594. The corresponding connection diagram will have been supplied with the Schneider Electric order acknowledgement for the P594.

It is especially important that the dc supplies are wired with the correct polarity.

5.4.4 Auxiliary supply

P594 units operate from a dc auxiliary supply within the operative range of 19V to 150V for a 24 - 125V version and 33V to 300V for the 48 - 250V version. The 48 - 250V version also operates from an ac auxiliary supply within the operative range of 96V to 240V

Without energizing the P594 units measure the auxiliary supply to ensure it is within the operating range.

It should be noted that the P594 interface unit is designed to withstand an ac ripple component of up to 12% of the normal dc auxiliary supply. However, in all cases the peak value of the dc supply must not exceed the maximum specified operating limit.

Do not energize the P594 using the battery charger with the battery disconnected as this can irreparably damage the unit's power supply circuitry.

Energize the P594 only if the auxiliary supply is within the specified operating ranges. If a P991 test block is provided, it may be necessary to link across the front of the test plug to connect the auxiliary supply to the P594.

5.4.5 Light emitting diodes

On power up the green 'Healthy' LED should have illuminated and stayed on indicating that the unit is healthy. If the LED is flashing check the antenna is connected. Initially the red '0' LED will be illuminated indicating the P594 has not initialized and is not outputting a signal to the P54x. The remaining red LED '1-3' and green LED '4 – 8' indicate the number of satellites being seen by the P594. The P594 takes up to 3 hours to initialize before it starts to output a signal. This is indicated by the red '0' LED being extinguished and indicating four or more satellites. If the number of satellites drops below four the output again turns off again until the number of satellites exceeds four. Once the initialization is complete the antenna can be disconnected (see next section) and reconnected without the power on initialization time. However, if the power to the P594 is lost it will take up to 3 hours to re-initialize.

5.4.6 Synchronizing signal

The normal optical output from the P594 is a 200ms light on with 800ms light off. Most optical power meters can not measure this signal. A commissioning feature has been added which is activated by disconnecting the antenna cable from the P594. This replaces the output signal by a 250kHz signal. This condition is indicated by the green 'healthy' LED flashing. The P54x is immune to this signal and treats it as a loss of GPS. Measure and record the optical power of each transmitter using an optical power meter and length of 50/125цm optical fiber. The mean value should be in the range –24.8dBm to –30.8dBm. Reconnect the antenna cable.

Note: If the antenna is removed for longer than 1 hour the GPS until will reset. It will require up to 3 hours to re-initialize following reconnection of the antenna.

5.4.7 Connection to P54x relay

Connect module to the P54x series relay. Enable GPS synchronization in [201A: PROT COMMS/IM64, GPS Sync Enabled] of the relay. Check that the relay is recognizing the GPS synchronization in [0507 and 0508:MEASUREMENTS 4, Channel Status] of the relay. If this is satisfactory bit 4 should be 1 i.e. * * 1 * * * *.

Note: The P594 can take 2¾ hours following detection of at least 4 satellites before it outputs a signal to the P54x.

5.4.8 Final checks

If the secondary front cover has been removed it should now be re-fitted to the P594.

6. SETTING CHECKS

The setting checks ensure that all of the application-specific relay settings (i.e. both the relay's function and programmable scheme logic settings), for the particular installation, have been correctly applied to the relay.

If the application-specific settings are not available, ignore sections 6.1 and 6.2.

> Note: The trip circuit should remain isolated during these checks to prevent accidental operation of the associated circuit breaker.

6.1 Apply application-specific settings

There are two methods of applying the settings to the relay:

- Transferring them from a pre-prepared setting file to the relay using a portable PC running the appropriate software via the relay's front EIA(RS)232 port, located under the bottom access cover, or rear communications port (with a KITZ protocol converter connected). This method is preferred for transferring function settings as it is much faster and there is less margin for error. If programmable scheme logic other than the default settings with which the relay is supplied are to be used then this is the only way of changing the settings.
- If a setting file has been created for the particular application and provided on a diskette, this will further reduce the commissioning time and should always be the case where application-specific programmable scheme logic is to be applied to the relay.
- Enter them manually via the relay's operator interface. This method is not suitable for changing the programmable scheme logic.

> Note: It is essential that where the installation needs application-specific Programmable Scheme Logic, that the appropriate .psl file, is downloaded (sent) to the relay, for each and every setting group that will be used. If the user fails to download the required .psl file to any setting group that may be brought into service, then factory default PSL will still be resident. This may have severe operational and safety consequences.

6.2 Demonstrate correct relay operation

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Tests 5.2.10 and 5.2.11 have already demonstrated that the relay is within calibration, thus the purpose of these tests is as follows:

- To determine that the primary protection function of the relay, current differential or distance can trip according to the correct application settings
- To verify correct correct setting of any aided scheme DEF (ground overcurrent) protection

To verify correct assignment of the trip contacts, by monitoring the response to a selection of fault injections.

6.2.1 Current differential bias characteristic

To avoid spurious operation of any distance, overcurrent, earth fault or breaker fail elements, these should be disabled for the duration of the differential element tests. This is done in the relay's CONFIGURATION column. Ensure that cells [090B: Distance], [090C: Directional E/F], [0910: Overcurrent], [0913: Earth Fault] and [0920: CB Fail] are all set to "Disabled". Make a note of which elements need to be re-enabled after testing. The relay should also be set to loopback mode isolating it from the remote end. Refer to Section 5.3.1.

6.2.1.1 Connect the test circuit

The following tests require a variable transformer and two resistors connected as shown in Figure 3. Alternatively an injection test set can be used to supply Ia and Ib.

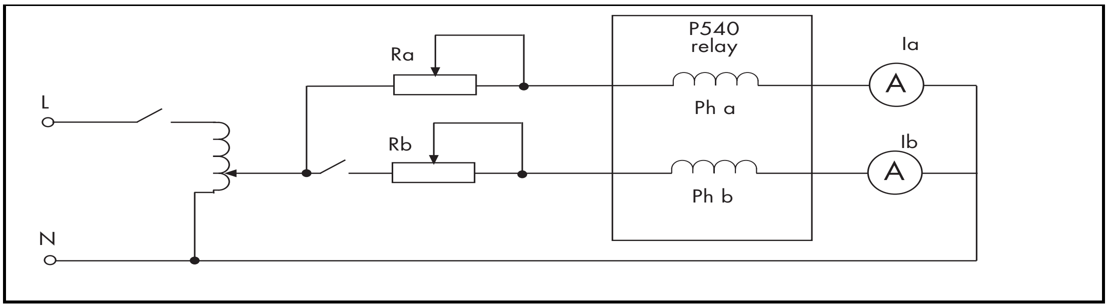

Figure 3: Connection for bias characteristic testing

A current is injected into the A phase which is used as the bias current and another current is injected into the B phase which is used as differential current. Ia is always greater than Ib.

6.2.1.2 Lower slope

If three LEDs have been assigned to give phase segregated trip information, Trip A, Trip B and Trip C, these may be used to indicate correct per-phase operation. If not, monitor options will need to be used - see the next paragraph.

Go to the COMMISSION TESTS column in the menu, scroll down and change cells [0F05: Monitor Bit 1] to 523, [0F06: Monitor Bit 2] to 524 and [0F07: Monitor Bit 3] to 525. Doing so, cell [0F04: Test Port Status] will appropriately set or reset the bits that now represent Trip Output A (DDB #523), Trip Output B (DDB #524) and Trip Output C (DDB #525) with the rightmost bit representing Phase A Trip. From now on you should monitor the indication of [0F03: Test Port Status]. Also make sure that the relay is in loopback mode by setting cell [0F13 Test Loopback] to 'External' and applying either a loop-back fiber on the relay or loopback is selected on the P590 as described in 5.3. Alternatively setting cell [0F13 Test Loopback] to 'Internal'.

CM

Adjust the variac and the resistor to give a bias current of 1pu in the A-phase.
(NOTE: 1pu = 1A into terminals C3-C2 for 1A applications; or 1pu = 5A into terminals C1-C2 for 5A applications). The relay will trip and any contacts associated with the A-phase will operate, and bit 1 (rightmost) of [0F03: Test Port Status] will be set to 1. Some LEDs, including the yellow alarm LED, will go off, but ignore them for the moment.

When the current in A Phase is established, close the switch and slowly increase the current in the B phase from zero until Phase B trips (bit 2 of [0F03: Test Port Status] is set to 1). Record the phase B current magnitude and check that it corresponds to the information overleaf.

Switch OFF the ac supply, read and clear all alarms.

Bias Current		**Differential Current**	**Magnitude of Differential Current**	
Phase	**Magnitude**	**Phase**		
A	1pu	B	2 Terminal & Dual Redundant	0.25pu +/-10%
			3 Terminal	0.216pu +/-10%

Assumption: I_{s1} = 0.2pu, k_1 = 30%, I_{s2} = 2.0pu

For other differential settings or current injected into A phase (I_a), the formula below can be used (enter slope in pu form, i.e. percentage/100):

2 Terminal & Dual Redundant:

B phase operate current is 0.5 x [I_{s1} + [I_a x k_1)] pu +/- 10% -

3 Terminal:

B phase operate current is 0.333 x [I_{s1} + (1.5 x I_a x k_1)] pu +/- 10% -

Ensure that $I_a < I_{S2}$

6.2.1.3 Upper slope

Repeat the test in 5.2.1.2 with the bias current set in the A-phase to be 3pu.

When the current in A Phase is established, close the switch and slowly increase the current in the B phase from zero until phase B trips (bit 2 of [0F03: Test Port Status] is set to 1). Record the phase B current magnitude and check that it corresponds to the information below.

Switch OFF the ac supply and reset the alarms.

Bias Current		**Differential Current**	**Magnitude of Differential Current**		
Phase	**Magnitude**	**Phase**		**k_2**	
A	3pu	B	2 Terminal & Dual Redundant	150%	1.15pu +/-10%
				100%	0.9pu +/-10%
			3 Terminal	150%	1.51pu +/-10%
				100%	1.1pu +/-10%

Assumption: I_{s1} = 0.2pu, k_1 = 30%, I_{s2} = 2.0pu, k_2 as above

For other differential settings or current injected into A phase (I_a), the formula below can be used (enter slopes in pu form, i.e. percentage/100):

2 Terminal & Dual Redundant:

Operate current is 0.5 x [(I_a x k_2) – {($k_2 - k_1$) x I_{s2} } + I_{s1}] pu +/- 20%

3 Terminal:

Operate current is 0.333 x [(1.5 x I_a x k_2) – {($k_2 - k_1$) x I_{s2} } + I_{s1}] pu +/- 20%

Ensure that $I_a > I_{S2}$

Note that especially for 5A applications the duration of current injections should be short to avoid overheating of the variac or injection test set.

CM

6.2.2 Current differential operation and contact assignment

6.2.2.1 Phase A

Retaining the same test circuit as before, prepare for an instantaneous injection of 3pu current in the A phase, with no current in the B phase (B phase switch open). Connect a timer to start when the fault injection is applied, and to stop when the trip occurs. To verify correct output contact mapping use the trip contacts that would be expected to trip the circuit breaker(s), as shown in the table. For two breaker applications, stop the timer once both CB1 and CB2 trip contacts have closed. This can be achieved by connecting the contacts in series to stop the timer.

	Single Breaker	**Two Circuit Breakers**
Three Pole Tripping	Any Trip	Any Trip (CB1) and Any Trip (CB2)
Single Pole Tripping	Trip A	Trip A (CB1) and Trip A (CB2)

6.2.2.2 Phase B

Reconfigure the test equipment to inject fault current into the B phase. Repeat the test in 6.2.2.1, this time ensuring that the breaker trip contacts relative to B phase operation close correctly. Record the phase B trip time. Switch OFF the ac supply and reset the alarms.

6.2.2.3 Phase C

Repeat 6.2.2.3 for the C phase.
The average of the recorded operating times for the three phases should be less than 40ms for 50Hz, and less than 35ms for 60Hz when set for instantaneous operation. Switch OFF the ac supply and reset the alarms.

Notes: For applications using magnetizing inrush current restraint, use a test current higher than the [3313: Inrush High] setting to obtain fast operating times. At least twice setting is recommended.

Where an IDMT or definite time delay is set in the GROUP 1 PHASE DIFF menu column, the expected operating time is typically within +/- 5% of that for the curve equation plus the “instantaneous” delay quoted above.

Upon completion of the tests any distance, overcurrent, earth fault or breaker fail elements which were disabled for testing purposes must have their original settings restored in the CONFIGURATION column.

6.2.3 Distance protection single-end testing

If the distance protection function is being used, the reaches and time delays should be tested. If not, skip to section 6.2.8

To avoid spurious operation of current differential, overcurrent, DEF/earth fault or breaker fail elements, these should be disabled for the duration of the distance element tests. This is done in the relay’s CONFIGURATION column. Ensure that cells [090F: Phase Diff], [090C: Directional E/F DEF], [0910: Overcurrent], [0913: Earth Fault] and [0920: CB Fail] are all set to “Disabled”. Make a note of which elements need to be re-enabled after testing.

6.2.3.1 Connection and preliminaries

The relay should now be connected to equipment able to supply phase-phase and phase-neutral volts with current in the correct phase relation for a particular type of fault on the selected relay characteristic angle. The facility for altering the loop impedance (phase-to-ground fault or phase-phase) presented to the relay is essential.

It is recommended that a three phase digital/electronic injection test set is used for ease of commissioning. If this is not available, two setting changes may need to be made on the relay, for the duration of testing:

1. In order to facilitate testing of the Distance elements using test sets which do not provide a dynamic model to generate true fault delta conditions, a Static Test Mode setting is provided. This setting is found in the COMMISSIONING TESTS menu column. When set, this disables phase selector control and forces the relay to use a conventional (non-delta) directional line.

2. For lower specification test equipment that cannot apply a full three phase set of healthy simulated pre-fault voltages, the VT supervision may need to be disabled to avoid spurious pickup. This is achieved in the CONFIGURATION column, by setting cell [0921: Supervision] to “Disabled”).

Connect the test equipment to the relay via the test block(s) taking care not to open-circuit any CT secondary. If MMLG type test blocks are used, the live side of the test plug **must** be provided with shorting links before it is inserted into the test block.

6.2.3.2 Zone 1 reach check

The zone 1 element is set to be directional forward.

Apply a dynamic A phase to neutral fault, slightly in excess of the expected reach. The duration of the injection should be in excess of the tZ1 timer setting, but less than tZ2 (settings found in the DISTANCE menu column). Observe that no trip should occur, and the red Trip LED remains extinguished.

Reduce the impedance and reapply this to the relay. This procedure should be repeated until a trip occurs. The display will show Alarms/Faults present and the Alarm and Trip LEDs will illuminate. To view the alarm message press the read key, repeat presses of this key should be used to verify that phase A was the "Start Element". Keep pressing the key until the yellow alarm LED changes from flashing to being steadily on. At the prompt 'Press clear to reset alarms', press the 'C' key. This will clear the fault record from the display

Record the impedance at which the relay tripped. The measured impedance should be within +/- 10% of the expected reach.

Modern injection test sets usually calculate the expected fault loop impedance from the relay settings, for those that do not:

– Connections for an A-N fault. The appropriate loop impedance is given by the vector sum:

Z1 + Z1 residual = Z1 + (Z1 x kZN Res Comp∠kZN Angle) Ω.

6.2.3.3 Zone 2 reach check

The zone 2 element is set to be directional forward.

Apply a dynamic B-C fault, slightly in excess of the expected reach. The duration of the injection should be in excess of the tZ2 timer setting, but less than tZ3. Repeat as in 6.2.3.2 to find the zone reach.

Record the impedance at which the relay tripped. The measured impedance should be within +/- 10% of the expected reach. Read and reset the alarms.

Modern injection test sets usually calculate the expected fault loop impedance from the relay settings, for those that do not:

Connections for a B-C fault. The reach for phase-phase should be checked and the operation of the appropriate contacts confirmed. The appropriate loop impedance is now given by:

2 x Z2 Ω

6.2.3.4 Zone 3 reach check

The zone 3 element is set to be directional forward.

Apply a dynamic C-A fault, slightly in excess of the expected reach. The duration of the injection should be in excess of the tZ3 timer setting (typically tZ3 + 100ms). Repeat as in to find the zone reach.

Record the impedance at which the relay tripped. The measured impedance should be within +/- 10% of the expected reach. Read and reset the alarms.

Only a visual check that the correct reverse offset (Z3') has been applied is needed. The setting is found in cell [3143: Z3' Ph Rev Reach] and [31A3: Z3' Gnd Rev Reach].

6.2.3.5 Zone 4 reach check (if enabled)

The zone 4 element is set to be directional reverse.

Apply a dynamic B-N fault, slightly in excess of the expected reach. The duration of the injection should be in excess of the tZ4 timer setting (typically tZ4 + 100ms). Repeat as in 6.2.3.2 to find the zone reach.

Record the impedance at which the relay tripped. The measured impedance should be within +/- 10% of the expected reach. Read and reset the alarms.

6.2.3.6 Zone P reach check (if enabled)

The zone P element can be set to be forward or reverse directional. The current injected must be in the appropriate direction to match the setting in the "DISTANCE SETUP" menu column (cells [3151] and [31B1]).

Apply a dynamic C-N fault, slightly in excess of the expected reach. The duration of the injection should be in excess of the tZP timer setting (typically tZP + 100ms). Repeat as in 6.2.3.2 to find the zone reach.

Record the impedance at which the relay tripped. The measured impedance should be within +/- 10% of the expected reach. Read and reset the alarms.

6.2.3.7 Resistive reach (quadrilateral characteristics only)

Only a visual check that the correct settings for phase and ground element resistive reaches have been applied is needed. The relevant settings are R1Ph, R2Ph, R3Ph, R3Ph reverse, R4Ph and RP Ph for phase fault zones. The settings are R1Gnd, R2Gnd, R3Gnd, R3Gnd reverse, R4Gnd and RP Gnd for ground fault zones. Note that zone 3 has an independent setting for the forward resistance reach (right-hand resistive reach line), and the reverse resistance reach (left-hand resistive reach line).

6.2.3.8 Load blinder

Only a visual check that the correct settings for the load blinder have been applied is needed. The settings are found at the end of the DISTANCE SETUP menu column, cells [31D4] to [31D6]. It must be verified that [31D5: Load B/Angle] is set at least 10 degrees less than the [3004: Line Angle] setting in the LINE PARAMETERS menu column.

6.2.4 Distance protection operation and contact assignment

6.2.4.1 Phase A

Prepare a dynamic A phase to neutral fault, at half the Zone 1 reach. Connect a timer to start when the fault injection is applied, and to stop when the trip occurs. To verify correct output contact mapping use the trip contacts that would be expected to trip the circuit breaker(s), as shown in the table. For two breaker applications, stop the timer once CB1 and CB2 trip contacts have <u>both</u> closed, monitored by connecting the contacts in series to stop the timer if necessary.

	Single Breaker	**Two Circuit Breakers**
Three Pole Tripping	Any Trip	Any Trip (CB1) and Any Trip (CB2)
Single Pole Tripping	Trip A	Trip A (CB1) and Trip A (CB2)

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Apply the fault and record the phase A trip time. Switch OFF the ac supply and reset the alarms.

6.2.4.2 Phase B

Reconfigure to test a B phase fault. Repeat the test in 6.2.4.1, this time ensuring that the breaker trip contacts relative to B phase operation close correctly. Record the phase B trip time. Switch OFF the ac supply and reset the alarms.

6.2.4.3 Phase C

Repeat 6.2.4.2 for the C phase.

The average of the recorded operating times for the three phases should typically be less than 20ms for 50Hz, and less than 16.7ms for 60Hz when set for instantaneous operation. Switch OFF the ac supply and reset the alarms.

– Where a non-zero tZ1 Gnd time delay is set in the DISTANCE menu column, the expected operating time is typically within +/- 5% of the tZ1 setting plus the “instantaneous” delay quoted above.

6.2.4.4 Time delay settings tZ1 Ph, and tZ2 - tZ4

Only a visual check that the correct time delay settings have been applied is needed. The relevant settings in the SCHEME LOGIC column are:

[3409: tZ1 Ph Time Delay]

[3411: tZ2 Ph Time Delay] and [3412: tZ2 Gnd Time Delay]

[3419: tZ3 Ph Time Delay] and [341A: tZ3 Gnd Time Delay]

[3421: tZP Ph Time Delay] and [3422: tZP Gnd Time Delay]

[3429: tZ4 Ph Time Delay] and [342A: tZ4 Gnd Time Delay]

Note how the P54x allows separate time delay settings for phase (“Ph”) and ground (“Gnd”) fault elements. BOTH must be checked to ensure that they have been set correctly.

6.2.5 Distance protection scheme testing

The relay will be tested for it’s response to internal and external fault simulations, but the engineer must note that the response will depend upon the aided channel (pilot) scheme that is selected. The table overleaf indicates the expected response for various test scenarios, according to the scheme selection, and status of the opto-input that is assigned to the “Aided Receive Ext” channel receive for the distance scheme. The response to the “Reset Z1 Extension” opto is shown in the case of a Zone 1 Extension scheme.

Ensure that the injection test set timer is still connected to measure the time taken for the relay to trip. A series of fault injections will be applied, with a Zone 1, end-of-line, or Zone 4 fault simulated. At this stage, merely note the method in which each fault will be applied, but do not inject yet:

– Zone 1 fault: A dynamic forward A-B fault at half the Zone 1 reach will be simulated.

– End of line fault: A dynamic forward A-B fault at the remote end of the line will be simulated. The fault impedance simulated should match the [3003: Line Impedance] setting in the LINE PARAMETERS menu column.

– Zone 4 fault: A dynamic reverse A-B fault at half the Zone 4 reach will be simulated.

Fault Type Simulated	**RELAY RESPONSE**					
	Forward Fault in Zone 1		**Forward Fault at End of Line (Within Z1X/Z2)**		**Reverse Fault in Zone 4**	
Signal Receive Opto	**ON**	**OFF**	**ON**	**OFF**	**ON**	**OFF**
Zone 1 Extension	Trip	Trip	No Trip	Trip	No Trip	No Trip
Blocking Scheme	Trip, No Signal Send	Trip, No Signal Send	No Trip, No Signal Send	Trip, No Signal Send	No Trip, Signal Send	No Trip, Signal Send
Permissive Scheme (PUR/PUTT)	Trip, Signal Send	Trip, Signal Send	Trip, No Signal Send	No Trip, No Signal Send	No Trip, No Signal Send	No Trip, No Signal Send
Permissive Scheme (POR/POTT)	Trip, Signal Send	Trip, Signal Send	Trip, Signal Send	No Trip, Signal Send	No Trip, No Signal Send	No Trip, No Signal Send

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6.2.5.1 Scheme trip test for zone 1 extension only

The Reset Zone 1 Extension opto input should first be ON (energized). This should be performed by applying a continuous DC voltage onto the required opto input, either from the test set, station battery, or relay field voltage (commissioning engineer to ascertain the best method).

With the opto energized, inject an end of line fault. The duration of injection should be set to 100ms. No trip should occur.

De-energize the Reset Z1X opto (remove the temporary energization link, to turn it OFF).

Repeat the test injection, and record the operating time. This should typically be less than 20ms for 50Hz, and less than 16.7ms for 60Hz when set for instantaneous operation. Switch OFF the ac supply and reset the alarms.

– Where a non-zero tZ1 Ph time delay is set in the DISTANCE menu column, the expected operating time is typically within +/- 5% of the tZ1 setting plus the "instantaneous" delay quoted above.

6.2.5.2 Scheme trip tests for permissive schemes (PUR/POR only)

This test applies to both Permissive Underreach, and Permissive Overreach aided scheme applications.

As in the table, for a Permissive scheme the Signal Receive opto input will need to be ON (energized). This should be performed by applying a continuous DC voltage onto the required opto input, either from the test set, station battery, or relay field voltage (commissioning engineer to ascertain the best method).

With the opto energized, inject an end of line fault, and record the operating time. The measured operating time should typically be less than 20ms for 50Hz, and less than 16.7ms for 60Hz when set for instantaneous operation. Switch OFF the ac supply and reset the alarms.

– Where a non-zero Distance Dly time delay is set in the DISTANCE menu column, the expected operating time is typically within +/- 5% of the tZ1 setting plus the "instantaneous" delay quoted above.

De-energize the channel received opto (remove the temporary energization link, to turn it OFF).

6.2.5.3 Scheme trip tests for blocking scheme only

The Signal Receive opto input should first be ON (energized). This should be performed by applying a continuous DC voltage onto the required opto input, either from the test set, station battery, or relay field voltage (commissioning engineer to ascertain the best method).

With the opto energized, inject an end of line fault. The duration of injection should be set to 100ms. No trip should occur.

De-energize the channel received opto (remove the temporary energization link, to turn it OFF).

Repeat the test injection, and record the operating time. Switch OFF the ac supply and reset the alarms.

– For blocking schemes, a non-zero Distance Dly time delay is set, so the expected operating time is typically within +/- 5% of the delay setting plus the P54x "instantaneous" operating delay. The trip time should thus be less than 20ms for 50Hz, and less than 16.7ms for 60Hz, plus 1.05 x Delay setting.

6.2.5.4 Signal send test for permissive schemes (PUR/POR only)

This test applies to both Permissive Underreach, and Permissive Overreach scheme applications.

Firstly, reconnect the test set so that the timer is no longer stopped by the Trip contact, but is now stopped by the **Signal Send contact** (the contact that would normally be connected to the pilot/signaling channel).

Inject a Zone 1 fault, and record the signal send contact operating time. The measured operating time should typically be less than 20ms for 50Hz, and less than 16.7ms for 60Hz applications. Switch OFF the ac supply and reset the alarms.

6.2.5.5 Signal send test for blocking scheme only

Firstly, reconnect the test set so that the timer is no longer stopped by the Trip contact, but is now stopped by the **Signal Send contact** (the contact that would normally be connected to the pilot/signaling channel).

Inject a Zone 4 fault, and record the signal send contact operating time. The measured operating time should typically be less than 20ms for 50Hz, and less than 16.7ms for 60Hz applications. Switch OFF the ac supply and reset the alarms.

6.2.6 Scheme timer settings

Only a visual check that the correct time delay settings have been applied is needed. The relevant settings in the AIDED SCHEMES column are:

- [344A: tRev. Guard] if applicable/visible
- [344B: Unblocking Delay] if applicable/visible
- [3453: WI Trip Delay] if applicable/visible

Upon completion of the tests any Phase diff, DEF, overcurrent, earth fault, breaker fail or supervision elements which were disabled for testing purposes must have their original settings restored in the CONFIGURATION column. Ensure that the Static Test Mode has been left *Disabled*. Ensure that any wires/leads temporarily fitted to energize the channel receive opto input have been removed.

6.2.7 Out of step protection (if enabled)

Out of Step protection is only applicable to P54x J, software version 33 onwards.

This test is suitable for injection sets with a state sequencer function as dynamic impedance conditions are going to be tested. Up to four states impedances that will be applied during the Out of Step commissioning are presented in Figure 4.

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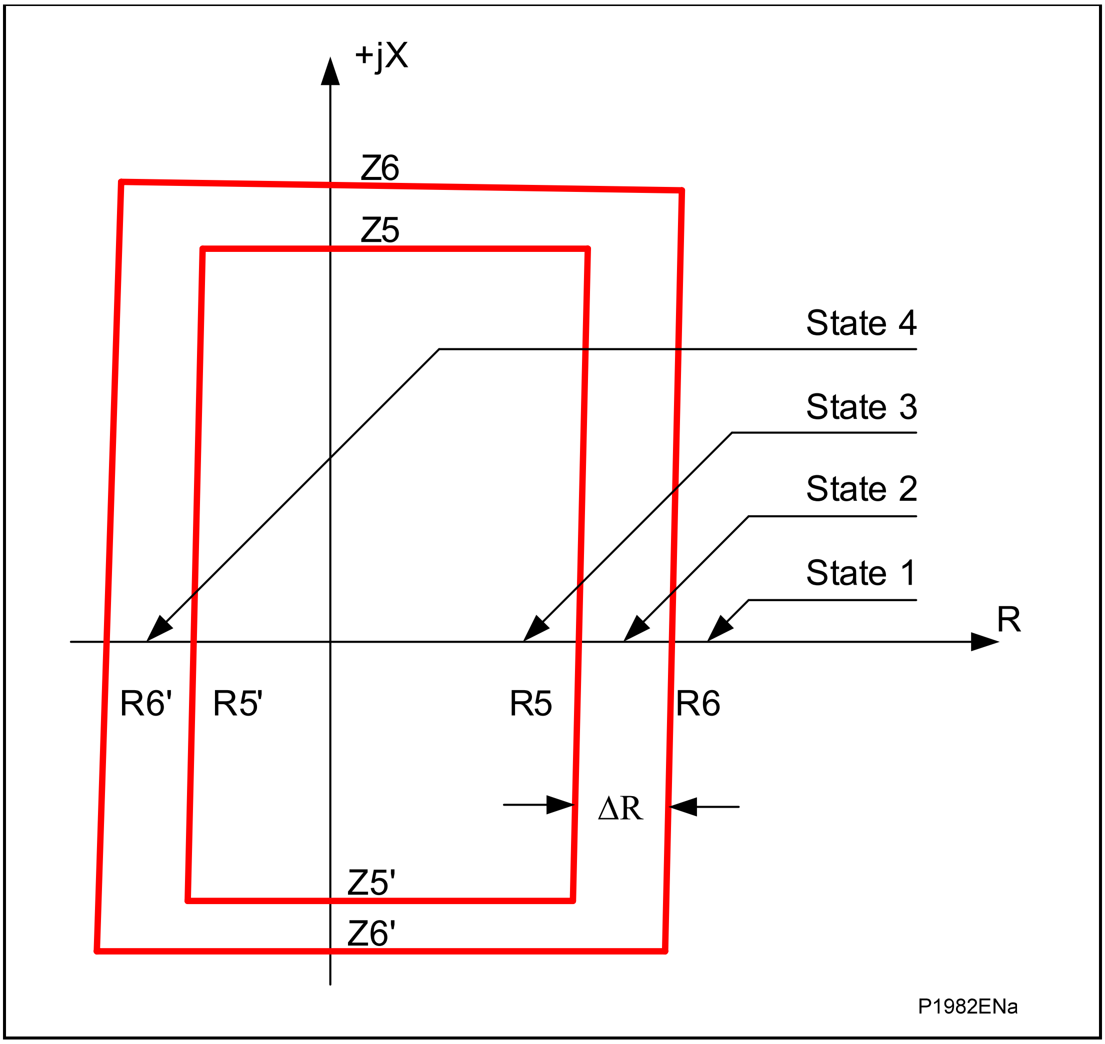

Figure 4: Four state impedances

Depending on the Out of Step settings, follow one of the three options.

6.2.7.1 Predictive OST setting

Clear all alarms. Set Tost to zero. Based on healthy voltages (VA = VB = VC = 57.8V) calculate the currents to generate the impedances as per Table 11.

	State 1	State 2	State 3
Apply IA = IB = IC =	$\frac{57.8}{1.1*R6}$	$\frac{57.8}{R5+\frac{1}{2}(R6-R5)}$	$\frac{57.8}{0.9*R5}$
Angle	0°	0°	0°
Duration	500ms	Longer than 25ms but shorter that 'Delta t' set time	500ms

Table 11: Predictive OST state sequence

Note: Angle in the table above is the angle between voltages and their respective currents.

Now apply the 3 state sequence to the relay under test and observe that the relay has tripped 3 phase and that an associated 'Predictive OST' alarm is displayed on the local LCD.

Clear all alarms.

6.2.7.2 OST setting

Clear all alarms. Set Tost to zero. Based on healthy voltages (VA = VB = VC = 57.8V) calculate the currents to generate the impedances as per Table 12.

	State 1	State 2	State 3	State 4
Apply IA = IB = IC =	$\frac{57.8}{1.1*R6}$	$\frac{57.8}{R5+\frac{1}{2}(R6-R5)}$	$\frac{57.8}{0.9*R5}$	$\frac{57.8}{1.1*R5'}$
Angle	0°	0°	0°	180°
Duration	500ms	Longer than ‘Delta t’ set time	100ms	500ms

Table 12: OST state sequence

Note: Angle in the table above is the angle between voltages and their respective currents. Also note that in state 4 the currents are displaced 180° from their respective voltages.

Now apply the 4 state sequence to the relay under test and observe that the relay has tripped 3 phase and that an associated ‘OST’ alarm is displayed on the local LCD.

6.2.7.3 Predictive and OST setting

As per ‘Predictive OST’ above.

6.2.7.4 ‘Tost’ timer test

Repeat the test as for ‘Predictive OST’ and observe that the 3phase tripping will come up after ‘Tost’ set time delay. Record the operating time in the commissioning record sheet.

6.2.8 Directional earth fault aided scheme (ground current pilot scheme)

If the Aided DEF protection function is being used, it should be tested. If not, skip to section 6.3.

To avoid spurious operation of any phase diff, distance, overcurrent, earth fault or breaker fail elements, these should be disabled for the duration of the DEF tests. This is done in the relay’s CONFIGURATION column. Make a note of which elements need to be re-enabled after testing.

This set of injection tests aims to determine that a single P54x relay, at one end of the scheme is performing correctly. The relay is tested in isolation, with the communications channel to the remote line terminal disconnected. Verify that the P54x relay cannot send or receive channel scheme signals to/from the remote line end.

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6.2.8.1 Connect the test circuit

Determine which output relay(s) has/have been selected to operate when a DEF trip occurs by viewing the relay’s programmable scheme logic.

If the trip outputs are phase-segregated (i.e. a different output relay allocated for each phase), the relay assigned for tripping on ‘A’ phase faults should be used.

Connect the output relay so that its operation will trip the test set and stop the timer.

Connect the current output of the test set to the ‘A’ phase current transformer input of the relay. Connect, all three phase voltages to the relay Va, Vb, and Vc. Ensure that the timer will start when the current is applied to the relay.

Ensure that the timer is reset, and prepare the test shot below:

– Simulate a forward fault on the A-phase. The A-phase voltage must be simulated to drop by 4 times the [3905] or [3906] : "DEF Vpol" setting, i.e.:

  Va = Vn - (4 x DEF Vpol)

The fault current on the A-phase should be set to 2 times the [3907: DEF Threshold] setting, and in the forward direction. For a forward fault, the current Ia should lag the voltage Va by the "DEF Char Angle" setting, i.e.:

$Ia = 2 \times IN_{\text{DEF Threshold}} \angle \theta_{\text{DEF}}$

Phases B and C should retain their healthy prefault voltage, and no current. The duration of the injection should be in excess of the **DEF Delay** setting (typically tDEF Delay + 100ms).

Direction of Fault Test Injection	**RELAY RESPONSE**			
	Forward Fault		**Reverse Fault**	
Signal Receive Opto	**ON**	**OFF**	**ON**	**OFF**
Blocking Scheme	No Trip, No Signal Send	Trip, No Signal Send	No Trip, Signal Send	No Trip, Signal Send
Permissive Scheme (POR/POTT)	Trip, Signal Send	No Trip, Signal Send	No Trip, No Signal Send	No Trip, No Signal Send

A forward fault will be injected as described, with the intention to cause a scheme trip. As in the table, for a Permissive scheme the Signal Receive opto input will need to be ON (energized). This should be performed by applying a continuous DC voltage onto the required opto input, either from the test set, station battery, or relay field voltage (commissioning engineer to ascertain the best method).

For a blocking scheme, the opto should remain de-energized ("OFF").

6.2.8.2 DEF aided scheme - forward fault trip test

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Apply the fault and record the (phase A) trip time. Switch OFF the ac supply and reset the alarms.

– The aided ground fault (DEF) scheme trip time for POR schemes should be less than 40ms.

– For blocking schemes, where a non-zero DEF Dly time delay is set, the expected operating time is typically within +/- 5% of the delay setting plus the "instantaneous" (40ms) delay quoted above.

– There is no need to repeat the test for phases B and C, as these trip assignments have already been proven by the distance/delta trip tests.

6.2.9 DEF aided scheme - scheme testing

6.2.9.1 Signal send test for permissive schemes (POR/POTT only)

Firstly, reconnect the test set so that the timer is no longer stopped by the Trip contact, but is now stopped by the **Signal Send contact** (the contact that would normally be connected to the pilot/signaling channel).

Repeat the forward fault injection, and record the signal send contact operating time. The measured operating time should typically be less than 40ms. Switch OFF the ac supply and reset the alarms.

6.2.9.2 Signal send test for blocking schemes only

Firstly, reconnect the test set so that the timer is no longer stopped by the Trip contact, but is now stopped by the **Signal Send contact** (the contact that would normally be connected to the pilot/signaling channel).

Secondly, reverse the current flow direction on the “A” phase, to simulate a reverse fault.

Perform the reverse fault injection, and record the signal send contact operating time. The measured operating time should typically be less than 40ms. Switch OFF the ac supply and reset the alarms.

Upon completion of the tests any phase diff, distance, overcurrent, earth fault, breaker fail or supervision elements which were disabled for testing purposes must have their original settings restored in the CONFIGURATION column. Ensure that any wires/leads temporarily fitted to energize the channel receive opto input have been removed.

6.3 Signaling channel check

This section aims to check that the signaling channel is able to transmit the ON/OFF signals used in aided schemes between the remote line ends. Before testing, check that the channel is healthy (for example, if a power line carrier link is being used, it may not be possible to perform the tests until the protected circuit is live and has in-service). If the channel tests must be postponed, make a note to perform them as a part of the “ON-LOAD CHECKS” in section 8 of these Commissioning Instructions.

If any channel uses InterMiCOM^{64} signaling, sections 5.3 must be observed.

6.3.1 Aided scheme 1

If Aided Scheme 1 is enabled, it must be tested. This is achieved by operating output contacts as in section 5.2.7 to mimic the relay sending an aided channel signal.

Note: **For these tests, it will be necessary that an engineer is present at both ends of the line - at the local end to send aided signals, and at the remote end to observe that the signals have been received as required. A telephone link between the two commissioning engineers will be necessary, to allow conversation.**

Put the relay in test mode by setting cell [0F0D: COMMISSION TESTS, Test Mode] to ‘Blocked’.

Record which contact is assigned as the *Signal Send 1* output. Select this output contact as the one to test. And advise the remote end engineer that the contact is about to be tested.

6.3.1.1 Remote end preparation to observe channel arrival

At the remote end, the engineer must confirm the assignment of the Monitor Bits in the COMMISSION TESTS column in the menu, in order to be able to see the aided channel on arrival. Scroll down and ensure cells are set: [0F05: Monitor Bit 1] to 493, and [0F09: Monitor Bit 5] to 507. In doing so, cell [0F03: Test Port Status] will appropriately set or reset the bits that now represent Aided 1 Scheme Receive (DDB #493), and Aided 2 Scheme Receive (DDB #507), with the rightmost bit representing Aided Channel 1. From now on the remote end engineer should monitor the indication of [0F03: Test Port Status].

6.3.1.2 Application of the test

At the local end, to operate the output relay set cell [0F0F: COMMISSION TESTS, Contact Test] to ‘Apply Test’.

Reset the output relay by setting cell [0F0F: COMMISSION TESTS, Contact Test] to ‘Remove Test’.

Note: It should be ensured that thermal ratings of anything connected to the output relays during the contact test procedure are not exceeded by the associated output relay being operated for too long. It is therefore advised that the time between application and removal of the contact test is kept to the minimum.

Check with the engineer at the remote end that the Aided Channel 1 signal did change state as expected. The Test Port Status should have responded as in the table below:

DDB No.				**507**				**493**
Monitor Bit	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Contact Test OFF	X	X	X	X	X	X	X	0
Contact Test Applied (ON)	X	X	X	X	X	X	X	1
Test OFF	X	X	X	X	X	X	X	0

Note: “x” = Wildcard/denotes don’t care.

Return the relay to service by setting cell [0F0D: COMMISSION TESTS, Test Mode] to ‘Disabled’.

6.3.1.3 Channel check in the opposite direction

Repeat the aided scheme 1 test procedure, but this time to check that the channel responds correctly when keyed from the remote end. The remote end commissioning engineer should perform the contact test, with the Monitor Option observed at the local end.

6.3.2 Aided scheme 2

If applicable, now repeat the test for Aided Channel 2. Repeat as per 6.3.1 above, checking that Monitor Bit 5 responds correctly for channel transmission in both directions (from the local end to the remote end, and vice versa).

Return the relay to service by setting cell [0F0D: COMMISSION TESTS, Test Mode] to ‘Disabled’.

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6.3.3 Backup phase overcurrent protection

If the overcurrent protection function is being used, the I>1 element should be tested. If not, skip to section 6.4 .

To avoid spurious operation of any current differential, distance, DEF, earth fault or breaker fail elements, these should be disabled for the duration of the overcurrent tests. This is done in the relay’s CONFIGURATION column. Make a note of which elements need to be re-enabled after testing.

Note: If the I>1 element is set to be “Enabled on Channel Fail” it will be necessary to deliberately force a communications channel failure in order to test it. This can be achieved by removing the loopback test, and ensuring that the relay cannot communicate with the remote end relay.

Set cell [0F13: Test Loopback] to “Disabled”

Observe that the relay raises a Comms Fail alarm.

6.3.3.1 Connect the test circuit

Determine which output relay has been selected to operate when an I>1 trip occurs by viewing the relay’s programmable scheme logic.

The relay assigned for Trip Output A (DDB 523) faults should be used.

Stage 1 should be mapped directly to an output relay in the programmable scheme logic. If default PSL is used, Relay 3 can be used as I1> is mapped to Trip inputs 3 Ph (DDB 529) that in turn is internally mapped to Any Trip (DDB 522) mapped to relay 3 (see trip conversion logic on section P54x/EN OP) .

Connect the output relay so that its operation will trip the test set and stop the timer.

Connect the current output of the test set to the 'A' phase current transformer input of the relay (terminals C3 and C2 where 1A current transformers are being used and terminals C1 and C2 for 5A current transformers).

If [3503: GROUP 1 OVERCURRENT, I>1 Directional] is set to 'Directional Fwd', the current should flow out of terminal C2 but into C2 if set to 'Directional Rev'.

If cell [3503: GROUP 1 OVERCURRENT, I>1 Directional] has been set to 'Directional Fwd' or 'Directional Rev' then rated voltage should be applied to terminals C20 and C21.

Ensure that the timer will start when the current is applied to the relay.

Note: If the timer does not stop when the current is applied and stage 1 has been set for directional operation, the connections may be incorrect for the direction of operation set. Try again with the current connections reversed.

6.3.3.2 Perform the test

Ensure that the timer is reset.

Apply a current of twice the setting in cell [3504: GROUP 1 OVERCURRENT, I>1 Current Set] to the relay and note the time displayed when the timer stops.

Check that the red trip LED has illuminated.

6.3.3.3 Check the operating time

Check that the operating time recorded by the timer is within the range shown in Table 13.

Note: Except for the definite time characteristic, the operating times given in Table 14 are for a time multiplier or time dial setting of 1. Therefore, to obtain the operating time at other time multiplier or time dial settings, the time given in Table 14 must be multiplied by the setting of cell [3506: GROUP 1 OVERCURRENT, I>1 TMS] for IEC and UK characteristics or cell [3507: GROUP 1 OVERCURRENT, Time Dial] for IEEE and US characteristics.

In addition, for definite time and inverse characteristics there is an additional delay of up to 0.02 second and 0.08 second respectively that may need to be added to the relay's acceptable range of operating times.

For all characteristics, allowance must be made for the accuracy of the test equipment being used.

Characteristic	Operating Time at Twice Current Setting and Time Multiplier/ Time Dial Setting of 1.0	
	Nominal (seconds)	**Range (seconds)**
DT	[3505: I>1 Time Delay] setting	Setting ±2%
IEC S Inverse	10.03	9.53 - 10.53
IEC V Inverse	13.50	12.83 - 14.18
IEC E Inverse	26.67	24.67 - 28.67
UK LT Inverse	120.00	114.00 - 126.00
IEEE M Inverse	3.8	3.61 - 4.0
IEEE V Inverse	7.03	6.68 - 7.38
IEEE E Inverse	9.50	9.02 - 9.97
US Inverse	2.16	2.05 - 2.27
US ST Inverse	12.12	11.51 - 12.73

Table 13: Characteristic operating times for I>1

Upon completion of the tests any current differential, distance, overcurrent, earth fault, breaker fail or supervision elements which were disabled for testing purposes must have their original settings restored in the CONFIGURATION column.

6.4 Check trip and auto-reclose cycle (only P543 and P545 models)

If the auto-reclose function is being used, the circuit breaker trip and auto-reclose cycle can be tested automatically at the application-specific settings.

