MiCOM P791 & P793

Integrated Resistor and Varistor Unit
for High Impedance Differential Schemes

P79x/EN T/B11_

Technical Guide

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.

MiCOM P791/P793
INTEGRATED RESISTOR AND VARISTOR UNIT FOR HIGH IMPEDANCE DIFFERENTIAL SCHEMES
TECHNICAL GUIDE

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SAFETY SECTION

STANDARD SAFETY STATEMENTS AND EXTERNAL LABEL INFORMATION FOR SCHNEIDER ELECTRIC EQUIPMENT

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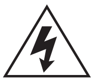
1. INTRODUCTION

This guide and the relevant equipment documentation provide full information on safe handling, commissioning and testing of this equipment. This Safety Guide also includes descriptions of equipment label markings.

Documentation for equipment ordered from Schneider Electric is despatched 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 guide is typical only, see the technical data section of the relevant product publication(s) for data specific to a particular equipment.



Before carrying out any work on the equipment the user should be familiar with the contents of this Safety Guide 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 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 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:

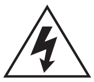
- Are familiar with the installation, commissioning, and operation of the equipment and of the system to which it is being connected;
- Are able to safely perform switching operations in accordance with accepted safety engineering practices and are authorised to energize and de-energize equipment and 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 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.

3. SYMBOLS AND EXTERNAL LABELS ON THE EQUIPMENT

For safety reasons the following symbols and external labels, which may be used on the equipment or referred to in the equipment documentation, should be understood before the equipment 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.

*NOTE: THE TERM EARTH USED THROUGHOUT THIS GUIDE IS THE DIRECT EQUIVALENT OF THE NORTH AMERICAN TERM GROUND.

3.2 Labels

See Safety Guide (SFTY/4L M/G11-S) for equipment labelling information.

4. INSTALLING, COMMISSIONING AND SERVICING

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.

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 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. DECOMMISSIONING 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

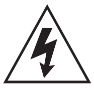
It is recommended that incineration and disposal to water courses is avoided. The equipment should be disposed of in a safe manner. Any equipment containing batteries should have them removed before disposal, taking precautions to avoid short circuits. Particular regulations within the country of operation,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



CAUTION - CTs must NOT be fused since open circuiting them may produce lethal hazardous voltages.

6.2 Protective Class

IEC 60255-27: 2005 EN 60255-27: 2006	Class I (unless otherwise specified in the equipment documentation). 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: 2006	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 or 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 Altitude - Operation up to 2000m	Compliance is demonstrated by reference to safety standards.

IEC 60255-27:2005

EN 60255-27: 2006

INTRODUCTION

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1. INTRODUCTION

MiCOM P791 and P793 high impedance differential accessories are an integrated stabilizing resistor and varistor units suitable for use with any high impedance differential scheme.

The MiCOM P791 and P793 are used in high impedance differential schemes to achieve stability for external faults, and to limit the peak voltage developed by the current transformers during internal faults.

– The MiCOM P79x is designed with a number of internal fixed resistors and with simple parallel/series jumper connections on the unit terminals, so that various stabilizing resistance values can be obtained to meet the application requirements. Three options of stabilizing resistors are available.

– The varistor unit limits the peak voltage developed during internal faults. Two options of varistors are available. The half power and full power options allow a maximum transient energy of 10 kJ and 20 kJ respectively.

MiCOM P791 is intended for single phase applications, MiCOM P793 is intended for three phase applications

2. HOW TO USE THIS MANUAL

This manual provides a description of **MiCOM P791** and **P793** units. The goal of this manual is to allow the user to become familiar with the application, installation, setting and commissioning of these accessories.

This manual has the following format:

P79x/EN IT	*Introduction*
	The introduction presents the documentation structure and a brief presentation of the units.
P79x/EN IN	*Handling, installation and case dimensions*
	This section provides logistics general instructions for handling, installing and stocking.
P79x/EN AP	*Application Notes*
	This section includes a description of common power system applications. Several operating conditions are considered to establish the suitability of the P79x in any application.
P79x/EN TD	*Technical data*
	This section provides technical data including recommended operating conditions and ratings. Compliance with norms and international standards is quoted where appropriate.
P79x/EN CM	*Commissioning and Maintenance Guide*
	Instructions on how to commission the unit as well as comprising checks on its functionality are given.
P79x/EN CO	*Connection diagrams*
	This section provides the mechanical and electrical description. External wiring connections to the P79x are indicated.
P79x/EN RS	*Commissioning test & records sheets*
	This section contains checks on the calibration and functionality of the product.
P79x/EN VC	*Hardware version history and compatibility*
	History of all hardware releases for the product.

3. INTRODUCTION TO THE MiCOM RANGE

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

MiCOM provides the ability to define an application solution and, through extensive communication capabilities, to integrate this solution 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 behaviour of a power system, using disturbance and fault records.

They can also provide measurements of the power system at regular intervals to a control centre enabling remote monitoring and control to take place.

For up-to-date information on any MiCOM product, refer to the technical publications, which can be obtained from: Schneider Electric or your local sales office; alternatively visit our web site.

www.schneider-electric.com

4. MAIN FUNCTIONS

4.1 Main functions

The following table shows the functions available for the different models of the MiCOM P79x.

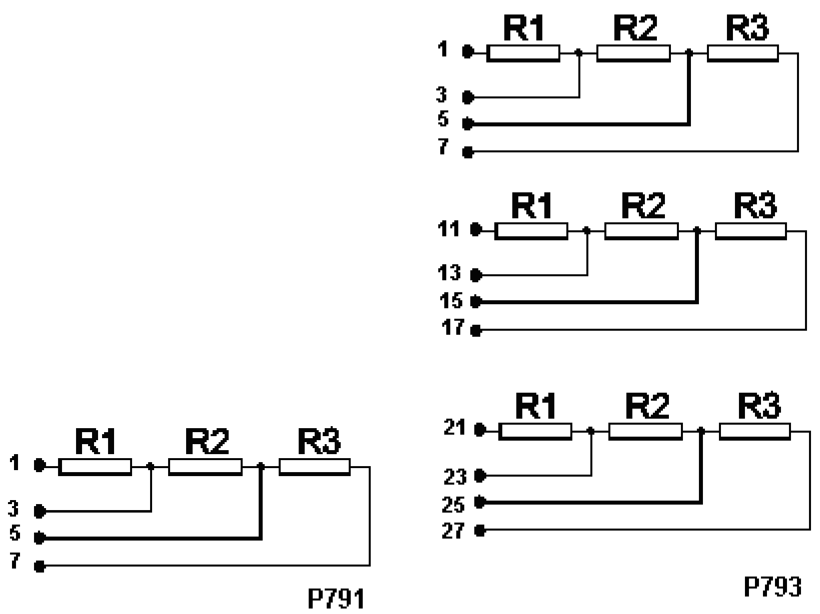
FEATURES	P791	P793
Stabilising resistance for earth / single phase applications	•	
Stabilising resistance for three phase applications		•
Voltage limitation for single phase applications	•	
Voltage limitation for three phase applications		•
Shorting relays	•	•

4.2 General functions

The following table shows the general features available.