To test the first three-phase auto-reclose cycle, set cell [0F11: COMMISSION TESTS, Test Auto-reclose] to ‘3 Pole Test’. The relay will perform a trip/reclose cycle. Repeat this operation to test the subsequent three-phase auto-reclose cycles.

Check all output relays used for circuit breaker tripping and closing, blocking other devices, etc. operate at the correct times during the trip/close cycle.

The auto-reclose cycles for single phase trip conditions can be checked one at a time by sequentially setting cell [0F11: COMMISSION TESTS, Test Auto-reclose] to ‘Pole A Test’, ‘Pole B Test’ and ‘Pole C Test’.

6.5 Disable all commissioning testing options

Ensure that all Test Mode, and Static Test options have been **disabled**. Clear, then re-read any alarms present to be certain that no alarms relating to these test options remain.

6.6 Check application settings

The settings applied should be carefully checked against the required application-specific settings to ensure that they are correct, and have not been mistakenly altered during the injection test.

There are two methods of checking the settings:

– Extract the settings from the relay using a portable PC running the appropriate software via the front EIA(RS)232 port, located under the bottom access cover, or rear communications port (with a KITZ protocol converter connected). Compare the settings transferred from the relay with the original written application-specific setting record. (For cases where the customer has only provided a printed copy of the required settings but a portable PC is available).

– Step through the settings using the relay’s operator interface and compare them with the original application-specific setting record. Ensure that all protection elements required have been ENABLED in the CONFIGURATION column.

Unless previously agreed to the contrary, the application-specific programmable scheme logic will not be checked as part of the commissioning tests.

7. END TO END TESTS

In section 5.3.1 a loopback test was initiated on the relay fiber optic communications channels, together with the P590 interface units, if installed, to verify correct operation of the communications channel local to the P54x relay whilst completing the remaining tests. In this section the loopback test is removed and, if possible, satisfactory communications between P54x relays in the same group will be confirmed.

Note: The trip circuit should remain isolated during these checks to prevent accidental operation of the associated circuit breaker.

7.1 Remove the loopback test

As well as removing the loopback test, this section checks that all wiring and optical fibers are reconnected. If P592 or P593 interface units are installed the application-specific settings will also be applied.

Check the alarm records to ensure that no communications failure alarms have occurred whilst the loopback test has been in progress.

Set cell [0F13 LoopBack Mode] to 'Loopback off'.

Restore the communications channels as per the appropriate sub-section below.

7.1.1 Direct fiber optic communications

Remove the loopback test fiber and reconnect the fiber optic cables for communications between relays, ensuring correct placement.

When connecting or disconnecting optical fibers care should be taken not to look directly into the transmit port or end of the optical fibers.

7.1.2 Communications using P591 interface units

Return to the P591 units.

Ensure that all external wiring that has been removed to facilitate testing is replaced in accordance with the relevant connection diagram or scheme diagram.

If applicable, replace the secondary front cover on the P591 units.

7.1.3 Communications using P592 interface units

Return to the P592 units.

Ensure that all external wiring that has been removed to facilitate testing is replaced in accordance with the relevant connection diagram or scheme diagram.

Set the 'V.35 LOOPBACK' switch to the '0' position.

Set the 'CLOCK SWITCH', 'DSR', 'CTS' and 'DATA RATE' DIL switches on each unit to the positions required for the specific application and ensure the 'OPTO LOOPBACK' switch is in the '0' position.

If applicable, replace the secondary front cover on the P592 units.

Note: V.35 Loopback on the remote P592 can be selected to check the communications between the local relay, the local P592 and the communication link itself.

7.1.4 Communications using P593 interface units

Return to the P593 units.

Ensure that all external wiring that has been removed to facilitate testing is replaced in accordance with the relevant connection diagram or scheme diagram.

Set the ‘X.21 LOOPBACK’ switch to the ‘OFF’ position and ensure the ‘OPTO LOOPBACK’ switch is also in the ‘OFF’ position.

If applicable, replace the secondary front cover on the P593 units.

Note: X.21 Loopback on the remote P593 can be selected to check the communications between the local relay, the local P593 and the X.21 communication link itself. This setting on the local P593 can also be used to check the communications between the local relay and the local P593 if required.

7.2 Verify communications between relays

The following communication checks confirm that the optical power at the transmit and receive ports of the local relay are within the recommended operating limits. However, these checks can only be performed with the relays, and P590 interface units, if installed, at the other ends of the feeder known to be functional and energized.

Measure and record the optical signal strength received by the local P54x relay by disconnecting the optical fiber from the Channel 1 receive port and connecting it to an optical power meter. The mean level should be in the range -16.8dBm to -25.4dBm for an 850nm port and in the range -7dBm to -37dBm for a 1300nm port. If the mean level is outside of this range check the size and type of fiber being used.

When connecting or disconnecting optical fibers care should be taken not to look directly into the transmit port or end of the optical fiber.

Repeat for Channel 2 receive port (if applicable).

Measure and record the optical power of the Channel 1 transmit port using the optical power meter and length of optical fiber. The mean value should be in the range -16.8dBm to 22.8dBm for an 850nm port and in the range -7dBm to -13dBm for a 1300nm port.

Repeat for Channel 2 transmit port (if applicable).

Ensure that all transmit (Tx) and receive (Rx) optical fibers are reconnected to the P54x, ensuring correct placement.

Reset any alarm indications and check that no further communications failure alarms are raised. Check channel status and propagation delays in [MEASUREMENTS 4] column. Specifically check that all 12 bits in ‘Channel Status’ are zero. Clear the statistics and record the number of valid messages and the number of errored messages after a minimum period of 1 hour. Check that the ratio of errored/good messages is better than 10^{-4}. Record the measured message propagation delays for channel 1, and channel 2 (if fitted).

8. ON-LOAD CHECKS

The objectives of the on-load checks are to:

- Confirm the external wiring to the current and voltage inputs is correct
- Measure the magnitude of capacitive current
- Ensure the on-load differential current is well below the relay setting
- Check the polarity of the line current transformers at each end is consistent
- Directionality check for distance elements

However, these checks can only be carried out if there are no restrictions preventing the energization of the plant being protected and the other P54x relays in the group have been commissioned.

Remove all test leads, temporary shorting leads, etc. and replace any external wiring that has been removed to allow testing.

If it has been necessary to disconnect any of the external wiring from the relay in order to perform any of the foregoing tests, it should be ensured that all connections are replaced in accordance with the relevant external connection or scheme diagram.

8.1 Confirm current and voltage transformer wiring

8.1.1 Voltage connections

Using a multimeter measure the voltage transformer secondary voltages to ensure they are correctly rated. Check that the system phase rotation is correct using a phase rotation meter.

Compare the values of the secondary phase voltages with the relays measured values, which can be found in the MEASUREMENTS 1 menu column.

Voltage	Cell in MEASUREMENTS 1 Column (02)	Corresponding VT Ratio in 'VT and CT RATIO' Column (0A) of Menu)
VAB	[0214: VAB Magnitude]	[0A01 : Main VT Primary] / [0A02 : Main VT Secondary]
VBC	[0216: VBC Magnitude]	
VCA	[0218: VCA Magnitude]	
VAN	[021A: VAN Magnitude]	
VBN	[021C: VBN Magnitude]	
VCN	[021E: VCN Magnitude]	
VCHECKSYNC.	[022E: C/S Voltage Mag.]	[0A03 : C/S VT Primary] / [0A04 : C/S VT Secondary]

Table 14: Measured voltages and VT ratio settings

If cell [0D02: MEASURE'T. SETUP, Local Values] is set to 'Secondary', the values displayed on the relay LCD or a portable PC connected to the front EIA(RS)232 communication port should be equal to the applied secondary voltage. The values should be within 1% of the applied secondary voltages. However, an additional allowance must be made for the accuracy of the test equipment being used.

If cell [0D02: MEASURE'T. SETUP, Local Values] is set to 'Primary', the values displayed should be equal to the applied secondary voltage multiplied the corresponding voltage transformer ratio set in the 'CT & VT RATIOS' menu column (see Table 10). Again the values should be within 1% of the expected value, plus an additional allowance for the accuracy of the test equipment being used.

8.1.2 Current connections

Measure the current transformer secondary values for each input using a multimeter connected in series with the corresponding relay current input.

Check that the current transformer polarities are correct by measuring the phase angle between the current and voltage, either against a phase meter already installed on site and known to be correct or by determining the direction of power flow by contacting the system control center.

Ensure the current flowing in the neutral circuit of the current transformers is negligible.

Compare the values of the secondary phase currents and phase angle with the relay's measured values, which can be found in the MEASUREMENTS 1 menu column.

If cell [0D02: MEASURE'T. SETUP, Local Values] is set to 'Secondary', the currents displayed on the LCD or a portable PC connected to the front EIA(RS)232 communication port of the relay should be equal to the applied secondary current. The values should be within 1% of the applied secondary currents. However, an additional allowance must be made for the accuracy of the test equipment being used.

If cell [0D02: MEASURE'T. SETUP, Local Values] is set to 'Primary', the currents displayed on the relay should be equal to the applied secondary current multiplied by the corresponding current transformer ratio set in 'CT & VT RATIOS' menu column . Again the values should be within 1% of the expected value, plus an additional allowance for the accuracy of the test equipment being used.

8.2 Measure capacitive charging current

With the feeder energized from one end only, compare the local and remote measured currents in the MEASUREMENTS 3 menu column to confirm that the feeder capacitive charging current is similar to that expected on all three phases.

Check that the setting of cell [3302: GROUP 1 PHASE DIFF, Phase Is1] is higher than 2.5 times the capacitive charging current. If this is not the case, notify the Engineer who determined the original settings of the setting required to ensure stability under normal operating conditions.

8.3 Check differential current

With the feeder supplying load current check that the relay measurements in the MEASUREMENTS 3 menu column are as expected and that the differential current is similar to the value of capacitive charging current previously measured for all.

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8.4 Check consistency of current transformer polarity

The load current should be high enough to be certain beyond doubt that the main current transformers are connected with the same polarity to each relay in the group.

There is a possibility on cable circuits with high line capacitance that the load current could be masked by the capacitive charging current. If necessary reverse the connections to the main current transformers and check that the 'A' phase differential current in cell [0419: MEASUREMENTS 3, IA Differential] is significantly higher than for the normal connection. If the differential current falls with the connection reversed, the main current transformers may not be correct and should be thoroughly checked. Repeat the test for phases 'B' and 'C' using cells [0420: MEASUREMENTS 3, IB Differential] and [0419: MEASUREMENTS 3, IC Differential] respectively.

8.5 On load directional test

This test is important to ensure that directionalized overcurrent and fault locator functions have the correct forward/reverse response to fault and load conditions.

Firstly the actual direction of power flow on the system must be ascertained, using adjacent instrumentation or protection already in-service, or a knowledge of the prevailing network operation conditions.

- For load current flowing in the Forward direction - i.e. power export to the remote line end, cell [0301: MEASUREMENTS 2, A Phase Watts] should show **positive** power signing
- For load current flowing in the Reverse direction - i.e. power import from the remote line end, cell [0301: MEASUREMENTS 2, A Phase Watts] should show **negative** power signing

Note: The check above applies only for Measurement Modes 0 (default), and 2. This should be checked in [0D05: MEASURE'T. SETUP, Measurement Mode = 0 or 2]. If measurement modes 1 or 3 are used, the expected power flow signing would be opposite to that shown in the bullets above.

In the event of any uncertainty, check the phase angle of the phase currents with respect to the their phase voltage.

8.6 Signaling channel check (if not already completed)

If the aided scheme signaling channel(s) was/were not tested already in section 5.3 they should be tested now. This test may be avoided only with the agreement of the customer, or if only the basic scheme is used.

9. FINAL CHECKS

The tests are now complete.

Remove all test or temporary shorting leads, etc. If it has been necessary to disconnect any of the external wiring from the relay in order to perform the wiring verification tests, it should be ensured that all connections (wiring, fuses and links) are replaced in accordance with the relevant external connection or scheme diagram.

Ensure that the relay has been restored to service by checking that cell [0F0D: COMMISSION TESTS, Test Mode] is set to 'Disabled'.

If the relay is in a new installation or the circuit breaker has just been maintained, the circuit breaker maintenance and current counters should be zero. These counters can be reset using cell [0609: CB CONDITION, Reset All Values]. If the required access level is not active, the relay will prompt for a password to be entered so that the setting change can be made.

If the menu language has been changed to allow accurate testing it should be restored to the customer's preferred language.

If a P991/MMLG test block is installed, remove the P992/MMLB test plug and replace the cover so that the protection is put into service.

Ensure that all event records, fault records, disturbance records, alarms and LEDs have been reset before leaving the relay.

If applicable, replace the secondary front cover on the relay.

10. COMMISSIONING TEST RECORD

Date:		Engineer:	
Station:		Circuit:	
		System Frequency:	Hz
VT Ratio:	/ V	CT Ratio (tap in use):	/ A

Front Plate Information

Distance protection relay	**P54____**
Model number	
Serial number	
Rated current In	1A ☐ 5A ☐
Rated voltage Vn	
Auxiliary voltage Vx	

Test Equipment Used

This section should be completed to allow future identification of protective devices that have been commissioned using equipment that is later found to be defective or incompatible but may not be detected during the commissioning procedure.

Injection test set	Model: Serial No:	
Optical power meter	Model: Serial No:	
Phase angle meter	Model: Serial No:	
Phase rotation meter	Model: Serial No:	
Insulation tester	Model: Serial No:	
Setting software:	Type: Version:	

*Delete as appropriate

	Have all relevant safety instructions been followed?	Yes* ☐ No* ☐
5.	**Product checks**	
5.1	**With the relay de-energized**	
5.1.1	Visual inspection	
	Relay damaged?	Yes* ☐ No* ☐
	Rating information correct for installation?	Yes* ☐ No* ☐
	Case earth installed?	Yes* ☐ No* ☐
5.1.2	Current transformer shorting contacts close?	Yes* ☐ No* ☐ Not checked* ☐
5.1.3	Insulation resistance >100MΩ at 500V dc	Yes* ☐ No* ☐ Not tested* ☐
5.1.4	External wiring	
	Wiring checked against diagram?	Yes* ☐ No* ☐
	Test block connections checked?	Yes* ☐ No* ☐ N/A* ☐
5.1.5	Watchdog contacts (auxiliary supply off)	
	Terminals 11 and 12 Contact closed?	Yes* ☐ No* ☐
	Terminals 13 and 14 Contact open?	Yes* ☐ No* ☐
5.1.6	Measured auxiliary supply	______ V ac/dc*
5.2	**With the relay energized**	
5.2.1	Watchdog contacts (auxiliary supply on)	
	Terminals 11 and 12 Contact open?	Yes* ☐ No* ☐
	Terminals 13 and 14 Contact closed?	Yes* ☐ No* ☐
5.2.2	LCD front panel display	
	LCD contrast setting used	______
5.2.3	Date and time	
	Clock set to local time?	Yes* ☐ No* ☐
	Time maintained when auxiliary supply removed?	Yes* ☐ No* ☐
5.2.4	Light emitting diodes	
5.2.4.1	Alarm (yellow) LED working?	Yes* ☐ No* ☐
	Out of service (yellow) LED working?	Yes* ☐ No* ☐
5.2.4.3	All 18 programmable LEDs working?	Yes* ☐ No* ☐
5.2.5	Field supply voltage	
	Value measured between terminals 8 and 9	______ V dc

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5.2.6 Input opto-isolators

Opto input 1 working?	Yes* ☐ No* ☐
Opto input 2 working?	Yes* ☐ No* ☐
Opto input 3 working?	Yes* ☐ No* ☐
Opto input 4 working?	Yes* ☐ No* ☐
Opto input 5 working?	Yes* ☐ No* ☐
Opto input 6 working?	Yes* ☐ No* ☐
Opto input 7 working?	Yes* ☐ No* ☐
Opto input 8 working?	Yes* ☐ No* ☐
Opto input 9 working?	Yes* ☐ No* ☐
Opto input 10 working?	Yes* ☐ No* ☐
Opto input 11 working?	Yes* ☐ No* ☐
Opto input 12 working?	Yes* ☐ No* ☐
Opto input 13 working?	Yes* ☐ No* ☐
Opto input 14 working?	Yes* ☐ No* ☐
Opto input 15 working?	Yes* ☐ No* ☐
Opto input 16 working?	Yes* ☐ No* ☐
Opto input 17 working?	Yes* ☐ No* ☐ N/A* ☐
Opto input 18 working?	Yes* ☐ No* ☐ N/A* ☐
Opto input 19 working?	Yes* ☐ No* ☐ N/A* ☐
Opto input 20 working?	Yes* ☐ No* ☐ N/A* ☐
Opto input 21 working?	Yes* ☐ No* ☐ N/A* ☐
Opto input 22 working?	Yes* ☐ No* ☐ N/A* ☐
Opto input 23 working?	Yes* ☐ No* ☐ N/A* ☐
Opto input 24 working?	Yes* ☐ No* ☐ N/A* ☐

5.2.7 Output relays

Relay 1 working?	Yes* ☐ No* ☐
Relay 2 working?	Yes* ☐ No* ☐
Relay 3 working?	Yes* ☐ No* ☐
Relay 4 working?	Yes* ☐ No* ☐
Relay 5 working?	Yes* ☐ No* ☐
Relay 6 working?	Yes* ☐ No* ☐

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Relay 7	working?	Yes* ☐ No* ☐
Relay 8	working?	Yes* ☐ No* ☐
Relay 9	working?	Yes* ☐ No* ☐
Relay 10	working?	Yes* ☐ No* ☐
Relay 11	working?	Yes* ☐ No* ☐
Relay 12	working?	Yes* ☐ No* ☐
Relay 13	working?	Yes* ☐ No* ☐
Relay 14	working?	Yes* ☐ No* ☐
Relay 15	working?	Yes* ☐ No* ☐
Relay 16	working?	Yes* ☐ No* ☐
Relay 17	working?	Yes* ☐ No* ☐
Relay 18	working?	Yes* ☐ No* ☐
Relay 19	working?	Yes* ☐ No* ☐
Relay 20	working?	Yes* ☐ No* ☐
Relay 21	working?	Yes* ☐ No* ☐
Relay 22	working?	Yes* ☐ No* ☐
Relay 23	working?	Yes* ☐ No* ☐
Relay 24	working?	Yes* ☐ No* ☐
Relay 25	working?	Yes* ☐ No* ☐ N/A* ☐
Relay 26	working?	Yes* ☐ No* ☐ N/A* ☐
Relay 27	working?	Yes* ☐ No* ☐ N/A* ☐
Relay 28	working?	Yes* ☐ No* ☐ N/A* ☐
Relay 29	working?	Yes* ☐ No* ☐ N/A* ☐
Relay 30	working?	Yes* ☐ No* ☐ N/A* ☐
Relay 31	working?	Yes* ☐ No* ☐ N/A* ☐
Relay 32	working?	Yes* ☐ No* ☐ N/A* ☐

*Delete as appropriate

5.2.8	Communication standard	Courier* ☐ IEC60870-5-103* ☐ DNP3.0* ☐
	Communications established?	Yes* ☐ No* ☐
	Protocol converter tested?	Yes* ☐ No* ☐ N/A* ☐
	Fiber optic communications	
	Type of communications:	
	Channel 1	Dedicated fiber** ☐ Via P590* ☐
	Channel 2	Dedicated fiber** ☐ Via P590* ☐
5.3	Direct fiber communication	
	Communication working	Yes* ☐ No* ☐ N/A* ☐
	Type of P590 interface:	
	Channel 1 unit	P59_____* ☐ N/A* ☐
	Channel 2 unit	P59_____* ☐ N/A* ☐
5.3.1	Visual inspection (P590 units only)	
	Unit damaged?	
	Channel 1 unit	Yes* ☐ No* ☐ N/A* ☐
	Channel 2 unit	Yes* ☐ No* ☐ N/A* ☐
	Rating information correct?	
	Channel 1 unit	Yes* ☐ No* ☐ N/A* ☐
	Channel 2 unit	Yes* ☐ No* ☐ N/A* ☐
	Case earth installed?	
	Channel 1 unit	Yes* ☐ No* ☐ N/A* ☐
	Channel 2 unit	Yes* ☐ No* ☐ N/A* ☐
5.2	Insulation resistance (P590 units only)	
	Channel 1 unit	Yes* ☐ No* ☐ Not tested* ☐ N/A* ☐

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	Channel 2 unit	Yes* ☐ No* ☐ Not tested* ☐ N/A* ☐
5.3.3	External wiring (P590 units only)	
	Wiring checked against diagram?	
	Channel 1 unit	Yes* ☐ No* ☐ N/A* ☐
	Channel 2 unit	Yes* ☐ No* ☐ N/A* ☐
5.3.4	Measured auxiliary supply (P590 units only)	
	Channel 1 unit	_____ Vdc* _____ Vac* _____ N/A*
	Channel 2 unit	_____ Vdc* _____ Vac* _____ N/A*
5.3.5	Light emitting diodes (P590 units only)	
	All LED's working?	
	Channel 1 unit	Yes* ☐ No* ☐ N/A* ☐
	Channel 2 unit	Yes* ☐ No* ☐ N/A* ☐
5.3.6	Loopback test	
	Signal strength received by P590	
	Channel 1 unit	_____ dBm* N/A* ☐
	Channel 2 unit	_____ dBm* N/A* ☐
	Signal strength transmitted by P590	
	Channel 1 unit	_____ dBm* N/A* ☐
	Channel 2 unit	_____ dBm* N/A* ☐
	Signal strength within tolerance	Yes* ☐ No* ☐ N/A* ☐
	Loopback test applied?	
	Channel 1 unit	Yes* ☐ No* ☐
	Channel 2 unit	Yes* ☐ No* ☐ N/A* ☐
	Communications working	Yes* ☐ No* ☐ N/A* ☐

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5.4.1	Visual Inspection (P594 units only)	
	Unit damaged?	Yes* ☐ No* ☐ N/A* ☐
	Rating information correct?	Yes* ☐ No* ☐ N/A* ☐
	Case earth installed?	Yes* ☐ No* ☐ N/A* ☐
5.4.2	Insulation resistance (P594 units only)	Yes* ☐ No* ☐ Not tested* ☐ N/A* ☐
5.4.3	External wiring (P594 units only)	
	Wiring checked against diagram?	Yes* ☐ No* ☐ N/A* ☐
5.4.4	Measured auxiliary supply (P594 units only)	______ Vdc* ______ Vac* ______ N/A*
5.4.5	Light emitting diodes (P594 units only)	
	All LED's working?	Yes* ☐ No* ☐ N/A* ☐
5.4.6	Synchronizing signal	
	Channel 1	______ dBm* N/A* ☐
	Channel 2	______ dBm* N/A* ☐
	Channel 3	______ dBm* N/A* ☐
	Channel 4	______ dBm* N/A* ☐
5.4.7	Signal strength within tolerance	Yes* ☐ No* ☐ N/A* ☐
5.4.8	Connection to P54x	
	Channel status correct?	Yes* ☐ No* ☐ N/A* ☐

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5.5.1	Current inputs		
	Displayed current		Primary* ☐ Secondary* ☐
	Phase CT ratio		_____ N/A* ☐
	Mutual CT ratio		_____ N/A* ☐
	Input CT	Applied Value	Displayed Value
	IA	_____ A	_____ A
	IB	_____ A	_____ A
	IC	_____ A	_____ A
	IM	_____ A N/A* ☐	_____ A N/A* ☐

5.5.1	Voltage inputs		
	Displayed voltage		Primary* ☐ Secondary* ☐
	Main VT ratio		_____ N/A* ☐
	C/S VT ratio		_____ N/A* ☐
	Input VT	Applied Value	Displayed value
	VAN	_____ V	_____ V
	VBN	_____ V	_____ V
	VCN	_____ V	_____ V
	C/S voltage	_____ V N/A* ☐	_____ V

6.	Setting checks	
6.1	Application-specific function settings applied?	Yes* ☐ No* ☐
	Application-specific programmable scheme logic settings applied?	Yes* ☐ No* ☐ N/A* ☐
6.2	Injection testing - current diff	
6.2.1	Elements to be re-enabled after testing (mark any that have been temporarily disabled)	Distance ☐ Earth fault ☐ Overcurrent ☐ DEF ☐ CB fail ☐ Na* ☐
6.2.1.2	Current differential lower slope pickup	_____ A
6.2.1.3	Current differential upper slope pickup	_____ A
6.2.2.1	Current differential phase A contact routing OK?	Yes* ☐ No* ☐
	Current differential phase A trip time	_____ s
6.2.2.2	Current differential phase B contact routing OK?	Yes* ☐ No* ☐
	Current differential phase B trip time	_____ s

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6.2.2.3	Current differential phase C contact routing OK?	Yes* ☐ No* ☐
	Current differential phase C trip time	_____ s
	Average trip time, phases A, B and C	_____ s
6.2.3	Injection testing - distance zones	
6.2.3.1	Elements to be re-enabled after testing (mark any that have been temporarily disabled)	Current diff ☐ Earth fault ☐ Overcurrent ☐ DEF ☐ CB fail ☐ Na* ☐
6.2.3.2	Zone 1 reach check - impedance at trip	_____ Ω Not measured* ☐
6.2.3.3	Zone 2 reach check - impedance at trip	_____ Ω Not measured* ☐
6.2.3.4	Zone 3 reach check - impedance at trip	_____ Ω Not measured* ☐
6.2.3.5	Zone 4 reach check - impedance at trip	_____ Ω Not measured* ☐
6.2.3.6	Zone P reach check - impedance at trip	_____ Ω Not measured* ☐
6.2.3.7	Resistive reach	
	Visual inspection	
	Phase & ground element resistive reach settings are correct?	Yes* ☐ No* ☐
6.2.3.8	Load blinder	
	Visual inspection	
	Load blinder settings are correct?	Yes* ☐ No* ☐ N/A* ☐
	Load blinder angle applied	_____ ° N/A* ☐
6.2.4.1	Distance phase A contact routing OK?	Yes* ☐ No* ☐
	Distance phase A trip time	_____ ms
6.2.4.2	Distance phase B contact routing OK?	Yes* ☐ No* ☐
	Distance phase B trip time	_____ ms
6.2.4.3	Distance phase C contact routing OK?	Yes* ☐ No* ☐
	Distance phase C trip time	_____ ms
	Average trip time, phases A, B and C	_____ ms

CM

*Delete as appropriate

6.2.4.4	Time delay settings tZ1 Ph, and tZ2 - tZ4	
	Visual inspection	
	Time delay settings are correct?	Yes* ☐ No* ☐
6.2.5	Distance protection scheme testing	
6.2.5.1	Scheme trip zone 1 extension scheme	
	No trip for fault with reset Z1X energized	Yes* ☐ No* ☐
	Trip time with reset Z1X de-energized	_____ ms
6.2.5.2	Scheme trip permissive schemes (PUR/POR)	
	Trip time with signal receive energized	_____ ms
6.2.5.3	Scheme trip blocking scheme	
	No trip for fault with signal receive energized	Yes* ☐ No* ☐
	Trip time with signal receive de-energized	_____ ms
6.2.5.4	Signal send test for permissive schemes	
	Signal send operate time	_____ ms
6.2.5.5	Signal send blocking schemes	
	Signal send operate time	_____ ms
6.2.6	Scheme timer settings	
	Visual inspection	
	Time delays settings are correct?	Yes* ☐ No* ☐
	All disabled elements which were noted/circled previously are restored?	Yes* ☐ No* ☐
6.2.7	Out of step protection	
6.2.7.1	Predictive OST	Enabled*☐ N/A* ☐
	Operated correctly?	Yes* ☐ No* ☐
	Operating time	_____ ms
6.2.7.2	OST	Enabled*☐ N/A* ☐
	Operated correctly?	Yes* ☐ No* ☐
	Operating time	_____ ms
6.2.7.3	Predictive and OST	Enabled*☐ N/A* ☐
	Operated correctly?	Yes* ☐ No* ☐
	Operating time	_____ ms
6.2.7.4	Tost timer test	
	Trip time	_____ ms

CM

*Delete as appropriate

6.2.8	Injection testing - DEF aided scheme	
6.2.8.1	Elements to be re-enabled after testing (mark any that have been temporarily disabled)	Current Diff ☐ Distance ☐ Earth fault ☐ Overcurrent ☐ CB fail ☐ Na* ☐
6.2.82	DEF aided scheme trip time	______ ms
6.2.9.1	DEF signal send time permissive scheme	______ ms
6.2.9.2	DEF signal send time blocking scheme	______ ms
	All disabled elements which were noted/circled previously are restored?	Yes* ☐ No* ☐
6.3	Signaling channel check	
6.3.1	Aided scheme 1 signaling channel test	
6.3.1.1	Local - remote end signal received	Yes* ☐ No* ☐ N/A* ☐
6.3.1.3	Remote - local end signal received	Yes* ☐ No* ☐ N/A* ☐
6.3.2	Aided scheme 2 signaling channel test	
	Local - remote end signal received	Yes* ☐ No* ☐ N/A* ☐
	Remote - local end signal received	Yes* ☐ No* ☐ N/A* ☐
	Protection function timing tested?	Yes* ☐ No* ☐
6.3.3	Overcurrent type (set in cell [I>1 Direction])	Directional* ☐ Non-directional* ☐
	Applied voltage	V/na*
	Applied current	A
6.3.3.3	Expected operating time	s
	Measured operating time	s
6.4	Trip and auto-reclose cycle checked (for models P543 and P545)	
	3 pole cycle tested?	Yes* ☐ No* ☐ N/A* ☐
	Pole A cycle tested?	Yes* ☐ No* ☐ N/A* ☐
	Pole B cycle tested?	Yes* ☐ No* ☐ N/A* ☐

CM

*Delete as appropriate

Pole C cycle tested?	Yes* ☐ No* ☐ N/A* ☐

7. End to end test

7.1 Remove the loopback test

Any Ch 1 communication alarm?	Yes* ☐ No* ☐
Any Ch 2 communication alarm?	Yes* ☐ No* ☐ N/A* ☐
Ch 1	Yes* ☐ No* ☐
Ch 2	Yes* ☐ No* ☐ N/A* ☐

All connections restored?

Ch 1	Yes* ☐ No* ☐
Ch 2	Yes* ☐ No* ☐ N/A* ☐

Application-specific settings applied? (P592/P593 only)

Ch 1	Yes* ☐ No* ☐ N/A* ☐
Ch 2	Yes* ☐ No* ☐ N/A* ☐

Cover replaced? (P59x only)

Ch 1	Yes* ☐ No* ☐ N/A* ☐
Ch 2	Yes* ☐ No* ☐ N/A* ☐

7.2 Verify communications between relays

Ch 1 optical port type	850nm* ☐ 1300nm* ☐
Ch 2 optical port type	850nm* ☐ 1300nm* ☐ N/A* ☐
Signal strength received by P54x on Ch 1	______ dBm*
Signal strength received by P54x on Ch 2	______ dBm* N/A* ☐
Signal strength transmitted by P54x on Ch 1	______ dBm*
Signal strength transmitted by P54x on Ch 2	______ dBm* N/A* ☐
Signal strength within tolerance?	Yes* ☐ No* ☐

CM

*Delete as appropriate

Optical fibers reconnected?

Ch 1	Yes* ☐ No* ☐
Ch 2	Yes* ☐ No* ☐ N/A* ☐
Alarms reset?	Yes* ☐ No* ☐
Ch 1 propagation time delay	_____ ms
Ch 2 propagation time delay	_____ ms N/A* ☐
Ch 1 No. valid messages	_____
Ch 1 No. err messages	_____
Ch 1 errored/valid	_____
Ch 1 errored/valid < 10-4	_____
Ch 2 No. valid messages	_____ N/A* ☐
Ch 2 No. err messages	_____ N/A* ☐
Ch 2 errored/valid	_____ N/A* ☐
Ch 2 errored/valid < 10-4	_____ N/A* ☐
Enter 12 bits channel status from MEASUREMENTS 4	_____
Was reverting to service condition successful and in accordance to Commissioning section 5.3?	Yes* ☐ No* ☐

CM

8. On-load checks

	Test wiring removed?	Yes* ☐ No* ☐
8.1.1	Voltage inputs and phase rotation OK?	Yes* ☐ No* ☐
8.1.2	Current inputs and polarities OK?	Yes* ☐ No* ☐
8.2	On-load test performed?	Yes* ☐ No* ☐
	(If “No”, give reason why) …	_____
	Relay is correctly directionalized?	Yes* ☐ No* ☐ N/A* ☐

9.1 Final checks

All test equipment, leads, shorts and test blocks removed safely?	Yes* ☐ No* ☐
Disturbed customer wiring re-checked?	Yes* ☐ No* ☐ N/A* ☐
All commissioning tests disabled?	Yes* ☐ No* ☐

*Delete as appropriate

Circuit breaker operations counter reset?	Yes* ☐ No* ☐ N/A* ☐
Current counters reset?	Yes* ☐ No* ☐ N/A* ☐
Event records reset?	Yes* ☐ No* ☐
Fault records reset?	Yes* ☐ No* ☐
Disturbance records reset?	Yes* ☐ No* ☐
Alarms reset?	Yes* ☐ No* ☐
LEDs reset?	Yes* ☐ No* ☐
Secondary front cover replaced?	Yes* ☐ No* ☐ N/A* ☐

COMMENTS #
(# Optional, for site observations or utility-specific notes).

CM

Commissioning Engineer	Customer Witness
Date:	Date:

11. SETTING RECORD

Date:		Engineer:	
Station:		Circuit:	
		System Frequency:	Hz
VT Ratio:	/ V	CT Ratio (tap in use):	/ A

Front Plate Information

Feeder protection relay	**P54x**
Model number	
Serial number	
Rated current In	1A ☐ 5A ☐
Rated voltage Vn	
Auxiliary voltage Vx	

Setting Groups Used

*Delete as appropriate

Group 1	Yes* ☐ No* ☐
Group 2	Yes* ☐ No* ☐
Group 3	Yes* ☐ No* ☐
Group 4	Yes* ☐ No* ☐

0000 SYSTEM DATA

0001	Language	English* ☐ Francais* ☐ Deutsche* ☐ Espanol* ☐
0002	Password	
0003	Sync. Fn. links	
0004	Description	
0005	Plant reference	
0006	Model number	
0008	Serial number	
0009	Frequency	
000B	Relay address	
0011	Software ref. 1	
00D1	Password control	Level 0* ☐ Level 1* ☐ Level 2* ☐
00D2	Password level 1	
00D3	Password level 2	

CM

0700 CB CONTROL

0701	CB Control by	Disabled* ☐ Local* ☐ Remote* ☐ Local + Remote* ☐ Opto* ☐ Opto + Local* ☐ Opto + Remote* ☐ Opto + Rem. + Local ☐
0702	Close Pulse Time	
0703	Trip Pulse Time	
0704	Man Close t Max.	
0705	Man Close Delay	
0706	CB Healthy Time	
0707	Check Sync. Time	
0709	Reset Lockout By	User Interface* ☐ CB Close* ☐
070A	Man Close RstDly.	
070B	AR Telecontrol	No Operation* ☐ Auto* ☐ Non-Auto ☐
070C	Single Pole A/R	Disabled* ☐ Enabled* ☐
070D	Three Pole A/R	Disabled* ☐ Enabled* ☐
0711	CB Status Input	

0800 DATE AND TIME

0804	IRIG-B Sync.	Disabled* ☐ Enabled* ☐
0807	Battery Alarm	Disabled* ☐ Enabled* ☐

0900 CONFIGURATION

0902	Setting Group	Select via Menu* ☐ Select via Optos* ☐
0903	Active Settings	Group 1* ☐ Group 2* ☐ Group 3* ☐ Group 4* ☐
0907	Setting Group 1	Disabled* ☐ Enabled* ☐
0908	Setting Group 2	Disabled* ☐ Enabled* ☐
0909	Setting Group 3	Disabled* ☐ Enabled* ☐
090A	Setting Group 4	Disabled* ☐ Enabled* ☐
090B	Distance	Disabled* ☐ Enabled* ☐
090C	Directional E/F	Disabled* ☐ Enabled* ☐
090F	Phase Diff	Disabled* ☐ Enabled* ☐
0910	Overcurrent	Disabled* ☐ Enabled* ☐
0911	Neg Sequence O/C	Disabled* ☐ Enabled* ☐
0912	Broken Conductor	Disabled* ☐ Enabled* ☐
0913	Earth Fault	Disabled* ☐ Enabled* ☐
0915	Sensitive E/F	Disabled* ☐ Enabled* ☐
0916	Residual O/V NVD	Disabled* ☐ Enabled* ☐
0917	Thermal Overload	Disabled* ☐ Enabled* ☐
0918	PowerSwing Block	Disabled* ☐ Enabled* ☐

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0900 CONFIGURATION

091D	Volt Protection	Disabled*	☐	Enabled*	☐
0920	CB Fail	Disabled*	☐	Enabled*	☐
0921	Supervision	Disabled*	☐	Enabled*	☐
0923	System Checks	Disabled*	☐	Enabled*	☐
0924	Auto-Reclose	Disabled*	☐	Enabled*	☐
0925	Input Labels	Invisible*	☐	Visible*	☐
0926	Output Labels	Invisible*	☐	Visible*	☐
0928	CT & VT Ratios	Invisible*	☐	Visible*	☐
0929	Record Control	Invisible*	☐	Visible*	☐
092A	Disturb Recorder	Invisible*	☐	Visible*	☐
092B	Measure't Setup	Invisible*	☐	Visible*	☐
092C	Comms Settings	Invisible*	☐	Visible*	☐
092D	Commission Tests	Invisible*	☐	Visible*	☐
092E	Setting Values	Primary*	☐	Secondary*	☐
092F	Control Inputs	Invisible*	☐	Visible*	☐
0935	Control I/P Config	Invisible*	☐	Visible*	☐
0936	Ctrl I/P Labels	Invisible*	☐	Visible*	☐
0939	Direct Access	Disabled*	☐	CB Control only*	☐
		Hotkey only*	☐	Enabled*	☐
0941	InterMiCOM^{64} Fiber	Disabled*	☐	Enabled*	☐
0950	Function Key	Invisible*	☐	Visible*	☐
09FF	LCD Contrast				

0A00 CT AND VT RATIOS

0A00	CT AND VT RATIOS						
0A01	Main VT Primary						
0A02	Main VT Sec'y						
0A03	C/S VT Primary						
0A04	C/S VT Secondary						
0A07	Phase CT Primary						
0A08	Phase CT Sec'y						
0A0B	SEF CT Primary						
0A0C	SEF CT Secondary						
0A0D	MComp CT Primary						
0A0E	MComp CT Sec'y						
0A0F	C/S Input	A - N* ☐	B - N* ☐	C - N* ☐			
		A - B* ☐	B - C* ☐	C - A* ☐			
0A10	Main VT Location	Line* ☐	Bus* ☐				
0A11	CT Polarity	Standard* ☐	Inverted* ☐				
0A12	CT2 Polarity						

CM

0A13	SEF CT Polarity	Standard* ☐	Inverted* ☐
0A14	M CT Polarity	Standard* ☐	Inverted* ☐
0A18	VTs Connected		

0B00 RECORD CONTROL

0B04	Alarm Event	Disabled* ☐	Enabled* ☐
0B05	Relay O/P Event	Disabled* ☐	Enabled* ☐
0B06	Opto Input Event	Disabled* ☐	Enabled* ☐
0B07	General Event	Disabled* ☐	Enabled* ☐
0B08	Fault rec. Event	Disabled* ☐	Enabled* ☐
0B09	Maint. rec. Event	Disabled* ☐	Enabled* ☐
0B0A	Protection Event	Disabled* ☐	Enabled* ☐

0C00 DISTURB. RECORDER

0C01	Duration		
0C02	Trigger Position	Single* ☐	Extended* ☐
0C04	Analog Channel 1		
0C05	Analog Channel 2		
0C06	Analog Channel 3		
0C07	Analog Channel 4		
0C08	Analog Channel 5		
0C09	Analog Channel 6		
0C0A	Analog Channel 7		
0C0B	Analog Channel 8		
0C0C	Digital Input 1		
0C0D	Input 1 Trigger	No Trigger* ☐ Trigger H – L* ☐	Trigger L – H* ☐
0C0E	Digital Input 2		
0C0F	Input 2 Trigger	No Trigger* ☐ Trigger H – L* ☐	Trigger L – H* ☐
0C10	Digital Input 3		
0C11	Input 3 Trigger	No Trigger* ☐ Trigger H – L* ☐	Trigger L – H* ☐
0C12	Digital Input 4		
0C13	Input 4 Trigger	No Trigger* ☐ Trigger H – L* ☐	Trigger L – H* ☐
0C14	Digital Input 5		
0C15	Input 5 Trigger	No Trigger* ☐ Trigger H – L* ☐	Trigger L – H* ☐
0C16	Digital Input 6		

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0C00	DISTURB. RECORDER	
0C17	Input 6 Trigger	No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐
0C18	Digital Input 7	
0C19	Input 7 Trigger	No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐
0C1A	Digital Input 8	
0C1B	Input 8 Trigger	No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐
0C1C	Digital Input 9	
0C1D	Input 9 Trigger	No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐
0C1E	Digital Input 10	
0C1F	Input 10 Trigger	No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐
0C20	Digital Input 11	
0C21	Input 11 Trigger	No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐
0C22	Digital Input 12	
0C23	Input 12 Trigger	No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐
0C24	Digital Input 13	
0C25	Input 13 Trigger	No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐
0C26	Digital Input 14	
0C27	Input 14 Trigger	No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐
0C28	Digital Input 15	
0C29	Input 15 Trigger	No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐
0C2A	Digital Input 16	
0C2B	Input 16 Trigger	No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐
0C2C	Digital Input 17	
0C2D	Input 17 Trigger	No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐
0C2E	Digital Input 18	
0C2F	Input 18 Trigger	No Trigger* ☐ Trigger L – H* ☐ Trigger H – L* ☐
0C30	Digital Input 19	
0C31	Input 19 Trigger	No Trigger* ☐ Trigger L – H* ☐

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0C00 DISTURB. RECORDER

		Trigger H – L*	☐		
0C32	Digital Input 20				
0C33	Input 20 Trigger	No Trigger* Trigger H – L*	☐ ☐	Trigger L – H*	☐
0C34	Digital Input 21				
0C35	Input 21 Trigger	No Trigger* Trigger H – L*	☐ ☐	Trigger L – H*	☐
0C36	Digital Input 22				
0C37	Input 22 Trigger	No Trigger* Trigger H – L*	☐ ☐	Trigger L – H*	☐
0C38	Digital Input 23				
0C39	Input 23 Trigger	No Trigger* Trigger H – L*	☐ ☐	Trigger L – H*	☐
0C3A	Digital Input 24				
0C3B	Input 24 Trigger	No Trigger* Trigger H – L*	☐ ☐	Trigger L – H*	☐
0C3C	Digital Input 25				
0C3D	Input 25 Trigger	No Trigger* Trigger H – L*	☐ ☐	Trigger L – H*	☐
0C3E	Digital Input 26				
0C3F	Input 26 Trigger	No Trigger* Trigger H – L*	☐ ☐	Trigger L – H*	☐
0C40	Digital Input 27				
0C41	Input 27 Trigger	No Trigger* Trigger H – L*	☐ ☐	Trigger L – H*	☐
0C42	Digital Input 28				
0C43	Input 28 Trigger	No Trigger* Trigger H – L*	☐ ☐	Trigger L – H*	☐
0C44	Digital Input 29				
0C45	Input 29 Trigger	No Trigger* Trigger H – L*	☐ ☐	Trigger L – H*	☐
0C46	Digital Input 30				
0C47	Input 30 Trigger	No Trigger* Trigger H – L*	☐ ☐	Trigger L – H*	☐
0C48	Digital Input 31				
0C49	Input 31 Trigger	No Trigger* Trigger H – L*	☐ ☐	Trigger L – H*	☐
0C4A	Digital Input 32				
0C4B	Input 32 Trigger	No Trigger* Trigger H – L*	☐ ☐	Trigger L – H*	☐

0C00	**DISTURB. RECORDER**	
0C50	Analog Channel 9	
0C51	Analog Channel 10	
0C52	Analog Channel 11	
0C53	Analog Channel 12	

0D00	**MEASURE'T. SETUP**						
0D01	Default Display	3Ph + N Current* ☐		3h Voltage* ☐			
		Power* ☐		Date & Time* ☐			
		Description* ☐		Plant Reference* ☐			
		Frequency* ☐		Access Level* ☐			
0D02	Local Values	Primary* ☐		Secondary* ☐			
0D03	Remote Values	Primary* ☐		Secondary* ☐			
0D04	Measurement Ref.	VA* ☐	VB* ☐	VC* ☐			
		IA* ☐	IB* ☐	IC* ☐			
0D05	Measurement Mode						
0D06	Fix Dem. Period						
0D07	Roll Sub Period						
0D08	Num. Sub Periods						
0D09	Distance Unit	Kilometers* ☐		Miles* ☐			
0D0A	Fault Location	Distance* ☐	Ohms* ☐	______ % of Line*			
0D0B	Remote2 Values	Primary* ☐		Secondary* ☐			

0E00	**COMMUNICATIONS**			
0E01	RP1 Protocol	Courier* ☐		IEC870-5-103* ☐
		DNP3.0* ☐		
0E02	RP1 Address			
0E03	RP1 InactivTimer			
0E04	RP1 Baud Rate	1200* ☐	2400* ☐	4800* ☐
		9600* ☐	19200* ☐	38400* ☐
0E05	RP1 Parity	Odd* ☐	Even* ☐	None* ☐
0E06	RP1 Meas. Period			
0E07	RP1 Physical Link	EIA(RS)485* ☐		Fiber Optic* ☐
0E08	RP1 Time Sync.	Disabled* ☐		Enabled* ☐
0E0A	RP1 CS103 Blocking	Disabled* ☐		Monitor Blocking* ☐
		Command Blocking* ☐		
0E64	NIC Tunl Timeout			
0E6A	NIC Link Report	Alarm* ☐	Event* ☐	None* ☐
0E6B	NIC Link Timeout			
0E88	RP2 Port Config.	K Bus* ☐		EIA(RS)485* ☐
0E8A	RP2 Comms. Mode	IEC60870 FT1.2* ☐		10-Bit Frame* ☐

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0E00 COMMUNICATIONS

0E90	RP2 Address	
0E92	RP2 InactivTimer	
0E94	RP2 Baud Rate	9600* ☐ 19200* ☐ 38400* ☐

0F00 COMMISSION TESTS

0F05	Monitor Bit 1	
0F06	Monitor Bit 2	
0F07	Monitor Bit 3	
0F08	Monitor Bit 4	
0F09	Monitor Bit 5	
0F0A	Monitor Bit 6	
0F0B	Monitor Bit 7	
0F0C	Monitor Bit 8	

1000 CB MONITOR SETUP

1001	Broken I^	
1002	I^ Maintenance	Alarm Disabled* ☐ Alarm Enabled* ☐
1003	I^ Maintenance	
1004	I^ Lockout	Alarm Disabled* ☐ Alarm Enabled* ☐
1005	I^ Lockout	
1006	No. CB Ops. Maint.	Alarm Disabled* ☐ Alarm Enabled* ☐
1007	No. CB Ops. Maint.	
1008	No. CB Ops. Lock	Alarm Disabled* ☐ Alarm Enabled* ☐
1009	No. CB Ops. Lock	
100A	CB Time Maint.	Alarm Disabled* ☐ Alarm Enabled* ☐
100B	CB Time Maint.	
100C	CB Time Lockout	Alarm Disabled* ☐ Alarm Enabled* ☐
100D	CB Time Lockout	
100E	Fault Freq. Lock	Alarm Disabled* ☐ Alarm Enabled* ☐
100F	Fault Freq. Count	
1010	Fault Freq. Time	

1100 OPTO CONFIG.

1101	Global Nominal V	
1102	Opto Input 1	
1103	Opto Input 2	
1104	Opto Input 3	
1105	Opto Input 4	
1106	Opto Input 5	
1107	Opto Input 6	

1100 OPTO CONFIG.

1108	Opto Input 7	
1109	Opto Input 8	
110A	Opto Input 9	
110B	Opto Input 10	
110C	Opto Input 11	
110D	Opto Input 12	
110E	Opto Input 13	
110F	Opto Input 14	
1110	Opto Input 15	
1111	Opto Input 16	
1112	Opto Input 17	
1113	Opto Input 18	
1114	Opto Input 19	
1115	Opto Input 20	
1116	Opto Input 21	
1117	Opto Input 22	
1118	Opto Input 23	
1119	Opto Input 24	
111A	Opto Input 25	
111B	Opto Input 26	
111C	Opto Input 27	
111D	Opto Input 28	
111E	Opto Input 29	
111F	Opto Input 30	
1120	Opto Input 31	
1121	Opto Input 32	
1150	Filter Control	
1180	Characteristic	Standard 60% - 80%* ☐ 50% - 70%* ☐

1300 CTRL. I/P CONFIG.

1301	Hotkey Enabled	
1310	Control Input 1	Latched* ☐ Pulsed* ☐
1311	Ctrl Command 1	
1314	Control Input 2	Latched* ☐ Pulsed* ☐
1315	Ctrl Command 2	
1318	Control Input 3	Latched* ☐ Pulsed* ☐
1319	Ctrl Command 3	
131C	Control Input 4	Latched* ☐ Pulsed* ☐
131D	Ctrl Command 4	
1320	Control Input 5	Latched* ☐ Pulsed* ☐

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1300 CTRL. I/P CONFIG.

1321	Ctrl Command 5				
1324	Control Input 6	Latched*	☐	Pulsed*	☐
1325	Ctrl Command 6				
1328	Control Input 7	Latched*	☐	Pulsed*	☐
1329	Ctrl Command 7				
132C	Control Input 8	Latched*	☐	Pulsed*	☐
132D	Ctrl Command 8				
1330	Control Input 9	Latched*	☐	Pulsed*	☐
1331	Ctrl Command 9				
1334	Control Input 10	Latched*	☐	Pulsed*	☐
1335	Ctrl Command 10				
1338	Control Input 11	Latched*	☐	Pulsed*	☐
1339	Ctrl Command 11				
133C	Control Input 12	Latched*	☐	Pulsed*	☐
133C	Ctrl Command 12				
1340	Control Input 13	Latched*	☐	Pulsed*	☐
1341	Ctrl Command 13				
1344	Control Input 14	Latched*	☐	Pulsed*	☐
1345	Ctrl Command 14				
1348	Control Input 15	Latched*	☐	Pulsed*	☐
1349	Ctrl Command 15				
134C	Control Input 16	Latched*	☐	Pulsed*	☐
134D	Ctrl Command 16				
1350	Control Input 17	Latched*	☐	Pulsed*	☐
1351	Ctrl Command 17				
1354	Control Input 18	Latched*	☐	Pulsed*	☐
1355	Ctrl Command 18				
1358	Control Input 19	Latched*	☐	Pulsed*	☐
1359	Ctrl Command 19				
135C	Control Input 20	Latched*	☐	Pulsed*	☐
135D	Ctrl Command 20				
1360	Control Input 21	Latched*	☐	Pulsed*	☐
1361	Ctrl Command 21				
1364	Control Input 22	Latched*	☐	Pulsed*	☐
1365	Ctrl Command 22				
1368	Control Input 23	Latched*	☐	Pulsed*	☐
1369	Ctrl Command 23				
136C	Control Input 24	Latched*	☐	Pulsed*	☐
136D	Ctrl Command 24				
1370	Control Input 25	Latched*	☐	Pulsed*	☐

1300 CTRL. I/P CONFIG.

1371	Ctrl Command 25				
1374	Control Input 26	Latched*	☐	Pulsed*	☐
1375	Ctrl Command 26				
1378	Control Input 27	Latched*	☐	Pulsed*	☐
1379	Ctrl Command 27				
137C	Control Input 28	Latched*	☐	Pulsed*	☐
137D	Ctrl Command 28				
1380	Control Input 29	Latched*	☐	Pulsed*	☐
1381	Ctrl Command 29				
1384	Control Input 30	Latched*	☐	Pulsed*	☐
1385	Ctrl Command 30				
1388	Control Input 31	Latched*	☐	Pulsed*	☐
1389	Ctrl Command 31				
138C	Control Input 32	Latched*	☐	Pulsed*	☐
138D	Ctrl Command 32				

1700 FUNCTION KEYS

1702	Fn. Key 1 Status	Unlock*	☐	Enable*	☐
1703	Fn. Key 1 Mode	Normal*	☐	Toggle*	☐
1704	Fn. Key 1 Label				
1705	Fn. Key 2 Status	Unlock*	☐	Enable*	☐
1706	Fn. Key 2 Mode	Normal*	☐	Toggle*	☐
1707	Fn. Key 2 Label				
1708	Fn. Key 3 Status	Unlock*	☐	Enable*	☐
1709	Fn. Key 3 Mode	Normal*	☐	Toggle*	☐
170A	Fn. Key 3 Label				
170B	Fn. Key 4 Status	Unlock*	☐	Enable*	☐
170C	Fn. Key 4 Mode	Normal*	☐	Toggle*	☐
170D	Fn. Key 4 Label				
170E	Fn. Key 5 Status	Unlock*	☐	Enable*	☐
170F	Fn. Key 5 Mode	Normal*	☐	Toggle*	☐
1710	Fn. Key 5 Label				
1711	Fn. Key 6 Status	Unlock*	☐	Enable*	☐
1712	Fn. Key 6 Mode	Normal*	☐	Toggle*	☐
1713	Fn. Key 6 Label				
1714	Fn. Key 7 Status	Unlock*	☐	Enable*	☐
1715	Fn. Key 7 Mode	Normal*	☐	Toggle*	☐
1716	Fn. Key 7 Label				
1717	Fn. Key 8 Status	Unlock*	☐	Enable*	☐
1718	Fn. Key 8 Mode	Normal*	☐	Toggle*	☐

1700 FUNCTION KEYS

1719	Fn. Key 8 Label				
171A	Fn. Key 9 Status	Unlock*	☐	Enable*	☐
171B	Fn. Key 9 Mode	Normal*	☐	Toggle*	☐
171C	Fn. Key 9 Label				
171D	Fn. Key 10 Status	Unlock*	☐	Enable*	☐
171E	Fn. Key 10 Mode	Normal*	☐	Toggle*	☐
171F	Fn. Key 10 Label				

1900 IED CONFIGURATOR

1905	Switch Conf. Bank	No Action*	☐	Switch Banks*	☐
1970	GoEna	Disabled*	☐	Enabled*	☐
1971	Test Mode	Disabled* Forced*	☐ ☐	Pass Through*	☐
1972	VOP Test Pattern				
1973	Ignore Test Flag	No*	☐	Yes*	☐

2000 PROT COMMS/IM64

2001	Scheme Setup	2 end ☐	dual red. ☐	3 end	☐
2002/3	Address				
2010	Comms Mode				
2011	Baud Rate Ch1	56kbits	☐	64kbits	☐
2012	Baud Rate Ch2	56kbits	☐	64kbits	☐
2013	Clock Source Ch1	Internal	☐	External	☐
2014	Clock Source Ch2	Internal	☐	External	☐
2015	Ch1 N*64kbits/s				
2016	Ch2 N*64kbits/s				
2018	Comm Fail Timer				
2019	Comm Fail Mode				
201A	GPS Sync				
201B	Char Mod Time				
201C	Prop Delay Equal				
201D	Re-Configuration				
201E	Channel Timeout				
201F	IM Msg Alarm Lvl				
2030	IM1 Cmd Type				
2031	IM1 FallBackMode				
2032	IM1 DefaultValue				
2034	IM2 Cmd Type				
2035	IM2 FallBackMode				

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2000	PROT COMMS/IM64	
2036	IM2 DefaultValue	
2038	IM3 Cmd Type	
2039	IM3 FallBackMode	
203A	IM3 DefaultValue	
203C	IM4 Cmd Type	
203D	IM4 FallBackMode	
203E	IM4 DefaultValue	
2040	IM5 Cmd Type	
2041	IM5 FallBackMode	
2042	IM5 DefaultValue	
2044	IM6 Cmd Type	
2045	IM6 FallBackMode	
2046	IM6 DefaultValue	
2048	IM7 Cmd Type	
2049	IM7 FallBackMode	
204A	IM7 DefaultValue	
204C	IM8 Cmd Type	
204D	IM8 FallBackMode	
204E	IM8 DefaultValue	
201A	GPS Sync	

2900	CNTRL. I/P LABELS	
2901	Control Input 1	
2902	Control Input 2	
2903	Control Input 3	
2904	Control Input 4	
2905	Control Input 5	
2906	Control Input 6	
2907	Control Input 7	
2908	Control Input 8	
2909	Control Input 9	
290A	Control Input 10	
290B	Control Input11	
290C	Control Input 12	
290D	Control Input 13	
290E	Control Input 14	
290F	Control Input 15	
2910	Control Input 16	
2911	Control Input 17	
2912	Control Input 18	

2900	**CNTRL. I/P LABELS**	
2913	Control Input 19	
2914	Control Input 20	
2915	Control Input 21	
2916	Control Input 22	
2917	Control Input 23	
2918	Control Input 24	
2919	Control Input 25	
291A	Control Input 26	
291B	Control Input 27	
291C	Control Input 28	
291D	Control Input 29	
291E	Control Input 30	
291F	Control Input 31	
2920	Control Input 32	

3000 LINE PARAMETERS

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3001/2	Line Length (km/miles*)				
3003	Line Impedance				
3004	Line Angle				
3005	kN Residual Comp				
3006	kN Residual Angle				
3007	Mutual Comp				
3008	kZm Mutual Set				
3009	kZm Mutual Angle				
300A	Mutual cut-off (k)				
300B	Phase Rotation				
300C	Trip Mode				

3100 DISTANCE SETUP

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
310C	Setting Mode				
3111	Phase Chars				
3112	Quad Resistance				
3113	Fault Resistance				
3120	Zone 1 Ph Status				
3121	Zone 1 Ph Reach				
3130	Zone 2 Ph Status				
3131	Zone 2 Ph Reach				
3140	Zone 3 Ph Status				
3141	Zone 3 Ph Reach				
3142	Zone 3 Ph Offset				
3143	Z3Ph Rev Reach				
3150	Zone P Ph Status				
3151	Zone P Ph Dir				
3152	Zone P Ph Reach				
3160	Zone 4 Ph Status				
3161	Zone 4 Ph Reach				
3171	Ground Chars				
3172	Quad Resistance				
3173	Fault Resistance				
3180	Zone1 Gnd Status				
3181	Zone1 Gnd Reach				
3190	Zone2 Gnd Status				

3100 DISTANCE SETUP

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3191	Zone2 Gnd Reach				
31A0	Zone3 Gnd Status				
31A1	Zone3 Gnd Reach				
31A2	Zone3 Gnd Offset				
31A3	Z3Gnd Rev Reach				
31B0	ZoneP Gnd Status				
31B1	ZoneP Gnd Direction				
31B2	ZoneP Gnd Reach				
31C0	Zone4 Gnd Status				
31C1	Zone4 Gnd Reach				
31D0	Digital Filter				
31D1	CVT Filters				
31D2	SIR Setting				
31D3	Load Blinders				
31D4	Load/B Impedance				
31D5	Load/B Angle				
31D6	Load Blinder V<				
31D7	Distance Polarizing				
31E0	DELTA DIRECTION				
31E1	Delta Status				
31E2	AidedDeltaStatus				
31E3	Delta Char Angle				
31E4	Delta V Fwd				
31E5	Delta V Rev				
31E6	Delta I Fwd				
31E7	Delta I Rev				

3200 DIST. ELEMENTS

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3202	Z1 Phase Reach				
3203	Z1 Phase Angle				
3207	Z1 Ph Resistive				
3208	Z1 Tilt Top-Line				
3209	Z1 Ph Sensit. Iph>1				
3210	Z2 Ph. Reach				
3211	Z2 Ph. Angle				
3215	Z2 Ph Resistance				

3200 DIST. ELEMENTS

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3216	Z2 Tilt Top-Line				
3217	Z2 Ph Sensit. Iph>2				
3220	Z3 Ph. Reach				
3221	Z3 Ph. Angle				
3222	Z3’ Ph Rev Reach				
3225	Z3’ Ph Rev Reach				
3226	Z3 Ph Res. Rev				
3227	Z3 Tilt Top-Line				
3228	Z3 Ph Sensit. Iph>3				
3230	ZP Ph Reach				
3231	ZP Ph Angle				
3235	ZP Ph Resistance				
3236	ZP Tilt Top-Line				
3237	ZP Ph Sensit. Iph>P				
3240	Z4 Ph. Reach				
3241	Z4 Ph. Angle				
3242	Z4 Ph Resistive				
3245	Z4 Tilt Top-Line				
3246	Z4 Ph Sensit. Iph>4				
3251	Z1 Gnd. Reach				
3252	Z1 Gnd Angle				
3255	kZN1 Res. Comp.				
3256	kZN1 Res. Angle				
3257	kZm1 Mut. Comp.				
3258	kZm1 Mut. Angle				
3259	R1 Gnd. Resistive				
325B	Z1 Sensit Ignd>1				
3260	Z2 Gnd. Reach				
3261	Z2 Gnd. Angle				
3265	kZN1 Res. Comp.				
3266	kZN2 Res. Angle				
3267	kZm2 Mut. Comp				
3268	kZm2 Mut. Angle				
3269	R2 Gnd Resistive				
326B	Z2 Sensit Ignd>2				
3270	Z3 Gnd Reach				
3271	Z3 Gnd Angle				
3272	Z3’ Gnd Rev Rch				

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3200 DIST. ELEMENTS

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3275	kZN3 Res. Comp.				
3276	kZN3 Res. Angle				
3277	kZN3 Mut. Comp.				
3278	kZN3 Mut. Angle				
3279	R3 Gnd. Res. Fwd				
327A	R3 Gnd. Res. Rev				
327C	Z3 Sensit Ignd>3				
3280	ZP Ground Reach				
3281	ZP Ground Angle				
3285	kZNP Res. Comp				
3286	kZNP Res. Angle				
3287	kZmP Mut. Comp				
3288	kZmP Mut. Angle				
3289	RP Gnd Resistive				
328B	ZP Sensit. Ignd>P				
3290	Z4 Gnd. Reach				
3291	Z4 Gnd Angle				
3295	kZN4 Res. Comp				
3296	kZN4 Res. Angle				
3297	kZm4 Mut Comp.				
3298	kZm4 Mut Angle				
3299	R4 G Resistive				
329B	Z4 Gnd Sensitivity				

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3300 PHASE DIFF

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3301	Phase Diff				
3302	Phase Is1				
3303	Phase Is2				
3304	Phase k1				
3305	Phase k2				
3306	Phase Is1				
3307	Phase Is2				
3308	Phase k1				
3309	Phase k2				
330A	Phase Char				
330B	Phase Time Delay				

3300 PHASE DIFF

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
330C	Phase TMS				
330D	Phase Time Dial				
330E	PIT Time				
330F	Ph CT Corr'tion				
3310	Compensation				
3311	Susceptance				
3312	Inrush Restraint				
3313	Id High Set				
3314	Kr (Temporary)				
3315	Vectorial Comp				
3316	Phase Is1 CTS				

3400 SCHEME LOGIC

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3408	Zone 1 Tripping				
3409	Zone 1 Ph Delay				
340A	Zone 1 Gnd Delay				
3410	Zone 2 Tripping				
341	Zone 2 Ph Delay				
3412	Zone 2 Gnd Delay				
3418	Zone 3 Tripping				
3419	Zone 3 Ph Delay				
341A	Zone 3 Gnd Delay				
3420	Zone P Tripping				
3421	Zone P Ph Delay				
3422	Zone P Gnd Delay				
3428	Zone 4 Tripping				
3429	Zone 4 Ph Delay				
342A	Zone 4 Gnd Delay				
3441	Aided 1 Selection				
3442	Aided 1 Distance				
3443	Aided 1 Dist Dly				
3444	Aided 1 DEF				
3445	Aided 1 DEF Dly				
3446	Aided 1 DEF Trip				
3447	Aided 1 Delta				
3448	Aided1 Delta Dly				

3400 SCHEME LOGIC

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3449	Aided1 DeltaTrip				
344A	tReversal Guard				
344B	Unblocking Delay				
3450	Weak Infeed				
3451	WI Single Pole Trip				
3452	WI V< Threshold				
3453	WI Trip Delay				
3458	Custom Send Mask				
3459	Custom Time PU				
345A	Custom Time DO				
3461	Aided 2 Selection				
3462	Aided 2 Distance				
3463	Aided 2 Dist Dly				
3464	Aided 2 DEF				
3465	Aided 2 DEF Dly				
3466	Aided 2 DEF Trip				
3467	Aided 2 Delta				
3468	Aided2 Delta Dly				
3469	Aided2 DeltaTrip				
346A	tReversal Guard				
346B	Unblocking Delay				
3470	Weak Infeed				
3471	WI Single Pole Trip				
3472	WI V< Threshold				
3473	WI Trip Delay				
3478	Custom Send Mask				
3479	Custom Time PU				
347A	Custom Time DO				
3480	Trip on Close				
3481	SOTF Status				
3482	SOTF Delay				
3483	SOTF Tripping				
3484	TOR Status				
3485	TOR Tripping				
3486	TOC Reset Delay				
34B1	Zone 1Ext Scheme				
34B2	Zone1 Ext Ph				
34B3	Zone1 Ext Gnd				

3400 SCHEME LOGIC

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
34C1	LoL Scheme				
34C3	LoL I<				
34C4	LoL Window				

3500 OVERCURRENT

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3501	I>1 Status				
3502	I>1 Function				
3503	I>1 Directional				
3504	I>1 Current Set				
3505	I>1 Time Delay				
3506	I>1 TMS				
3507	I>1 Time Dial				
3508	I>1 Reset Char				
3509	I>1 tRESET				
350A	I>2 Status				
350B	I>2 Function				
350C	I>2 Directional				
350D	I>2 Current Set				
350E	I>2 Time Delay				
350F	I>2 TMS				
3510	I>2 Time Dial				
3511	I>2 Reset Char				
3512	I>2 tRESET				
3513	I>3 Status				
3514	I>3 Directional				
3515	I>3 Current Set				
3516	I>3 Time Delay				
3518	I>4 Status				
3519	I>4 Directional				
351A	I>4 Current Set				
351B	I>4 Time Delay				
351C	I> Char Angle				
351D	I> Blocking				

3600 NEG. SEQ. O/C

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3601	I2> Status				
3602	I2> Directional				
3603	I2> VTS				
3604	I2> Current Set				
3605	I2> Time Delay				
3606	I2> Char Angle				
3607	I2> V2pol Set				

3700 BROKEN CONDUCTOR

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3701	Broken Conductor				
3702	I2/I1 Setting				
3703	I2/I1 Time Delay				

3800 EARTH FAULT

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3801	IN>1 Status				
3802	IN>1 Function				
3803	IN>1 Directional				
3804	IN>1 Current Set				
3805	IN>1 Time Delay				
3806	IN>1 TMS				
3807	IN>1 Time Dial				
3808	IN>1 Reset Char				
3809	IN>1 tRESET				
380A	IN>2 Status				
380B	IN>2 Function				
380C	IN>2 Directional				
380D	IN>2 Current Set				
380E	IN>2 Time Delay				
380F	IN>2 TMS				
3810	IN>2 Time Dial				
3811	IN>2 Reset Char				
3812	IN>2 tRESET				

3800 EARTH FAULT

Group 1 Settings		**Group 1 Settings**	**Group 2 Settings**	**Group 3 Settings**	**Group 4 Settings**
3813	IN>3 Status				
3814	IN>3 Directional				
3815	IN>3 Current Set				
3816	IN>3 Time Delay				
3817	IN>4 Status				
3818	IN>4 Directional				
3819	IN>4 Current Set				
381A	IN>4 Time Delay				
381B	IN> Blocking				
381C	IN> Char Angle				
381D	IN> Polarization				
381F	IN> VNpol Set				
3820	IN> V2pol Set				
3822	IN> I2pol Set				

3900 AIDED DEF

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3902	DEF Status				
3903	DEF Polarizing				
3904	DEF Char Angle				
3905	DEF VNpol Set				
3906	DEF V2pol Set				
3907	DEF Threshold				

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3A00 SENSITIVE E/F

Group 1 Settings		**Group 1 Settings**	**Group 2 Settings**	**Group 3 Settings**	**Group 4 Settings**
3A01	Sens E/F Options				
3A02	ISEF>1 Function				
3A03	ISEF>1 Direction				
3A04	ISEF>1 Current				
3A05	ISEF>1 Delay				
3A06	ISEF>1 TMS				
3A07	ISEF>1 Time Dial				
3A08	ISEF>1 Reset Chr				
3A09	ISEF>1 tRESET				
3A0A	ISEF>2 Function				
3A0B	ISEF>2 Direction				

3A00 SENSITIVE E/F

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3A0C	ISEF>2 Current				
3A0D	ISEF>2 Delay				
3A0E	ISEF>2 TMS				
3A0F	ISEF>2 Time Dial				
3A10	ISEF>2 Reset Chr				
3A11	ISEF>2 tRESET				
3A12	ISEF>3 Status				
3A13	ISEF>3 Direction				
3A14	ISEF>3 Current				
3A15	ISEF>3 Delay				
3A16	ISEF>4 Status				
3A17	ISEF>4 Direction				
3A18	ISEF>4 Current				
3A19	ISEF>4 Delay				
3A1A	ISEF> Blocking				
3A1B	ISEF DIRECTIONAL				
3A1C	ISEF> Char Angle				
3A1D	ISEF> Vpol Input				
3A1E	ISEF> VNpol Set				
3A1F	Wattmetric SEF				
3A20	PN> Setting				

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3B00 RESIDUAL O/V NVD

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3B01	VN Input				
3B02	VN>1 Function				
3B03	VN>1 Voltage Set				
3B04	VN>1 Time Delay				
3B05	VN>1 TMS				
3B06	VN>1 tReset				
3B07	VN>2 Status				
3B08	VN>2 Voltage Set				
3B09	VN>2 Time Delay				

3C00 THERMAL OVERLOAD

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3C01	Characteristic				
3C02	Thermal Trip				
3C03	Thermal Alarm				
3C04	Time Constant 1				
3C05	Time Constant 2				

3D00 POWER SWING BLK

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3D01	PSB Status				
3D03	Zone 1 Ph PSB				
3D05	Zone 2 Ph PSB				
3D07	Zone 3 Ph PSB				
3D09	Zone P Ph PSB				
3D0B	Zone 4 Ph PSB				
3D0D	Zone 1 Gnd PSB				
3D1F	Zone 2 Gnd PSB				
3D11	Zone 3 Gnd PSB				
3D13	Zone P Gnd PSB				
3D15	Zone 4 Gnd PSB				
3D20	PSB Unblocking				
3D21	PSB Unblock Dly				
3D22	PSB Reset Delay				
3D23	OST Mode				
3D24	Z5				
3D25	Z6				
3D26	Z5’				
3D27	Z6’				
3D28	R5				
3D29	R6				
3D2A	R5’				
3D2B	R6’				
3D2C	Blinder Angle				
3D2D	Delta T				
3D2E	Tost				

4200 VOLTAGE PROTECTION

Group 1 Settings		**Group 1 Settings**	**Group 2 Settings**	**Group 3 Settings**	**Group 4 Settings**
4202	V< Measur't. Mode				
4203	V< Operate Mode				
4204	V<1 Function				
4205	V<1 Voltage Set				
4206	V<1 Time Delay				
4207	V<1 TMS				
4208	V<1 Poledead Inh				
4209	V<2 Status				
420A	V<2 Voltage Set				
420B	V<2 Time Delay				
420C	V<2 Poledead Inh				
420E	V> Measur't. Mode				
420F	V> Operate Mode				
4210	V>1 Function				
4211	V>1 Voltage Set				
4212	V>1 Time Delay				
4213	V>1 TMS				
4214	V>2 Status				
4215	V>2 Voltage Set				
4216	V>2 Time Delay				

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4500 CB FAIL & I<

Group 1 Settings		**Group 1 Settings**	**Group 2 Settings**	**Group 3 Settings**	**Group 4 Settings**
4502	CB Fail 1 Status				
4503	CB Fail 1 Timer				
4504	CB Fail 2 Status				
4505	CB Fail 2 Timer				
4506	Volt Prot. Reset				
4507	Ext. Prot. Reset				
4508	WI Prot. Reset				
450B	I< Current Set				
450D	ISEF< Current				
450E	BLOCKED O/C				
450F	Remove I> Start				
4510	Remove IN> Start				

4600 SUPERVISION

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4602	VTS Status				
4603	VTS Reset Mode				
4604	VTS Time Delay				
4605	VTS I> Inhibit				
4606	VTS I2> Inhibit				
4607	CT SUPERVISION				
4608	CTS Status				
4609	CTS VN< Inhibit				
460A	CTS IN> Set				
460B	CTS Time Delay				
460E	INRUSH DETECTION				
460F	I>2nd Harmonic				
4610	WEAK INFEED BLK				
4611	WI Inhibit				
4612	I2/I1 Setting				
461F	CTS I DIFF				
4620	CTS Status (Diff)				
4621	CTS Reset Mode				
4622	CTS i1				
4623	CTS i2/i1>				
4624	CTS i2/i1>>				
4625	CTS Time Delay				

4800 SYSTEM CHECKS

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4815	Live Voltage				
4816	Dead Voltage				
4818	CS1 Status				
4819	CS1 Phase Angle				
481A	CS1 Slip Control				
481B	CS1 Slip Freq.				
481C	CS1 Slip Timer				
481D	CS2 Status				
481E	CS2 Phase Angle				
481F	CS2 Slip Control				
4820	CS2 Slip Freq.				
4821	CS2 Slip Timer				

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4800 SYSTEM CHECKS

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4822	CS Undervoltage				
4823	CS Overvoltage				
4824	CS Diff. Voltage				
4825	CS Voltage Block				
4827	SS Status				
4828	SS Phase Angle				
4829	SS Under V Block				
482A	SS Undervoltage				
482B	SS Timer				

4900 AUTO-RECLOSE

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4905	Single Pole Shot				
4906	Three Pole Shot				
4907	1 Pole Dead Time				
4908	Dead Time 1				
4909	Dead Time 2				
490A	Dead Time 3				
490B	Dead Time 4				
490C	CB Healthy Time				
490F	Reclaim Time				
4910	AR Inhibit Time				
4925	Check Sync Time				
4927	Z2T AR				
4928	Z3T AR				
4929	ZPT AR				
492A	Z4T AR				
492B	DEF Aided AR				
492C	Dir. Comp AR				
492D	TOR AR				
492F	I>1 AR				
4930	I>2 AR				
4931	I>3 AR				
4932	I>4 AR				
4933	IN>1 AR				
4934	IN>2 AR				
4935	IN>3 AR				

4900 AUTO-RECLOSE

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4936	IN>4 AR				
4939	Mult Phase AR				
493A	Dead Time Start				
493B	Discrim Time				
493C	ISEF>1 AR				
493D	ISEF>2 AR				
493E	ISEF>3 AR				
493F	ISEF>4 AR				
4940	SYSTEM CHECKS				
4941	CheckSync1 Close				
4942	CheckSync2 Close				
4943	LiveLine/DeadBus				
4944	DeadLine/LiveBus				
4945	DeadLine/DeadBus				
4946	CS AR Immediate				
4947	SysChk on Shot 1				

4A00 INPUT LABELS

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4A01	Opto Input 1				
4A02	Opto Input 2				
4A03	Opto Input 3				
4A04	Opto Input 4				
4A05	Opto Input 5				
4A06	Opto Input 6				
4A07	Opto Input 7				
4A08	Opto Input 8				
4A09	Opto Input 9				
4A0A	Opto Input 10				
4A0B	Opto Input 11				
4A0C	Opto Input 12				
4A0D	Opto Input 13				
4A0E	Opto Input 14				
4AOF	Opto Input 15				
4A10	Opto Input 16				
4A11	Opto Input 17				
4A12	Opto Input 18				

4A00 INPUT LABELS

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4A13	Opto Input 19				
4A14	Opto Input 20				
4A15	Opto Input 21				
4A16	Opto Input 22				
4A17	Opto Input 23				
4A18	Opto Input 24				

4B00 OUTPUT LABELS

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4B01	Relay 1				
4B02	Relay 2				
4B03	Relay 3				
4B04	Relay 4				
4B05	Relay 5				
4B06	Relay 6				
4B07	Relay 7				
4B08	Relay 8				
4B09	Relay 9				
4B0A	Relay 10				
4B0B	Relay 11				
4B0C	Relay 12				
4B0D	Relay 13				
4B0E	Relay 14				
4B0F	Relay 15				
4B10	Relay 16				
4B11	Relay 17				
4B12	Relay 18				
4B13	Relay 19				
4B14	Relay 20				
4B15	Relay 21				
4B16	Relay 22				
4B17	Relay 23				
4B18	Relay 24				
4B19	Relay 25				
4B1A	Relay 26				
4B1B	Relay 27				
4B1C	Relay 28				

4B00 OUTPUT LABELS

Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4B1D	Relay 29				
4B1E	Relay 30				
4B1F	Relay 31				
4B20	Relay 32				

Commissioning Engineer	Customer Witness
Date:	Date:

MAINTENANCE

Date:	**7th August 2006**
Hardware Suffix:	**K**
Software Version:	**41 and 51**
Connection Diagrams:	**10P54302xx (xx = 01 to 02) & 10P54303xx (xx = 01 to 02)**
	10P54402xx (xx = 01 to 02) & 10P54403xx (xx = 01 to 02)
	10P54502xx (xx = 01 to 02) & 10P54503xx (xx = 01 to 02)
	10P54602xx (xx = 01 to 02) & 10P54603xx (xx = 01 to 02)

CONTENTS

(MT) 11-

1. MAINTENANCE

1.1 Maintenance period

It is recommended that products supplied by Schneider Electric receive periodic monitoring after installation. In view of the critical nature of protective relays and their infrequent operation, it is desirable to confirm that they are operating correctly at regular intervals.

Schneider Electric protective relays are designed for a life in excess of 20 years.

MiCOM relays are self-supervizing and so require less maintenance than earlier designs of relay. Most problems will result in an alarm so that remedial action can be taken. However, some periodic tests should be done to ensure that the relay is functioning correctly and the external wiring is intact.

1.2 Maintenance checks

Although some functionality checks can be performed from a remote location by utilizing the communications ability of the relays, these are predominantly restricted to checking that the relay is measuring the applied currents and voltages accurately, and checking the circuit breaker maintenance counters. Therefore it is recommended that maintenance checks are performed locally (i.e. at the substation itself).

Before carrying out any work on the equipment, the user should be familiar with the contents of the Safety Guide (SFTY/4L M/C11) or later issue, or the Safety and Technical Data sections of this Technical Manual and also the ratings on the equipment's rating label.

1.2.1 Alarms

The alarm status LED should first be checked to identify if any alarm conditions exist. If so, press the read key [ ] repeatedly to step through the alarms.

Clear the alarms to extinguish the LED.

1.2.2 Opto-isolators

The opto-isolated inputs can be checked to ensure that the relay responds to their energization by repeating the commissioning test detailed in section 5.2.6 of the Commissioning section (P54x/EN CM).

1.2.3 Output relays

The output relays can be checked to ensure that they operate by repeating the commissioning test detailed in section 5.2.7 of the Commissioning section (P54x/EN CM).

1.2.4 Measurement accuracy

If the power system is energized, the values measured by the relay can be compared with known system values to check that they are in the approximate range that is expected. If they are then the analog/digital conversion and calculations are being performed correctly by the relay. Suitable test methods can be found in sections 8.1.1 and 8.1.2 of the Commissioning section (P54x/EN CM).

Alternatively, the values measured by the relay can be checked against known values injected into the relay via the test block, if fitted, or injected directly into the relay terminals. Suitable test methods can be found in sections 5.2.10 and 5.2.11 of the Commissioning section (P54x/EN CM). These tests will prove the calibration accuracy is being maintained.

1.3 Method of repair

1.3.1 P54x relay

If the relay should develop a fault whilst in service, depending on the nature of the fault, the watchdog contacts will change state and an alarm condition will be flagged. Due to the extensive use of surface-mount components faulty PCBs should be replaced, as it is not possible to perform repairs on damaged circuits. Thus either the complete relay or just the faulty PCB, identified by the in-built diagnostic software, can be replaced. Advice about identifying the faulty PCB can be found in the Troubleshooting section (P54x/EN TS).

The preferred method is to replace the complete relay as it ensures that the internal circuitry is protected against electrostatic discharge and physical damage at all times and overcomes the possibility of incompatibility between replacement PCBs. However, it may be difficult to remove an installed relay due to limited access in the back of the cubicle and rigidity of the scheme wiring.

Replacing PCBs can reduce transport costs but requires clean, dry conditions on site and higher skills from the person performing the repair. However, if the repair is not performed by an approved service center, the warranty will be invalidated.

Before carrying out any work on the equipment, the user should be familiar with the contents of the Safety and Technical Data sections and the ratings on the equipment's rating label. This should ensure that no damage is caused by incorrect handling of the electronic components.

1.3.1.1 Replacing the complete relay

The case and rear terminal blocks have been designed to facilitate removal of the complete relay should replacement or repair become necessary without having to disconnect the scheme wiring.

Before working at the rear of the relay, isolate all voltage and current supplies to the relay.

> Note: The MiCOM range of relays have integral current transformer shorting switches which will close when the heavy duty terminal block is removed.

Disconnect the relay earth, IRIG-B and fiber optic connections, as appropriate, from the rear of the relay.

There are two types of terminal block used on the relay, medium and heavy duty, which are fastened to the rear panel using crosshead screws, as in Figure 1 of the Commissioning section (P54x/EN CM).

> Note: The use of a magnetic bladed screwdriver is recommended to minimize the risk of the screws being left in the terminal block or lost.

Without exerting excessive force or damaging the scheme wiring, pull the terminal blocks away from their internal connectors.

Remove the screws used to fasten the relay to the panel, rack, etc. These are the screws with the larger diameter heads that are accessible when the access covers are fitted and open.

If the top and bottom access covers have been removed, do not remove the screws with the smaller diameter heads which are accessible. These screws secure the front panel to the relay.

Withdraw the relay carefully from the panel, rack, etc. because it will be heavy due to the internal transformers.

To reinstall the repaired or replacement relay, follow the above instructions in reverse, ensuring that each terminal block is relocated in the correct position and the case earth, IRIG-B and fiber optic connections are replaced. To facilitate easy identification of each terminal block, they are labeled alphabetically with 'A' on the left hand side when viewed from the rear.

Once reinstallation is complete the relay should be re-commissioned using the instructions in sections 1 to 9 of the Commissioning section (P54x/EN CM).

1.3.1.2 Replacing a PCB

Replacing printed circuit boards and other internal components of protective relays must be undertaken only by Service Centers approved by Schneider Electric. Failure to obtain the authorization of Schneider Electric After Sales Engineers prior to commencing work may invalidate the product warranty.

Before removing the front panel to replace a PCB the auxiliary supply must be removed, and wait 5s for capacitors to discharge. It is also strongly recommended that the voltage and current transformer connections and trip circuit are isolated.

Schneider Electric support teams are available world-wide, and it is strongly recommended that any repairs be entrusted to those trained personnel. For this reason, details on product disassembly and re-assembly are not included here.

1.4 Re-calibration

1.4.1 P54x relay

Re-calibration is not required when a PCB is replaced **unless it happens to be one of the boards in the input module;** the replacement of either directly affects the calibration.

Although it is possible to carry out re-calibration on site, this requires test equipment with suitable accuracy and a special calibration program to run on a PC. It is therefore recommended that the work be carried out by the manufacturer, or entrusted to an approved service center.

1.5 Changing the relay battery

Each relay has a battery to maintain status data and the correct time when the auxiliary supply voltage fails. The data maintained includes event, fault and disturbance records and the thermal state at the time of failure.

This battery will periodically need changing, although an alarm will be given as part of the relay’s continuous self-monitoring in the event of a low battery condition.

If the battery-backed facilities are not required to be maintained during an interruption of the auxiliary supply, the steps below can be followed to remove the battery, but do not replace with a new battery.

Before carrying out any work on the equipment, the user should be familiar with the contents of the safety and technical data sections and the ratings on the equipment's rating label.

1.5.1 Instructions for replacing the battery

Open the bottom access cover on the front of the relay.

Gently extract the battery from its socket. If necessary, use a small, insulated screwdriver to prize the battery free.

Ensure that the metal terminals in the battery socket are free from corrosion, grease and dust.

The replacement battery should be removed from its packaging and placed into the battery holder, taking care to ensure that the polarity markings on the battery agree with those adjacent to the socket.

Note: Only use a type ½AA Lithium battery with a nominal voltage of 3.6V and safety approvals such as UL (Underwriters Laboratory), CSA (Canadian Standards Association) or VDE (Vereinigung Deutscher Elektrizitätswerke).

Ensure that the battery is securely held in its socket and that the battery terminals are making good contact with the metal terminals of the socket.

Close the bottom access cover.

1.5.2 Post modification tests

To ensure that the replacement battery will maintain the time and status data if the auxiliary supply fails, check cell [0806: DATE and TIME, Battery Status] reads ‘Healthy’.

Additionally, if further confirmation that the replacement battery is installed correctly is required, the commissioning test described in section 5.2.3 of the Commissioning section (P54x/EN CM), ‘Date and Time’, can be performed.

1.5.3 Battery disposal

The battery that has been removed should be disposed of in accordance with the disposal procedure for Lithium batteries in the country in which the relay is installed.

1.6 Cleaning

Before cleaning the equipment ensure that all ac and dc supplies, current transformer and voltage transformer connections are isolated to prevent any chance of an electric shock whilst cleaning.

The equipment may be cleaned using a lint-free cloth moistened with clean water. The use of detergents, solvents or abrasive cleaners is not recommended as they may damage the relay’s surface and leave a conductive residue.

TROUBLESHOOTING

Date:	**7th August 2006**
Hardware Suffix:	**K**
Software Version:	**41 and 51**
Connection Diagrams:	**10P54302xx (xx = 01 to 02) & 10P54303xx (xx = 01 to 02) 10P54402xx (xx = 01 to 02) & 10P54403xx (xx = 01 to 02) 10P54502xx (xx = 01 to 02) & 10P54503xx (xx = 01 to 02) 10P54602xx (xx = 01 to 02) & 10P54603xx (xx = 01 to 02)**

CONTENTS

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1. INTRODUCTION

Before carrying out any work on the equipment, the user should be familiar with the contents of the Safety Guide (SFTY/4L M/C11) or later issue, or the Safety and Technical Data sections of this Technical Manual and also the ratings on the equipment's rating label.

The purpose of this section of the service manual is to allow an error condition on the relay to be identified so that appropriate corrective action can be taken.

Should the relay have developed a fault, it should be possible in most cases to identify which relay module requires attention. The Maintenance Section (P54x/EN MT) advises on the recommended method of repair where faulty modules need replacing. It is not possible to perform an on-site repair to a faulted module.

In cases where a faulty relay/module is being returned to the manufacturer or one of their approved service centers, completed copy of the Repair/Modification Return Authorization Form located at the end of this section should be included.

2. INITIAL PROBLEM IDENTIFICATION

Consult the table below to find the description that best matches the problem experienced, then consult the section referenced to perform a more detailed analysis of the problem.

Symptom	Refer To
Relay fails to power up	Section 3
Relay powers up - but indicates error and halts during power-up sequence	Section 4
Relay Powers up but Out of Service LED is illuminated	Section 5
Error during normal operation	Section 6
Mal-operation of the relay during testing	Section 7

Table 1: Problem identification

3. POWER UP ERRORS

If the relay does not appear to power up then the following procedure can be used to determine whether the fault is in the external wiring, auxiliary fuse, power supply module of the relay or the relay front panel.

Test	Check	Action
1	Measure auxiliary voltage on terminals 1 and 2; verify voltage level and polarity against rating the label on front. Terminal 1 is –dc, 2 is +dc	If auxiliary voltage is present and correct, then proceed to test 2. Otherwise the wiring/fuses in auxiliary supply should be checked.
2	Do LEDs/and LCD backlight illuminate on power-up, also check the N/O watchdog contact for closing.	If they illuminate or the contact closes and no error code is displayed then error is probably in the main processor board (front panel). If they do not illuminate and the contact does not close then proceed to test 3.
3	Check Field voltage output (nominally 48V DC)	If field voltage is not present then the fault is probably in the relay power supply module.

Table 2: Failure of relay to power up

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4. ERROR MESSAGE/CODE ON POWER-UP

During the power-up sequence of the relay self-testing is performed as indicated by the messages displayed on the LCD. If an error is detected by the relay during these self-tests then an error message will be displayed and the power-up sequence will be halted. If the error occurs when the relay application software is executing then a maintenance record will be created and the relay will reboot.