GENERAL FEATURES

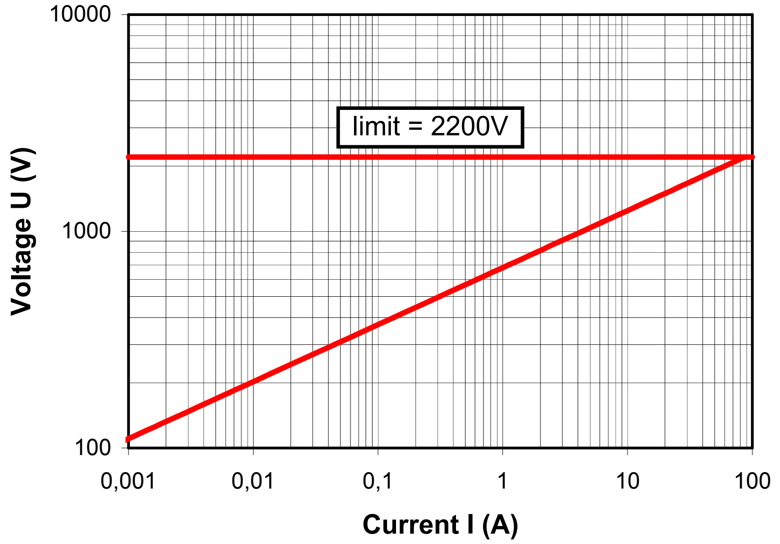
Values for the stabilising resistors



Option A	R1//R2//R3	55 Ω
	R1//R2	82.5 Ω
	R1+R2+R3	495 Ω
	R1+R2	330 Ω
Option B	R1//R2//R3	166 Ω
	R1//R2	250 Ω
	R1+R2+R3	1500 Ω
	R1+R2	1000 Ω
Option C	R1//R2//R3	366 Ω
	R1//R2	550 Ω
	R1+R2+R3	3300 Ω
	R1+R2	2200 Ω
Rated power at 25°C		
Option A, B or C	R1//R2//R3	105 W
	R1//R2	70 W
	R1+R2+R3	105 W
	R1+R2	70 W

GENERAL FEATURES

Varistors characterisitics



Maximum transient energy	
Simple no linear resistors – Half power option	10 kJ
Dual no linear resistors – Full power option	20 kJ

Application overview

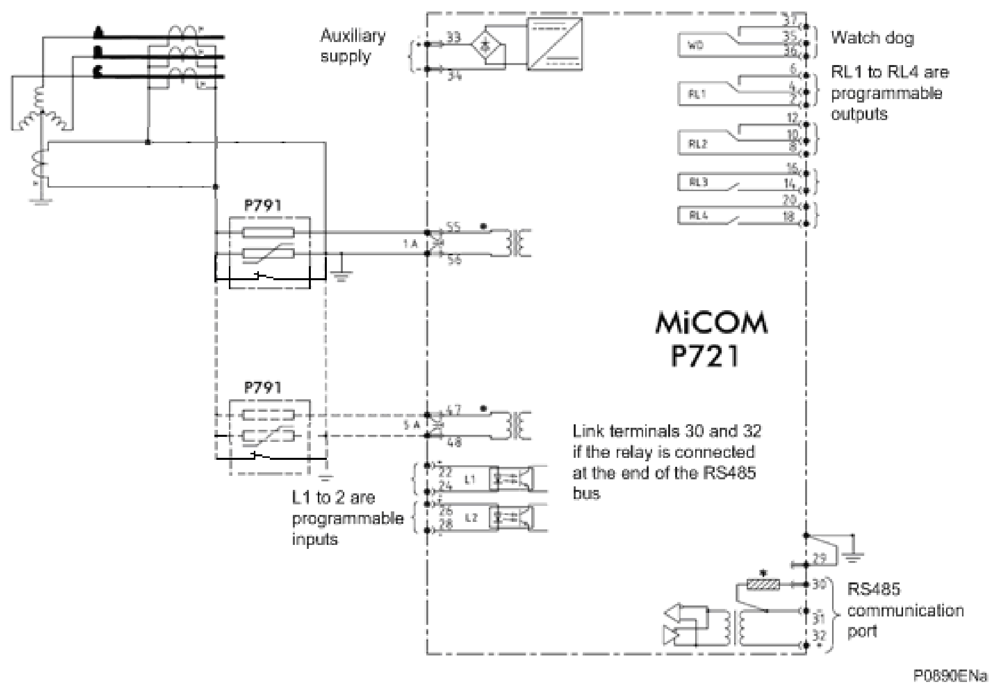


FIGURE 1: MiCOM P721 AND P791 IN A REF PROTECTION SCHEME

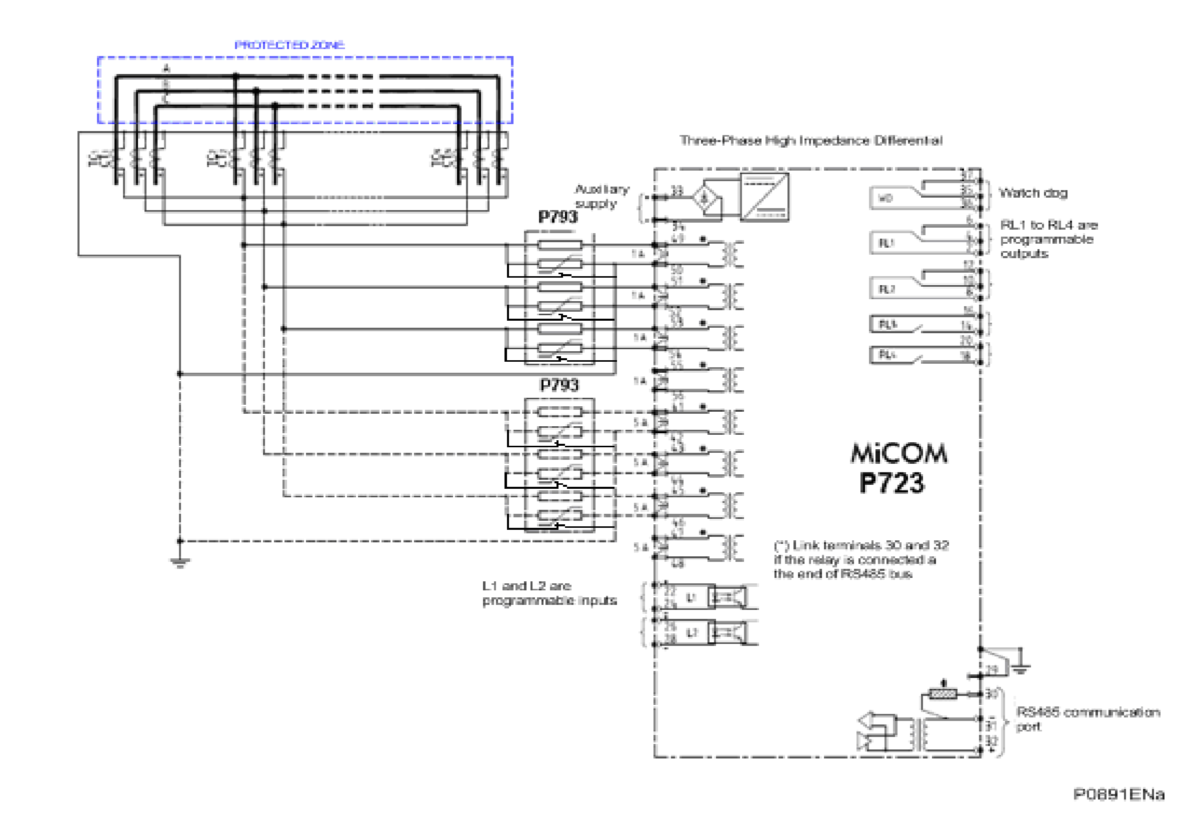


FIGURE 2: MiCOM P723 AND P793 IN A REF PROTECTION SCHEME

4.3 Ordering options

Information Required with Order

Stabilising adjustable resistors	**P79** ☐ ☐ ☐ **0** ☐ **2**
Variant	
Earth or single phase	1
Three phases	3
Stabilising resistor	
Resistor values (55Ω, 82.5Ω, 330Ω, 495Ω)	A
Resistor values (166Ω, 250Ω, 1000Ω, 1500Ω)	B
Resistor values (366Ω, 550Ω, 2200Ω, 3300Ω)	C
Voltage Peaks Limitation	
Without	0
Simple non linear resistors – half power (10 kJ)	H
Dual non linear resistors – Full power (20 kJ)	F
Auxiliary Voltage	
Shorting relays coil nominal voltage 24Vdc	B
Shorting relays coil nominal voltage 48Vdc,110Vac/Vdc, 125Vdc	E
Shorting relays coil voltage 220Vac/Vdc,250 Vdc	N
Hardware release release	
Phase 2	2

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HANDLING, INSTALLATION AND CASE DIMENSIONS

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1. GENERAL CONSIDERATIONS

BEFORE CARRYING OUT ANY WORK ON THE EQUIPMENT, THE USER SHOULD BE FAMILIAR WITH THE CONTENTS OF THE SAFETY GUIDE SFTY/4LM/G11-S OR LATER ISSUE, OR THE SAFETY AND TECHNICAL DATA SECTIONS OF THE TECHNICAL MANUAL AND ALSO THE RATINGS ON THE EQUIPMENT RATING LABEL.