Test	Check	Action
1	Is an error message or code permanently displayed during power up?	If relay locks up and displays an error code permanently then proceed to test 2. If the relay prompts for input by the user proceed to test 4. If the relay re-boots automatically then proceed to test 5
2	Record displayed error, then remove and re-apply relay auxiliary supply.	Record whether the same error code is displayed when the relay is rebooted. If no error code is displayed then contact the local service center stating the error code and relay information. If the same code is displayed proceed to test 3.
3	Error code Identification Following text messages (in English) will be displayed if a fundamental problem is detected preventing the system from booting: Bus Fail – address lines SRAM Fail – data lines FLASH Fail format error FLASH Fail checksum Code Verify Fail The following hex error codes relate to errors detected in specific relay modules:	These messages indicate that a problem has been detected on the main processor board of the relay (located in the front panel).
	0c140005/0c0d0000	Input Module (inc. opto-isolated inputs)
	0c140006/0c0e0000	Output Relay Cards
	93830000	Co-Processor Fail (see section 6.1)
	Last 4 digits provide details on the actual error.	Other error codes relate to problems within the main processor board hardware or software. It will be necessary to contact Schneider Electric with details of the problem for a full analysis.
4	Relay displays message for corrupt settings and prompts for restoration of defaults to the affected settings.	The power up tests have detected corrupted relay settings, it is possible to restore defaults to allow the power-up to be completed. It will then be necessary to re-apply the application-specific settings.

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Test	Check	Action
5	Relay resets on completion of power up - record error code displayed	Error 0x0E080000, programmable scheme logic error due to excessive execution time. Restore default settings by performing a power up with ⇐ and ⇒ keys depressed, confirm restoration of defaults at prompt using ↵ key. If relay powers up successfully, check programmable logic for feedback paths. Other error codes will relate to software errors on the main processor board, contact SCHNEIDER ELECTRIC.

Table 3: Power-up self test error

5. OUT OF SERVICE LED ILLUMINATED ON POWER UP

Test	Check	Action
1	Using the relay menu confirm whether the Commission Test/Test Mode setting is Enabled. Otherwise proceed to test 2.	If the setting is Enabled then disable the test mode and, verify that the Out of Service LED is extinguished.
2	Select and view the last maintenance record from the menu (in the View Records).	Check for H/W Verify Fail this indicates a discrepancy between the relay model number and the hardware; examine the “Maint. Data”, this indicates the causes of the failure using bit fields: Bit Meaning 0 The application type field in the model number does not match the software ID 1 The application field in the model number does not match the software ID 2 The variant 1 field in the model number does not match the software ID 3 The variant 2 field in the model number does not match the software ID 4 The protocol field in the model number does not match the software ID 5 The language field in the model number does not match the software ID 6 The VT type field in the model number is incorrect (110V VTs fitted) 7 The VT type field in the model number is incorrect (440V VTs fitted) 8 The VT type field in the model number is incorrect (no VTs fitted)

Table 4: Out of service LED illuminated

6. ERROR CODE DURING OPERATION

The relay performs continuous self-checking, if an error is detected then an error message will be displayed, a maintenance record will be logged and the relay will reset (after a 1.6 second delay). A permanent problem (for example due to a hardware fault) will generally be detected on the power up sequence, following which the relay will display an error code and halt. If the problem was transient in nature then the relay should reboot correctly and continue in operation. The nature of the detected fault can be determined by examination of the maintenance record logged.

There are also two cases where a maintenance record will be logged due to a detected error where the relay will not reset. These are detection of a failure of either the field voltage or the lithium battery, in these cases the failure is indicated by an alarm message, however the relay will continue to operate.

If the field voltage is detected to have failed (the voltage level has dropped below threshold), then a scheme logic signal is also set. This allows the scheme logic to be adapted in the case of this failure (for example if a blocking scheme is being used).

In the case of a battery failure it is possible to prevent the relay from issuing an alarm using the setting under the Date and Time section of the menu. This setting ‘Battery Alarm’ can be set to 'Disabled' to allow the relay to be used without a battery, without an alarm message being displayed.

6.1 Failure of co-processor card

The relay Current Differential and distance protection algorithms and other main protection elements are executed on the co-processor card.

In the unlikely event that the co-processor card is determined to have failed either following power on, or in normal operation the relay will reboot in an attempt to re-establish normal operation. An error code will be displayed on the relay front panel prior to the restart (0x9383**** note the value denoted by **** will vary depending on the exact nature of the failure and a maintenance record logged).

If the restart fails to recover the co-processor card then the relay will log a maintenance event with the same error code defined above. It will then create an alarm indication (Main Prot. Fail) to indicate that the main protection is unavailable. Any enabled back-up protection, programmable logic and relay communication facilities will continue to operate in this mode.

7. MAL-OPERATION OF THE RELAY DURING TESTING

7.1 Failure of output contacts

An apparent failure of the relay output contacts may be caused by the relay configuration; the following tests should be performed to identify the real cause of the failure. Note that the relay self-tests verify that the coil of the contact has been energized, an error will be displayed if there is a fault in the output relay board.

Test	Check	Action
1	Is the Out of Service LED illuminated?	Illumination of this LED may indicate that the relay is in test mode or that the protection has been disabled due to a hardware verify error (see Table 4).
2	Examine the Contact status in the Commissioning section of the menu.	If the relevant bits of the contact status are operated then proceed to test 4, if not proceed to test 3.
3	Verify by examination of the fault record or by using the test port whether the protection element is operating correctly.	If the protection element does not operate verify whether the test is being correctly applied. If the protection element does operate then it will be necessary to check the programmable logic, to ensure that the mapping of the protection element to the contacts is correct.
4	Using the Commissioning/Test mode function apply a test pattern to the relevant relay output contacts and verify whether they operate (note the correct external connection diagram should be consulted). A continuity tester can be used at the rear of the relay for this purpose.	If the output relay does operate then the problem must be in the external wiring to the relay. If the output relay does not operate this could indicate a failure of the output relay contacts (note that the self-tests verify that the relay coil is being energized). Ensure that the closed resistance is not too high for the continuity tester to detect.

Table 5: Failure of output contacts

7.2 Failure of opto-isolated inputs

The opto-isolated inputs are mapped onto the relay internal signals using the programmable scheme logic. If an input does not appear to be recognized by the relay scheme logic the Commission Tests/Opto Status menu option can be used to verify whether the problem is in the opto-isolated input itself or the mapping of its signal to the scheme logic functions. If the opto-isolated input does appear to be read correctly then it will be necessary to examine its mapping within the programmable logic.

Ensure the voltage rating for the opto inputs has been configured correctly with applied voltage. If the opto-isolated input state is not being correctly read by the relay the applied signal should be tested. Verify the connections to the opto-isolated input using the correct wiring diagram. Next, using a voltmeter verify that 80% opto setting voltage is present on the terminals of the opto-isolated input in the energized state. If the signal is being correctly applied to the relay then the failure may be on the input card itself. Depending on which opto-isolated input has failed this may require replacement of either the complete analog input module (the board within this module cannot be individually replaced without re-calibration of the relay) or a separate opto board.

7.3 Incorrect analog signals

The measurements may be configured in primary or secondary to assist. If it is suspected that the analog quantities being measured by the relay are not correct then the measurement function of the relay can be used to verify the nature of the problem. The measured values displayed by the relay should be compared with the actual magnitudes at the relay terminals. Verify that the correct terminals are being used (in particular the dual rated CT inputs) and that the CT and VT ratios set on the relay are correct. The correct 120 degree displacement of the phase measurements should be used to confirm that the inputs have been correctly connected.

7.4 Current differential failures

The Co Processor board may cause the relay to report one or more of the following alarms:

Signaling failure alarm (on its own)

This indicates that there is a problem with one of the fiber optic signaling channels. This alarm can occur in dual redundant or three terminal schemes. The fiber may have been disconnected, the relay incorrectly configured at one of the ends, or there is a problem with the communications equipment if P59x relays are being used. The current differential protection is still in service. Further information about the status of the signaling channels can be found in MEASUREMENTS 4 column.

Signaling failure and C diff failure alarms together

This indicates that there is a problem with one or both fiber optic signaling channels. The fiber may have been disconnected, the relay incorrectly configured at one of the ends, or there is a problem with the communications equipment if P59x relays are being used. As a result the current differential protection is not available and backup protection will operate, if configured to do so. Further information about the status of the signaling channels can be found in MEASUREMENTS 4 column.

C diff failure alarm (on its own)

This indicates there is a problem with the Co - Processor board. As a result the current differential/distance protection is not available and backup protection will operate, if configured to do so. Further information can be found in the maintenance records.

Incompatible relay

This occurs if the relays trying to communicate with each other are of incompatible types. Relay types P541 and P542 can be freely mixed. Relay type P543, P544, P545 and P546 can be freely mixed. However, the two groups are mutually exclusive.

Comms changed

This indicates that the setting 2010 Comms Mode has been changed without a subsequent power off and on.

IEEE C37.94 fail

This indicates a Signal Lost, a Path Yellow or a mismatch in the number ofN*64 channels used on either channel 1 or channel 2. Further information can be found in the MEASUREMENTS 4 column.

7.5 PSL editor troubleshooting

A failure to open a connection could be because of one or more of the following:

- The relay address is not valid (note: this address is always 1 for the front port).
- Password in not valid
- Communication Set-up - COM port, Baud rate, or Framing - is not correct
- Transaction values are not suitable for the relay and/or the type of connection
- Modem configuration is not valid. Changes may be necessary when using a modem
- The connection cable is not wired correctly or broken. See MiCOM S1 V2 connection configurations
- The option switches on any KITZ101/102 this is in use may be incorrectly set

7.5.1 Diagram reconstruction after recover from relay

Although the extraction of a scheme from a relay is supported, the facility is provided as a way of recovering a scheme in the event that the original file is unobtainable.

The recovered scheme will be logically correct, but much of the original graphical information is lost. Many signals will be drawn in a vertical line down the left side of the canvas. Links are drawn orthogonally using the shortest path from A to B.

Any annotation added to the original diagram (titles, notes, etc.) are lost.

Sometimes a gate type may not be what was expected, e.g. a 1-input AND gate in the original scheme will appear as an OR gate when uploaded. Programmable gates with an inputs-to-trigger value of 1 will also appear as OR gates.

7.5.2 PSL version check

The PSL is saved with a version reference, time stamp and CRC check. This gives a visual check whether the default PSL is in place or whether a new application has been downloaded.

8. REPAIR AND MODIFICATION PROCEDURE

Please follow these 5 steps to return an Automation product to us:

1. Get the Repair and Modification Authorization Form (RMA)

Find a copy of the RMA form at the end of this section.

2. Fill in RMA form

Fill in only the white part of the form.

Please ensure that all fields marked **(M)** are completed such as:

- Equipment model
- Model No. and Serial No.
- Description of failure or modification required (please be specific)
- Value for customs (in case the product requires export)
- Delivery and invoice addresses
- Contact details

3. Receive from local service contact, the information required to ship the product

Your local service contact will provide you with all the information:

- Pricing details
- RMA n°
- Repair center address

If required, an acceptance of the quote must be delivered before going to next stage.

4. Send the product to the repair center

- Address the shipment to the repair center specified by your local contact
- Ensure all items are protected by appropriate packaging: anti-static bag and foam protection
- Ensure a copy of the import invoice is attached with the unit being returned
- Ensure a copy of the RMA form is attached with the unit being returned
- E-mail or fax a copy of the import invoice and airway bill document to your local contact.

TS

Schneider Electric

REPAIR/MODIFICATION RETURN AUTHORIZATION FORM

FIELDS IN GREY TO BE FILLED IN BY SCHNEIDER ELECTRIC PERSONNEL ONLY

Reference **RMA:** ______		Date:
Repair Center Address (for shipping)	**Service Type** ☐ Retrofit ☐ Warranty ☐ Paid service ☐ Under repair contract ☐ Wrong supply	LSC PO No.:
Schneider Electric - Local Contact Details Name: Telephone No.: Fax No.: E-mail:		

IDENTIFICATION OF UNIT

Fields marked (M) are mandatory, delays in return will occur if not completed.

Model No./Part No.: **(M)**	Site Name/Project:
Manufacturer Reference: **(M)**	Commissioning Date:
Serial No.: **(M)**	Under Warranty: ☐ Yes ☐ No
Software Version:	Additional Information:
Quantity:	Customer P.O (if paid):

FAULT INFORMATION

Type of Failure	**Found Defective**
Hardware fail ☐	During FAT/inspection ☐
Mechanical fail/visible defect ☐	On receipt ☐
Software fail ☐	During installation/commissioning ☐
Other:	During operation ☐
	Other:
Fault Reproducibility	
Fault persists after removing, checking on test bench ☐	
Fault persists after re-energization ☐	
Intermittent fault ☐	

Description of Failure Observed or Modification Required - *Please be specific* **(M)**

FOR REPAIRS ONLY

Would you like us to install an updated firmware version after repair?	☐ Yes	☐ No

CUSTOMS & INVOICING INFORMATION

Required to allow return of repaired items

Value for Customs (M)	
Customer Invoice Address ((M) if paid)	**Customer Return Delivery Address (full street address) (M)** Part shipment accepted ☐ Yes ☐ No **OR** Full shipment required ☐ Yes ☐ No
Contact Name: Telephone No.: Fax No.: E-mail:	Contact Name: Telephone No.: Fax No.: E-mail:

REPAIR TERMS

1. **Please ensure that a copy of the import invoice is attached with the returned unit, together with the airway bill document.** Please fax/e-mail a copy of the appropriate documentation (M).
2. Please ensure the Purchase Order is released, for paid service, to allow the unit to be shipped.
3. Submission of equipment to Schneider Electric is deemed as authorization to repair and acceptance of quote.
4. Please ensure all items returned are marked as Returned for ‘Repair/Modification’ and **protected by appropriate packaging** (anti-static bag for each board and foam protection).

SCADA COMMUNICATIONS

Date:	**7th August 2006**
Hardware Suffix:	**K**
Software Version:	**41 and 51**
Connection Diagrams:	**10P54302xx (xx = 01 to 02) & 10P54303xx (xx = 01 to 02)**
	10P54402xx (xx = 01 to 02) & 10P54403xx (xx = 01 to 02)
	10P54502xx (xx = 01 to 02) & 10P54503xx (xx = 01 to 02)
	10P54602xx (xx = 01 to 02) & 10P54603xx (xx = 01 to 02)

CONTENTS

SC

FIGURES

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1. SCADA COMMUNICATIONS

1.1 Introduction

This section outlines the remote communications interfaces of the MiCOM relay. The relay supports a choice of one of five protocols via the rear communication interface, selected via the model number when ordering. This is in addition to the front serial interface and 2nd rear communications port, which supports the Courier protocol only.

The rear EIA(RS)485 interface is isolated and is suitable for permanent connection whichever protocol is selected. The advantage of this type of connection is that up to 32 relays can be ‘daisy chained’ together using a simple twisted pair electrical connection.

It should be noted that the descriptions contained within this section do not aim to fully detail the protocol itself. The relevant documentation for the protocol should be referred to for this information. This section serves to describe the specific implementation of the protocol in the relay.

1.2 Rear port information and connection advice - EIA(RS)485 protocols

1.2.1 Rear communication port EIA(RS)485 interface

The rear EIA(RS)485 communication port is provided by a 3-terminal screw connector located on the back of the relay. See section P54x/EN IN for details of the connection terminals. The rear port provides K-Bus/EIA(RS)485 serial data communication and is intended for use with a permanently wired connection to a remote control center. Of the three connections, two are for the signal connection, and the other is for the earth shield of the cable. When the K-Bus option is selected for the rear port, the two signal connections are not polarity conscious, however for IEC60870-5-103 and DNP3.0 care must be taken to observe the correct polarity.

The protocol provided by the relay is indicated in the relay menu in the ‘Communications’ column. Using the keypad and LCD, firstly check that the ‘Comms. settings’ cell in the ‘Configuration’ column is set to ‘Visible’, then move to the ‘Communications’ column. The first cell down the column shows the communication protocol being used by the rear port.

1.2.1.1 EIA(RS)485 bus

The EIA(RS)485 two-wire connection provides a half-duplex fully isolated serial connection to the product. The connection is polarized and whilst the product’s connection diagrams indicate the polarization of the connection terminals it should be borne in mind that there is no agreed definition of which terminal is which. If the master is unable to communicate with the product, and the communication parameters match, then it is possible that the two-wire connection is reversed.

1.2.1.2 Bus termination

The EIA(RS)485 bus must have 120Ω (Ohm) ½ Watt terminating resistors fitted at either end across the signal wires – see Figure 1. Some devices may be able to provide the bus terminating resistors by different connection or configuration arrangements, in which case separate external components will not be required. However, this product does not provide such a facility, so if it is located at the bus terminus then an external termination resistor will be required.

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1.2.1.3 Bus connections & topologies

The EIA(RS)485 standard requires that each device be directly connected to the physical cable that is the communications bus. Stubs and tees are expressly forbidden, as are star topologies. Loop bus topologies are not part of the EIA(RS)485 standard and are forbidden by it.

Two-core screened cable is recommended. The specification of the cable will be dependent on the application, although a multi-strand 0.5mm^2 per core is normally adequate. Total cable length must not exceed 1000m. The screen must be continuous and connected to ground at one end, normally at the master connection point; it is important to avoid circulating currents, especially when the cable runs between buildings, for both safety and noise reasons.

This product does not provide a signal ground connection. If a signal ground connection is present in the bus cable then it must be ignored, although it must have continuity for the benefit of other devices connected to the bus. At no stage must the signal ground be connected to the cables screen or to the product's chassis. This is for both safety and noise reasons.

1.2.1.4 Biasing

It may also be necessary to bias the signal wires to prevent jabber. Jabber occurs when the signal level has an indeterminate state because the bus is not being actively driven. This can occur when all the slaves are in receive mode and the master is slow to turn from receive mode to transmit mode. This may be because the master purposefully waits in receive mode, or even in a high impedance state, until it has something to transmit. Jabber causes the receiving device(s) to miss the first bits of the first character in the packet, which results in the slave rejecting the message and consequentially not responding. Symptoms of this are poor response times (due to retries), increasing message error counters, erratic communications, and even a complete failure to communicate.

Biasing requires that the signal lines be weakly pulled to a defined voltage level of about 1V. There should only be one bias point on the bus, which is best situated at the master connection point. The DC source used for the bias must be clean; otherwise noise will be injected. Note that some devices may (optionally) be able to provide the bus bias, in which case external components will not be required.

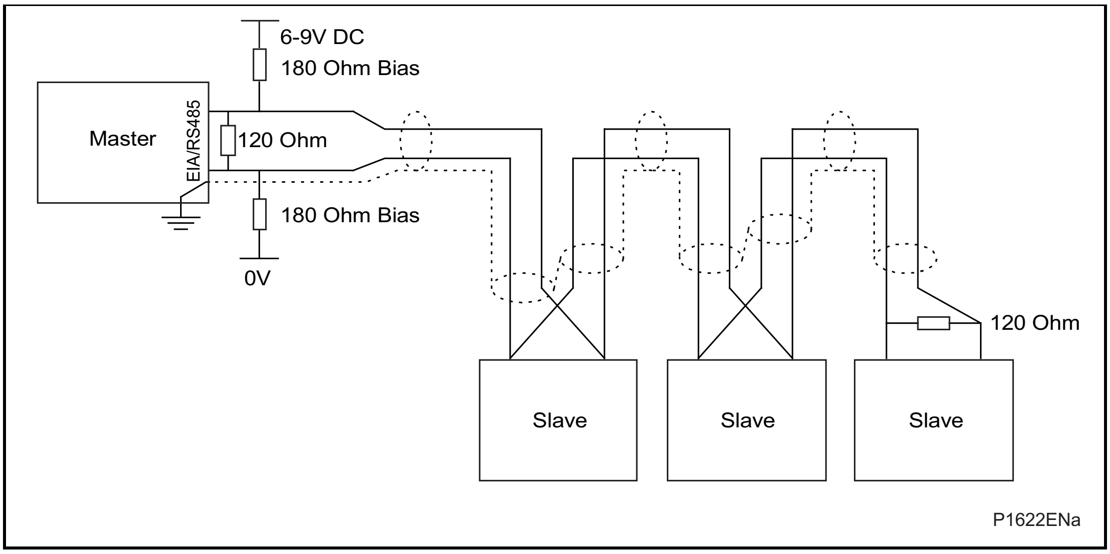

Figure 1: EIA(RS)485 bus connection arrangements

It is possible to use the products field voltage output (48V DC) to bias the bus using values of 2.2kΩ (½W) as bias resistors instead of the 180Ω resistors shown in the above diagram.

Note the following warnings apply:

- It is extremely important that the 120Ω termination resistors are fitted. Failure to do so will result in an excessive bias voltage that may damage the devices connected to the bus
- As the field voltage is much higher than that required, Schneider Electric cannot assume responsibility for any damage that may occur to a device connected to the network as a result of incorrect application of this voltage
- Ensure that the field voltage is not being used for other purposes (i.e. powering logic inputs) as this may cause noise to be passed to the communication network

1.2.2 Courier communication

Courier works on a master/slave basis where the slave units contain information in the form of a database, and respond with information from the database when it is requested by a master unit.

The relay is a slave unit that is designed to be used with a Courier master unit such as MiCOM S1, MiCOM S10, PAS&T or a SCADA system.

To use the rear port to communicate with a PC-based master station using Courier, a KITZ K-Bus to EIA(RS)232 protocol converter is required. This unit is available from Schneider Electric. A typical connection arrangement is shown in Figure 2. For more detailed information on other possible connection arrangements refer to the manual for the Courier master station software and the manual for the KITZ protocol converter. Each spur of the K-Bus twisted pair wiring can be up to 1000m in length and have up to 32 relays connected to it.

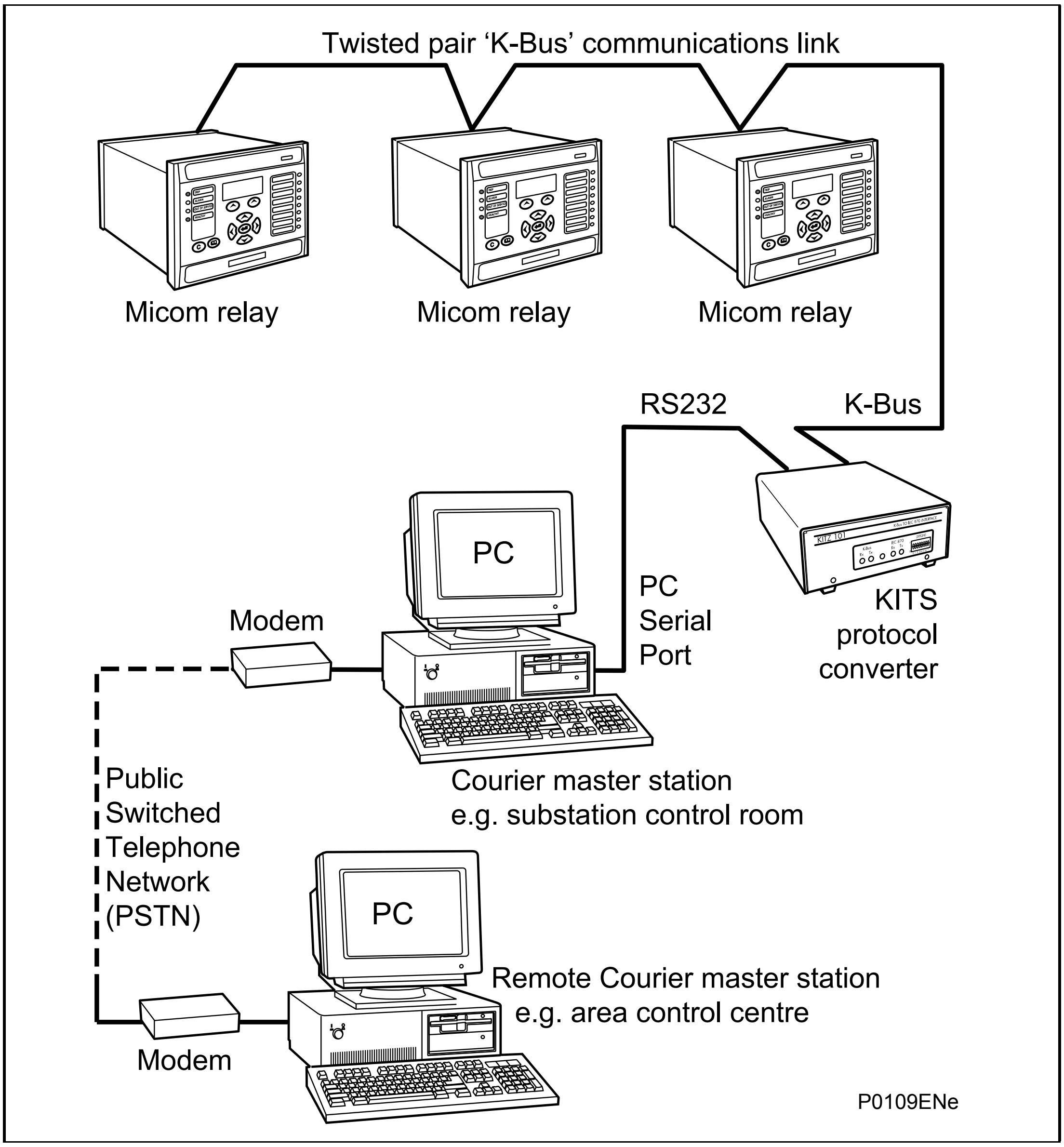

Figure 2: Remote communication connection arrangements

Having made the physical connection to the relay, the relay's communication settings must be configured. To do this use the keypad and LCD user interface. In the relay menu firstly check that the 'Comms. settings' cell in the 'Configuration' column is set to 'Visible', then move to the 'Communications' column. Only two settings apply to the rear port using Courier, the relay's address and the inactivity timer. Synchronous communication is used at a fixed baud rate of 64kbits/s.

Move down the 'Communications' column from the column heading to the first cell down which indicates the communication protocol:

Protocol Courier

The next cell down the column controls the address of the relay:

Remote address 1

Since up to 32 relays can be connected to one K-bus spur, as indicated in Figure 2, it is necessary for each relay to have a unique address so that messages from the master control station are accepted by one relay only. Courier uses an integer number between 0 and 254 for the relay address, which is set with this cell. It is important that no two relays have the same Courier address. The Courier address is then used by the master station to communicate with the relay. Default value of remote address is 255 and must be changed to a value in the range of 1 to 254 before use.

The next cell down controls the inactivity timer:

Inactivity timer 10.00 mins.

The inactivity timer controls how long the relay will wait without receiving any messages on the rear port before it reverts to its default state, including revoking any password access that was enabled. For the rear port this can be set between 1 and 30 minutes.

Note that protection and disturbance recorder settings that are modified using an on-line editor such as PAS&T must be confirmed with a write to the 'Save changes' cell of the 'Configuration' column. Off-line editors such as MiCOM S1 do not require this action for the setting changes to take effect.

1.2.3 IEC60870-5 CS 103 communication

The IEC specification IEC60870-5-103: Telecontrol Equipment and Systems, Part 5: Transmission Protocols Section 103 defines the use of standards IEC60870-5-1 to IEC60870-5-5 to perform communication with protection equipment. The standard configuration for the IEC60870-5-103 protocol is to use a twisted pair EIA(RS)485 connection over distances up to 1000m. The relay operates as a slave in the system, responding to commands from a master station.

To use the rear port with IEC60870-5-103 communication, the relay's communication settings must be configured. To do this use the keypad and LCD user interface. In the relay menu firstly check that the 'Comms. settings' cell in the 'Configuration' column is set to 'Visible', then move to the 'Communications' column. Four settings apply to the rear port using IEC60870-5-103 that are described below. Move down the 'Communications' column from the column heading to the first cell that indicates the communication protocol:

Protocol IEC60870-5-103

The next cell down controls the IEC60870-5-103 address of the relay:

Remote address 162

Up to 32 relays can be connected to one IEC60870-5-103 spur, and therefore it is necessary for each relay to have a unique address so that messages from the master control station are accepted by one relay only. IEC60870-5-103 uses an integer number between 0 and 254 for the relay address. It is important that no two relays have the same IEC60870-5-103 address. The IEC60870-5-103 address is then used by the master station to communicate with the relay.

The next cell down the column controls the baud rate to be used:

Baud rate 9600 bits/s

IEC60870-5-103 communication is asynchronous. Two baud rates are supported by the relay, '9600 bits/s' and '19200 bits/s'. It is important that whatever baud rate is selected on the relay is the same as that set on the IEC60870-5-103 master station.

The next cell down controls the period between IEC60870-5-103 measurements:

Measure't. period 30.00 s

The IEC60870-5-103 protocol allows the relay to supply measurements at regular intervals. The interval between measurements is controlled by this cell, and can be set between 1 and 60 seconds.

The following cell is not currently used but is available for future expansion

Inactive timer

The next cell down can be used for monitor or command blocking:

CS103 blocking

There are three settings associated with this cell; these are:

- Disabled - No blocking selected.
- Monitor Blocking - When the monitor blocking DDB Signal is active high, either by energizing an opto input or control input, reading of the status information and disturbance records is not permitted. When in this mode the relay returns a "Termination of general interrogation" message to the master station.
- Command Blocking - When the command blocking DDB signal is active high, either by energizing an opto input or control input, all remote commands will be ignored (i.e. CB Trip/Close, change setting group etc.). When in this mode the relay returns a "negative acknowledgement of command" message to the master station.

1.2.4 DNP3.0 communication

The DNP 3.0 protocol is defined and administered by the DNP User Group. Information about the user group, DNP 3.0 in general and protocol specifications can be found on their website: www.dnp.org

The relay operates as a DNP 3.0 slave and supports subset level 2 of the protocol plus some of the features from level 3. DNP 3.0 communication is achieved via a twisted pair EIA(RS)485 connection to the rear port and can be used over a distance of 1000m with up to 32 slave devices.

To use the rear port with DNP 3.0 communication, the relay's communication settings must be configured. To do this use the keypad and LCD user interface. In the relay menu firstly check that the 'Comms. setting' cell in the 'Configuration' column is set to 'Visible', then move to the 'Communications' column. Four settings apply to the rear port using DNP 3.0, which are described below. Move down the 'Communications' column from the column heading to the first cell that indicates the communications protocol:

Protocol DNP 3.0

The next cell controls the DNP 3.0 address of the relay:

DNP 3.0 address 232

Up to 32 relays can be connected to one DNP 3.0 spur, and therefore it is necessary for each relay to have a unique address so that messages from the master control station are accepted by only one relay. DNP 3.0 uses a decimal number between 1 and 65519 for the relay address. It is important that no two relays have the same DNP 3.0 address. The DNP 3.0 address is then used by the master station to communicate with the relay.

The next cell down the column controls the baud rate to be used:

Baud rate 9600 bits/s

DNP 3.0 communication is asynchronous. Six baud rates are supported by the relay '1200bits/s', '2400bits/s', '4800bits/s', '9600bits/s', '19200bits/s' and '38400bits/s'. It is important that whatever baud rate is selected on the relay is the same as that set on the DNP 3.0 master station.

The next cell down the column controls the parity format used in the data frames:

Parity None

The parity can be set to be one of 'None', 'Odd' or 'Even'. It is important that whatever parity format is selected on the relay is the same as that set on the DNP 3.0 master station.

The next cell down the column sets the time synchronization request from the master by the relay:

Time Sync. Enabled

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The time sync. can be set to either enabled or disabled. If enabled it allows the DNP 3.0 master to synchronize the time.

1.3 Fiber optic converter

An optional fiber optic card is available in this product. This converts the EIA(RS)485 protocols into a fiber optic output. This communication card is available for use on Courier, IEC60870-5-103 and DNP3.0 it adds the following setting to the communication column.

This controls the physical media used for the communication:

Physical link Copper

The default setting is to select the electrical EIA(RS)485 connection. If the optional fiber optic connectors are fitted to the relay, then this setting can be changed to 'Fiber optic'. This cell is also invisible if a second rear comms. port, or Ethernet card is fitted, as it is mutually exclusive with the fiber optic connectors, and occupies the same physical location.

1.4 Second rear communication port (SK4)

For relays with Courier, IEC60870-5-103 or DNP3.0 protocol on the first rear communications port there is the hardware option of a second rear communications port, which will run the Courier language. This can be used over one of three physical links: twisted pair K-Bus (non-polarity sensitive), twisted pair EIA(RS)485 (connection polarity sensitive) or EIA(RS)232.

The settings for this port are located immediately below the ones for the first port as described in previous sections of P54x/EN IT. Move down the settings until the following sub heading is displayed.

REAR PORT2 (RP2)

The next cell down indicates the language, which is fixed at Courier for RP2.

RP2 protocol Courier

The next cell down indicates the status of the hardware, e.g.

RP2 card status EIA(RS)232 OK

The next cell allows for selection of the port configuration.

RP2 port config. EIA(RS)232

The port can be configured for EIA(RS)232, EIA(RS)485 or K-Bus.

In the case of EIA(RS)232 and EIA(RS)485 the next cell selects the communication mode.

RP2 comms. mode IEC60870 FT1.2

The choice is either IEC60870 FT1.2 for normal operation with 11-bit modems, or 10-bit no parity.

The next cell down controls the comms. port address.

RP2 address 255

Since up to 32 relays can be connected to one K-bus spur, as indicated in Figure 2, it is necessary for each relay to have a unique address so that messages from the master control station are accepted by one relay only. Courier uses an integer number between 0 and 254 for the relay address that is set with this cell. It is important that no two relays have the same Courier address. The Courier address is then used by the master station to communicate with the relay. The default value is 255 and must be changed in the range 0 to 254 before use.

The next cell down controls the inactivity timer.

RP2 inactivity timer 15 mins.

The inactivity timer controls how long the relay will wait without receiving any messages on the rear port before it reverts to its default state, including revoking any password access that was enabled. For the rear port this can be set between 1 and 30 minutes.

In the case of EIA(RS)232 and EIA(RS)485 the next cell down controls the baud rate. For K-Bus the baud rate is fixed at 64kbit/second between the relay and the KITZ interface at the end of the relay spur.

RP2 baud rate 19200

Courier communications is asynchronous. Three baud rates are supported by the relay, ‘9600 bits/s’, ‘19200 bits/s’ and ‘38400 bits/s’.

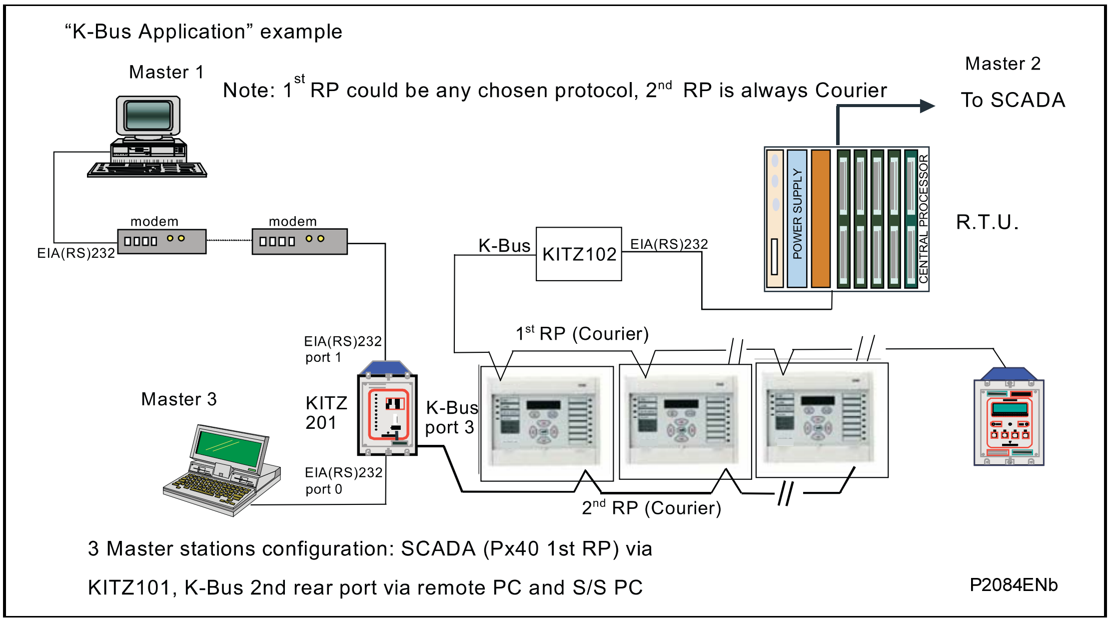

Figure 3: Second rear port K-Bus application

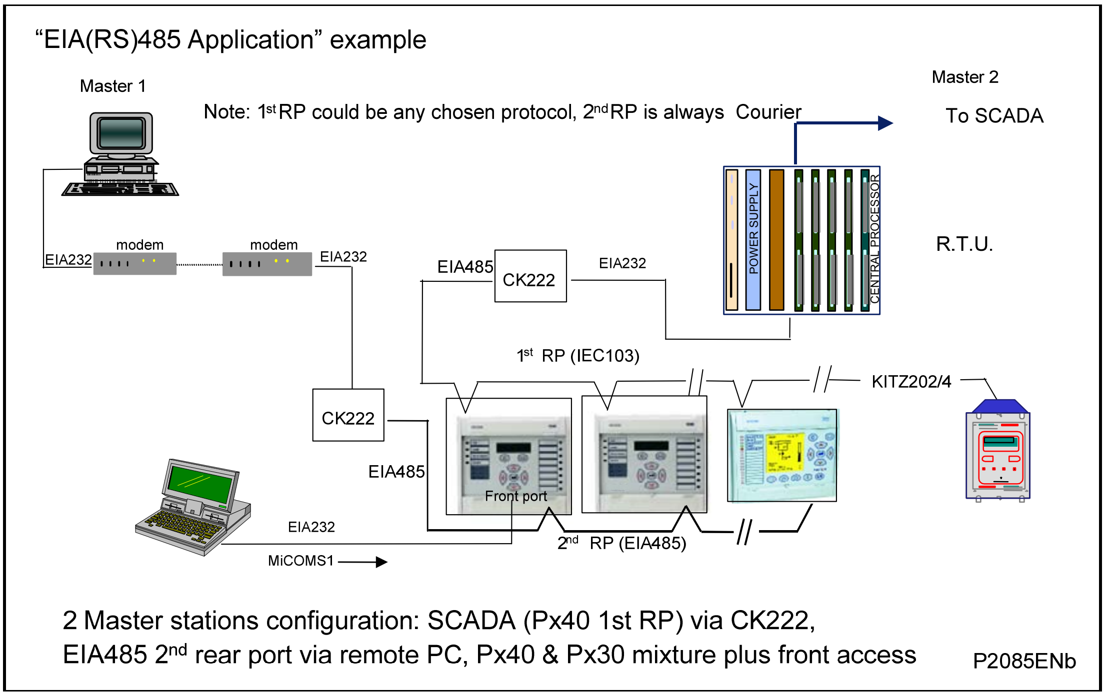

Figure 4: Second rear port EIA(RS)485 example

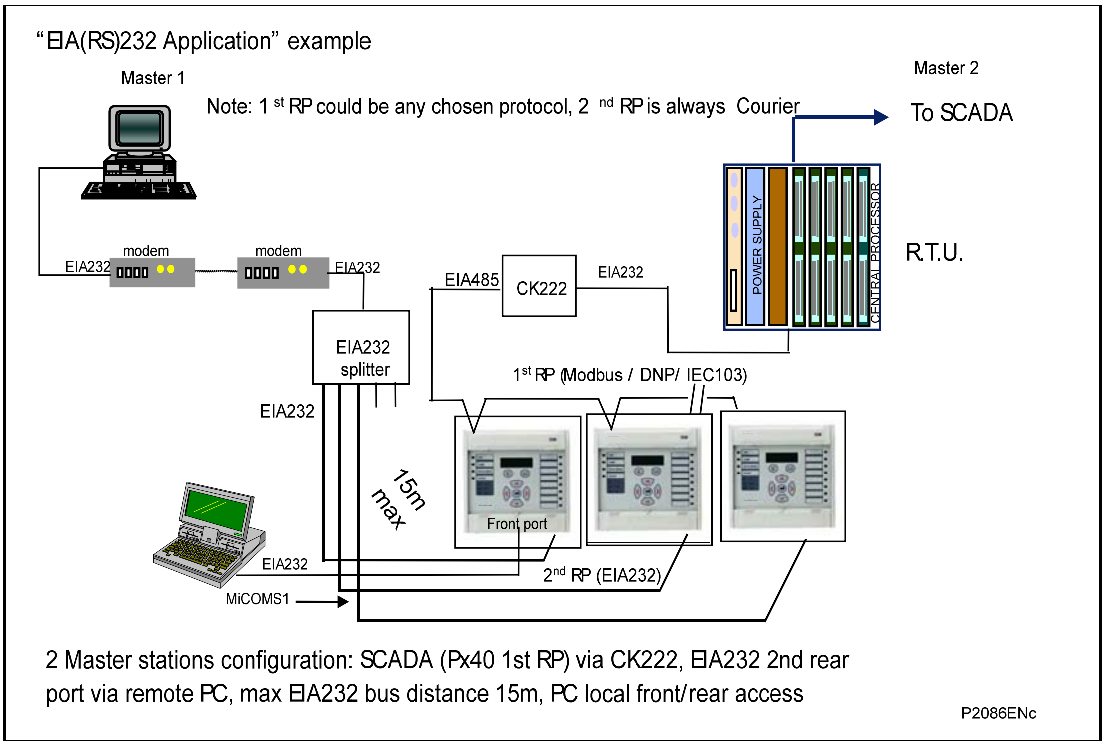

Figure 5: Second rear port EIA(RS)232 example

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2. COURIER INTERFACE

2.1 Courier protocol

K-Bus is based on EIA(RS)485 voltage levels with HDLC FM0 encoded synchronous signaling and its own frame format. The K-Bus twisted pair connection is unpolarized, whereas the EIA(RS)485 and EIA(RS)232 interfaces are polarized.

The EIA(RS)232 interface uses the IEC60870-5 FT1.2 frame format.

The relay supports an IEC60870-5 FT1.2 connection on the front-port. This is intended for temporary local connection and is not suitable for permanent connection. This interface uses a fixed baud rate, 11-bit frame, and a fixed device address.

The rear interface is used to provide a permanent connection for K-Bus and allows multi-drop connection. It should be noted that although K-Bus is based on EIA(RS)485 voltage levels it is a synchronous HDLC protocol using FM0 encoding. It is not possible to use a standard EIA(RS)232 to EIA(RS)485 converter to convert IEC60870-5 FT1.2 frames to K-Bus. Nor is it possible to connect K-Bus to an EIA(RS)485 computer port. A protocol converter, such as the KITZ101, should be employed for this purpose.

Alternatively for direct connections, the fiber optic converter card may be used to convert the rear EIA(RS)485 port into a fiber optic (ST) port. See section 1.3 for more information.

2.2 Supported command set

The following Courier commands are supported by the relay:

Protocol Layer

- Reset Remote Link
- Poll Status
- Poll Buffer*

Low Level Commands

- Send Event*
- Accept Event*
- Send Block
- Store Block Identifier
- Store Block Footer

Menu Browsing

- Get Column Headings
- Get Column Text
- Get Column Values
- Get Strings
- Get Text
- Get Value
- Get Column Setting Limits

Setting Changes

- Enter Setting Mode
- Preload Setting
- Abort Setting

Execute Setting

Reset Menu Cell

Set Value

Control Commands

Select Setting Group

Change Device Address*

Set Real Time

Note: Commands indicated with a * are not supported via the front Courier port.

2.3 Relay courier database

The Courier database is a two dimensional structure with each cell in the database being referenced by a row and column address. Both the column and the row can take a range from 0 to 255. Addresses in the database are specified as hexadecimal values; e.g. 0A02 is column 0A (10 decimal) row 02. Associated settings/data will be part of the same column, row zero of the column contains a text string to identify the contents of the column, i.e. a column heading.

P54x/EN MD contains the complete database definition for the relay. For each cell location the following information is stated:

– Cell text

– Cell datatype

– Cell value

– Whether the cell is settable, if so

– Minimum value

– Maximum value

– Step size

– Password level required to allow setting changes

– String information (for Indexed String or Binary flag cells)

2.4 Setting changes

(See R6512, Courier User Guide - Chapter 9)

There are three categories of settings within the relay database:

– Control and support

– Disturbance recorder

– Protection settings group

Setting changes made to the control and support settings are implemented immediately and stored in non-volatile memory. Changes made to either the disturbance recorder settings or the protection settings groups are stored in a ‘scratchpad’ memory and are not immediately implemented by the relay.

To action setting changes stored in the scratchpad the save changes cell in the configuration column must be written to. This allows the changes to either be confirmed and stored in non-volatile memory, or the setting changes to be aborted.

2.4.1 Setting transfer mode

If it is necessary to transfer all of the relay settings to or from the relay a cell within the communication system data column can be used. This cell (location BF03) when set to 1 makes all of the relay settings visible. Any setting changes made, with the relay set in this mode, are stored in scratchpad memory (including control and support settings). When the value of BF03 is set back to 0 any setting changes are verified and stored in non-volatile memory.