1.1 Receipt of integrated stabilizing resistor and varistor units

Integrated stabilizing resistor and varistor units, although generally of robust construction, require careful treatment prior to installation on site. On receipt, units should be examined immediately to ensure no damage has been sustained in transit. If damage has been sustained during transit a claim should be made to the transport contractor and Schneider Electric should be promptly notified.

Units that are supplied unmounted and not intended to be installed immediately should be returned with their protective polythene bags.

2. UNIT MOUNTING

Integrated stabilizing resistor and varistor units are dispatched either individually or as part of a panel/rack assembly.

IT IS ADVISABLE TO MOUNT THE P79X IN A VENTILATED AREA AND THE MINIMUM RECOMMENDED SPACE AROUND THE P79X BOX IS 4IN.

If an MMLG test block is to be included it should be positioned at the right-hand side of the assembly (viewed from the front). Modules should remain protected by their metal case during assembly into a panel or rack.

For individually mounted units an outline diagram is supplied in section 6 of this chapter showing the panel cut-outs and hole centres.

3. UNPACKING

Care must be taken when unpacking and installing the units so that none of the parts are damaged. Integrated stabilizing resistor and varistor units must only be handled by skilled personnel. The installation should be clean, dry and reasonably free from dust and excessive vibration. The site should be well lit to facilitate inspection. Units that have been removed from their cases should not be left in situations where they are exposed to dust or damp. This particularly applies to installations which are being carried out at the same time as construction work.

Ensure that any User's CDROM or technical documentation is NOT discarded – this should accompany the unit to its destination substation.

4. STORAGE

If integrated stabilizing resistor and varistor units 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. The action of the de-humidifier crystals will be impaired if the bag has been exposed to ambient conditions and may be restored by gently heating the bag for about an hour, prior to replacing it in the carton.

Dust which collects on a carton may, on subsequent unpacking, find its way into the unit; in damp conditions the carton and packing may become impregnated with moisture and the de-humifier will lose its efficiency.

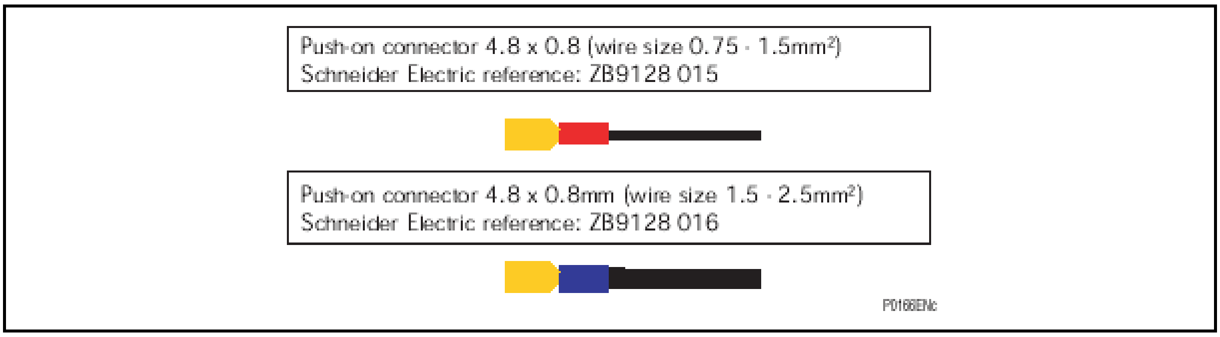
Storage temperature: –25°C to +70°C.

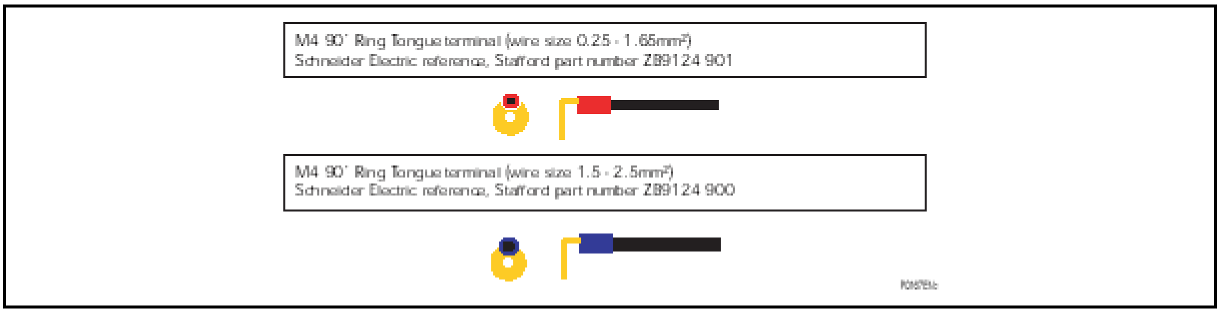
5. DIMENSIONS

5.1 Connection of power terminals, and Signals terminals

The individual items of equipment are delivered with sufficient M4 screws to connect the unit via annular terminals, with a maximum recommended of two annular terminals per contact.

If necessary, Schneider Electric can provide annular terminals to crimp. 5 references exist according to the section of the wire (see below). Each reference corresponds to a sachet of 100 terminals.





Use and isolated sleeve to insulate the terminals and to comply with the security and safety instructions.

We recommend the following cable cross-sections:

– Auxiliary sources Vaux: 1.5 mm²

– Other circuits 1.0 mm²

Because of the limitations of the annular terminals, the maximum wire cross-section which can be used for the connector blocks (for current inputs and signals) is of 6 mm² by using non-insulated annular terminals. When only pre-insulated terminals can be used, the maximum wire cross-section is reduced to 2,63 mm² per annular terminal. If a more significant wire cross-section is necessary, two wires can be connected in parallel, each one with a separate annular terminal.

All the terminal blocks used for connections must be able to withstand a nominal voltage of minimum 300 V peak value.

We recommend protecting the auxiliary source connection by using a fuse of type NIT or TIA with a breaking capacity of 16 A. For security reasons, never install fuses in current transformers circuits. The other circuits must be protected by fuses.

5.2 Protective conductor (earth) connection

Each item of equipment must be connected to the local earth bar using the M4 earth terminals. The minimum recommended wire size is 2.5 mm², and should have a ring terminal at the relay end. Due to the limitations of the ring terminals, the maximum wire size that can be used for any of the medium or heavy duty terminals is 6 mm² per wire. If a greater cross-sectional area is required, use two wires in parallel, each terminated in a separate ring terminal at the relay, or use a metal earth bar.