2.5 Event extraction

Events can be extracted either automatically (rear port only) or manually (either Courier port). For automatic extraction all events are extracted in sequential order using the standard Courier event mechanism, this includes fault/maintenance data if appropriate. The manual approach allows the user to select events, faults, or maintenance data at random from the stored records.

2.5.1 Automatic event extraction

(See Chapter 7 Courier User Guide, publication R6512)

This method is intended for continuous extraction of event and fault information as it is produced. It is only supported via the rear Courier port.

When new event information is created the event bit is set within the status byte, this indicates to the master device that event information is available. The oldest, unextracted event can be extracted from the relay using the send event command. The relay will respond with the event data, which will be either a Courier Type 0 or Type 3 event. The Type 3 event is used for fault records and maintenance records.

Once an event has been extracted from the relay, the accept event can be used to confirm that the event has been successfully extracted. If all events have been extracted then the event bit will reset, if there are more events still to be extracted the next event can be accessed using the send event command as before.

2.5.2 Event types

Events will be created by the relay under the following circumstances:

- Change of state of output contact
- Change of state of opto input
- Protection element operation
- Alarm condition
- Setting change
- Password entered/timed-out
- Fault record (Type 3 Courier Event)
- Maintenance record (Type 3 Courier Event)

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2.5.3 Event format

The send event command results in the following fields being returned by the relay:

- Cell reference
- Timestamp
- Cell text
- Cell value

The menu database, P54x/EN MD, contains a table of the events created by the relay and indicates how the contents of the above fields are interpreted. Fault records and maintenance records will return a Courier Type 3 event, which contains the above fields together with two additional fields:

– Event extraction column

– Event number

These events contain additional information that is extracted from the relay using the referenced extraction column. Row 01 of the extraction column contains a setting that allows the fault/maintenance record to be selected. This setting should be set to the event number value returned within the record; the extended data can be extracted from the relay by uploading the text and data from the column.

2.5.4 Manual event record extraction

Column 01 of the database can be used for manual viewing of event, fault, and maintenance records. The contents of this column will depend on the nature of the record selected. It is possible to select events by event number and to directly select a fault record or maintenance record by number.

Event Record Selection (Row 01) - This cell can be set to a value between 0 to 249 to select which of the 512 stored events is selected, 0 will select the most recent record; 249 the oldest stored record. For simple event records, (Type 0) cells 0102 to 0105 contain the event details. A single cell is used to represent each of the event fields. If the event selected is a fault or maintenance record (Type 3) then the remainder of the column will contain the additional information.

Fault Record Selection (Row 05) - This cell can be used to directly select a fault record using a value between 0 and 4 to select one of up to five stored fault records. (0 will be the most recent fault and 4 will be the oldest). The column will then contain the details of the fault record selected.

Maintenance Record Selection (Row F0) - This cell can be used to select a maintenance record using a value between 0 and 4 and operates in a similar way to the fault record selection.

It should be noted that if this column is used to extract event information from the relay the number associated with a particular record will change when a new event or fault occurs.

2.6 Disturbance record extraction

Select Record Number (Row 01) - This cell can be used to select the record to be extracted. Record 0 will be the oldest unextracted record, already extracted older records will be assigned positive values, and negative values will be used for more recent records. To facilitate automatic extraction via the rear port the disturbance bit of the status byte is set by the relay whenever there are unextracted disturbance records.

Once a record has been selected, using the above cell, the time and date of the record can be read from cell 02. The disturbance record itself can be extracted using the block transfer mechanism from cell B00B.

As has been stated, the rear Courier port can be used to automatically extract disturbance records as they occur. This operates using the standard Courier mechanism defined in Chapter 8 of the Courier User Guide. The front Courier port does not support automatic extraction although disturbance record data can be extracted manually from this port.

2.7 Programmable scheme logic settings

The programmable scheme logic (PSL) settings can be uploaded from and downloaded to the relay using the block transfer mechanism defined in Chapter 12 of the Courier User Guide.

The following cells are used to perform the extraction:

- B204 Domain/: Used to select either PSL settings (Upload or download) or PSL configuration data (Upload only)
- B208 Sub-Domain: Used to select the Protection Setting Group to be uploaded/downloaded.
- B20C Version: Used on a download to check the compatibility of the file to be downloaded with the relay.
- B21C Transfer Mode: Used to set-up the transfer process.
- B120 Data Transfer Cell: Used to perform upload/download.

The programmable scheme logic settings can be uploaded and downloaded to and from the relay using this mechanism. If it is necessary to edit the settings MiCOM S1 must be used as the data format is compressed. MiCOM S1 also performs checks on the validity of the settings before they are downloaded to the relay.

3. IEC60870-5-103 INTERFACE

The IEC60870-5-103 interface is a master/slave interface with the relay as the slave device. The relay conforms to compatibility level 2; compatibility level 3 is not supported.

The following IEC60870-5-103 facilities are supported by this interface:

– Initialization (reset)

– Time synchronization

– Event record extraction

– General interrogation

– Cyclic measurements

– General commands

– Disturbance record extraction

– Private codes

3.1 Physical connection and link layer

Two connection options are available for IEC60870-5-103, either the rear EIA(RS)485 port or an optional rear fiber optic port. Should the fiber optic port be fitted the selection of the active port can be made via the front panel menu or the front Courier port, however the selection will only be effective following the next relay power up.

For either of the two modes of connection it is possible to select both the relay address and baud rate using the front panel menu/front Courier. Following a change to either of these two settings a reset command is required to re-establish communications, see reset command description below.

3.2 Initialization

Whenever the relay has been powered up, or if the communication parameters have been changed a reset command is required to initialize the communications. The relay will respond to either of the two reset commands (Reset CU or Reset FCB), the difference being that the Reset CU will clear any unsent messages in the relay's transmit buffer.

The relay will respond to the reset command with an identification message ASDU 5, the Cause Of Transmission COT of this response will be either Reset CU or Reset FCB depending on the nature of the reset command. The content of ASDU 5 is described in the IEC60870-5-103 section of the menu database, P54x/EN MD.

In addition to the above identification message, if the relay has been powered up it will also produce a power up event.

3.3 Time synchronization

The relay time and date can be set using the time synchronization feature of the IEC60870-5-103 protocol. The relay will correct for the transmission delay as specified in IEC60870-5-103. If the time synchronization message is sent as a send/confirm message then the relay will respond with a confirm. Whether the time-synchronization message is sent as a send confirm or a broadcast (send/no reply) message, a time synchronization Class 1 event will be generated/produced.

If the relay clock is being synchronized using the IRIG-B input then it will not be possible to set the relay time using the IEC60870-5-103 interface. An attempt to set the time via the interface will cause the relay to create an event with the current date and time taken from the IRIG-B synchronized internal clock.

3.4 Spontaneous events

Events are categorized using the following information:

- Function type
- Information number

The IEC60870-5-103 profile in the menu database, P54x/EN MD, contains a complete listing of all events produced by the relay.

3.5 General interrogation

The GI request can be used to read the status of the relay, the function numbers, and information numbers that will be returned during the GI cycle are indicated in the IEC60870-5-103 profile in the menu database, P54x/EN MD.

3.6 Cyclic measurements

The relay will produce measured values using ASDU 9 on a cyclical basis, this can be read from the relay using a Class 2 poll (note ADSU 3 is not used). The rate at which the relay produces new measured values can be controlled using the measurement period setting. This setting can be edited from the front panel menu/front Courier port and is active immediately following a change.

It should be noted that the measurands transmitted by the relay are sent as a proportion of 2.4 times the rated value of the analog value.

3.7 Commands

A list of the supported commands is contained in the menu database, P54x/EN MD. The relay will respond to other commands with an ASDU 1, with a cause of transmission (COT) indicating ‘negative acknowledgement’.

3.8 Test mode

It is possible using either the front panel menu or the front Courier port to disable the relay output contacts to allow secondary injection testing to be performed. This is interpreted as ‘test mode’ by the IEC60870-5-103 standard. An event will be produced to indicate both entry to and exit from test mode. Spontaneous events and cyclic measured data transmitted whilst the relay is in test mode will have a COT of ‘test mode’.

3.9 Disturbance records

The disturbance records are stored in uncompressed format and can be extracted using the standard mechanisms described in IEC60870-5-103.

Note: IEC60870-5-103 only supports up to 8 records.

3.10 Blocking of monitor direction

The relay supports a facility to block messages in the monitor direction and also in the command direction. Messages can be blocked in the monitor and command directions using the menu commands, Communications - CS103 Blocking - Disabled/Monitor Blocking/ Command Blocking or DDB signals Monitor Blocked and Command Blocked.

4. DNP3.0 INTERFACE

4.1 DNP3.0 protocol

The descriptions given here are intended to accompany the device profile document that is included in the menu database, P54x/EN MD. The DNP3.0 protocol is not described here, please refer to the documentation available from the user group. The device profile document specifies the full details of the DNP3.0 implementation for the relay. This is the standard format DNP3.0 document that specifies which objects, variations and qualifiers are supported. The device profile document also specifies what data is available from the relay via DNP3.0. The relay operates as a DNP3.0 slave and supports subset level 2 of the protocol, plus some of the features from level 3.

DNP3.0 communication uses the EIA(RS)485 or fiber optic communication port at the rear of the relay. The data format is 1 start bit, 8 data bits, an optional parity bit and 1 stop bit. Parity is configurable (see menu settings below).

4.2 DNP3.0 menu setting

The settings shown below are available in the menu for DNP3.0 in the 'Communications' column.

Setting	Range	Description
Remote Address	0 - 65534	DNP3.0 address of relay (decimal)
Baud Rate	1200, 2400, 4800, 9600, 19200, 38400	Selectable baud rate for DNP3.0 communication
Parity	None, Odd, Even	Parity setting
Time Sync.	Enabled, Disabled	Enables or disables the relay requesting time sync. from the master via IIN bit 4 word 1

4.3 Object 1 binary inputs

Object 1, binary inputs, contains information describing the state of signals within the relay which mostly form part of the digital data bus (DDB). In general these include the state of the output contacts and input optos, alarm signals and protection start and trip signals. The 'DDB number' column in the device profile document provides the DDB numbers for the DNP3.0 point data. These can be used to cross-reference to the DDB definition list that is also found in the menu database, P54x/EN MD. The binary input points can also be read as change events via object 2 and object 60 for class 1-3 event data.

4.4 Object 10 binary outputs

Object 10, binary outputs, contains commands that can be operated via DNP3.0. As such the points accept commands of type pulse on [null, trip, close] and latch on/off as detailed in the device profile in the menu database, P54x/EN MD and execute the command once for either command. The other fields are ignored (queue, clear, trip/close, in time and off time).

Due to that fact that many of the relay's functions are configurable, it may be the case that some of the object 10 commands described below are not available for operation. In the case of a read from object 10 this will result in the point being reported as off-line and an operate command to object 12 will generate an error response.

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Examples of object 10 points that maybe reported as off-line are:

– Activate setting groups - Ensure setting groups are enabled

– CB trip/close - Ensure remote CB control is enabled

– Reset NPS thermal - Ensure NPS thermal protection is enabled

– Reset thermal O/L - Ensure thermal overload protection is enabled

– Reset RTD flags - Ensure RTD Inputs is enabled

– Control Inputs - Ensure control inputs are enabled

4.5 Object 20 binary counters

Object 20, binary counters, contains cumulative counters and measurements. The binary counters can be read as their present ‘running’ value from object 20, or as a ‘frozen’ value from object 21. The running counters of object 20 accept the read, freeze and clear functions. The freeze function takes the current value of the object 20 running counter and stores it in the corresponding object 21 frozen counter. The freeze and clear function resets the object 20 running counter to zero after freezing its value.

4.6 Object 30 analog input

Object 30, analog inputs, contains information from the relay’s measurements columns in the menu. All object 30 points are reported as fixed-point values although they are stored inside the relay in a floating-point format. The conversion to fixed-point format requires the use of a scaling factor, which differs for the various types of data within the relay e.g. current, voltage, phase angle etc. The data types supported are listed at the end of the device profile document with each type allocated a ‘D number’, i.e. D1, D2, etc. In the object 30 point list each data point has a D number data type assigned to it which defines the scaling factor, default deadband setting and the range and resolution of the deadband setting. The deadband is the setting used to determine whether a change event should be generated for each point. The change events can be read via object 32 or object 60 and will be generated for any point whose value has changed by more than the deadband setting since the last time the data value was reported.

Any analog measurement that is unavailable at the time it is read will be reported as offline, e.g. the frequency when the current and voltage frequency is outside the tracking range of the relay or the thermal state when the thermal protection is disabled in the configuration column. Note that all object 30 points are reported as secondary values in DNP3.0 (with respect to CT and VT ratios).

4.7 DNP3.0 configuration using MiCOM S1

A PC support package for DNP3.0 is available as part of the settings and records module of MiCOM S1. The S1 module allows configuration of the relay’s DNP3.0 response. The PC is connected to the relay via a serial cable to the 9-pin front part of the relay - see Introduction (P54x/EN IT). The configuration data is uploaded from the relay to the PC in a block of compressed format data and downloaded to the relay in a similar manner after modification. The new DNP3.0 configuration takes effect in the relay after the download is complete. The default configuration can be restored at any time by choosing ‘All Settings’ from the ‘Restore Defaults’ cell in the menu ‘Configuration’ column. In S1, the DNP3.0 data is displayed on a three-tabbed screen, one screen each for object 1, 20 and 30. Object 10 is not configurable.

4.7.1 Object 1

For every point included in the device profile document there is a check box for membership of class 0 and radio buttons for class 1, 2 or 3 membership. Any point that is in class 0 must be a member of one of the change event classes 1, 2 or 3.

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Points that are configured out of class 0 are by default not capable of generating change events. Furthermore, points that are not part of class 0 are effectively removed from the DNP3.0 response by renumbering the points that are in class 0 into a contiguous list starting at point number 0. The renumbered point numbers are shown at the left-hand side of the screen in S1 and can be printed out to form a revised device profile for the relay. This mechanism allows best use of available bandwidth by only reporting the data points required by the user when a poll for all points is made.

4.7.2 Object 20

The running counter value of object 20 points can be configured to be in or out of class 0. Any running counter that is in class 0 can have its frozen value selected to be in or out of the DNP3.0 response, but a frozen counter cannot be included without the corresponding running counter. As with object 1, the class 0 response will be renumbered into a contiguous list of points based on the selection of running counters. The frozen counters will also be renumbered based on the selection; note that if some of the counters that are selected as running are not also selected as frozen then the renumbering will result in the frozen counters having different point numbers to their running counterparts. For example, object 20 point 3 (running counter) might have its frozen value reported as object 21 point 1.

4.7.3 Object 30

For the analog inputs, object 30, the same selection options for classes 0, 1, 2 and 3 are available as for object 1. In addition to these options, which behave in exactly the same way as for object 1, it is possible to change the deadband setting for each point. The minimum and maximum values and the resolution of the deadband settings are defined in the device profile document; MiCOM S1 will allow the deadband to be set to any value within these constraints.

5. IEC 61850 ETHERNET INTERFACE

5.1 Introduction

IEC 61850 is the international standard for Ethernet-based communication in substations. It enables integration of all protection, control, measurement and monitoring functions within a substation, and additionally provides the means for interlocking and inter-tripping. It combines the convenience of Ethernet with the security which is essential in substations today.

The MiCOM protection relays can integrate with the PACiS substation control systems, to complete Schneider Electric's offer of a full IEC 61850 solution for the substation. The majority of MiCOM Px3x and Px4x relay types can be supplied with Ethernet, in addition to traditional serial protocols. Relays which have already been delivered with UCA2.0 on Ethernet can be easily upgraded to IEC 61850.

5.2 What is IEC 61850?

IEC 61850 is an international standard, comprising 14 parts, which defines a communication architecture for substations.

The standard defines and offers much more than just a protocol. It provides:

- Standardized models for IEDs and other equipment within the substation
- Standardized communication services (the methods used to access and exchange data)
- Standardized formats for configuration files
- Peer-to-peer (e.g. relay to relay) communication

The standard includes mapping of data onto Ethernet. Using Ethernet in the substation offers many advantages, most significantly including:

- High-speed data rates (currently 100 Mbits/s, rather than 10’s of kbits/s or less used by most serial protocols)
- Multiple masters (called “clients”)
- Ethernet is an open standard in every-day use

Schneider Electric has been involved in the Working Groups which formed the standard, building on experience gained with UCA2.0, the predecessor of IEC 61850.

5.2.1 Interoperability

A major benefit of IEC 61850 is interoperability. IEC 61850 standardizes the data model of substation IEDs. This responds to the utilities’ desire of having easier integration for different vendors’ products, i.e. interoperability. It means that data is accessed in the same manner in different IEDs from either the same or different IED vendors, even though, for example, the protection algorithms of different vendors’ relay types remain different.

When a device is described as IEC 61850-compliant, this does not mean that it is interchangeable, but does mean that it is interoperable. You cannot simply replace one product with another, however the terminology is pre-defined and anyone with prior knowledge of IEC 61850 should be able very quickly integrate a new device without the need for mapping of all of the new data. IEC 61850 will inevitably bring improved substation communications and interoperability, at a lower cost to the end user.

5.2.2 The data model

To ease understanding, the data model of any IEC 61850 IED can be viewed as a hierarchy of information. The categories and naming of this information is standardized in the IEC 61850 specification.

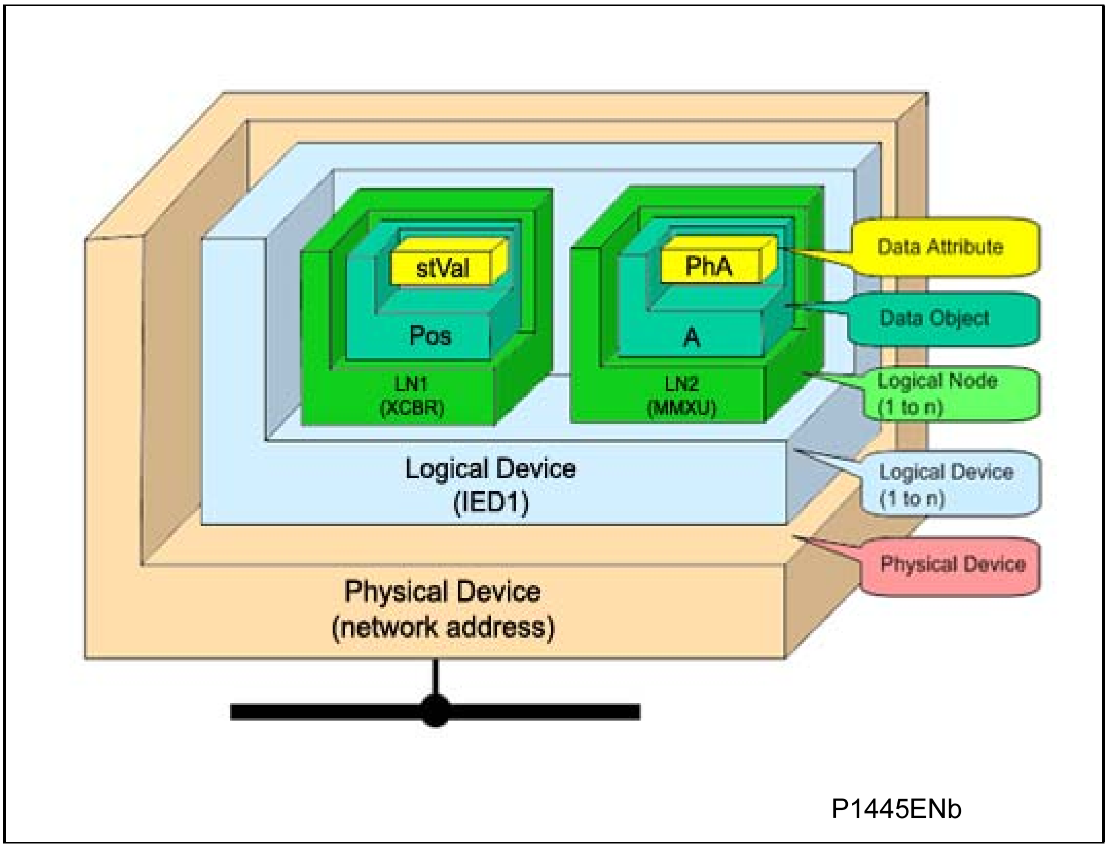

Figure 6: Data model layers in IEC 61850

The levels of this hierarchy can be described as follows:

–	Physical Device	– Identifies the actual IED within a system. Typically the device's name or IP address can be used (for example **Feeder_1** or **10.0.0.2**).
–	Logical Device	– Identifies groups of related Logical Nodes within the Physical Device. For the MiCOM relays, 5 Logical Devices exist: **Control, Measurements, Protection, Records, System**.
–	Wrapper/Logical Node Instance	– Identifies the major functional areas within the IEC 61850 data model. Either 3 or 6 characters are used as a prefix to define the functional group (wrapper) while the actual functionality is identified by a 4 character Logical Node name suffixed by an instance number. For example, XCBR1 (circuit breaker), MMXU1 (measurements), FrqPTOF2 (overfrequency protection, stage 2).
–	Data Object	– This next layer is used to identify the type of data you will be presented with. For example, **Pos** (position) of Logical Node type **XCBR**.
–	Data Attribute	– This is the actual data (measurement value, status, description, etc.). For example, **stVal** (status value) indicating actual position of circuit breaker for Data Object type **Pos** of Logical Node type **XCBR**.

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5.3 IEC 61850 in MiCOM relays

IEC 61850 is implemented in MiCOM relays by use of a separate Ethernet card. This card manages the majority of the IEC 61850 implementation and data transfer to avoid any impact on the performance of the protection.

In order to communicate with an IEC 61850 IED on Ethernet, it is necessary only to know its IP address. This can then be configured into either:

- An IEC 61850 "client" (or master), for example a PACiS computer (MiCOM C264) or HMI, or
- An "MMS browser", with which the full data model can be retrieved from the IED, without any prior knowledge

5.3.1 Capability

The IEC 61850 interface provides the following capabilities:

1. Read access to measurements

   All measurands are presented using the measurement Logical Nodes, in the 'Measurements' Logical Device. Reported measurement values are refreshed by the relay once per second, in line with the relay user interface.

2. Generation of unbuffered reports on change of status/measurement

   Unbuffered reports, when enabled, report any change of state in statuses and/or measurements (according to deadband settings).

3. Support for time synchronization over an Ethernet link

   Time synchronization is supported using SNTP (Simple Network Time Protocol); this protocol is used to synchronize the internal real time clock of the relays.

4. GOOSE peer-to-peer communication

   GOOSE communications of statuses are included as part of the IEC 61850 implementation. Please see section 5.6 for more details.

5. Disturbance record extraction

   Extraction of disturbance records, by file transfer, is supported by the MiCOM relays. The record is extracted as an ASCII format COMTRADE file.

Setting changes (e.g. of protection settings) are not supported in the current IEC 61850 implementation. In order to keep this process as simple as possible, such setting changes are done using MiCOM S1 Settings & Records program. This can be done as previously using the front port serial connection of the relay, or now optionally over the Ethernet link if preferred (this is known as "tunneling").

5.3.2 IEC 61850 configuration

One of the main objectives of IEC 61850 is to allow IEDs to be directly configured from a configuration file generated at system configuration time. At the system configuration level, the capabilities of the IED are determined from an IED capability description file (ICD) which is provided with the product. Using a collection of these ICD files from varying products, the entire protection of a substation can be designed, configured and tested (using simulation tools) before the product is even installed into the substation.

To aid in this process, the MiCOM S1 Support Software provides an IED Configurator tool which allows the pre-configured IEC 61850 configuration file (an SCD file or CID file) to be imported and transferred to the IED. Alongside this, the requirements of manual configuration are satisfied by allowing the manual creation of configuration files for MiCOM relays based on their original IED capability description (ICD file).

Other features include the extraction of configuration data for viewing and editing, and a sophisticated error checking sequence which ensures that the configuration data is valid for sending to the IED and that the IED will function within the context of the substation.

To aid the user, some configuration data is available in the 'IED CONFIGURATOR' column of the relay user interface, allowing read-only access to basic configuration data.

5.3.2.1 Configuration banks

To promote version management and minimize down-time during system upgrades and maintenance, the MiCOM relays have incorporated a mechanism consisting of multiple configuration banks. These configuration banks are categorized as:

- Active Configuration Bank
- Inactive Configuration Bank

Any new configuration sent to the relay is automatically stored into the inactive configuration bank, therefore not immediately affecting the current configuration. Both active and inactive configuration banks can be extracted at anytime.

When the upgrade or maintenance stage is complete, the IED Configurator tool can be used to transmit a command (to a single IED) authorizing the activation of the new configuration contained in the inactive configuration bank, by switching the active and inactive configuration banks. This technique ensures that the system down-time is minimized to the start-up time of the new configuration. The capability to switch the configuration banks is also available via the 'IED CONFIGURATOR' column.

For version management, data is available in the 'IED CONFIGURATOR' column in the relay user interface, displaying the SCL Name and Revision attributes of both configuration banks.

5.3.2.2 Network connectivity

Note: This section presumes a prior knowledge of IP addressing and related topics. Further details on this topic may be found on the Internet (search for IP Configuration) and in numerous relevant books.

Configuration of the relay IP parameters (IP Address, Subnet Mask, Gateway) and SNTP time synchronization parameters (SNTP Server 1, SNTP Server 2) is performed by the IED Configurator tool, so if these parameters are not available via an SCL file, they must be configured manually.

If the assigned IP address is duplicated elsewhere on the same network, the remote communications will operate in an indeterminate way. However, the relay will check for a conflict on every IP configuration change and at power up. An alarm will be raised if an IP conflict is detected.

The relay can be configured to accept data from networks other than the local network by using the 'Gateway' setting.

5.4 The data model of MiCOM relays

The data model naming adopted in the Px30 and Px40 relays has been standardized for consistency. Hence the Logical Nodes are allocated to one of the five Logical Devices, as appropriate, and the wrapper names used to instantiate Logical Nodes are consistent between Px30 and Px40 relays.

The data model is described in the Model Implementation Conformance Statement (MICS) document, which is available separately. The MICS document provides lists of Logical Device definitions, Logical Node definitions, Common Data Class and Attribute definitions, Enumeration definitions, and MMS data type conversions. It generally follows the format used in Parts 7-3 and 7-4 of the IEC 61850 standard.

5.5 The communication services of MiCOM relays

The IEC 61850 communication services which are implemented in the Px30 and Px40 relays are described in the Protocol Implementation Conformance Statement (PICS) document, which is available separately. The PICS document provides the Abstract Communication Service Interface (ACSI) conformance statements as defined in Annex A of Part 7-2 of the IEC 61850 standard.

5.6 Peer-to-peer (GSE) communications

The implementation of IEC 61850 Generic Substation Event (GSE) sets the way for cheaper and faster inter-relay communications. The generic substation event model provides the possibility for a fast and reliable system-wide distribution of input and output data values. The generic substation event model is based on the concept of an autonomous decentralization, providing an efficient method allowing the simultaneous delivery of the same generic substation event information to more than one physical device through the use of multicast services.

The use of multicast messaging means that IEC 61850 GOOSE uses a publisher-subscriber system to transfer information around the network*. When a device detects a change in one of its monitored status points it publishes (i.e. sends) a new message. Any device that is interested in the information subscribes (i.e. listens) to the data it contains.

Note: * Multicast messages cannot be routed across networks without specialized equipment.

Each new message is re-transmitted at user-configurable intervals until the maximum interval is reached, in order to overcome possible corruption due to interference, and collisions. In practice, the parameters which control the message transmission cannot be calculated. Time must be allocated to the testing of GSE schemes before or during commissioning, in just the same way a hardwired scheme must be tested.

5.6.1 Scope

A maximum of 32 virtual inputs are available within the PSL which can be mapped directly to a published dataset in a GOOSE message (only 1 fixed dataset is supported). All published GOOSE signals are BOOLEAN values.

Each GOOSE signal contained in a subscribed GOOSE message can be mapped to any of the 32 virtual inputs within the PSL. The virtual inputs allow the mapping to internal logic functions for protection control, directly to output contacts or LEDs for monitoring.

The MiCOM relay can subscribe to all GOOSE messages but only the following data types can be decoded and mapped to a virtual input:

- BOOLEAN
- BSTR2
- INT16
- INT32
- INT8
- UINT16
- UINT32
- UINT8

5.6.2 IEC 61850 GOOSE configuration

All GOOSE configuration is performed via the IED Configurator tool available within the MiCOM S1 Support Software.

All GOOSE publishing configuration can be found under the 'GOOSE Publishing' tab in the configuration editor window. All GOOSE subscription configuration can be found under the 'External Binding' tab in the configuration editor window. Care should be taken to ensure that the configuration is correct, to ensure efficient GOOSE scheme operation.

Settings to enable GOOSE signaling and to apply Test Mode are available via the relay user interface.

5.7 Ethernet functionality

Settings relating to a failed Ethernet link are available in the 'COMMUNICATIONS' column of the relay user interface.

5.7.1 Ethernet disconnection

IEC 61850 'Associations' are unique and made to the relay between the client (master) and server (IEC 61850 device). In the event that the Ethernet is disconnected, such associations are lost, and will need to be re-established by the client. The TCP_KEEPALIVE function is implemented in the relay to monitor each association, and terminate any which are no longer active.

5.7.2 Loss of power

The relay allows the re-establishment of associations by the client without a negative impact on the relay's operation after having its power removed. As the relay acts as a server in this process, the client must request the association. Uncommitted settings are cancelled when power is lost, and reports requested by connected clients are reset and must be re-enabled by the client when it next creates the new association to the relay.

6. SK5 PORT CONNECTION

The lower 9-way D-type connector (SK5) is currently unsupported. Do not connect to this port.

SYMBOLS AND GLOSSARY

Date:	**7th August 2006**
Hardware Suffix:	**K**
Software Version:	**41 and 51**
Connection Diagrams:	**10P54302xx (xx = 01 to 02) & 10P54303xx (xx = 01 to 02)**
	10P54402xx (xx = 01 to 02) & 10P54403xx (xx = 01 to 02)
	10P54502xx (xx = 01 to 02) & 10P54503xx (xx = 01 to 02)
	10P54602xx (xx = 01 to 02) & 10P54603xx (xx = 01 to 02)

Logic Symbols

Symbols	Explanation
<	**Less than:** Used to indicate an “under” threshold, such as undercurrent (current dropout).
>	**Greater than:** Used to indicate an “over” threshold, such as overcurrent (current overload)
&	**Logical “AND”:** Used in logic diagrams to show an AND-gate function.
1	**Logical “OR”:** Used in logic diagrams to show an OR-gate function.
o	**A small circle on the input or output of a logic gate:** Indicates a NOT (invert) function.
52a	**A circuit breaker closed auxiliary contact:** The contact is in the same state as the breaker primary contacts.
52b	**A circuit breaker open auxiliary contact:** The contact is in the opposite state to the breaker primary contacts.
Σ	**“Sigma”:** Used to indicate a summation, such as cumulative current interrupted.
τ	**“Tau”:** Used to indicate a time constant, often associated with thermal characteristics.
ABC	Anti-clockwise phase rotation.
ACB	Clock-wise phase rotation.
BAR	Block auto-reclose signal.
BOP	Abbreviation of “Blocking Overreach Protection”. A blocking aided-channel scheme.
BU	**Backup:** Typically a back-up protection element.
C/O	**A changeover contact having normally closed and normally open connections:** Often called a “form C” contact.
CB	Circuit breaker.
CB Aux.	**Circuit breaker auxiliary contacts:** Indication of the breaker open/closed status.
CBF	Circuit breaker failure protection.
Ch	Abbreviation of channel - usually a communications or signaling channel.
CRx	**Channel Receive:** Typically used to indicate a teleprotection signal received.
CS	Check synchronism.
CT	Current transformer.
CTRL.	**Abbreviation of “Control”:** As used for the Control Inputs function.
CTS	**Current transformer supervision:** To detect CT input failure.
CTx	**Channel Transmit:** Typically used to indicate a teleprotection signal send.

Symbols	Explanation
CVT	Capacitor-coupled Voltage Transformer - equivalent to terminology CCVT.
DDB	**Digital data bus within the programmable scheme logic:** A logic point that has a zero or 1 status. DDB signals are mapped in logic to customize the relay's operation.
DEF	**Directional earth fault protection:** A directionalized ground fault aided scheme.
Diff	Differential protection.
Dist	Distance protection.
Dly	Time delay.
DT	**Abbreviation of "Definite Time":** An element which always responds with the same constant time delay on operation.
E/F	**Earth fault:** Directly equivalent to ground fault.
FLC	**Full load current:** The nominal rated current for the circuit.
Flt.	**Abbreviation of "Fault":** Typically used to indicate faulted phase selection.
FN	Function.
Fwd.	Indicates an element responding to a flow in the "Forward" direction.
Gnd.	**Abbreviation of "Ground":** Used in distance settings to identify settings that relate to ground (earth) faults.
GPS	**Abbreviation of "Global Positioning Systems"**
GRP.	**Abbreviation of "Group":** Typically an alternative setting group.
I	Current.
I^	**Current raised to a power:** Such as when breaker statistics monitor the square of ruptured current squared (^ power = 2).
I<	**An undercurrent element:** Responds to current dropout.
I>1	**First stage of phase overcurrent protection:** Could be labeled 51-1 in ANSI terminology.
I>2	**Second stage of phase overcurrent protection:** Could be labeled 51-2 in ANSI terminology.
I>3	**Third stage of phase overcurrent protection:** Could be labeled 51-3 in ANSI terminology.
I>4	**Fourth stage of phase overcurrent protection:** Could be labeled 51-4 in ANSI terminology.
I_0	**Zero sequence current:** Equals one third of the measured neutral/residual current.
I_1	**Positive sequence current.**
I_2	**Negative sequence current.**
I2>	Negative sequence overcurrent protection (NPS element).

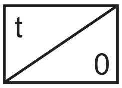
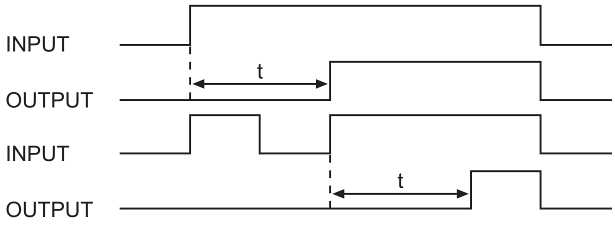
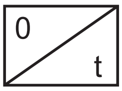
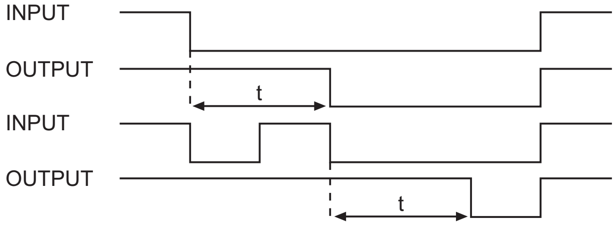
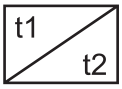
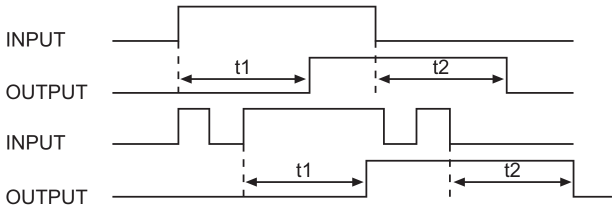
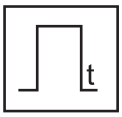
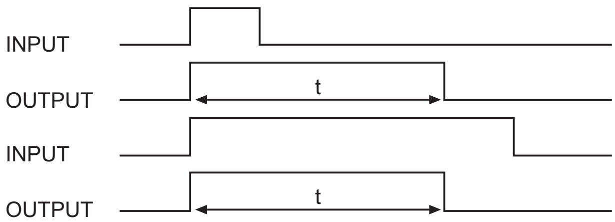
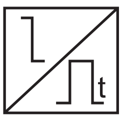
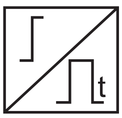
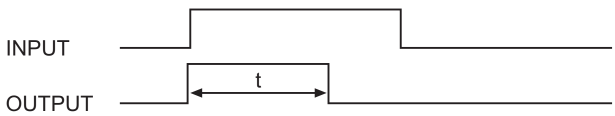
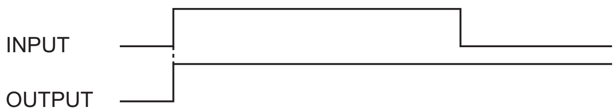
Symbols	Explanation
I2pol	Negative sequence polarizing current.
IA	**Phase A current:** Might be phase L1, red phase.. or other, in customer terminology.
IB	**Phase B current:** Might be phase L2, yellow phase.. or other, in customer terminology.
IC	**Phase C current:** Might be phase L3, blue phase.. or other, in customer terminology.
ID	**Abbreviation of “Identifier”:** Often a label used to track a software version installed.
IDMT	**Inverse definite minimum time:** A characteristic whose trip time depends on the measured input (e.g. current) according to an inverse-time curve.
Im	Mutual current
IMx	**InterMiCOM^{64} bit** (x=1 to 16)
IM64	InterMiCOM$^{64.}$
In	**The rated nominal current of the relay:** Software selectable as 1 amp or 5 amp to match the line CT input.
IN	**Neutral current, or residual current:** This results from an internal summation of the three measured phase currents.
IN>	**A neutral (residual) overcurrent element:** Detects earth/ground faults.
IN>1	**First stage of ground overcurrent protection:** Could be labeled 51N-1 in ANSI terminology.
IN>2	**Second stage of ground overcurrent protection:** Could be labeled 51N-2 in ANSI terminology.
Inh	An inhibit signal.
ISEF>	Sensitive earth fault overcurrent element.
Inst.	**An element with “instantaneous” operation:** i.e. having no deliberate time delay.
I/O	**Abbreviation of “Inputs and Outputs”:** Used in connection with the number of optocoupled inputs and output contacts within the relay.
I/P	Abbreviation of “Input”.
km	**Distance in kilometers**
kZm	The mutual compensation factor (mutual compensation of distance elements and fault locator for parallel line coupling effects).
kZN	**The residual compensation factor:** Ensuring correct reach for ground distance elements.
LCD	**Liquid crystal display:** The front-panel text display on the relay.
LD	**Abbreviation of “Level Detector”:** An element responding to a current or voltage below its set threshold.

Symbols	Explanation
LDOV	Overvoltage level detector, used in the distance aided channel schemes.
LED	**Light emitting diode:** Red or green indicator on the relay front-panel.
LoL	A loss of load scheme, providing a fast distance trip without needing a signaling channel.
MCB	**A “miniature circuit breaker”:** Used instead of a fuse to protect VT secondary circuits.
mi	Distance in miles.
N	**Indication of “Neutral” involvement in a fault:** i.e. a ground (earth) fault.
N/A	Not applicable.
N/C	**A normally closed or “break” contact:** Often called a “form B” contact.
N/O	**A normally open or “make” contact:** Often called a “form A” contact.
NPS	Negative phase sequence.
NXT	**Abbreviation of “Next”:** In connection with hotkey menu navigation.
NVD	**Neutral voltage displacement:** Equivalent to residual overvoltage protection.
O/P	Abbreviation of “output”.
Opto	**An optocoupled logic input:** Alternative terminology: binary input.
P1	**Used in IEC terminology to identify the primary CT terminal polarity:** Replace by a dot when using ANSI standards.
P2	**Used in IEC terminology to identify the primary CT terminal polarity:** The non-dot terminal.
PCB	Printed circuit board.
Ph	**Abbreviation of “Phase”:** Used in distance settings to identify settings that relate to phase-phase faults.
Pol	**Abbreviation of “Polarizing”:** Typically the polarizing voltage used in making directional decisions.
POR	A permissive overreaching transfer trip scheme (alternative terminology: POTT).
PN>	**Wattmetric earth fault protection:** Calculated using residual voltage and current quantities.
PSB	Power swing blocking, to detect power swing/out of step functions (ANSI 78).
PSL	**Programmable scheme logic:** The part of the relay’s logic configuration that can be modified by the user, using the graphical editor within MiCOM S1 software.
PUR	A permissive underreaching transfer trip scheme (alternative terminology: PUTT).
R	A resistance.
R Gnd.	**A distance zone resistive reach setting:** Used for ground (earth) faults.

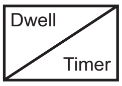
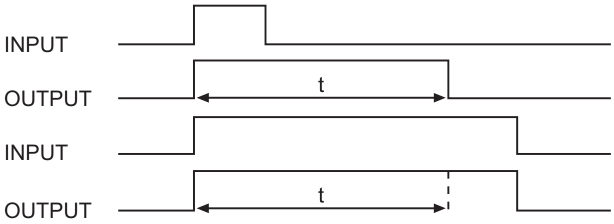
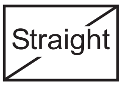
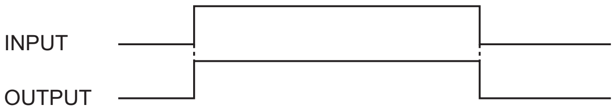
Symbols	Explanation
R Ph	A distance zone resistive reach setting used for Phase-Phase faults.
RCA	**Abbreviation of “Relay Characteristic Angle”:** The center of the directional characteristic.
Rev.	Indicates an element responding to a flow in the “reverse” direction.
RMS	**The equivalent a.c. current:** Taking into account the fundamental, plus the equivalent heating effect of any harmonics. Abbreviation of “root mean square”.
RP	**Abbreviation of “Rear Port”:** The communication ports on the rear of the relay.
Rx	**Abbreviation of “Receive”:** Typically used to indicate a communication receive line/pin.
S1	**Used in IEC terminology to identify the secondary CT terminal polarity:** Replace by a dot when using ANSI standards.
S2	**Used in IEC terminology to identify the secondary CT terminal polarity:** The non-dot terminal.
SIR	The source-to-line impedance ratio.
SOTF	Switch on to Fault protection. Modified protection on manual closure of the circuit breaker.
t	A time delay.
TCS	Trip circuit supervision.
TD	**The time dial multiplier setting:** Applied to inverse-time curves (ANSI/IEEE).
TE	**A standard for measuring the width of a relay case:** One inch = 5TE units.
TMS	The time multiplier setting applied to inverse-time curves (IEC).
TOC	Trip on Close (“line check”) protection. Offers SOTF and TOR functionality.
TOR	Trip on Reclose protection. Modified protection on autoreclosure of the circuit breaker.
Tx	**Abbreviation of “Transmit”:** Typically used to indicate a communication transmit line/pin.
V	Voltage.
V<	An undervoltage element.
V<1	**First stage of undervoltage protection:** Could be labeled 27-1 in ANSI terminology.
V<2	**Second stage of undervoltage protection:** Could be labeled 27-2 in ANSI terminology.
V>	An overvoltage element.
V>1	**First stage of overvoltage protection:** Could be labeled 59-1 in ANSI terminology.
V>2	**Second stage of overvoltage protection:** Could be labeled 59-2 in ANSI terminology.
V_0	**Zero sequence voltage:** Equals one third of the measured neutral/residual voltage.

Symbols	Explanation
V_1	Positive sequence voltage.
V_2	Negative sequence voltage.
V2pol	Negative sequence polarizing voltage.
VA	**Phase A voltage:** Might be phase L1, red phase.. or other, in customer terminology.
VB	**Phase B voltage:** Might be phase L2, yellow phase.. or other, in customer terminology.
VC	**Phase C voltage:** Might be phase L3, blue phase.. or other, in customer terminology.
Vk	IEC knee point voltage of a current transformer.
Vn	**The rated nominal voltage of the relay:** To match the line VT input.
VN	Neutral voltage displacement, or residual voltage.
VN>1	First stage of residual (neutral) overvoltage protection.
VN>2	Second stage of residual (neutral) overvoltage protection.
Vres.	Neutral voltage displacement, or residual voltage.
VT	Voltage transformer.
VTS	**Voltage transformer supervision:** To detect VT input failure.
Vx	**An auxiliary supply voltage:** Typically the substation battery voltage used to power the relay.
WI	Abbreviation of “Weak Infeed” logic used in teleprotection schemes.
Z_0	Zero sequence impedance.
Z_1	Positive sequence impedance.
Z_2	Negative sequence impedance.
Z1	Zone 1 distance protection.
Z1X	Reach-stepped Zone 1X, for zone extension schemes used with auto-reclosure.
Z2	Zone 2 distance protection.
ZP	Programmable distance zone that can be set forward or reverse looking.
Zs	Used to signify the source impedance behind the relay location.

Logic Timers

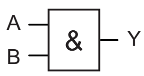
Logic Symbols	Explanation	Time Chart
	Delay on pick-up timer, t	
	Delay on drop-off timer, t	
	Delay on pick-up/drop-off timer	
	Pulse timer	
	Pulse pick-up falling edge	
	Pulse pick-up raising edge	
Latching	Latch	

SG

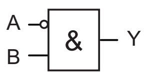
Logic Symbols	Explanation	Time Chart
	Dwell timer	
	**Straight (non latching):** Hold value until input reset signal	

Logic Gates

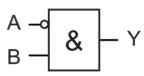
AND GATE



IN		OUT
0	1	0
0	1	0
0	1	0
1	0	0
1	1	1

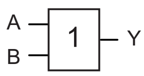


IN		OUT
A	B	Y
0	0	0
0	1	1
1	0	0
1	1	0

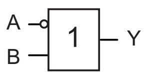


IN		OUT
A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

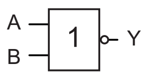
OR GATE



IN		OUT
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

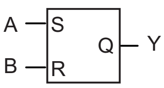


IN		OUT
A	B	Y
0	0	1
0	1	1
1	0	0
1	1	1

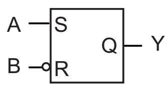


IN		OUT
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

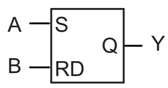
R - S FLIP-FLOP



A	B	QN	QN+	Active Mode
0	0			Hold Mode
0	1	0		Hold Mode
		1	0	Reset
1	0	0	1	Set
		1		Hold Mode
0	0	-	-	Inhibit Mode



A	B	QN	QN+	Active Mode
0	0	0		Hold Mode
		1	0	Reset
0	1			Hold Mode
1	0	-	-	Inhibit Mode
0	1	0	1	Set
		1		Hold Mode



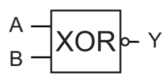
* RD = Reset Dominant

A	B	QN	QN+	Active Mode
0	0			Hold Mode
0	1			0
1	0	0	1	Set
		1		Hold Mode
1	1			0

EXCLUSIVE OR GATE

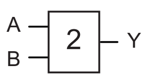
IN		OUT
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

IN		OUT
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

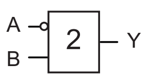


IN		OUT
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

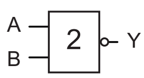
MULTI INPUT GATE



IN		OUT
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

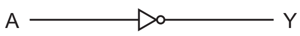


IN		OUT
A	B	Y
0	0	0
0	1	1
1	0	0
1	1	0



IN		OUT
A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

NOT GATE



Inverter (NOT)

IN	OUT
A	Y
0	1
1	0

SG

INSTALLATION

Date:	**7th August 2006**
Hardware Suffix:	**K**
Software Version:	**41 and 51**
Connection Diagrams:	**10P54302xx (xx = 01 to 02) & 10P54303xx (xx = 01 to 02)**
	10P54402xx (xx = 01 to 02) & 10P54403xx (xx = 01 to 02)
	10P54502xx (xx = 01 to 02) & 10P54503xx (xx = 01 to 02)
	10P54602xx (xx = 01 to 02) & 10P54603xx (xx = 01 to 02)

CONTENTS

FIGURES

IN

1. RECEIPT OF RELAYS

Upon receipt, relays should be examined immediately to ensure no external damage has been sustained in transit. If damage has been sustained, a claim should be made to the transport contractor and Schneider Electric should be promptly notified.

Relays that are supplied unmounted and not intended for immediate installation should be returned to their protective polythene bags and delivery carton. Section 3 of P54x/EN IN gives more information about the storage of relays.

2. HANDLING OF ELECTRONIC EQUIPMENT

Before carrying out any work on the equipment, the user should be familiar with the contents of the Safety Guide (SFTY/4L M/C11) or later issue, or the Safety and Technical Data sections of this Technical Manual and also the ratings on the equipment's rating label.

A person's normal movements can easily generate electrostatic potentials of several thousand volts. Discharge of these voltages into semiconductor devices when handling electronic circuits can cause serious damage that, although not always immediately apparent, will reduce the reliability of the circuit. The relay's electronic circuits are protected from electrostatic discharge when housed in the case. Do not expose them to risk by removing the front panel or printed circuit boards unnecessarily.

Each printed circuit board incorporates the highest practicable protection for its semiconductor devices. However, if it becomes necessary to remove a printed circuit board, the following precautions should be taken to preserve the high reliability and long life for which the relay has been designed and manufactured.

Before removing a printed circuit board, ensure that you are at the same electrostatic potential as the equipment by touching the case.

Handle analog input modules by the front panel, frame or edges of the circuit boards. Printed circuit boards should only be handled by their edges. Avoid touching the electronic components, printed circuit tracks or connectors.

Do not pass the module to another person without first ensuring you are both at the same electrostatic potential. Shaking hands achieves equipotential.

Place the module on an anti-static surface, or on a conducting surface that is at the same potential as yourself.

If it is necessary to store or transport printed circuit boards removed from the case, place them individually in electrically conducting anti-static bags.

In the unlikely event that you are making measurements on the internal electronic circuitry of a relay in service, it is preferable that you are earthed to the case with a conductive wrist strap. Wrist straps should have a resistance to ground between 500kΩ to 10MΩ. If a wrist strap is not available you should maintain regular contact with the case to prevent a build-up of electrostatic potential. Instrumentation which may be used for making measurements should also be earthed to the case whenever possible.

More information on safe working procedures for all electronic equipment can be found in BS EN 100015: Part 1:1992. It is strongly recommended that detailed investigations on electronic circuitry or modification work should be carried out in a special handling area such as described in the British Standard document.

3. STORAGE

If relays are not to be installed immediately upon receipt, they should be stored in a place free from dust and moisture in their original cartons. Where de-humidifier bags have been included in the packing they should be retained.

To prevent battery drain during transportation and storage a battery isolation strip is fitted during manufacture. With the lower access cover open, presence of the battery isolation strip can be checked by a red tab protruding from the positive polarity side.

Care should be taken on subsequent unpacking that any dust, which has collected on the carton, does not fall inside. In locations of high humidity the carton and packing may become impregnated with moisture and the de-humidifier crystals will lose their efficiency.

Prior to installation, relays should be stored at a temperature of between –25˚C to +70˚C (-13˚F to +158˚F).

4. UNPACKING

Care must be taken when unpacking and installing the relays so that none of the parts are damaged and additional components are not accidentally left in the packing or lost. Ensure that any User's CDROM or technical documentation is NOT discarded – this should accompany the relay to its destination substation.

Note: With the lower access cover open, the red tab of the battery isolation strip will be seen protruding from the positive (+) side of the battery compartment. Do not remove this strip because it prevents battery drain during transportation and storage and will be removed as part of the commissioning tests.

Relays must only be handled by skilled persons.

The site should be well lit to facilitate inspection, clean, dry and reasonably free from dust and excessive vibration.

5. RELAY MOUNTING

MiCOM relays are dispatched either individually or as part of a panel/rack assembly.

Individual relays are normally supplied with an outline diagram showing the dimensions for panel cutouts and hole centers. This information can also be found in the product publication.

Secondary front covers can also be supplied as an option item to prevent unauthorized changing of settings and alarm status. They are available in two different sizes:

60/80 TE (GN0038 001)

The design of the relay is such that the fixing holes in the mounting flanges are only accessible when the access covers are open and hidden from sight when the covers are closed.

If a P991 or MMLG test block is to be included, it is recommended that, when viewed from the front, it be positioned on the right-hand side of the relay (or relays) with which it is associated. This minimizes the wiring between the relay and test block, and allows the correct test block to be easily identified during commissioning and maintenance tests.

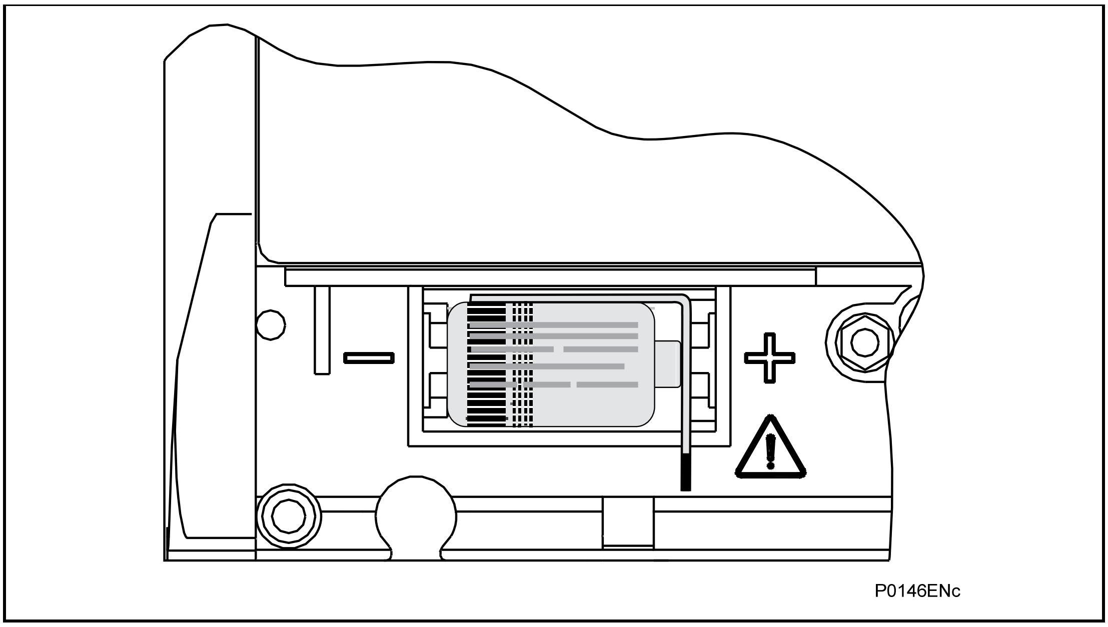


Figure 1: Location of battery isolation strip

If it is necessary to test correct relay operation during the installation, the battery isolation strip can be removed but should be replaced if commissioning of the scheme is not imminent. The red tab of the isolation strip can be seen protruding from the positive side of the battery compartment when the lower access cover is open. To remove the isolation strip, pull the red tab whilst lightly pressing the battery to prevent it falling out of the compartment. When replacing the battery isolation strip, ensure that the strip is refitted as shown in Figure 1, i.e. with the strip behind the battery with the red tab protruding.

5.1 Rack mounting

The P54x may be specifically-ordered for rack mounting. The model number must have an “N” selection as the 10th digit, example:

P54Xxxxxx**N**xxxxx

The relay case has mounting flanges factory-fitted, with dimensions in accordance with IEC60297, to fit directly into a standard 483mm (19”) rack system. The relay occupies the full width of the rack, with a tier height of 177mm (4U, equivalent to 7”).

IN

5.2 Panel mounting

The P54x may be specifically-ordered for panel mounting. The model number must have an "M" selection as the 10th digit, example:

P54Xxxxxx**M**xxxxx

The relays can be flush mounted into panels using M4 SEMS Taptite self-tapping screws with captive 3mm thick washers (also known as a SEMS unit). These fastenings are available in packs of 5 (our part number ZA0005 104).

Note: Conventional self-tapping screws, including those supplied for mounting MIDOS relays, have marginally larger heads which can damage the front cover moulding if used.

Alternatively tapped holes can be used if the panel has a minimum thickness of 2.5mm.

For applications where relays need to be semi-projection or projection mounted, a range of collars are available.

Where several relays are to mounted in a single cut-out in the panel, it is advised that they are mechanically grouped together horizontally and/or vertically to form rigid assemblies prior to mounting in the panel.

Note: It is not advised that MiCOM relays are fastened using pop rivets as this will not allow the relay to be easily removed from the panel in the future if repair is necessary.

If it is required to mount a relay assembly on a panel complying to IEC 60529 IP52 enclosure protection, it will be necessary to fit a metallic sealing strip between adjoining relays (Part no GN2044 001) and a sealing ring around the complete assembly.

Width	Single Tier	Double Tier
80TE	GJ9018 016	GJ9018 032
60TE	GJ9018 012	GJ9018 028

6. RELAY WIRING

This section serves as a guide to selecting the appropriate cable and connector type for each terminal on the MiCOM relay.

6.1 Medium and heavy duty terminal block connections

Key:

Heavy duty terminal block: CT and VT circuits, terminals with “D” prefix

Medium duty: All other terminal blocks (grey color)

Loose relays are supplied with sufficient M4 screws for making connections to the rear mounted terminal blocks using ring terminals, with a recommended maximum of two ring terminals per relay terminal.

If required, Schneider Electric can supply M4 90° crimp ring terminals in three different sizes depending on wire size (see table below). Each type is available in bags of 100.

Part Number	Wire Size	Insulation Color
ZB9124 901	0.25 - 1.65mm^2 (22 - 16AWG)	Red
ZB9124 900	1.04 - 2.63mm^2 (16 - 14AWG)	Blue
ZB9124 904	2.53 - 6.64mm^2 (12 - 10AWG)	Un-insulated*

*To maintain the terminal block insulation requirements for safety, an insulating sleeve should be fitted over the ring terminal after crimping.

The following minimum wire sizes are recommended:

Current Transformers 2.5mm^2

Auxiliary Supply, Vx 1.5mm^2

EIA(RS)485 Port See separate section

Other Circuits 1.0mm^2

Due to the limitations of the ring terminal, the maximum wire size that can be used for any of the medium or heavy duty terminals is 6.0mm^2 using ring terminals that are not pre-insulated. Where it required to only use pre-insulated ring terminals, the maximum wire size that can be used is reduced to 2.63mm^2 per ring terminal. If a larger wire size is required, two wires should be used in parallel, each terminated in a separate ring terminal at the relay.

The wire used for all connections to the medium and heavy duty terminal blocks, except the EIA(RS)485 port, should have a minimum voltage rating of 300Vrms.

It is recommended that the auxiliary supply wiring should be protected by a 16A high rupture capacity (HRC) fuse of type NIT or TIA. For safety reasons, current transformer circuits must never be fused. Other circuits should be appropriately fused to protect the wire used.

6.2 EIA(RS)485 port

Connections to the EIA(RS)485 port are made using ring terminals. It is recommended that a 2 core screened cable is used with a maximum total length of 1000m or 200nF total cable capacitance. A typical cable specification would be:

Each core: 16/0.2mm copper conductors

PVC insulated

Nominal conductor area: 0.5mm^2 per core

Screen: Overall braid, PVC sheathed

6.3 IRIG-B connections (if applicable)

The IRIG-B input and BNC connector have a characteristic impedance of 50Ω. It is recommended that connections between the IRIG-B equipment and the relay are made using coaxial cable of type RG59LSF with a halogen free, fire retardant sheath.

6.4 EIA(RS)232 front port

Short term connections to the EIA(RS)485 port, located behind the bottom access cover, can be made using a screened multi-core communication cable up to 15m long, or a total capacitance of 2500pF. The cable should be terminated at the relay end with a 9-way, metal shelled, D-type male plug. The pin allocations are detailed in section 1.8 of Getting Started (P54x/EN GS).

6.5 Ethernet port for IEC 61850 (if applicable)

Fiber Optic Port

The relays can have 100 Mbps Ethernet port. FO connection is recommended for use in permanent connections in a substation environment. The 100Mbit port uses type ST connector, compatible with fiber multimode 50/125µm or 62.5/125µm - 13000nm.

RJ-45 Metallic Port

The user can connect to either a 10Base-T or a 100Base-TX Ethernet hub; the port will automatically sense which type of hub is connected. Due to possibility of noise and interference on this part, it is recommended that this connection type be used for short-term connections and over short distance. Ideally where the relays and hubs are located in the same cubicle.

The connector for the Ethernet port is a shielded RJ-45. The table shows the signals and pins on the connector.

Pin	Signal Name	Signal Definition
1	TXP	Transmit (positive)
2	TXN	Transmit (negative)
3	RXP	Receive (positive)
4	-	Not used
5	-	Not used
6	RXN	Receive (negative)
7	-	Not used
8	-	Not used

Table 4: Signals on the Ethernet connector

6.6 Download/monitor port

Short term connections to the download/monitor port, located behind the bottom access cover, can be made using a screened 25-core communication cable up to 4m long. The cable should be terminated at the relay end with a 25-way, metal shelled, D-type male plug.

6.7 Earth connection

Every relay must be connected to the cubicle earth bar using the M4 earth studs in the bottom left hand corner of the relay case. The minimum recommended wire size is $2.5mm^2$ and should have a ring terminal at the relay end.

To prevent any possibility of electrolytic action between brass or copper earth conductors and the rear of the relay, precautions should be taken. Examples include placing a nickel-plated washer between the conductor and the relay case, or using tinned ring terminals.

7. P54x CASE DIMENSIONS

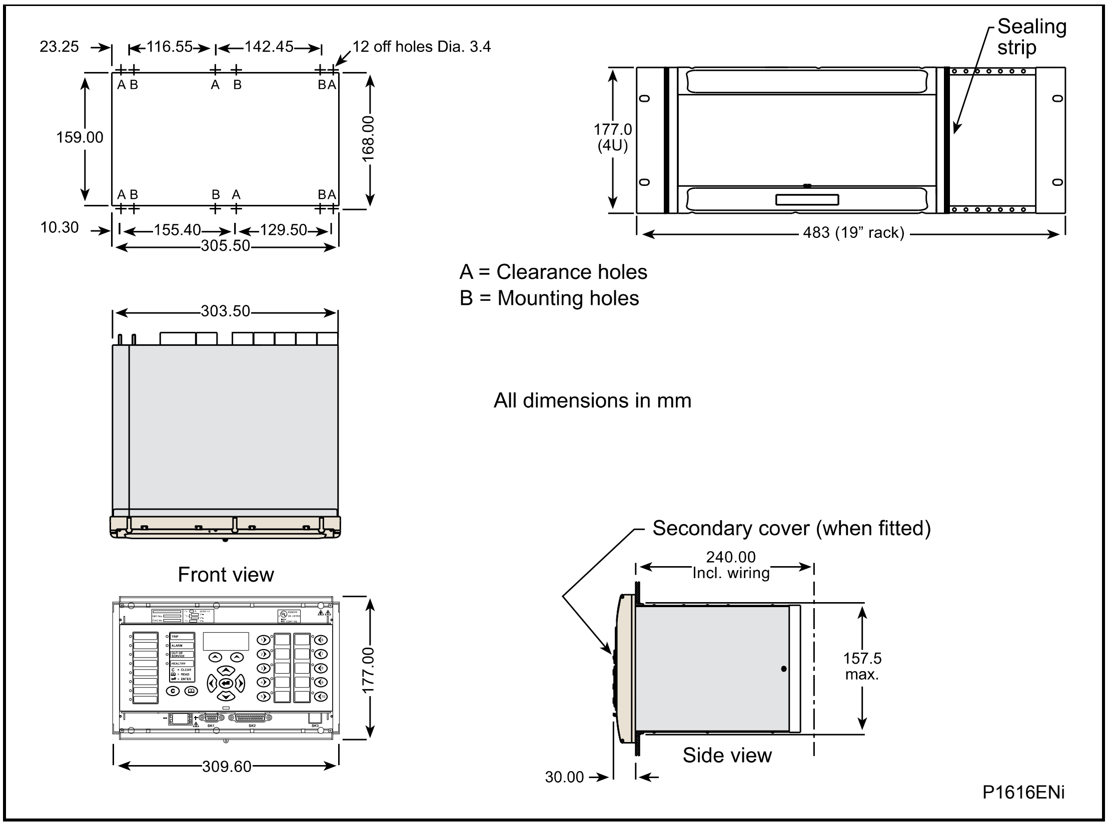


Figure 2: P543 and P544 models case dimensions - 60TE case

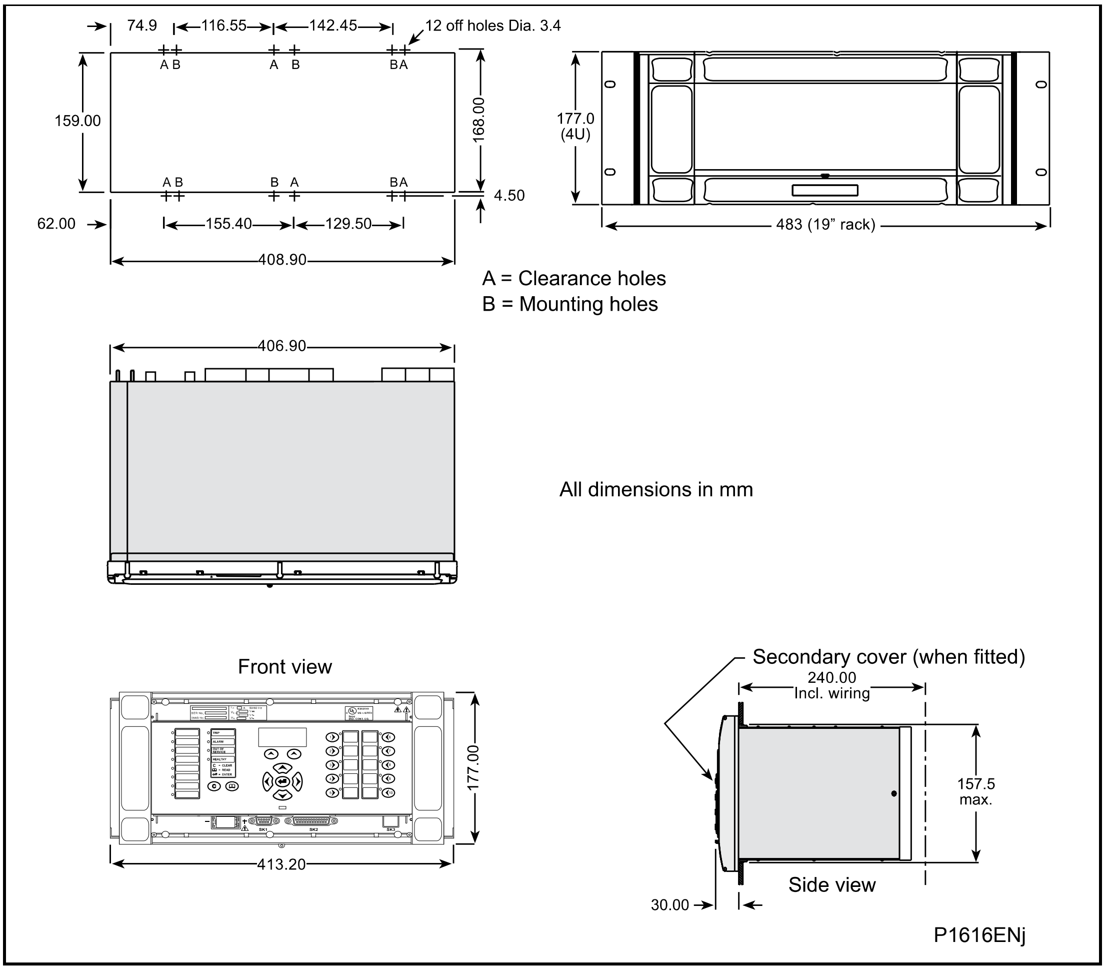


Figure 3: P545 and P546 models case dimensions - 80TE case

8. P54x 2ND REAR COMMUNICATION BOARD CONNECTION DIAGRAM

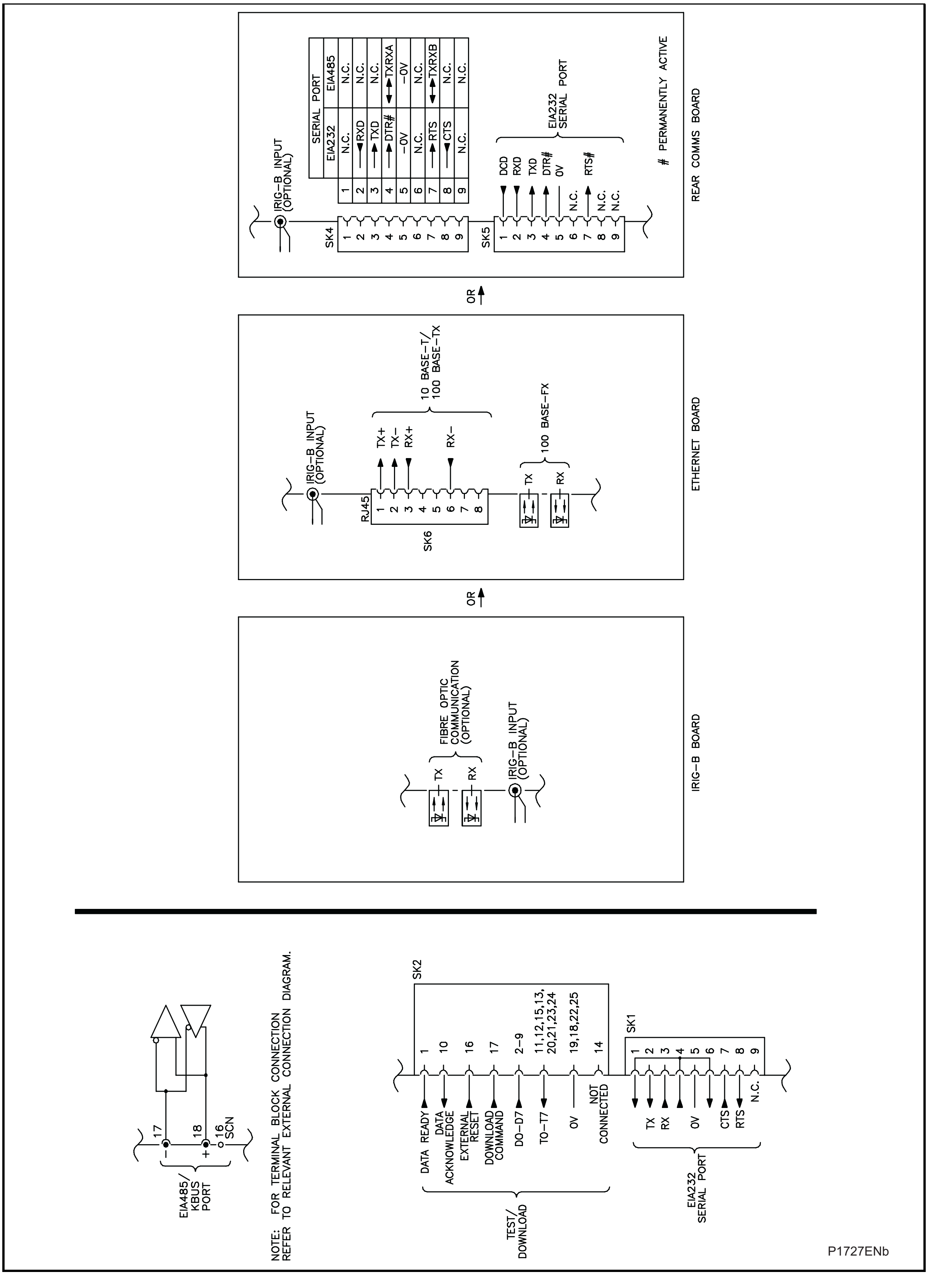


Figure 4: P54x second rear port connection

P54x EXTERNAL CONNECTION DIAGRAMS

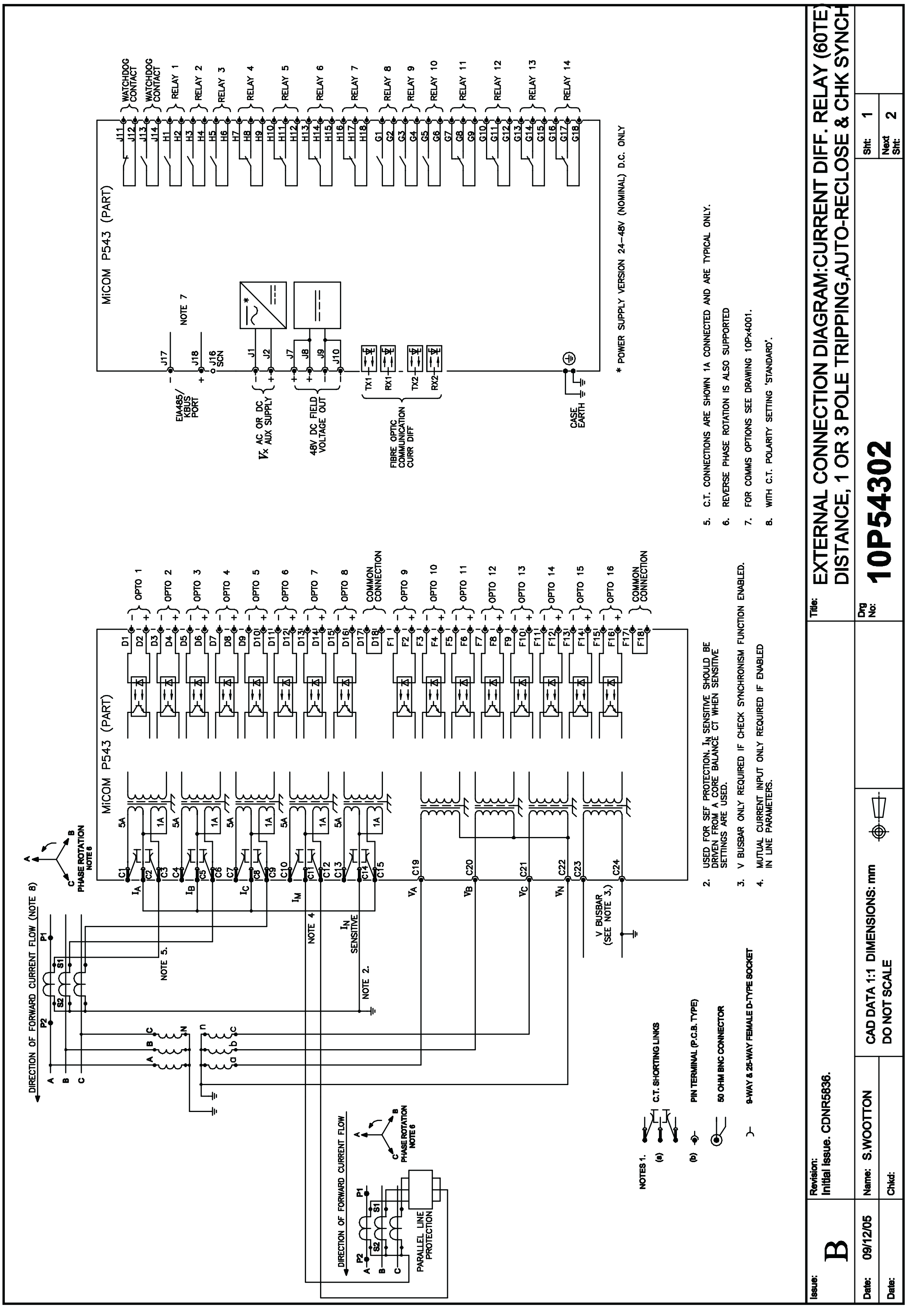


Figure 5: P543 external connection diagram - standard relay outputs

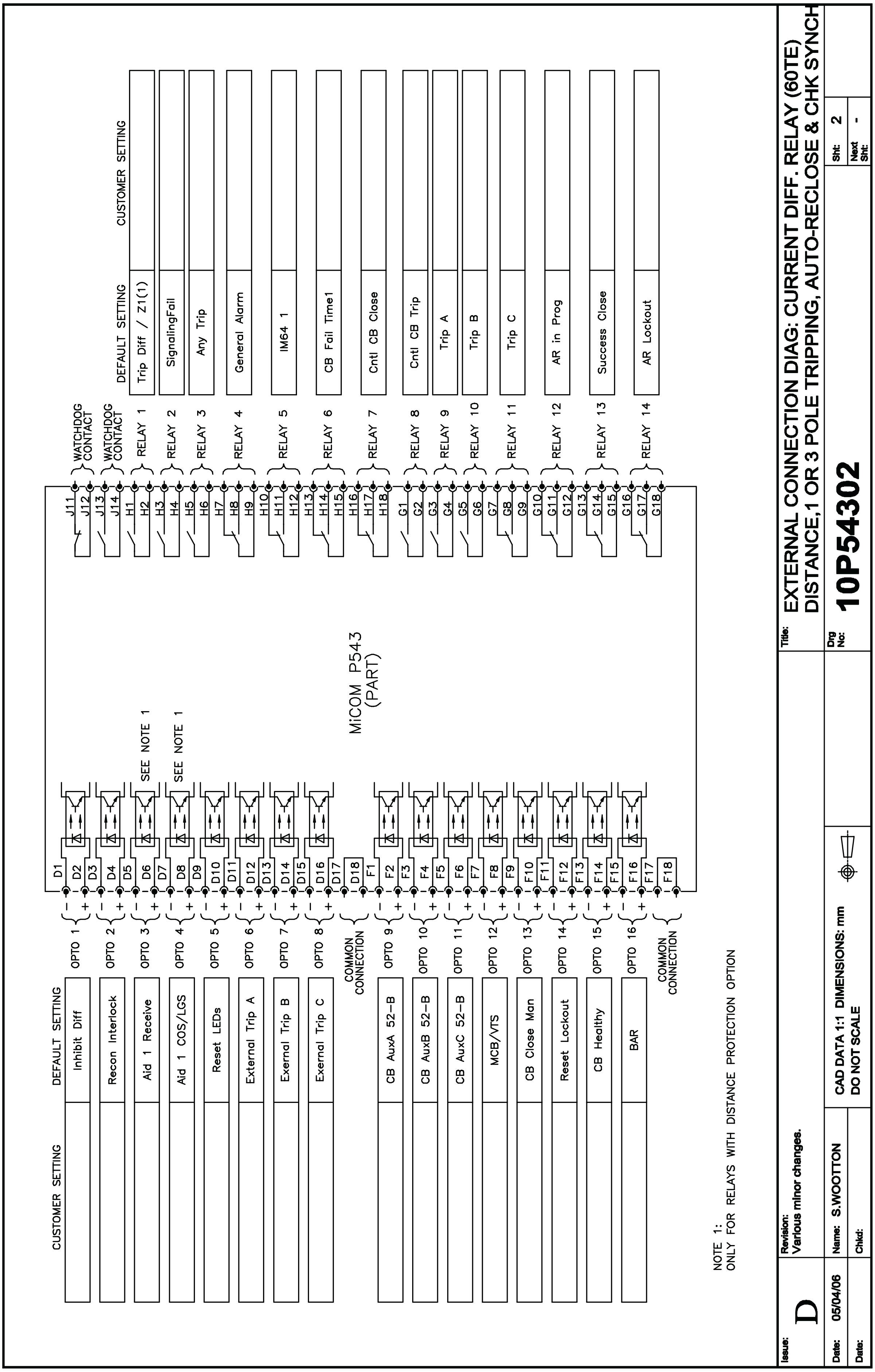


Figure 6: **P543 external connection diagram - inputs/outputs default mapping - standard relay outputs**

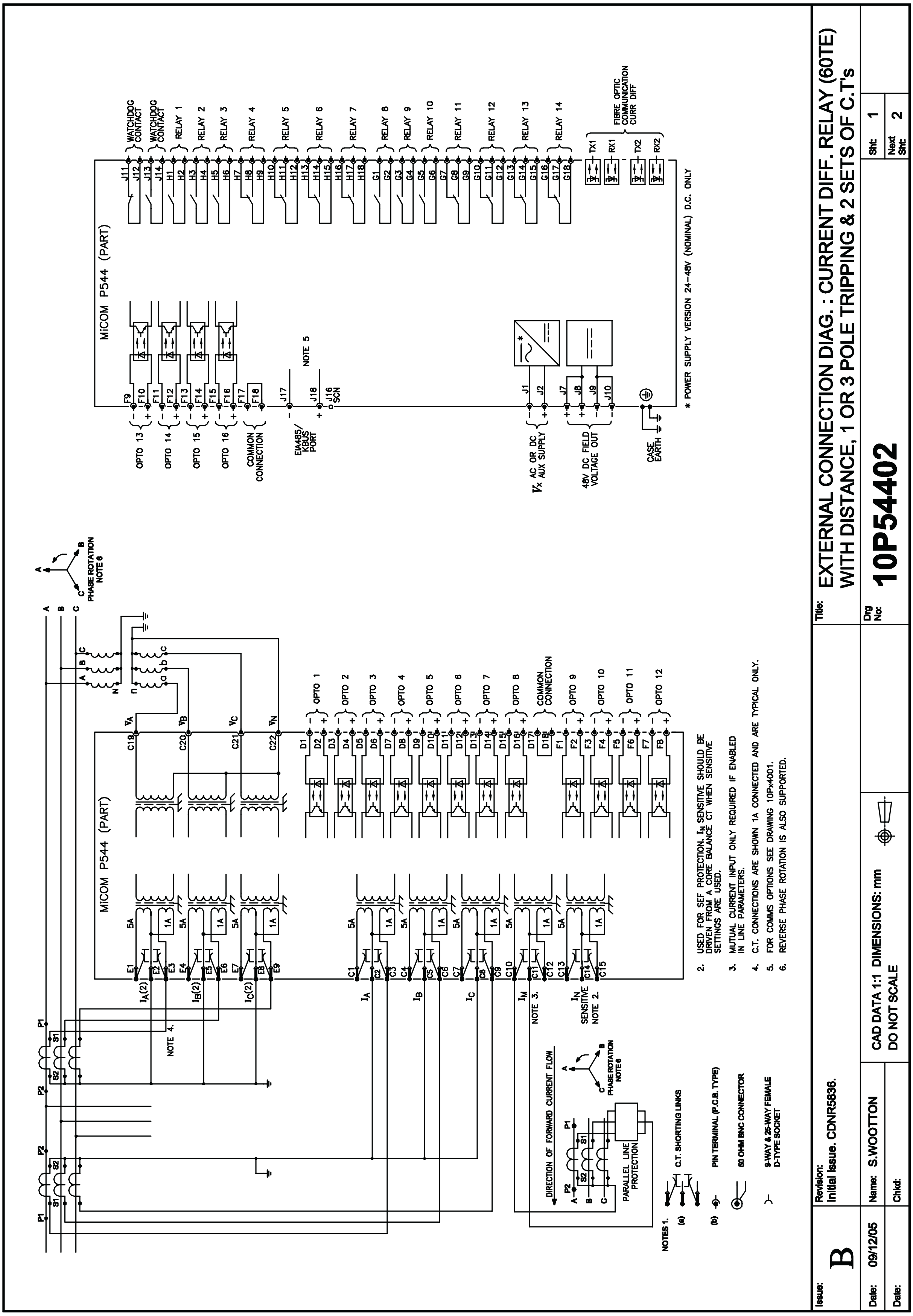


Figure 7: P544 external connection diagram - standard relay outputs

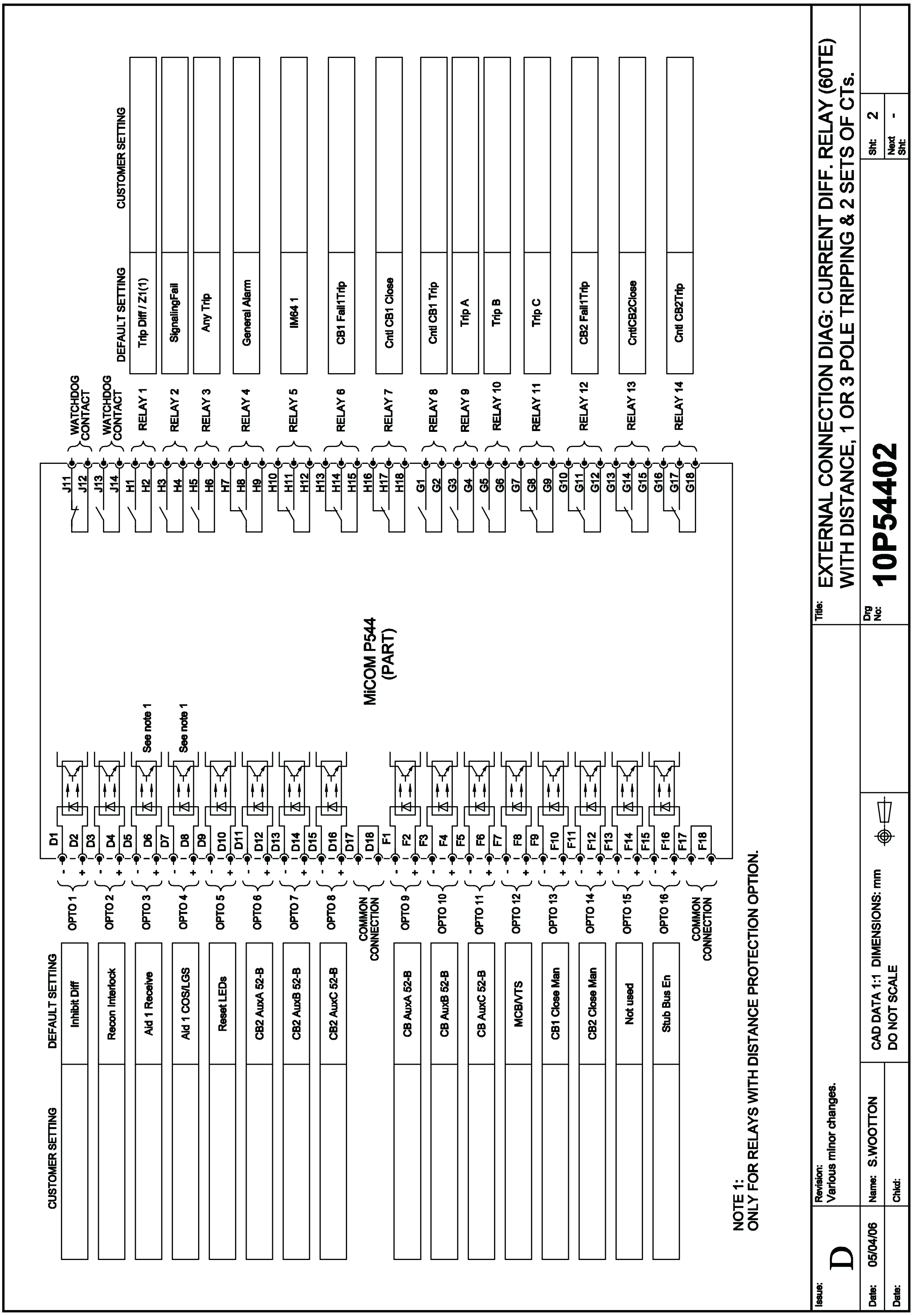


Figure 8: P544 external connection diagram - inputs/outputs default mapping - standard relay outputs