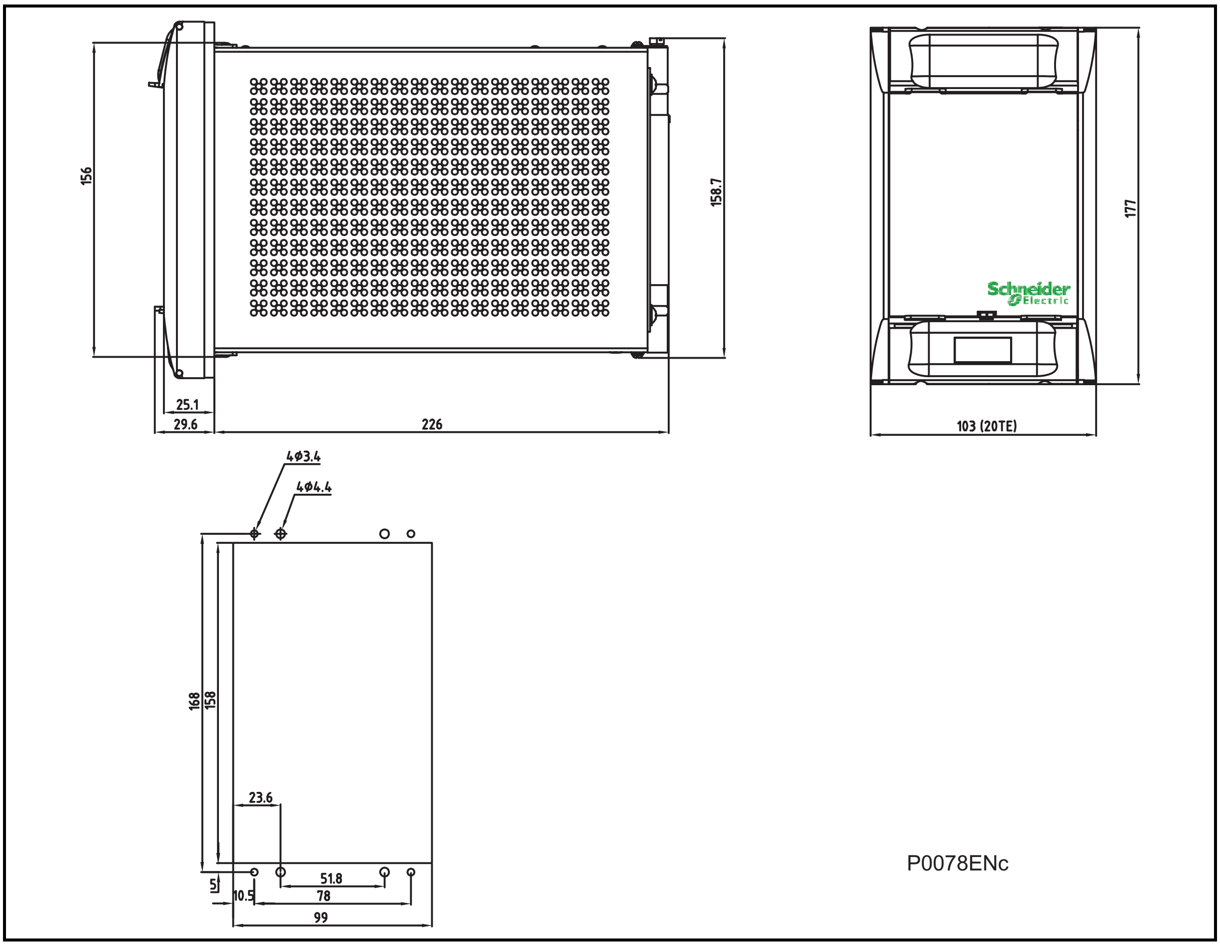
NOTE: To prevent any electrolytic risk between copper conductor or brass conductor and the back plate of the equipment, it is necessary to take precautions to isolate them one from the other. This can be done in several ways, for example by inserting between the conductor and the case a plated nickel or insulated ring washer or by using a tin terminals.

6. CASE DIMENSIONS

MiCOM P791 and **P793** units are available in a 4U metal case for panel or flush mounting.

Weight: 1.7 to 2.1 Kg

External size:	Height	case	152 mm
		front panel	177 mm
	Width	case	97 mm
		front panel	103 mm
	Depth	case	226 mm
		front panel + case	252 mm



MiCOM P791 AND P793 UNITS CASE DIMENSIONS

NOTE: The chassis is normally secured in the case by four screws (self tap screws 6 x 1.4), to ensure good seating. The fixing screws should be fitted in normal service (do not add washers). Do not discard these screws.

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APPLICATION NOTES

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1. INTRODUCTION

The P79x is an accessory to be used in high impedance differential schemes. In a 20TE case it integrates a series of resistors and varistors required in high impedance differential applications. A fixed number of resistors are available inside the box, and different values of stabilizing resistance may be achieved as a function of the wiring. The varistors, type $I = AI^k$, may reduce the peak voltages that may be present during internal faults to 2200 V. Two options of varistors are available. Option H as given in the P79x cortec is half power and it may withstand up to 10 kJ of transient energy. It consists of three varistors in parallel. Option F as given in the P79x cortec is full power, and it may withstand up to 20 kJ of transient energy. It consists of six varistors in parallel.

Two models are available the P791 and the P793. The P791 is intended for single phase applications such as restricted earth faults (REF) or balanced earth fault (BEF). The P793 is used in three phase applications, such as busbar protection.

The P79x also includes auxiliary relays. The auxiliary relay contacts should be wired across the high impedance path to help in energy dissipation during internal faults. As a result, the resistors and varistors will be protected against excessive thermal overload. The auxiliary contacts' make and carry current is 30 A.

The relay may or may not be short circuited by the auxiliary contacts. If the relay burden is negligible (e.g. P72x, P12x, P14x), then it is not necessary to short circuit it. On the other hand, if the relay burden is high, then it would be necessary to short circuit it. This is because the current flowing through the varistor should also be limited. By short circuiting the high burden relay the current flowing through the varistor will be as low as it can be. Therefore, the varistor energy dissipation is effectively limited. Note that latch trip contacts should be used whenever the relay is short-circuited; this is to ensure the trip of the lockout relay (86) and circuit breakers.

When using the P79x accessory it is mandatory to use shorting contacts across the high impedance differential path to reduce the energy dissipation in the resistors and varistors after relay operation during an internal fault. Other conditions that require the use of the shorting contacts are described in detail in section 2.3 Auxiliary relays.

To select the appropriate P79x required in any particular application, use the P79x Energy Limit Tool which is an easy-to-use spreadsheet file. The aim of this tool is to help safely select the P79x that should be used. Note that this tool calculates the maximum current that the P79x elements can withstand. The data required to run the tool are the CT primary and secondary nominal currents, the CT knee point voltage, the fault duration and the initial flux. If transient CT saturation is considered, then the primary time constant is also required. The maximum fault level of the system should always be below the fault level calculated by the tool. In section 4, P79x application examples are given for the different conditions that should be considered.

2. P79x DESIGN

2.1 Stabilizing Resistor Options

The P79x offers three options of stabilizing resistances.

Option A as indicated in the P79x cortec provides the following resistance values:

Option A	
Connection	Equivalent resistance
1//2//3	55 Ω
1//2	82.5 Ω
1+2	330 Ω
1+2+3	495 Ω

// = parallel connection
+ = series connection

In option A the equivalent resistances 1, 2 and 3 are all 5 x 33 Ω in series which equates to 165 Ω.

Option B as indicated in the P79x cortec provides the following resistance values:

Option B	
Connection	Equivalent resistance
1//2//3	166 Ω
1//2	250 Ω
1+2	1000 Ω
1+2+3	1500 Ω

// = parallel connection
+ = series connection

In option B the equivalent resistances 1, 2 and 3 are all 5 x 100 Ω in series which equates to 500 Ω.