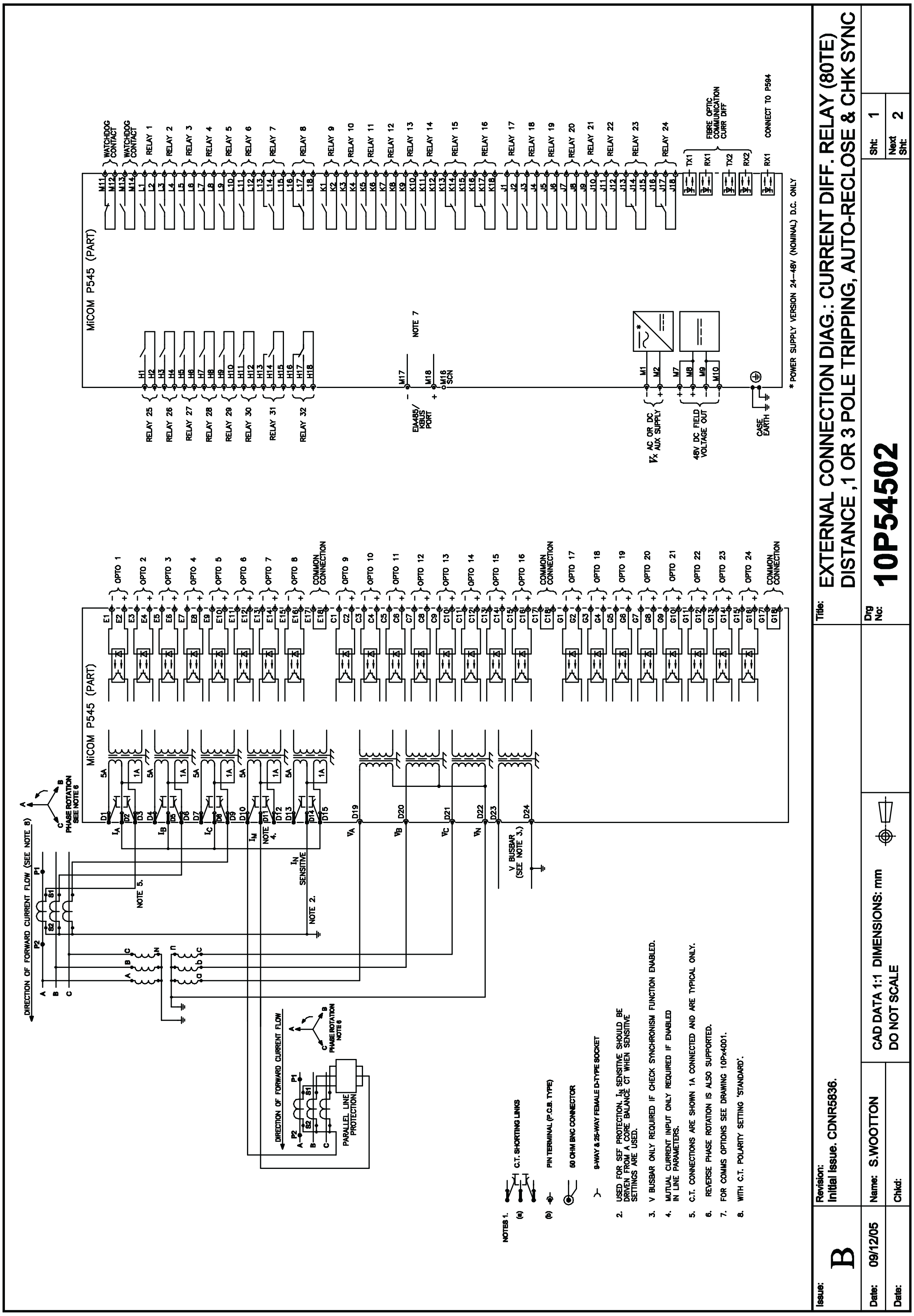


Figure 9: P545 external connection diagram - standard relay outputs

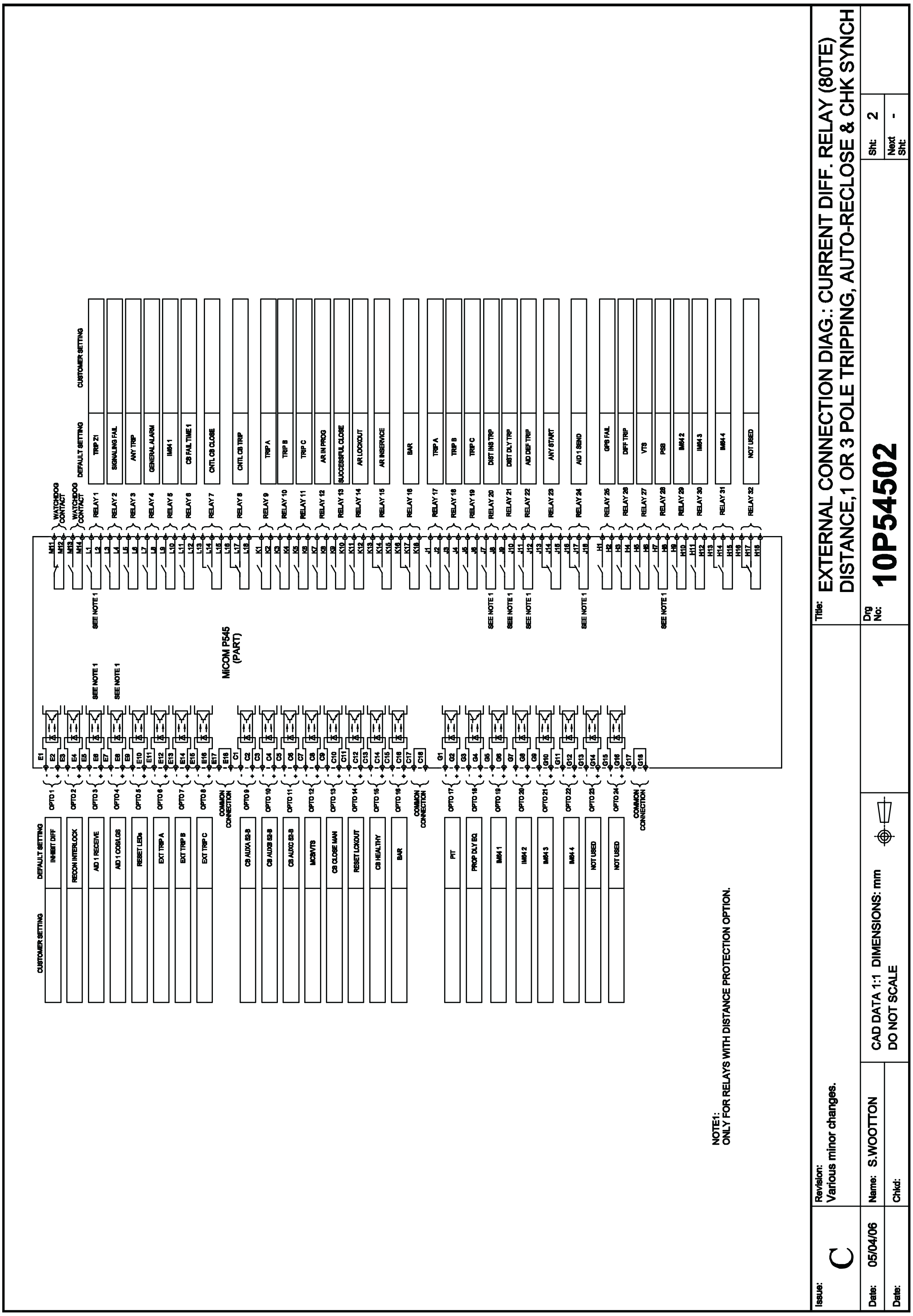


Figure 10: P545 external connection diagram - inputs/outputs default mapping - standard relay outputs

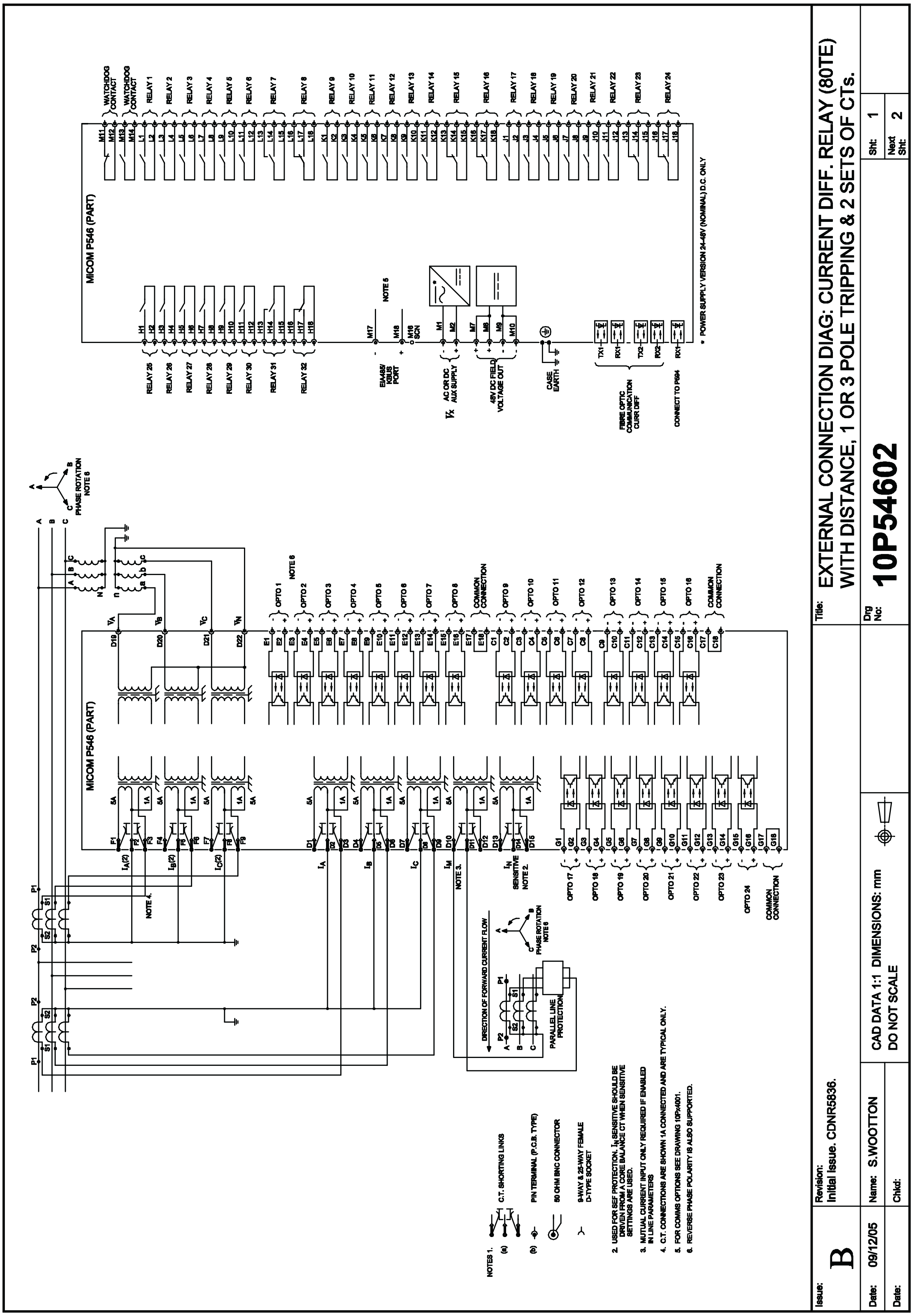


Figure 11: P546 external connection diagram - standard relay outputs

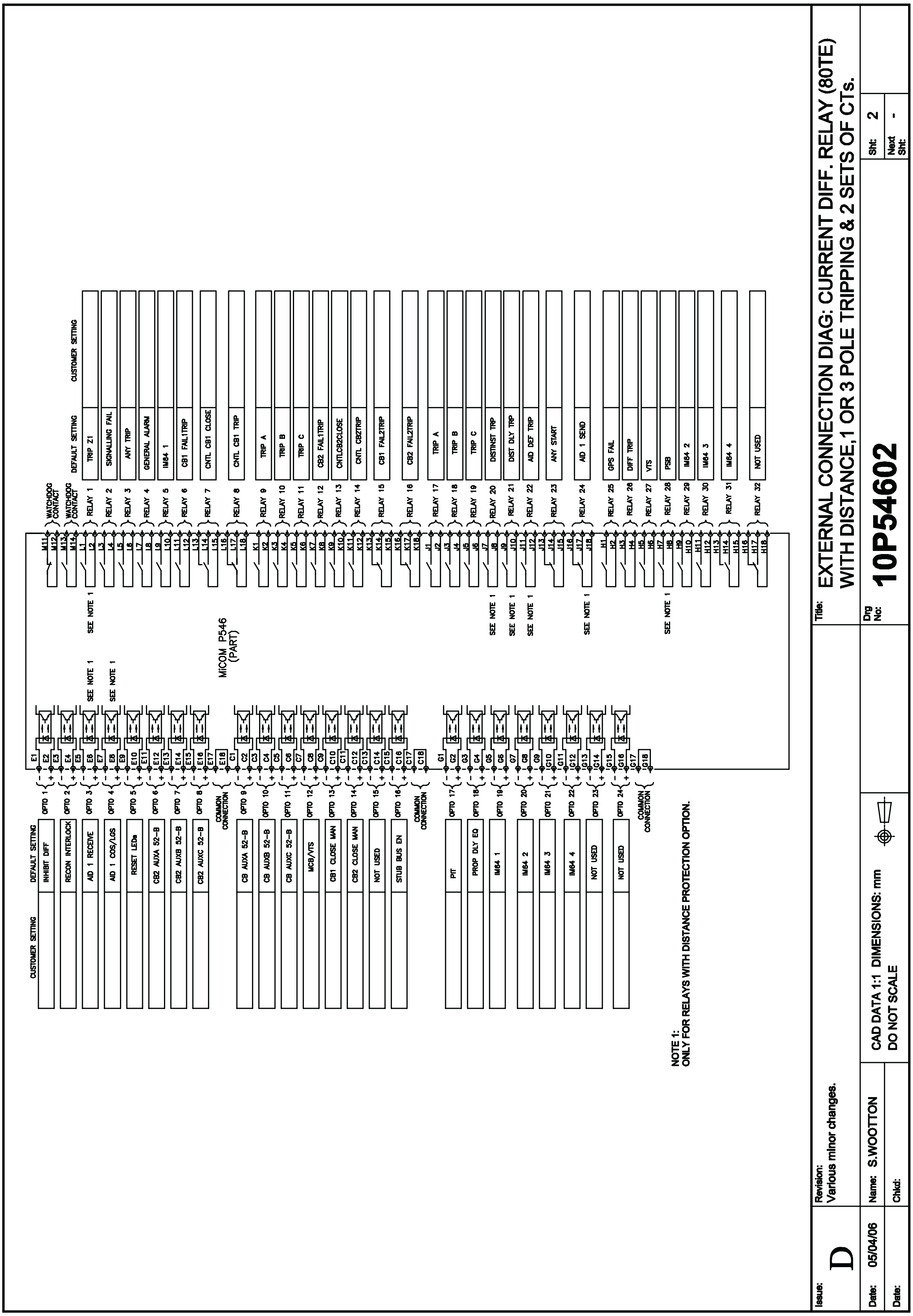


Figure 12: P546 external connection diagram - inputs/outputs default mapping - standard relay outputs

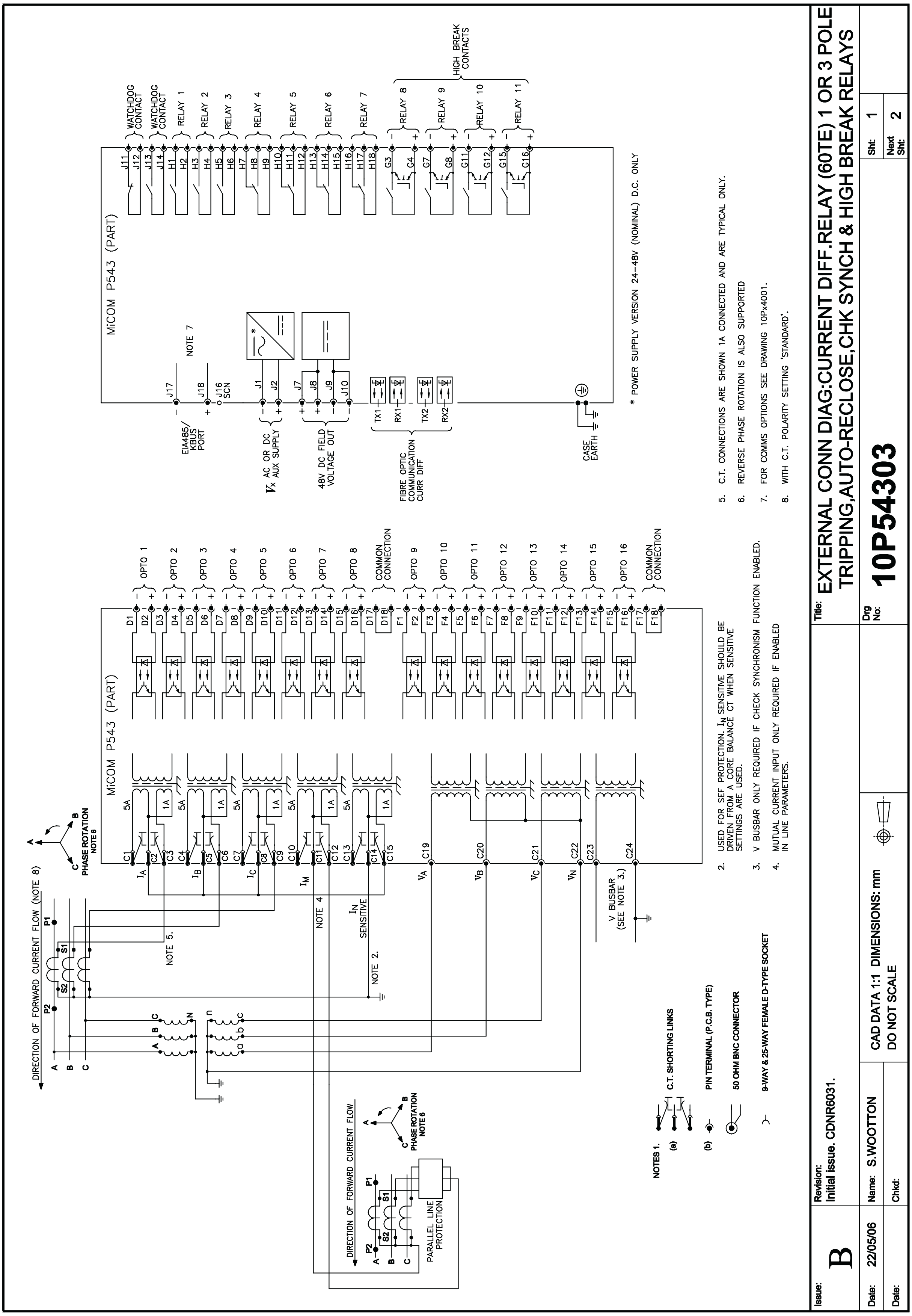


Figure 13: P543 external connection diagram - high break relay outputs

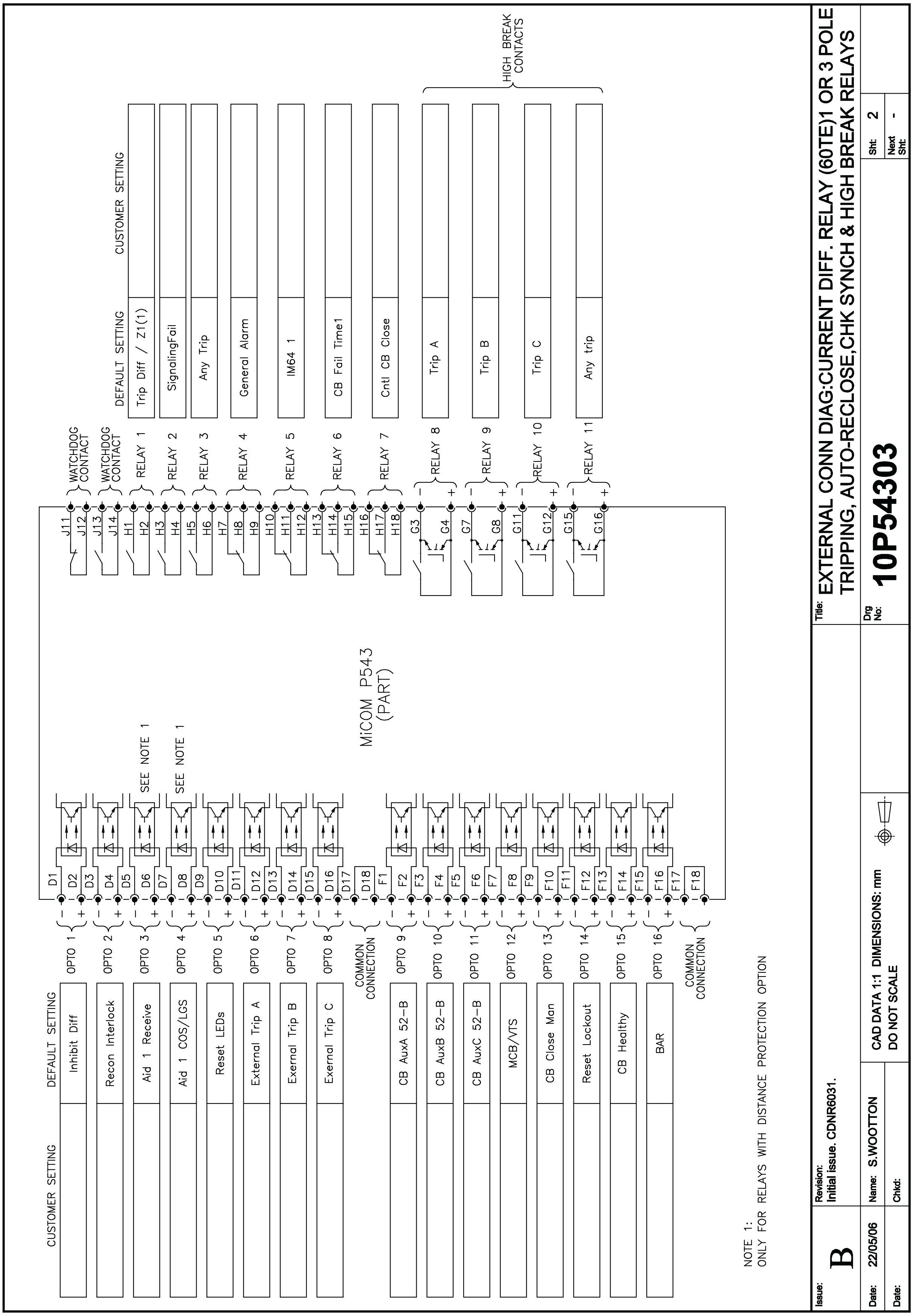


Figure 14: P543 external connection diagram - inputs/outputs default mapping - high break relay outputs

IN

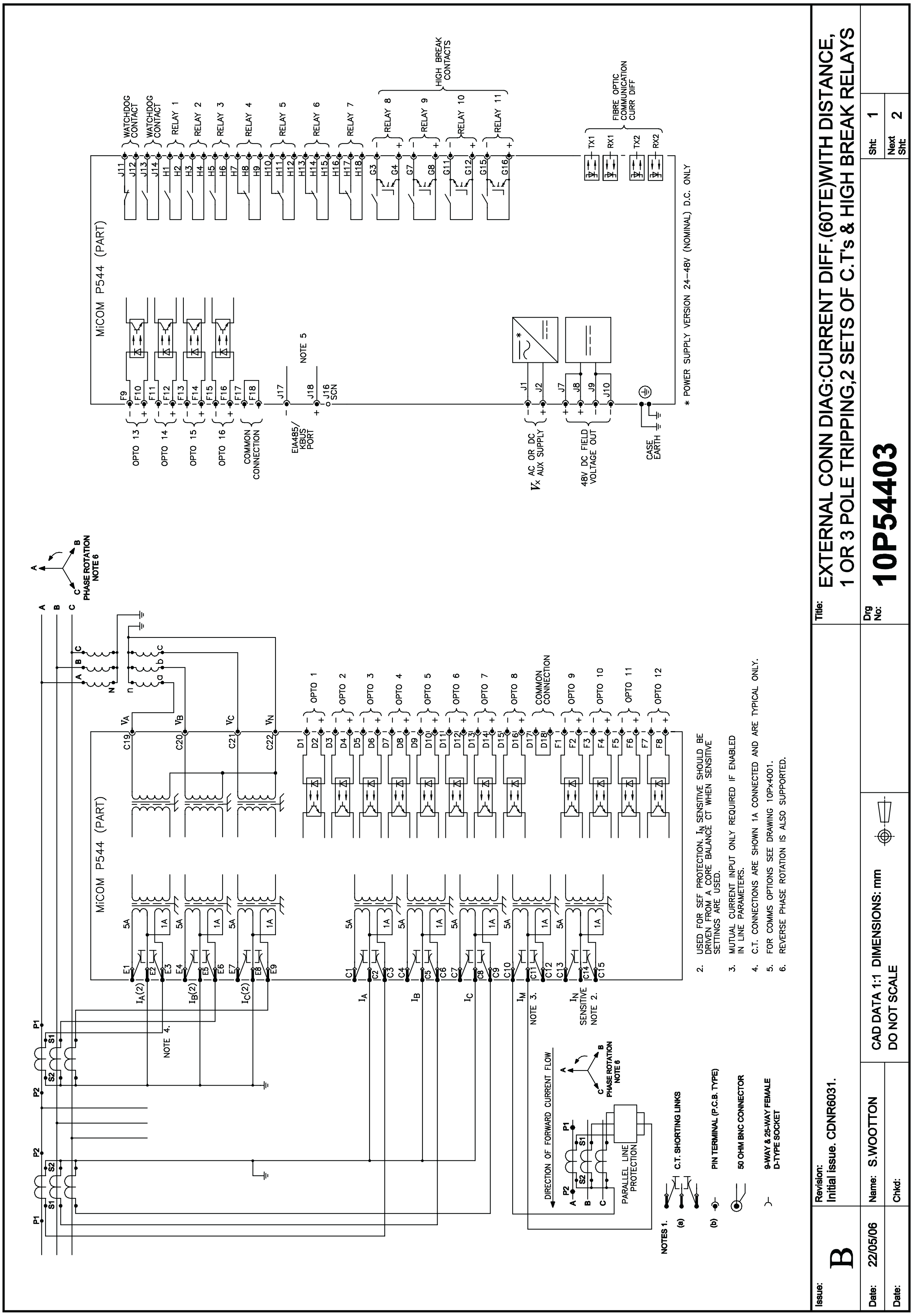


Figure 15: P544 external connection diagram - high break relay outputs

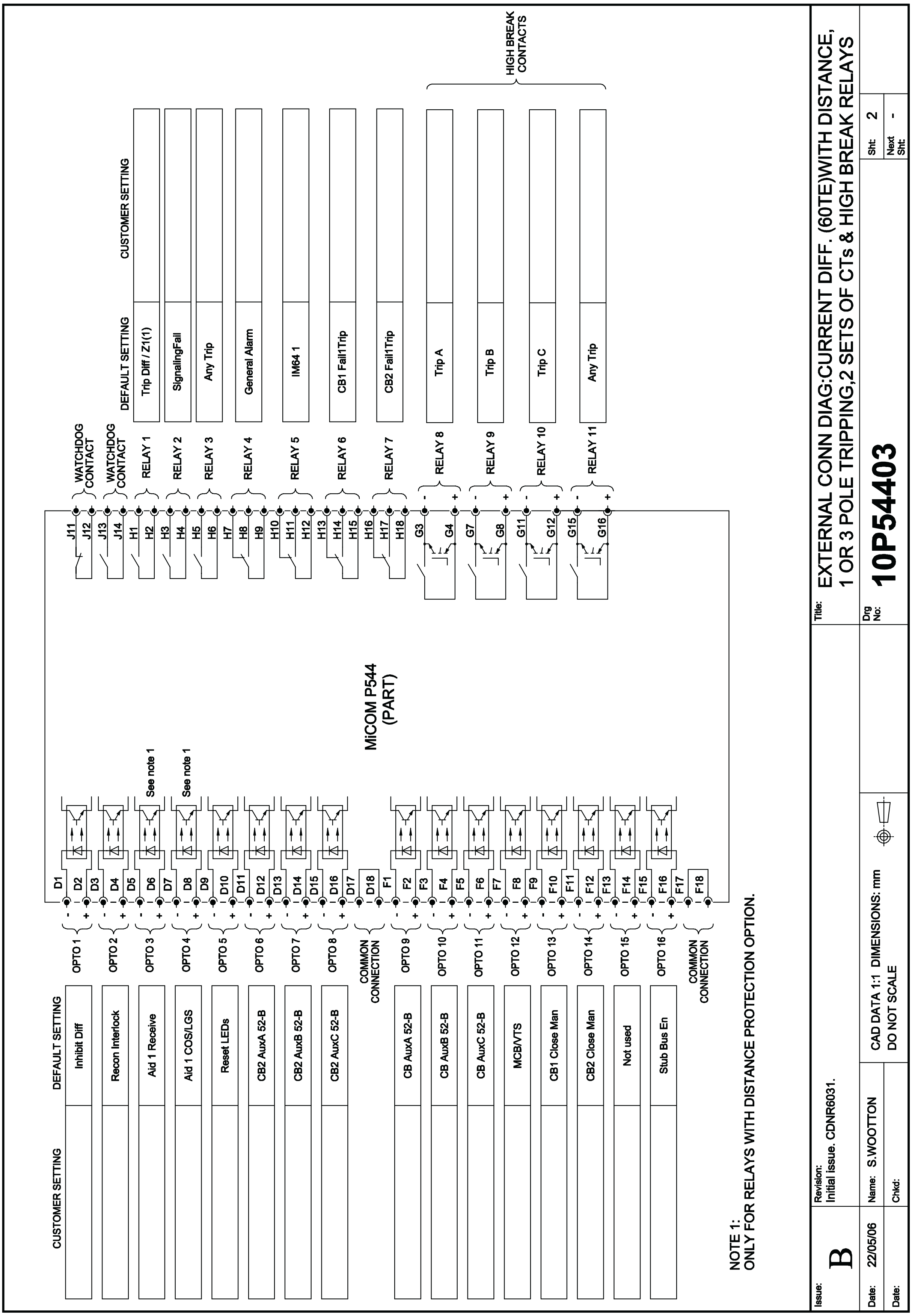


Figure 16: **P544 external connection diagram - inputs/outputs default mapping - high break relay outputs**

IN

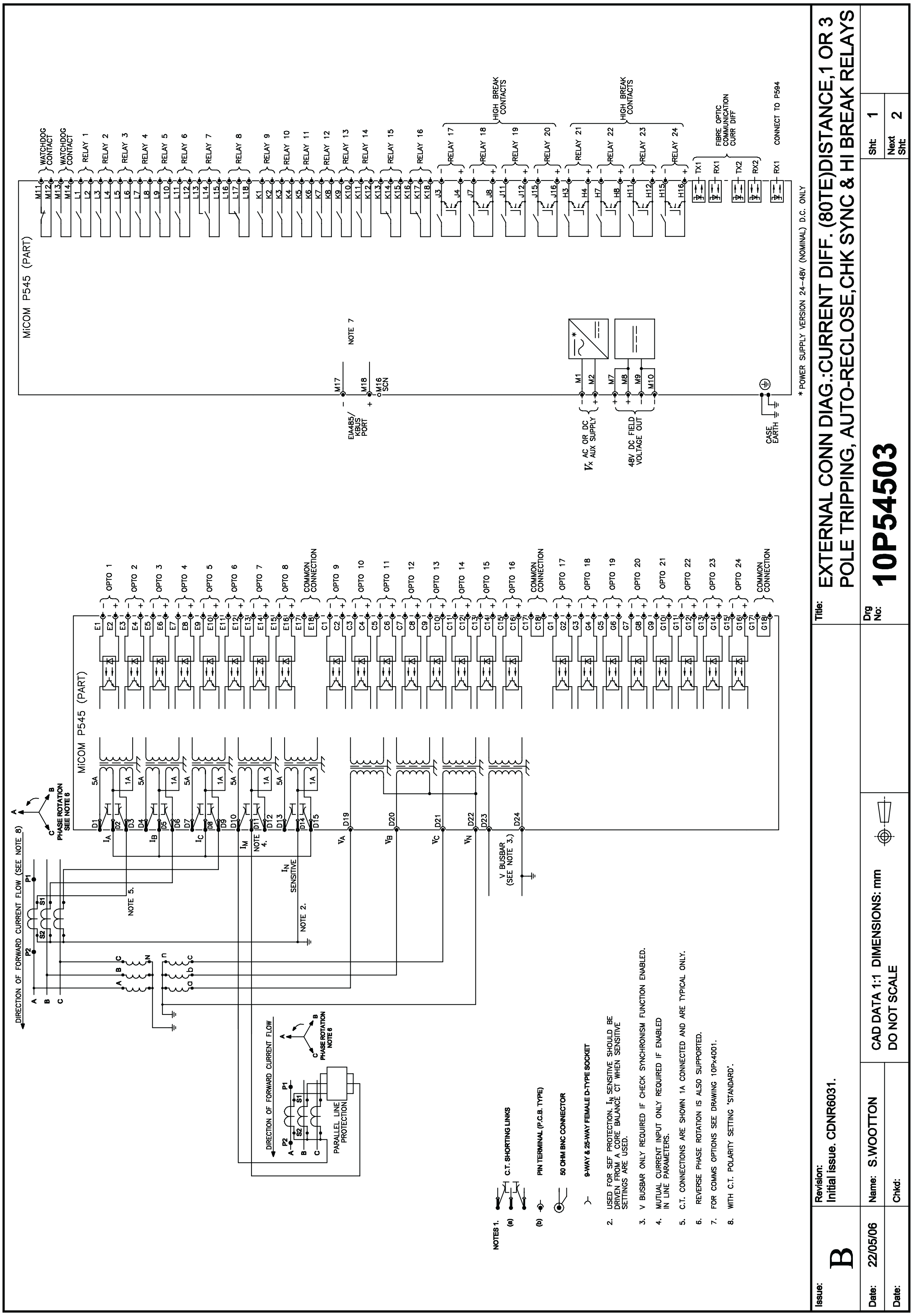


Figure 17: P545 external connection diagram - high break relay outputs

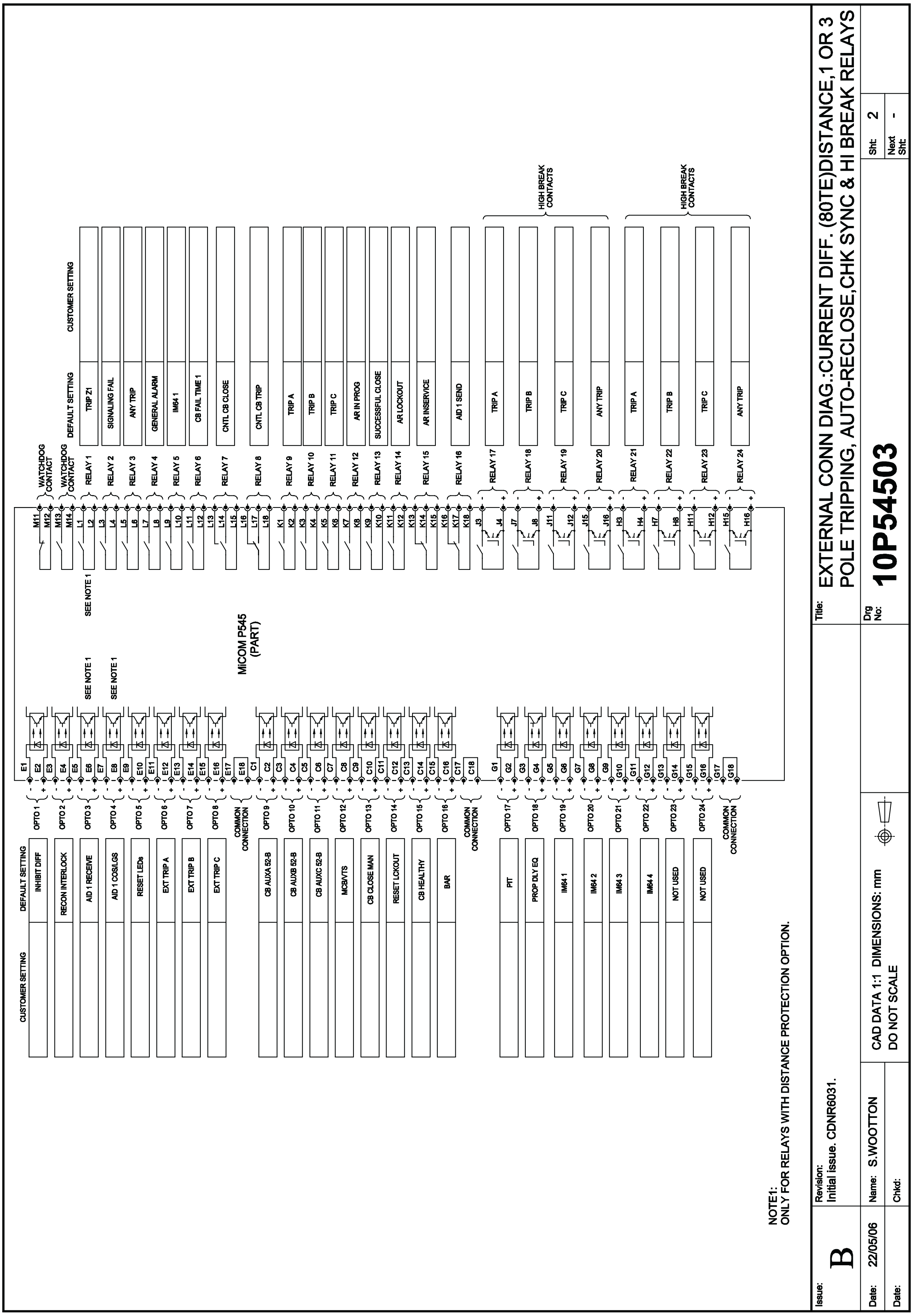


Figure 18: **P545 external connection diagram - inputs/outputs default mapping - high break relay outputs**

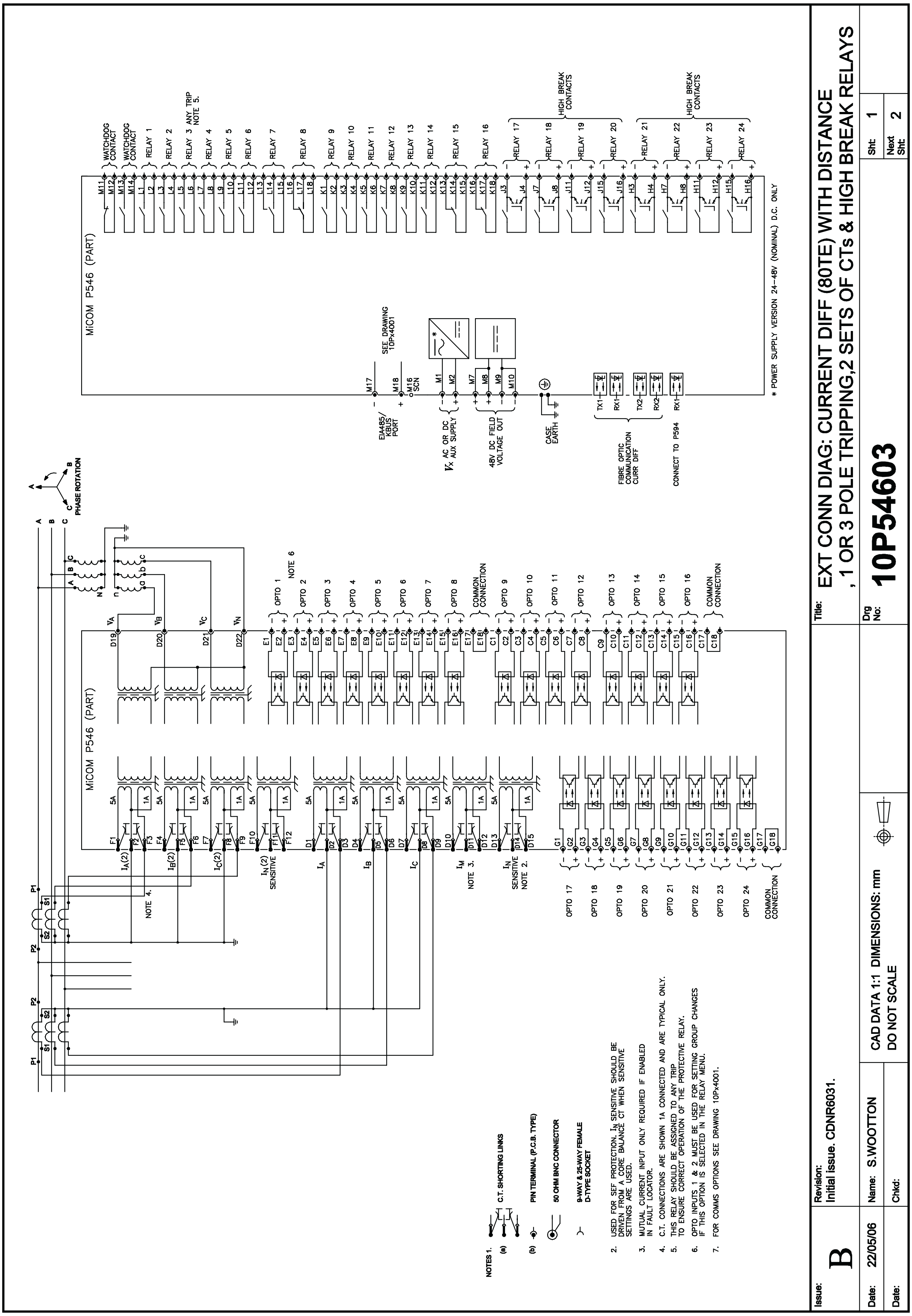


Figure 19: P546 external connection diagram - high break relay outputs

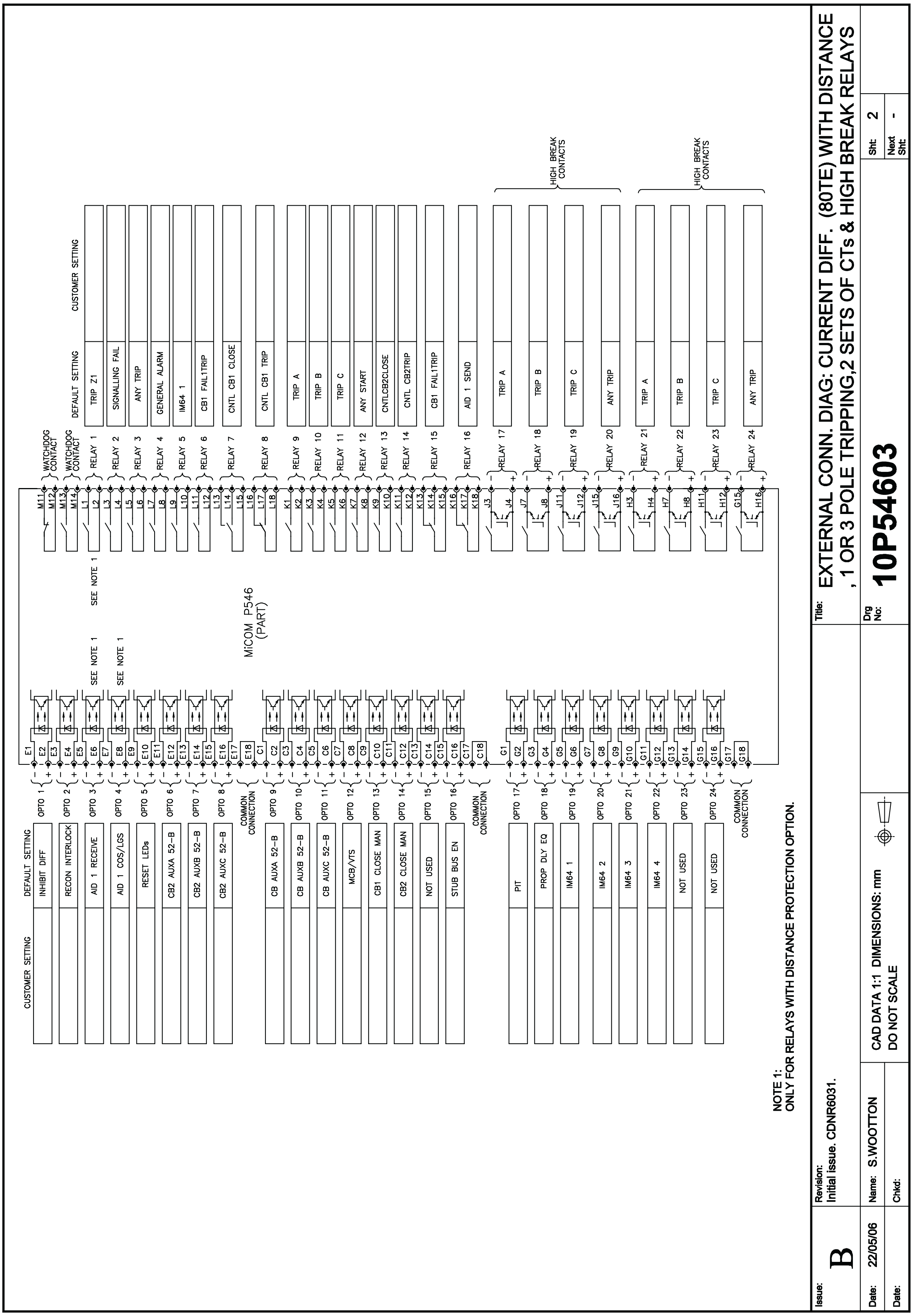


Figure 20: P546 external connection diagram - inputs/outputs default mapping - high break relay outputs

FIRMWARE AND SERVICE MANUAL VERSION HISTORY

Date:	**7th August 2006**
Hardware Suffix:	**K**
Software Version:	**41 and 51**
Connection Diagrams:	**10P54302xx (xx = 01 to 02) & 10P54303xx (xx = 01 to 02)**
	10P54402xx (xx = 01 to 02) & 10P54403xx (xx = 01 to 02)
	10P54502xx (xx = 01 to 02) & 10P54503xx (xx = 01 to 02)
	10P54602xx (xx = 01 to 02) & 10P54603xx (xx = 01 to 02)

Relay type: P54x …						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
01	A	A	Feb 2000	First release to production	V1.07 or Later	TG8613A
02	A	A	Mar 2000	✓ PSB. Three settings added to set zone 6 to increase flexibility ✓ Protection address. Universal address added ✓ SEF & EF. Polarizing voltage setting range increased ✓ Thermal. Setting range increased ✓ Trip conversion logic. 3 DDB signals added to simplify logic for users ✓ Distance. Min polarizing voltage increased to prevent tripping for close up three phase faults ✓ Check sync. angle measurement improved ✓ PSB. Text for power swing indication improved ✓ Include pole discrepancy logic to P543 ✓ Susceptance setting corrected	V1.08 or Later	TG8613B
03	A	A	May 2000	✓ German text changed ✓ Spanish text changed ✓ Changes to DDB names & properties ✓ Improvements in auto-reclose and reset from lockout code ✓ Changes to pole dead & trip conversion logic ✓ Changes to P544 circuit breaker fail logic ✓ Added DDB for CS103 test mode × Recommend upgrading to 03B software or later	V1.09 or Later	TG8613B

Relay type: P54x …

Software Version Major	Software Version Minor	Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
03 Cont.	B	A	Feb 2002	All builds released for maintenance upgrades ✓ Resolved possible reboot caused by disturbance recorder ✓ Resolved possible reboot caused by invalid MODBUS requests ✓ Resolved a loss of measurements (column 3 & 4) problem that can occur in 3 terminal applications ✓ Problem whereby MiCOM S1 could only set group 1 line length corrected ✓ Fixed capacitive charging current compensation in P544 ✓ Corrected P544 display of phase C current phase angle ✓ IDMT curves improvements ✓ Removed rounding error in calculation of tp ✓ Menu dependence using ripple bit corrected ✓ Directional/non-direction earth fault fixed ✓ Battery fail alarm improvements ✓ Power measurements read over MODBUS may be incorrect ✓ Resolved problem caused by rapid changing self resetting alarm resetting the relay when read key pressed ✓ Prevented software errors from clearing event log	V1.09 or Later	TG8613B
04	A	A	Aug 2000	✓ Trip conversion logic moved from internal fixed logic to PSL	V1.10 or Later	TG8613B
	B	A	Mar 2001	Only P543 CS103 builds released ✓ Improvements to the CS103 time synchronization	V1.10 or Later	TG8613B

Relay type: P54x …

Software Version: Major	Software Version: Minor	Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
04 Cont.	C	A	Jun 2001	Only P543 CS103 builds released. Based on 04B ✓ Resolved a loss of measurements (columns 3 & 4) problem that can occur in 3 terminal applications	V1.10 or Later	TG8613B
	D	A	Jun 2001	Only P543 CS103 build released. Based on 04C ✓ Prevents a reboot on power-up when battery is removed	V1.10 or Later	TG8613B
05	A	A	Sep 2000	Internal release for validation only ✓ Includes DNP3.0 ✓ Courier bay module compatibility modification ✓ MODBUS bay module compatibility modification ✓ Distance - Z3 selectable forward/reverse ✓ Spanish text corrected ✓ Menu dependence using ripple bit corrected ✓ MODBUS problem reading negative values of fault location corrected ✓ RDF file modified ✓ Directional/non-direction earth fault fixed ✓ Battery fail alarm corrected ✓ Very low fault location could be shown incorrectly as negative × Some MODBUS address changed	V2.0 or Later	TG8613B

Relay type: P54x …						
Software Version		**Hardware Suffix**	**Original Date of Issue**	**Description of Changes**	**S1 Compatibility**	**Technical Documentation**
Major	Minor					
05 Cont.	B	A	Oct 2000	Released to production ✓ Includes all of 05A changes ✓ Requirement to use relays 8, 9 & 10 for Trip A, B & C removed ✓ MODBUS communication problem when used with P140 fixed ✓ Power measurements read over MODBUS may be incorrect ✓ MODBUS status register reports disturbance records incorrectly following power cycle	V2.0 or Later	TG8613B
	C	A	Mar 2001	Only P543 & P544 builds released for customer tests ✓ PSB now works with single pole open	V2.0 or Later	TG8613B
	D	A	May 2001	Only P543 & P544 builds released for customer tests ✓ Distance directional line fixed at -30º ✓ PSB block issued when impedance passes into any Z1, Z2 or Z3 ✓ PSB unblock via negative sequence current now done via PSL	New PSL will be required	-
	E	A	Jun 2001	All builds released to production. Based on 05B software ✓ Resolved a loss of measurements (column 3 & 4) problem that can occur in 3 terminal applications × Recommended upgrading to 05K or later	V2.0 or Later	TG8613B

Relay type: P54x …						
Software Version		**Hardware Suffix**	**Original Date of Issue**	**Description of Changes**	**S1 Compatibility**	**Technical Documentation**
Major	Minor					
05 Cont.	F	A	Sep 2001	All builds released to production. Based on 05E software ✓ Problem whereby MiCOM S1 could only set group 1 line length corrected ✓ Fixed capacitive charging current compensation in P544 ✓ Corrected P544 display of phase C current phase angle ✓ IDMT curves improvements ✓ Removed rounding error in calculation of tp ✓ Fixed problems caused by changes to DNP3.0 address × Recommended upgrading to 05K or later	V2.0 or Later	TG8613B
	G	A	Jan 2002	All builds except MODBUS released to production. Based on 05F software ✓ Resolved possible reboot caused by disturbance recorder × Problem in MODBUS build which can cause a reboot × Recommended upgrading to 05K or later	V2.0 or Later	TG8613B
	H	A	Jan 2002	All builds released to production. Based on 05G software ✓ Resolved possible reboot caused by invalid MODBUS requests × Recommended upgrading to 05K or later	V2.0 or Later	TG8613B
	I	A	Oct 2002	Limited release - not released to production. Based on 05H software ✓ Correct the format used to display frequency over the MODBUS interface × Recommended upgrading to 05K or later	V2.0 or Later	TG8613B

Relay type: P54x …						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
05 Cont.	J	A	Nov 2002	All builds released to production. Based on 05I software ✓ Resolved incorrect operation of C diff failure alarm in 3 terminal schemes ✓ Correct operation of capacitive charging current compensation in 3 terminal schemes ✓ Resolved problem which caused short duration current differential trips in some applications × Recommended upgrading to 05K or later	V2.0 or Later	TG8613B
	K	A	Feb 2003	All builds released to production. Based on 05I software ✓ Resolved problem with IEC 60870-5-103 time synchronization	V2.0 or Later	TG8613B
	L	A	Jan 2004	Maintenance release based on 05K (not formally released) ✓ Prevents compressed disturbance recorder stalling ✓ Prevent a maintenance record when reading from an inaccessible MODBUS register	V2.0 or Later	TG8613B
	M	A	Jun 2004	Maintenance release based on 05L ✓ Improved self-checking of analogue data acquisition ✓ Improved self checking of SRAM ✓ Reception of MODBUS frame improved ✓ Rejection of spurious messages injected onto RS485 network improved ✓ Permissive intertrip in dual redundant schemes corrected	V2.0 or Later	TG8613B
	N	A	Jun 2005	Maintenance release based on 05M ✓ Changed MODBUS driver	V2.0 or Later	TG8613B

Relay type: P54x …						
Software Version		**Hardware Suffix**	**Original Date of Issue**	**Description of Changes**	**S1 Compatibility**	**Technical Documentation**
Major	Minor					
06	A	A	May 2001	Internal Release for validation only - runs on phase 1 hardware with an old co-processor board ✓ In non GPS mode the char modification timer has been made visible in P545/6 ✓ The char modification timer setting was not being seen by the co-processor board ✓ GPS detected flag was not cleared when switching from GPS to non GPS mode ✓ Equal prop delay command was not resetting inhibit following a comms. switch ✓ Problem displaying Rx & Tx when comms. path was short fixed ✓ Note: Non of the above are relevant to software in production	-	-
	B	A	Jun 2001	Internal release for validation only - runs on phase 1 hardware with an old co-processor board ✓ Prevent loss of measurements in 3 ended schemes ✓ Added a 1s drop off timer to C diff inhibit ✓ Changed max value of char mod timer to 2s ✓ Increased number of PSL timers to 16 (all models) ✓ Corrected PSL default reference ✓ Added a setting to P543/5 AR to select which edge of trip initiates AR ✓ Added 3 DDB signals to block distance ✓ Removed force 3 pole trip DDB	-	-

Relay type: P54x …						
Software Version Major	**Software Version** Minor	**Hardware Suffix**	**Original Date of Issue**	**Description of Changes**	**S1 Compatibility**	**Technical Documentation**
06 Cont.	B	A	Jun 2001	✓ Note: Non of the above are relevant to software in production	-	-
07	A	A	Feb 2002	Limited release (P543 only) - not released to production. Based on 05K software ✓ Additional check sync signals added to PSL	V2.08 or Later	-
10	A	B	Feb 2001	Internal release for validation only - runs on phase 1 hardware with a modified co-processor board to accept a 1pps input ✓ GPS synchronization ✓ Flexible intertripping ✓ Signaling message format changed ✓ Models 5 & 6 (but limited to 16 optos & 14 relays) ✓ Remains of neutral C diff removed ✓ Event optimization & filtering ✓ Watt hour measurement correction ✓ Addition of digital opto filtering control ✓ Changes & additions to error codes ✓ Increase in protection signaling address ✓ DDB increased in size to 1022 and also support functions changed ✓ Support for universal optos (model number suffix B) ✓ Support for new output relays added	No official release to support this version. Will need V2 to extract PSL files	-

Relay type: P54x …						
Software Version		**Hardware Suffix**	**Original Date of Issue**	**Description of Changes**	**S1 Compatibility**	**Technical Documentation**
Major	Minor					
10 Cont.	A	B	Feb 2001	✓ Internal loopback setting added (not full functional) ✓ PSL references added ✓ Reset LEDs DDB name change ✓ Text for cells 0F20 - 0F2F changed ✓ Problem whereby MiCOM S1 could only set group 1 line length corrected ✓ Control inputs added ✓ Restore defaults now restores DNP3.0 cells correctly ✓ Prevent non DNP3.0 builds generating fatal error when S1 request DNP3.0 upload ✓ MODBUS enabling/disabling of IRIG-B now works ✓ Courier/MODBUS event bit functionality corrected × DNP3.0 & MODBUS address are compatible but there are several new ones × Software is not compatible with previous software (signaling message)	No official release to support this version. Will need V2 to extract PSL files	-
	B	B	Apr 2001	Internal release for validation only - runs on phase 1 hardware with a modified co-processor board to accept a 1pps input ✓ Fixed a reset indications problem in CS103 build ✓ Fixed a problem with P544 display of phase C current phase angle ✓ Setting relay address via rear port corrupted other setting ranges	As per 10A	-

Relay type: P54x …

Software Version Major	Software Version Minor	Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
10 Cont.	C	B	May 2001	Internal release for validation only - runs on phase 2 hardware with a new co-processor board ✓ Support for new co-processor board added ✓ In non GPS mode the char modification timer has been made visible in P545/6 ✓ The char modification timer setting was not being seen by the co-processor board ✓ GPS detected flag was not cleared when switching from GPS to non GPS mode ✓ Equal prop delay command was not resetting inhibit following a comms. switch ✓ Problem displaying Rx & Tx when comms. path was short fixed ✓ Opto filtering corrected ✓ Note: Non of the above are relevant to software in production	As per 10A	-
	D	B	Jun 2001	Internal release for validation only - runs on phase 2 hardware with a new co-processor board ✓ Prevent loss of measurements in 3 ended schemes ✓ Added a 1s drop off timer to C diff inhibit ✓ Changed max value of char mod timer to 2s ✓ Increased number of PSL timers to 16 (all models) ✓ Corrected PSL default reference ✓ Added a setting to P543/5 AR to select which edge of trip initiates AR	V2.01b (not issued)	-

Relay type: P54x …						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
10 Cont.	D	B	Jun 2001	✓ Added 3 DDB signals to block distance ✓ Removed force 3 pole trip DDB ✓ Resolved problem caused by rapid changing self resetting alarm resetting the relay when read key pressed ✓ Note: Non of the above are relevant to software in production	V2.01b (not issued)	-
	E	B	Jul 2001	Internal release for validation only - runs on phase 2 hardware with a new co-processor board ✓ Fixed capacitive charging current compensation in P544 & P546 ✓ Fixed fast operating times for IDMT at a particular multiply of setting ✓ Added MODBUS control of opto filter cell ✓ Removed the quick start up for GPS because it was causing general startup problems ✓ Fixed the GPS inhibit in dual redundant mode ✓ Fixed an error in GPS synchronization when a timer wraps round ✓ Fixed comms. delay equal command in 3 terminal schemes ✓ CS103 time sync modified not to generate courier events ✓ Note: Non of the above are relevant to software in production	V2.01b (not issued)	-
	F	B		Internal release for validation only - runs on phase 2 hardware with a new co-processor board ✓ Added CS103 private codes	V2.01b (not issued)	-

Relay type: P54x …

Software Version Major	Software Version Minor	Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
10 Cont.	F	B		✓ Added uncompressed disturbance recorder to CS103 build ✓ Added translations for filter control ✓ Fixed the GI list for P545 & P546 ✓ Fixed the incorrect response in three terminal mode with GPS present and running on a split path followed by a power cycle at one end ✓ Fixed the occasional incorrect calculation of tp being caused by rounding errors ✓ Fixed the incorrect response in dual redundant schemes with GPS failure followed by a switch to a split path on one channel and a comms. failure on the other ✓ Prevented software errors from clearing event log ✓ Unextracted disturbance records now set the courier status flag on power up ✓ Added support for MODBUS function code 7 ✓ Corrected the MODBUS status bit 0 ✓ Corrected the OTEV bit in the status of fault in IEC60870-5-103 × Menu text files do not contain the additional translations ✓ Note: Non of the above are relevant to software in production	V2.01b (not issued)	-
11	A	B	Sep 2001	First phase 2 release to production ✓ Includes all of 10F ✓ Added CS103 monitor/command blocking	V2.03 or Later	P54x/EN T/D11

Relay type: P54x …						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
11 Cont.	A	B	Sep 2001	✓ PSB now uses 6 comparators ✓ Distance directional line fixed at -30º ✓ PSB block issued when impedance passes into any Z1, Z2 or Z3 ✓ PSB unblock via negative sequence current now done via PSL ✓ Modified co-processor initiation to run on 1 wait state (memory access problem) ✓ Fixed a problem with P545 & P546 opto & relay labels in disturbance record ✓ Fixed the GPS inhibit × Recommended upgrading to 11G or later	V2.03 or Later	P54x/EN T/D11
	B	B	Oct 2001	All builds released to production. Based on 11A software ✓ Modified the co-processor start-up routine to work with alternative types of SRAM ✓ Improved response to a CS103 poll class 1 when monitor blocked was active ✓ Resolved a time alignment problem which resulted in C diff failure alarms being raised ✓ Corrected some MODBUS address for P545 & P546 ✓ Fixed a problem with the relays response to MODBUS commands read coils and read inputs ✓ Fixed an incorrect response to a DNP3.0 command × Recommended upgrading to 11G or later	V2.03 or Later	P54x/EN T/D11

Relay type: P54x …						
Software Version		**Hardware Suffix**	**Original Date of Issue**	**Description of Changes**	**S1 Compatibility**	**Technical Documentation**
Major	Minor					
11 Cont.	C	B	Dec 2001	All builds released to production. Based on 11B software ✓ Fixed a problem in P541 & P542 CS103 builds where the voltage and power measurements were not being marked as invalid ✓ Fixed a problem in P544 & P546 where the SEF current measurement was incorrect when set to 1A & 60Hz × Recommended upgrading to 11G or later	V2.03 or Later	P54x/EN T/D11
	D	B	Jan 2002	All builds released to production. Based on 11C software ✓ Resolved possible reboot caused by disturbance recorder ✓ Resolved possible reboot caused by invalid MODBUS requests ✓ Resolved problem when internal loopback was selected with external clocks ✓ Resolved a problem which caused the loss of IEC 60870-5-103 class 1 messages × Recommended upgrading to 11G or later	V2.03 or Later	P54x/EN T/D11
	E	B	Oct 2002	All builds released to production. Based on 11D software ✓ Resolved incorrect operation of C diff failure alarm in 3 terminal schemes ✓ Correct operation of capacitive charging current compensation in 3 terminal schemes ✓ Resolved problem which caused short duration GPS failure alarms × Recommended upgrading to 11G or later	V2.03 or Later	P54x/EN T/D11

Relay type: P54x …						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
11 Cont.	F	B	Feb 2003	All builds ready. Based on 11E software ✓ Resolved several problems related to the IEC 60870-5-103 protocol ✓ Resolved problem which may cause short duration current differential trips ✓ Corrected the format used to display frequency over the MODBUS interface × Recommended upgrading to 11G or later	V2.03 or Later	P54x/EN T/D11
	G	B	May 2003	All builds ready. Based on 11F software ✓ Changes to clock recovery circuits to improve operation with multiplexers. ✓ PSL logic for user defined intertrips corrected P545 & P546 ✓ Permissive intertrip in dual redundant schemes corrected ✓ Prevented unwanted comms. delay alarms	V2.03 or Later	P54x/EN T/D11
	H	B	Sept 2003	All builds ready. Based on 11G software ✓ Prevents compressed disturbance recorder stalling ✓ Prevents CS103 reporting more non-compressed disturbance records than actually present	V2.03 or Later	P54x/EN T/D11
	I	B	Oct 2004	All builds released to production. Based on 11G software ✓ Improved self-checking of analogue data acquisition ✓ Differential intertrip in IEC 60870-5-103 reported with correct FAN ✓ SRAM self checking added to co-processor board	V2.03 or Later	P54x/EN T/D11

Relay type: P54x …

Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
11 Cont.	I	B	Oct 2004	✓ Reception of MODBUS frame improved ✓ Rejection of spurious messages injected onto RS485 network improved ✓ Improved self checking of SRAM ✓ Fixed an incorrect response of the summertime time bit in IEC 60870-5-103 protocol ✓ Prevented incorrect behavior of P545/P546 when one relay is energized when there is noise on the signaling channel ✓ Status of local GPS reported incorrectly in dual redundant schemes ✓ Setting “Char Mod Time” was missing on P541 - P544 ✓ Prevent a maintenance record when reading from an inaccessible MODBUS register ✓ Prevents relay crashing when phase 2 software used with phase 1 optos ✓ Cell 0709 now replies OK change	V2.03 or Later	P54x/EN T/D11
	J	B	Jul 2005	All builds released to production. Based on 11I software ✓ Changed MODBUS driver	V2.03 or Later	P54x/EN T/D11
12	A	B	Mar 2002	Released for validation testing only ✓ 2nd rear comms. added ✓ Alarms increased to 64 with user programmable alarms ✓ Enhancements and corrections to CS103 ✓ Prevented additional events being generated on power up	V2.05 or Later	P54x/EN T/E21

Relay type: P54x …						
Software Version		**Hardware Suffix**	**Original Date of Issue**	**Description of Changes**	**S1 Compatibility**	**Technical Documentation**
Major	Minor					
12 Cont.	A	B	Mar 2002	✓ French language text improvements ✓ Prevent a maintenance record when reading from an inaccessible MODBUS register ✓ Setting "Char Mod Time" was missing on P541 - P544 ✓ Prevents relay crashing when phase 2 software used with phase 1 optos ✓ Cell 0709 now replies OK change × Maximum pre-trigger time for disturbance recorder in IEC 870-103-5 builds reduced to allow extraction via rear port	V2.05 or Later	P54x/EN T/E21
	B	B	Nov 2002	All builds released to production. Based on 12A software ✓ Resolved incorrect operation of C diff failure alarm in 3 terminal schemes ✓ Correct operation of capacitive charging current compensation in 3 terminal schemes ✓ Resolved problem which caused short duration GPS failure alarms ✓ Resolved problem selecting setting group via optos ✓ Resolved a circuit breaker lockout problem ✓ Corrected the thermal measurement displayed when thermal protection is disabled ✓ Spanish text for user defined alarms contained an extra letter ✓ Blocked overcurrent elements now generate events ✓ Correct DNP3.0 operation of object 10	V2.05 or Later	P54x/EN T/E21

Relay type: P54x …

Software Version Major	Software Version Minor	Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
12 Cont.	B	B	Nov 2002	✓ Resolved problem with P541 & P542 IEC 60870-5-103 builds not running ✓ Resolved a problem with IEC 60870-5-103 class 1 polling ✓ Resolved a problem with IEC 60870-5-103 ASDU2 events which occurred prior to a start event ✓ Correct the format used to display frequency over the MODBUS interface ✓ Resolved problem related to incorrect CB trip/close commands via MODBUS ✓ Resolved problem related to CB trip/close commands via MODBUS being accepted when not selected ✓ Resolved a problem which prevented protection setting being saved after control and support setting had been saved ✓ Corrected the saving of fault locator settings in groups 2, 3, 7 & 4 when made via user interface ✓ Added object 10 to DNP3.0 class 0 poll ✓ Corrected the way DNP3.0 handled the season bit in the time & date × Recommended upgrading to 12D or later	V2.05 or Later	P54x/EN T/E21
	C	B	Mar 2003	All builds released to production. Based on 12B software ✓ Resolved several problems related to the IEC 60870-5-103 protocol ✓ Resolved problem which may cause short duration current differential trips	V2.05 or Later	P54x/EN T/E21

Relay type: P54x …						
Software Version		**Hardware Suffix**	**Original Date of Issue**	**Description of Changes**	**S1 Compatibility**	**Technical Documentation**
Major	Minor					
12 Cont.	C	B	Mar 2003	✓ Improved self diagnostics relating to input module clock ✓ Modified courier block transfer mechanism so it can handle more than 255 blocks ✓ Intermittent loss of data from 2nd rear comms. port corrected ✓ PSL logic for user defined intertrips corrected P545 & P546 ✓ Permissive intertrip in dual redundant schemes corrected ✗ Recommended upgrading to 12D or later	V2.05 or Later	P54x/EN T/E21
	D	B	Jun 2003	All builds released to production. Based on 12C software ✓ Changes to clock recovery circuits to improve operation with multiplexers ✓ Prevented unwanted comms. delay alarms	V2.05 or later	P54x/EN T/E21
	E	B	Sept 2003	All builds released to production. Based on 12D software ✓ Prevents compressed disturbance recorder stalling ✓ Correction to operation of reset relays/LEDs opto ✓ Prevents CS103 reporting more non-compressed disturbance records than actually present	V2.05 or later	P54x/EN T/E21
	F	B	Jun 2004	Not released to production. Supplied to one customer. Based on 12E software ✓ Improved self-checking of analogue data acquisition ✓ Differential intertrip in IEC 60870-5-103 reported with correct FAN	V2.05 or Later	P54x/EN T/E21
	G	B	Oct 2004	All builds released to production. Based on 12E software ✓ Improved self-checking of analogue data acquisition	V2.05 or Later	P54x/EN T/E21

Relay type: P54x …						
Software Version		**Hardware Suffix**	**Original Date of Issue**	**Description of Changes**	**S1 Compatibility**	**Technical Documentation**
Major	Minor					
12 Cont.	G	B	Oct 2004	✓ Differential intertrip in IEC 60870-5-103 reported with correct FAN ✓ SRAM self checking added to co-processor board ✓ Reception of MODBUS frame improved ✓ Rejection of spurious messages injected onto RS485 network improved ✓ Improved self checking of SRAM ✓ Fixed an incorrect response of the summertime time bit in IEC 60870-5-103 protocol ✓ Prevented incorrect behavior of P545/P546 when one relay is energized when there is noise on the signaling channel ✓ Status of local GPS reported incorrectly in dual redundant schemes	V2.05 or Later	P54x/EN T/E21
	H	B	May 2005	All builds released to production. Based on 12G software ✓ Changed MODBUS driver	V2.05 or Later	P54x/EN T/E21
	I	B	May 2006	All builds released to production. Based on 12G software ✓ Improvements to the distance protection	V2.05 or Later	P54x/EN T/E21
13	A	B	Apr 2004	All builds released to production. Based on 12E software ✓ Control inputs enhancements including non-volatile, latched, pulsed and support for DNP3.0 pulsed. ✓ Enhanced DNP3.0 ✓ Distance Residual compensation angle range extended	V2.10 or later	P54x/EN T/E21

Relay type: P54x …						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
13 Cont.	A	B	Apr 2004	✓ Display of number of good messages via MODBUS is corrected ✓ Prevented DNP3.0 time sync causes relay to reboot when IRIG-B is active ✓ Improved self-checking of analogue data acquisition ✓ Improved self checking of SRAM ✓ Added TRIP & ALARM to MODBUS status word ✓ Addition of MODBUS only setting to allow transmission of IEC time format in reverse IEC byte order ✓ Reception of MODBUS frame improved ✓ Rejection of spurious messages injected onto RS485 network improved ✓ Handling of FAN in IEC 60870-5-103 improved ✓ Differential intertrip in IEC 60870-5-103 reported with correct FAN	V2.10 or later	P54x/EN T/E21
	B	B	Aug 2004	All builds released to production. Based on 13A software ✓ SRAM self checking added to co-processor board ✓ Fault location & cumulative broken current measurements reported over DNP3.0 ✓ Accuracy of MODBUS time sync improved ✓ Invalid MODBUS register 4x00966 removed ✓ Reception of MODBUS frame improved	V2.10 or Later (DNP3.0 files) different to 13A	P54x/EN T/E21

Relay type: P54x …						
Software Version		**Hardware Suffix**	**Original Date of Issue**	**Description of Changes**	**S1 Compatibility**	**Technical Documentation**
Major	Minor					
13 Cont.	C	B	Oct 2004	All builds released to production. Based on 13B software ✓ Resolved a problem relating to co-processor SRAM checking ✓ Fixed an incorrect response of the summertime time bit in IEC 60870-5-103 protocol ✓ Prevented incorrect behavior of P545/P546 when one relay is energized when there is noise on the signaling channel ✓ Status of local GPS reported incorrectly in dual redundant schemes	V2.10 or Later (DNP3.0 files) different to 13A	P54x/EN T/E21
	D	B	Mar 2005	All builds released to production. Based on 13C software ✓ Correction to single pole auto-reclose ✓ Remapped fun/inf. 192/130 in P543 & P545 ✓ Display of no. valid messages on LCD corrected ✓ DNP3.0 improved binary scanning ✓ Operation of CB maintenance alarm corrected ✓ Corrections to allow extended courier characters to be used in string setting cells for courier and MODBUS ✓ Corrected default display of neutral current for 5A CTs ✓ Prevented a reboot for DNP3.0 versions when control & support settings are changed rapidly ✓ Changes to co-processor start-up to eliminate a timing problem	V2.10 or Later (DNP3.0 files) different to 13A	P54x/EN T/E21
	E	B	Apr 2005	All builds released to production. Based on 13D software ✓ Changed MODBUS driver	V2.10 or Later (DNP3.0 files) different to 13A	P54x/EN T/E21

Relay type: P54x …						
Software Version		**Hardware Suffix**	**Original Date of Issue**	**Description of Changes**	**S1 Compatibility**	**Technical Documentation**
Major	Minor					
13 Cont.	F	B	Jun 2006	All builds released to production. Based on 13E software ✓ Improvements to the distance protection ✓ Add interframe gap to DNP3.0 ✓ Corrections to IRIG-B ✓ Vector group compensations for YY2 and YY10 corrected ✓ Corrected reporting of distance & C diff stars over CS103 ✓ Reports the correct COT for reset LEDs command sent via S1 ✓ Corrected a problem which occurs when two relays power up when one is configured out	V2.10 or Later (DNP3.0 files) different to 13A	P54x/EN T/E21
16	A	B	Jul 2006	Release of P543 CS103 for Germany only. Based on 13F ✓ CS103/Auto-reclose modifications	Patch for V2.12	P54x/EN T/E21
20	A	G	Nov 2002	✓ Internal release for validation only - runs on phase 2 processor board. Based on 12B ✓ UCA2 option added ✓ Russian text added (not complete) ✓ Added fault location to for IEC 60870-5-103 ✓ Added TRIP & ALARM to MODBUS status word ✓ Distance direction setting added ✓ Distance residual compensation angle range extended ✓ Indication of password status on DDB (code added but not run) ✓ Improvements to auto-reclose	-	-

Relay type: P54x …						
Software Version		**Hardware Suffix**	**Original Date of Issue**	**Description of Changes**	**S1 Compatibility**	**Technical Documentation**
Major	Minor					
20 Cont.	A	G	Nov 2002	✓ Alarms increased to 96 ✓ Corrected the response to courier SEND EVENT ✓ Improved self diagnostics relating to input module clock ✓ Removed the setting for IEC 60870-5-103 over fiber when hardware not present ✓ Resolved problem related to CB trip/close commands via MODBUS being accepted when not selected ✓ Corrected the saving of fault locator settings in groups 2, 3 & 4 when made via user interface ✓ Added object 10 to DNP3.0 class 0 poll ✓ Corrected the way DNP3.0 handled the season bit in the time & date	-	-
	B	G	Apr 2003	Internal release for validation only. Based on 20A ✓ Enhanced check synchronization feature ✓ Control inputs enhancements including non-volatile, latched, pulsed and support for DNP3.0 pulsed ✓ BBRAM used in disturbance recorder optimized ✓ Resolved several problems related to the IEC 60870-5-103 protocol ✓ Resolved problem which may cause short duration current differential trips ✓ Improved self diagnostics relating to input module clock ✓ Modified courier block transfer mechanism so it can handle more than 255 blocks	-	-

Relay type: P54x …						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
20 Cont.	B	G	Apr 2003	✓ PSL logic for user defined intertrips corrected P545 & P546 ✓ Permissive intertrip in dual redundant schemes corrected ✓ Operation of manual reset alarms corrected ✓ A number of bug fixes relating to CPU2	-	-
	C	G	Apr 2003	Internal release for validation only. Based on 20B ✓ CB control via hot keys ✓ A number of bug fixes relating to CPU2	-	-
	D	G	Jul 2003	Internal release for validation only. Based on 20C ✓ Changes to clock recovery circuits to improve operation with multiplexers ✓ Prevented unwanted comms. delay alarms ✓ Enhanced auto-reclose feature added ✓ Alarms handled better in CS103 GI ✓ Time synchronization via opto added ✓ Platform alarms copied to DDB ✓ Correction to operation of reset relays/LEDs opto. ✓ Backup protection run if co-processor fails to start up on power on ✓ Correction to cell 0B25 ✓ A number of bug fixes relating to CPU2	V2.09 or Later	P54x/EN T/F32

VH

Relay type: P54x …

Software Version: Major	Software Version: Minor	Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
20 Cont.	E	G	Oct 2003	Limited release for NiCAP + selected others ✓ Extraction of disturbance recorder over MODBUS added ✓ Resolve nucleus missing HISR problems ✓ Enhancements to IDMT curves ✓ Display of number of good messages via MODBUS is corrected ✓ A number of bug fixes relating to CPU2	V2.09 or Later	P54x/EN T/F32
	F	G	Feb 2004	Release to production ✓ UCA2: Increase max. pending requests & max. connected clients ✓ Enhanced DNP3.0 ✓ Prevented DNP3.0 time sync causes relay to reboot when IRIG-B is active ✓ Corrected cause of transmission which may be returned for "Fault Location" ✓ Prevents relay rebooting during EMC ANSI fast transient and IEC high frequency ✓ A number of bug fixes relating to CPU2	V2.09 or Later	P54x/EN T/F32
	G	G	Jun 2004	Release to production. Based on 20F software ✓ Prevented repeated downloads of GSL files without Ethernet card restart rebooting Ethernet card ✓ Correction to uploading of disturbance records over UCA2 ✓ Corrected operation of Ethernet card link LED for 10 Base-FL	V2.09 or Later	P54x/EN T/G42

Relay type: P54x …

Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
20 Cont.	G	G	Jun 2004	✓ Closed UCA2 association after "dirty" client disconnection ✓ Made UCA2 disturbance record directory service compatible with PACiS ✓ Corrected under and over voltage blocking of check sync ✓ Improved self-checking of analogue data acquisition ✓ Handling of FAN in IEC 60870-5-103 improved ✓ Differential intertrip in IEC 60870-5-103 reported with correct FAN ✓ Prevented C diff fail alarm occurs before signaling fail alarm for loss of communications ✓ Improved self checking of SRAM	V2.09 or Later	P54x/EN T/G42
	H	G	Oct 2004	Release to production. Based on 20G software ✓ SRAM self checking added to co-processor board ✓ Fixed an incorrect response of the summertime time bit in IEC 60870-5-103 protocol ✓ Prevented incorrect behavior of P545/P546 when one relay is energized when there is noise on the signaling channel ✓ Status of local GPS reported incorrectly in dual redundant schemes ✓ Accuracy of MODBUS time sync improved ✓ Fixed an incorrect response of the summertime time bit in IEC 60870-5-103 protocol ✓ Prevented Ethernet card restarting after approximately 20 hours when no connection made ✓ Improvements to time sync for courier, CS103 and DNP3.0	V2.09 or Later	P54x/EN T/G42

Relay type: P54x …

Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
20 Cont.	H	G	Oct 2004	✓ Invalid MODBUS register 4x00966 removed	V2.09 or Later	P54x/EN T/G42
	I	G	Nov 2004	Release to production. Based on 20G software ✓ Display of no. valid messages on LCD corrected ✓ Operation of CB maintenance alarm corrected ✓ Corrections to allow extended courier characters to be used in string setting cells for courier and MODBUS ✓ Corrected default display of neutral current for 5A CTs ✓ Prevented a reboot for MODBUS versions during event extraction when messages where close together ✓ Correction to prevent the 2nd rear comms. locking up	V2.09 or Later	P54x/EN T/G42
	J	G	Apr 2006	Release to production. Based on 20G software ✓ Correction to IEEE/US inverse reset setting ✓ Changes to co-processor start-up to eliminate a timing problem	V2.09 or Later	P54x/EN T/G42
	K	G	Apr 2006	Release to production. Based on 20G software ✓ Improvements to the distance protection ✓ Add interframe gap to DNP3.0 ✓ Corrections to IRIG-B ✓ Vector group compensations for YY2 and YY10 corrected ✓ Corrected reporting of distance & C diff stars over CS103 ✓ Reports the correct COT for reset LEDs command sent via S1 ✓ Corrected a problem which occurs when two relays power up when one is configured out	V2.09 or Later	P54x/EN T/G42

Relay type: P54x …						
Software Version		**Hardware Suffix**	**Original Date of Issue**	**Description of Changes**	**S1 Compatibility**	**Technical Documentation**
Major	Minor					
30	A	J	Sep 2004	Released to selected customers only. Based on 20G ✓ Interface to optical multiplexer (IEEE standard C37.94) ✓ SRAM checking in co-processor ✓ Dual range optos ✓ AREVA livery & software changes ✓ Extended residual angle in fault locator to match distance ✓ Rename GOOSE signals in line with P443 ✓ Add virtual signals, control inputs & user alarms to DR in line with P443 ✓ Relay settings shall be stored in FLASH EEPROM instead of EEPROM memory ✓ Extend range of time dial to line up with P140 ✓ Accuracy of MODBUS time sync improved ✓ Invalid MODBUS register 4x00966 removed ✓ Improvements to time sync for courier, CS103 and DNP3.0 ✓ Addition of MODBUS only time and date format setting to common courier settings for access from the other interfaces ✓ Vector group compensations for YY2 and YY10 corrected ✓ Prevented Ethernet card restarting after approximately 20 hours when no connection made ✓ Prevented incorrect behavior of P545/P546 when one relay is energized when there is noise on the signaling channel	V2.09 or Later (No language file support)	P54x/EN T/G42
	B	J	Nov 2004	Released to production but held. Based on 30A ✓ Courier, MODBUS & DNP3.0 communications over Fiber added	V2.11 or Later	P54x/EN T/H53

Relay type: P54x …						
Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
30 Cont.	B	J	Nov 2004	✓ Display of no. valid messages on LCD corrected ✓ Operation of CB maintenance alarm corrected ✓ Some text in auto-reclose column made consistent with that in overcurrent column ✓ Improvements to VTS and auto-reclose in single pole tripping applications ✓ Corrections to allow extended courier characters to be used in string setting cells for courier and MODBUS ✓ Fixed an incorrect response of the summertime time bit in IEC 60870-5-103 protocol ✓ Corrected reporting of local GPS fail in dual redundant schemes ✓ Corrected default display of neutral current for 5A CTs ✓ Prevented a reboot for DNP3.0 versions when control & support settings are changed rapidly ✓ Prevented a reboot for MODBUS versions during event extraction when messages were close together	V2.11 or Later	P54x/EN T/H53
	C	J	Nov 2004	Released to production. Based on 30B ✓ Correction to prevent the 2nd rear comms. locking up ✓ Correction to prevent the front panel UI and comms. lockup after continued operation ✓ Changes to co-processor start-up to eliminate a timing problem	V2.11 or Later	P54x/EN T/H53
	D	J	Dec 2004	Released to production. Based on 30C ✓ Improvements to operation when subjected to multiple communication switches when operating in non-GPS mode	V2.11 or Later	P54x/EN T/H53

Relay type: P54x …						
Software Version		**Hardware Suffix**	**Original Date of Issue**	**Description of Changes**	**S1 Compatibility**	**Technical Documentation**
Major	Minor					
30 Cont.	E	J	Jan 2005	Released to production. Based on 30D ✓ VTS enhanced to restore 3 software version 20 performance for three pole tripping whist keeping the improvements for 1 pole tripping added at 30B	V2.11 or Later	P54x/EN T/H53
	F	J	Mar 2005	Released to production. Based on 30E ✓ Enhancements to the current differential performance under switched communication channels ✓ Correction to the CS103 mapping for platform alarms	V2.11 or Later	P54x/EN T/H53
	G	J	Apr 2006	Released to production. Based on 30E ✓ Correction to IEEE/US Inverse reset setting	V2.11 or Later	P54x/EN T/H53
	H	J	Apr 2006	Limited release P542 DNP3.0 to a customer ✓ Add interframe gap to DNP3.0	V2.11 or Later	P54x/EN T/H53
	I	J	May 2005	Released to production. Based on 30G ✓ Improvements to the distance protection ✓ Add interframe gap to DNP3.0 ✓ Corrections to IRIG-B ✓ Vector group compensations for YY2 and YY10 corrected ✓ Corrected reporting of distance & C diff stars over CS103 ✓ Reports the correct COT for reset LEDs command sent via S1 ✓ Corrected a problem which occurs when two relays power up when one is configured out ✓ Modification to allow individual MODBUS register access	V2.11 or Later	P54x/EN T/H53
40	A	K	May 2006	Release of P543, P544, P545 & P546 without distance protection ✓ CTS ✓ Definitive time directional negative sequence overcurrent I2>	Patch for V2.12	P54x/EN M/I64

Relay type: P54x …

Software Version Major	Software Version Minor	Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
40 Cont.	A	K	May 2006	✓ GPS synchronization of current differential in all models ✓ P543 and P545 now facilitate in zone transformer-feeder applications ✓ All models support ABC and ACB phase rotation ✓ Standard and Inverted CT polarity setting for each set of CTs in the relay ✓ User interface with tri colored LED and function keys ✓ InterMiCOM^{64} ✓ Voltage protection ✓ Backwards compatibility mode	Patch for V2.12	P54x/EN M/I64
41	C	K	Jul 2006	Release of P543, P544, P545 & P546 without distance protection based on 40A ✓ IEC 61850-8-1 ✓ High break options ✓ Demodulated IRIG-B options ✓ Reduction of distance minimum reach settings to 0.05 ohm ✓ Permissive trip reinforcement ✓ Poledead modifications for Hydro Quebec ✓ CS103/auto-reclose modifications	Patch for V2.12	P54x/EN M/J74
50	A	K	May 2006	Release of P543, P544, P545 & P546 with distance protection ✓ Distance protection from P443 ✓ DEF from P443 ✓ Aided distance & DEF schemes from P443 ✓ CTS	Patch for V2.12	P54x/EN M/I64

Relay type: P54x …						
Software Version		**Hardware Suffix**	**Original Date of Issue**	**Description of Changes**	**S1 Compatibility**	**Technical Documentation**
Major	Minor					
50 Cont.	A	K	May 2006	✓ Definitive time directional negative sequence overcurrent I2> ✓ GPS synchronization of current differential in all models ✓ P543 and P545 now facilitate in zone transformer-feeder applications ✓ All models support ABC and ACB phase rotation ✓ Standard and inverted CT polarity setting for each set of CTs in the relay ✓ User interface with tri colored LED and function keys ✓ InterMiCOM^{64} ✓ Voltage protection ✓ Backwards compatibility mode	Patch for V2.12	P54x/EN M/I64
51	C	K	Jul 2006	Release of P543, P544, P545 & P546 with distance protection based on 50A ✓ IEC 61850-8-1 ✓ High break options ✓ Demodulated IRIG-B options ✓ Reduction of distance minimum reach settings to 0.05 ohm ✓ Permissive trip reinforcement ✓ Poledead modifications for Hydro Quebec ✓ CS103/auto-reclose modifications ✓ Out of step tripping	Patch for V2.12	P54x/EN M/J74

Setting File Software Version	Relay Software Version																
	01	02	03	04	05	07	11	12	13	14	15	20	30	40	41	50	51
01	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
02	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
03	×	×	✓	1	×	×	×	×	×	×	×	×	×	×	×	×	×
04	×	×	×	✓	2	2	×	×	×	×	×	×	×	×	×	×	×
05	×	×	×	×	✓	✓	×	×	×	×	×	×	×	×	×	×	×
07	×	×	×	×	✓	✓	×	×	×	×	×	×	×	×	×	×	×
11	×	×	×	×	×	×	✓	✓	2	2	×	2	×	×	×	×	×
12	×	×	×	×	×	×	✓	✓	2	2	×	2	×	×	×	×	×
13	×	×	×	×	×	×	✓	✓	✓	2	×	2	×	×	×	×	×
14	×	×	×	×	×	×	×	×	×	✓	×	×	×	×	×	×	×
15	×	×	×	×	×	×	×	×	×	×	✓	×	×	×	×	×	×
20	×	×	×	×	×	×	×	×	×	×	×	✓	3	×	×	×	×
30	×	×	×	×	×	×	×	×	×	×	×	×	✓	×	×	×	×
40	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	×	4	×
41	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	×	4
50	×	×	×	×	×	×	×	×	×	×	×	×	×	5	×	✓	×
51	×	×	×	×	×	×	×	×	×	×	×	×	×	×	5	×	✓

1 Compatible except for Disturbance recorder digital channel selection

2 Additional functionality added such that setting files from earlier software versions will need additional settings to be made

3 Compatible except for Disturbance recorder digital channel selection & settings for additional functionality will be missing

4 Compatible except for the Disturbance recorder digital channel selection and the distance settings

5 Compatible except for Disturbance recorder digital channel selection & the setting file contains a large number of Distance setting which will each produce an error on download

PSL File Software Version	Relay Software Version																
	01	02	03	04	05	07	11	12	13	14	15	20	30	40	41	50	51
01	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
02	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
03	×	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	×
04	×	×	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	×
05	×	×	×	×	✓	1	×	×	×	×	×	×	×	×	×	×	×
07	×	×	×	×	×	✓	×	×	×	×	×	×	×	×	×	×	×
11	×	×	×	×	×	×	✓	✓	✓	×	×	1	1	×	×	×	×
12	×	×	×	×	×	×	×	✓	✓	×	×	1	1	×	×	×	×
13	×	×	×	×	×	×	×	×	✓	×	×	1	1	×	×	×	×
14	×	×	×	×	×	×	×	×	×	✓	×	×	×	×	×	×	×
15	×	×	×	×	×	×	×	×	×	×	✓	×	×	×	×	×	×
20	×	×	×	×	×	×	×	×	×	×	×	✓	1	×	×	×	×
30	×	×	×	×	×	×	×	×	×	×	×	×	✓	×	×	×	×
40	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	×	2	×
41	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	×	2
50	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	×
51	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓

1 Additional DDBs were added such that PSL files from earlier software versions will not be able to access them

2 Additional DDB for the Distance protection will not be included

VH

Menu Text File Software Version	Relay Software Version																
	01	02	03	04	05	07	11	12	13	14	15	20	30	40	41	50	51
01	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
02	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
03	×	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	×
04	×	×	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	×
05	×	×	×	×	✓	✓	×	×	×	×	×	×	×	×	×	×	×
07	×	×	×	×	✓	✓	×	×	×	×	×	×	×	×	×	×	×
11	×	×	×	×	×	×	✓	×	×	×	×	×	×	×	×	×	×
12	×	×	×	×	×	×	×	✓	×	×	×	×	×	×	×	×	×
13	×	×	×	×	×	×	×	×	✓	×	×	×	×	×	×	×	×
14	×	×	×	×	×	×	×	×	×	✓	×	×	×	×	×	×	×
15	×	×	×	×	×	×	×	×	×	×	✓	×	×	×	×	×	×
20	×	×	×	×	×	×	×	×	×	×	×	✓	×	×	×	×	×
30	×	×	×	×	×	×	×	×	×	×	×	×	✓	×	×	×	×
40	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	×	×	×
41	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	×	×
50	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	×
51	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	✓

Menu text remains compatible within each software version but is NOT compatible across different versions

INDEX

D

E

Q

R

Customer Care Centre

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