Option C as indicated in the P79x cortec provides the following resistance values:

Option C	
Connection	Equivalent resistance
1//2//3	366 Ω
1//2	550 Ω
1+2	2200 Ω
1+2+3	3300 Ω

// = parallel connection
+ = series connection

In option C the equivalent resistances 1, 2 and 3 are all 5 x 220 Ω in series which equates to 1100 Ω.

From the above tables, it can be observed that the different values for stabilizing resistance are achieved depending on the connection between the equivalent resistances 1, 2 and 3. Please refer to section *P79x/EN CO* for the connections diagrams.

NOTE THAT IT IS NOT ALLOWED TO USE RESISTANCES 1, 2 OR 3 ALONE DUE TO ENERGY DISSIPATION CONSTRAINTS.

Different thermal withstand limits should be considered depending on the condition to which the resistor is subjected. For example, during internal faults the transient energy dissipation is the limit. On the other hand, during a CT open circuit the 3 s withstand should be considered. It is 3 s because the 95 supervision alarm operates in 3 s after the CT open circuit condition is detected.

2.2 Varistors Options

The P79x may be ordered with or without varistors. The objective of the varistors is to limit the peak voltage developed by the CT during internal faults to a level below the insulation level of the current transformers, relay and interconnecting leads, which can normally withstand 2 kV rms (3 kV peak). There are two varistor options available. Option H varistors may withstand up to 10 kJ of transient energy, and Option F varistors may withstand up to 20 kJ of transient energy. The maximum energy that may be dissipated through the varistor during internal faults is the transient energy. This energy has the form of repetitive pulses.

Option H consists of three matched varistors connected in parallel, and Option F consists of six matched varistors connected in parallel.

The following equation is used to calculate the current through one varistor:

$$I = A \times U^{k} \qquad \text{(equation 1)}$$

Where:

I	=	Peak current in amperes
U	=	Peak voltage in volts
k	=	varistor non-linearity coefficient
A	=	varistor constant

The varistor used in the P79x has k = 3.8 and A = 1.73×10^{-11}.

From equation 1, the voltage across the varistor may be calculated as follows:

$$U = \left(\frac{1}{A} \times I\right)^{1/k}$$

$$U = C \times I^{\beta} \qquad \text{(equation 2)}$$

Where:

I	=	Peak current in amperes
U	=	Peak voltage in volts
C	=	$\left(\frac{1}{A}\right)^{1/k}$
β	=	$\frac{1}{k}$

Therefore, the varistor has C = 679.349 and β = 0.263.

Figure 1 shows the varistor characterisitics.

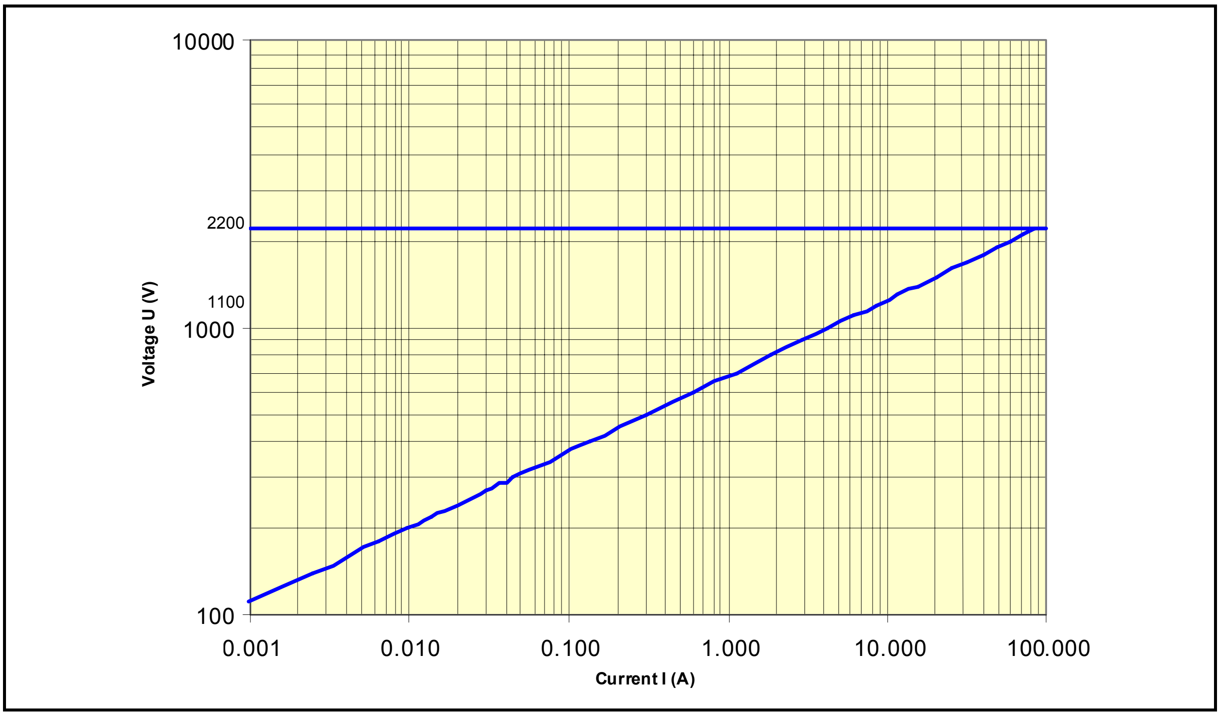


FIGURE 1: VARISTOR CHARACTERISTICS

During primary injection tests, the majority of the differential current flows through the relay and stabilizing resistor and it tends to be a low value. Therefore, as the varistor is not significantly conducting, the voltage developed is approximately sinusoidal. Equations 3 and 4 give an indication of the rms current drawn by the varistor during this condition.

When a sinusoidal voltage waveform is applied across the varistor, the rms current is calculated as follows:

$$I_{rms} = \text{constant} \times I_{peak}$$

The constant was calculated as 0.529 and the rms current is given either by equation 3 or 4, because these equations are equivalent.

$$I_{rms} = 0.529 \times A \times \left(\sqrt{2} \times U_{rms}\right)^{k} \qquad \text{(equation 3)}$$

or

$$I_{rms} = 0.529 \times \left(\frac{\sqrt{2} \times U_{rms}}{C}\right)^{1/\beta} \qquad \text{(equation 4)}$$

The Irms calculated using equations 3 or 4 must be multiplied by 3 (varistor Option H) or by 6 (varistor Option F) to calculate the total rms current.

Figure 2 shows the current and voltage waveforms when a 270 Vrms sinusoidal voltage is applied across one varistor.

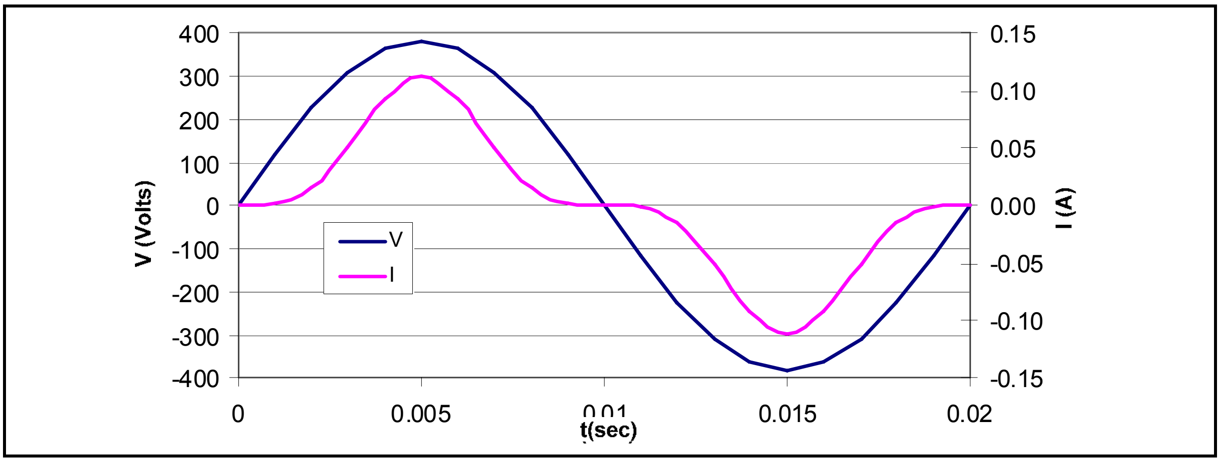


FIGURE 2: VARISTOR VOLTAGE AND CURRENT WAVEFORMS – SINUSOIDAL VOLTAGE APPLIED

Under internal fault conditions, where the differential current tends to be high, the majority of the current flows through the varistor.

When a sinusoidal current flows through the varistor the rms voltage is calculated as follows:

$$V_{rms} = \text{constant} \times V_{peak}$$

The constant was calculated as 0.868, and the rms voltage is given either by equation 5 or 6, because these equations are equivalent.

$$U_{rms} = 0.868 \times \left(\frac{\sqrt{2} \times I_{rms}}{A} \right)^{1/k} \qquad \text{(equation 5)}$$

or

$$U_{rms} = 0.868 \times C \times \left(\sqrt{2} \times I_{rms} \right)^{\beta} \qquad \text{(equation 6)}$$

Note that in equation 5 and 6, Irms is the current flowing through one varistor only.

Figure 3 shows the voltage and current waveforms when a 1 A rms sinusoidal current flows through one varistor.

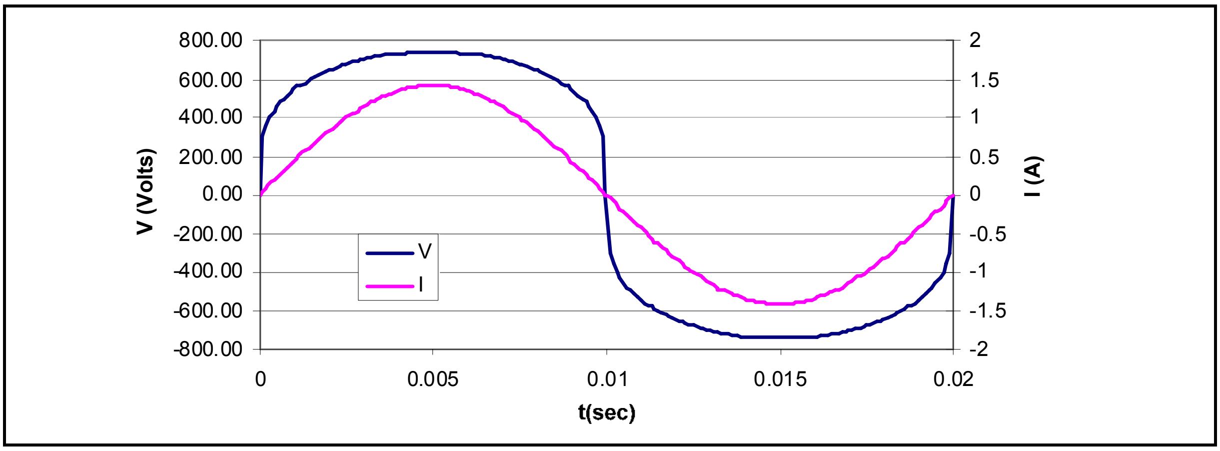


FIGURE 3: VARISTOR VOLTAGE AND CURRENT WAVEFORMS – SINUSOIDAL CURRENT APPLIED

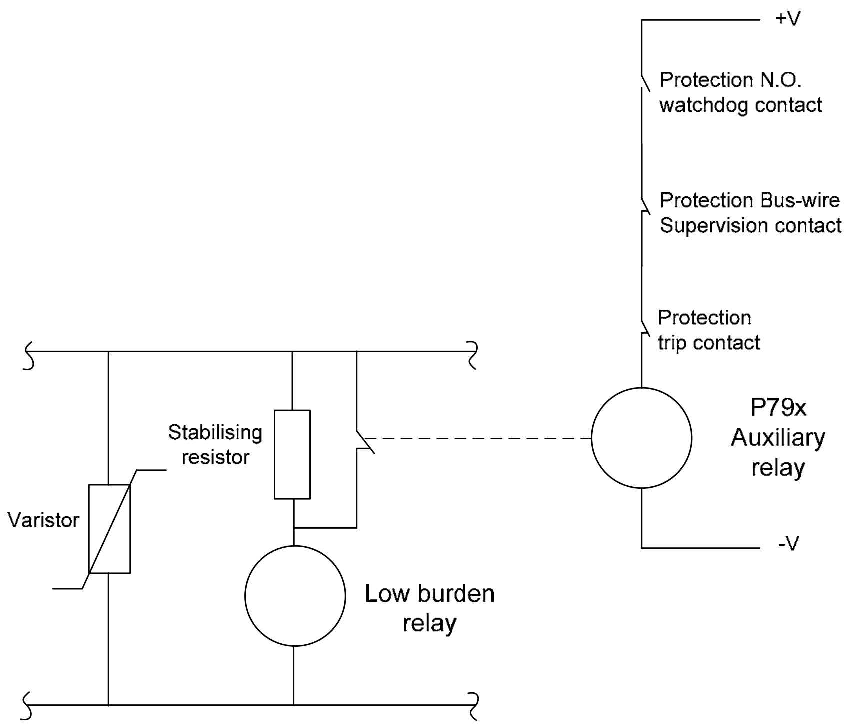
2.3 Auxiliary relays

The main objective of the auxiliary relays is to reduce the energy dissipation in the varistors and resistors. This is accomplished by short circuiting the high impedance path immediately after the protection trips. If the relay burden is negligible, such as the P72x, then it is not necessary to short circuit the relay. On the other hand if the relay burden is high, such as the MCAG14/34, then it is mandatory to short circuit the relay.

Figure 4 indicates that the auxiliary relay within the P79x is permanently energised while the protection is operative and it has not tripped. One normally open watchdog contact, one normally closed contact configured as trip, and one normally closed contact configured as bus-wire supervision energise the P79x auxiliary relay. Note that if the protection has not tripped, then the normally closed contact configured as trip remains closed. Also if the bus-wire supervision is not asserted, then the normally closed contact configured as bus-wire remains closed. If the protection is operative, then the normally open watchdog contact is closed. As a result, the auxiliary relay is energised and the auxiliary relay normally closed contact is kept open. The P79x auxiliary relay is de-energised when the protection relay trips because the normally closed trip contact opens. As a result, the auxiliary relay contacts closes, short circuiting the stabilizing resistor; therefore, providing the protection required. Since the burden of the relay is low, the varistor is also short circuited. In addition, if the DC supply is lost, the P79x auxiliary relay is also de-energised protecting the components.

It is also recommended to short circuit the high impedance path when the protection is out of service. If an internal fault occurs in the protected object, and the protection is out of service, the resistors and varistors in the P79x case may be subjected to energy levels well above their withstand limits. Under this condition the fault will be cleared by a backup protection, but by the time this protection operates, the P79x elements may have burned due to the excessive energy dissipation. It is important to consider that the varistor is designed to conduct certain amount of energy for very short durations; it does not have the capability to conduct sustained energy.

If a CT bus-wire failure occurs, then rated current could flow through the combined relay-stabilizing resistor-varistor path. As a result, significant current may be passed through the resistors or varistors for a considerable time. It is important to assure that the varistors and resistors are within their thermal withstand limits if this condition occurs.



Note:
1. The protection trip contact is normally closed. It opens when the relay trips.
2. The protection watchdog contact is normally open. It is closed when the relay is healthy.
3. The protection bus-wire supervision contact is normally closed. It opens for bus-wiring fault

P0895ENa

FIGURE 4: AUXILIARY RELAY SHORTING THE HIGH IMPEDANCE PATH - LOW BURDEN RELAY

Figure 5 shows that the relay should also be short circuited because its burden is high. Therefore, to effectively short circuit the varistor it is necessary to short circuit the differential relay.

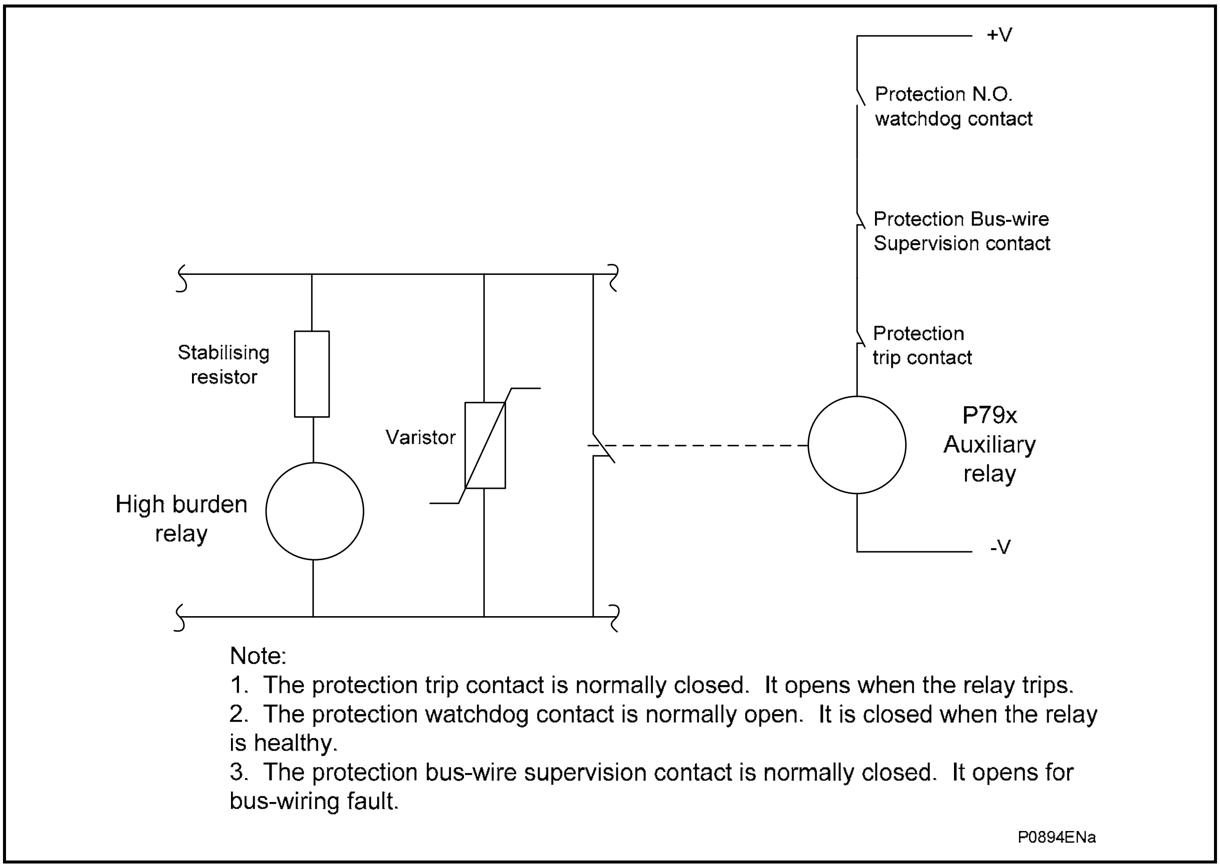


FIGURE 5: AUXILIARY RELAY SHORTING THE HIGH IMPEDANCE PATH - HIGH BURDEN RELAY

The differential relay watchdog contact is required by the P79x and by a SCADA system. When only one watchdog contact is available, it may be necessary to use an additional auxiliary relay external to the P79x case to multiply the watchdog signal. The external auxiliary relay contacts may be used to send the watchdog signal to a SCADA system and to the auxiliary relay in the P79x case. For example, one MVAA11 auxiliary relay may be used.

It is recommended to use the P79x auxiliary relay normally closed contacts as shown in Figure 4 and Figure 5. If the auxiliary relay DC supply fails, and a fault occurs, then the P79x elements will be protected against thermal damage. Under this condition, the backup protection should clear the fault. For a typical application where the P79x is fed from the same DC supply as the numerical differential relay, if the DC supply to this relay is wired as a single line and the relay is the last in the run, then the DC supervision of the P79x could be done by the numerical differential relay. This is assuming a separate supply supervision alarm is not required independently to the differential protection fail alarm. On the other hand, if the P79x DC supply is separately fused from that of the differential relay, then it is recommended to use a DC supervision relay such as the MVAX12 to provide the necessary alarm.

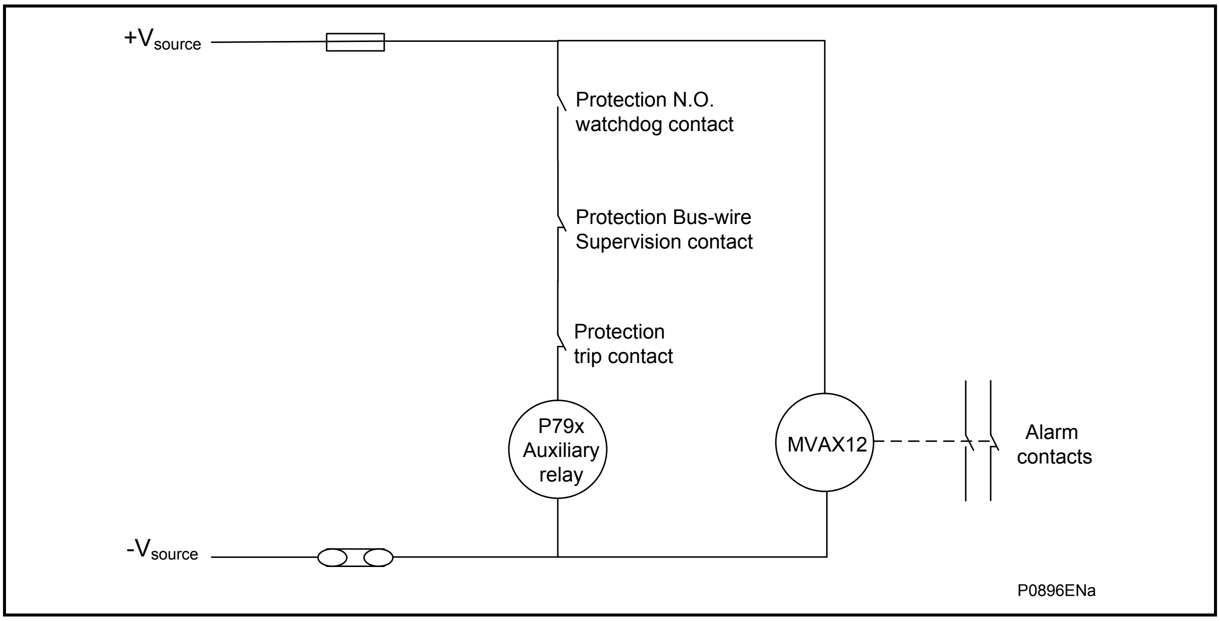


FIGURE 6: AUXILIARY RELAY DC SUPPLY SUPERVISION

It is important to note that failure to operate the resistors and varistors within their thermal limits may cause fire. The use of the P79x auxiliary relays is highly recommended to avoid this risk. It is mandatory to carefully consider the P79x energy dissipation capabilities under different conditions. In Section 4 P79x Application, advice is given on how to determine if the P79x is suitable for a particular application. Schneider Electric has developed a spreadsheet tool that calculates the maximum prospective current that the varistors and resistors can withstand. The user only needs to specify the CT primary and secondary rated current, the knee point voltage, the initial flux, the primary system time constant and the maximum fault duration to use the spreadsheet tool.

3. P79x ENERGY LIMIT TOOL

The P79x Energy Limit Tool is a spreadsheet file and it was developed by Schneider Electric to assist in determining the suitability of the P79x for a given application. This file has three worksheets as follows:

– P790_limits

– Resistors spec

– Varistors spec

The following sections discuss the use of these worksheets.

3.1 P790_limits

The P790_limits worksheet calculates the maximum prospective current that the P79x stabilizing resistor and varistor can withstand.

The user should set the CT primary and secondary currents, the knee point voltage, the initial flux, the primary time constant (only when transient CT saturation is considered) and the fault duration on the P790_limits worksheet. Then when the **Update all data** button is clicked, the maximum current levels are calculated for the different stabilizing resistance and varistor combinations. The following fault durations are considered 0.05s, 0.1s, 0.3s, 1s and 3s.

Also the maximum current withstand is calculated for the resistance only and for the varistor only. These are required under certain conditions such as the one discussed in Section 4.6.

The P790_limits tool performs iterative calculations to establish the maximum current that the P79x components might withstand. The calculations end and the maximum current is displayed when the energy or power rating is reached. The 100 ms energy rating and the permanent, 1 s and 3 s power ratings are known. If the maximum fault duration setting is set to a value other than 100 ms, 1 s or 3 s, the P790_limits tool interpolates the power rating.

FIGURE 7 shows the maximum prospective current that the P79x components can withstand. Note that steady state CT saturation and an initial flux of -100% are considered. To take into account steady state CT saturation the primary time constant should be set to a very small value. Note that Primary T C (s) can not be set to zero, but it can be set to a very small value such as 1e-100.

Parameters

CT primary winding (A)	1200
CT secondary winding (A)	5
Knee Point Voltage Vk (V)	480
Initial Flux (%)	-100
Primary TC (s)	0.00

Update All data | Update Res & Var | Update Res Only | Update Var Only

Maximum secondary current (A) – Resistor + Varistor

Resistance number	Req	R1	R2	R3	Mounting 1=parallel 2=serial	9kJ .05s	9kJ .1s	9kJ .3s	9kJ 1s	9kJ 3s	18kJ .05s	18kJ .1s	18kJ .3s	18kJ 1s	18kJ 3s
1	496	165	165	165	2	58.8	57.3	12.6	9.3	4.5	87.0	85.6	23.3	13.7	
2	330	165	165	0	2	46.9	11.0	4.3	4.2	3.3	88.0	19.1	6.6	6.5	
3	83	165	165	0	1	10.0	5.8	3.9	3.9	3.4	12.5	6.5	4.1	4.1	
4	55	165	165	165	1	13.7	8.3	5.6	5.6	5.0	16.4	9.1	5.9	5.9	
5	1500	500	500	500	2	57.4	55.5	20.7	8.2	3.7	85.6	63.9	32.3	12.6	
6	1000	500	500	0	2	57.7	38.1	20.2	8.4	3.9	85.9	74.7	32.7	12.9	
7	250	500	500	0	1	12.2	4.7	3.7	3.6	2.9	20.7	6.9	5.0	5.0	
8	167	500	500	500	1	14.0	6.0	4.7	4.7	3.9	22.6	8.2	6.2	6.1	
9	3300	1100	1100	1100	2	56.9	53.1	20.3	7.9	3.4	85.2	83.4	32.0	12.4	
10	2200	1100	1100	0	2	57.1	55.2	20.5	8.0	3.5	85.3	83.6	32.1	12.5	
11	550	1100	1100	0	1	35.4	8.5	7.7	7.5	4.3	68.7	15.4	13.6	13.3	
12	367	1100	1100	1100	1	36.7	9.3	8.3	8.3	4.9	69.8	16.3	14.4	14.1	

Maximum secondary current (A) – Res only

Resistance number	.05s	.1s	.3s	1s	3s
1	4.4	2.5	1.7	1.7	1.5
2	3.6	2.4	1.7	1.7	1.5
3	7.0	4.8	3.5	3.5	3.1
4	10.4	7.3	5.2	5.2	4.6
5	2.9	1.5	1.2	1.2	1.0
6	1.9	1.1	1.0	1.0	0.9
7	3.3	2.3	2.0	2.0	1.8
8	4.8	3.4	3.0	3.0	2.7
9	2.5	1.3	1.5	1.6	1.2
10	1.8	0.8	0.8	0.8	0.6
11	2.0	1.4	1.3	1.3	1.2
12	3.0	2.1	2.0	2.0	1.8

Maximum secondary current (A) – Varistor Only

9kJ .05s	9kJ .1s	9kJ .3s	9kJ 1s	9kJ 3s	18kJ .05s	18kJ .1s	18kJ .3s	18kJ 1s	18kJ 3s
28.3	28.3	11.5	4.3	1.8	56.6	56.6	23.0	8.7	3.7

Maximum primary current (kA) – Resistor + Varistor

Resistance number	9kJ .05s	9kJ .1s	9kJ .3s	9kJ 1s	9kJ 3s	18kJ .05s	18kJ .1s	18kJ .3s	18kJ 1s	18kJ 3s
1	14	14	3	2	1	21	21	6	3	0
2	11	3	1	1	1	21	5	2	2	0
3	2	1	1	1	1	3	2	1	1	0
4	3	2	1	1	1	4	2	1	1	0
5	14	13	5	2	1	21	20	8	3	0
6	14	9	5	2	1	21	18	8	3	0
7	3	1	1	1	1	5	2	1	1	0
8	3	1	1	1	1	5	2	1	1	0
9	14	13	5	2	1	20	20	8	3	0
10	14	13	5	2	1	20	20	8	3	0
11	8	2	2	2	1	16	4	3	3	0
12	9	2	2	2	1	17	4	3	3	0

Maximum primary current (kA) – Res only

Resistance number	.05s	.1s	.3s	1s	3s
1	1	1	0	0	0
2	1	1	0	0	0
3	2	1	1	1	1
4	2	2	1	1	1
5	1	0	0	0	0
6	0	0	0	0	0
7	1	1	0	0	0
8	1	1	1	1	1
9	1	0	0	0	0
10	0	0	0	0	0
11	0	0	0	0	0
12	1	1	0	0	0

Maximum primary current (kA) – Varistor Only

9kJ .05s	9kJ .1s	9kJ .3s	9kJ 1s	9kJ 3s	18kJ .05s	18kJ .1s	18kJ .3s	18kJ 1s	18kJ 3s
7	7	3	1	0	14	14	6	2	1

FIGURE 7: P790_LIMITS WORKSHEET – STEADY STATE CT SATURATION

FIGURE 8 shows the maximum prospective current that the P79x components can withstand. Note that transient CT saturation is considered. It is important to consider transient CT saturation especially when the fault duration (s) ≤ 100 ms. The Primary T C (s) should be set to consider transient CT saturation. In this example X/R = 15. The time constant is calculated as $\tau = \dfrac{X}{R \times 2\pi f}$. Consider that f = 50 Hz and X/R = 15, then $\tau = 0.048s$

The Primary T C (s) is set to 0.048 s. It is also possible to set the initial flux, and it might be of positive or negative polarity. It is not easy to determine what would be the initial flux in the CT. For example, a high remanence CT such as class C (IEEE) and classes P or TPX (both IEC) might have an initial flux that can be as high as 70 to 80% of the saturation flux. In this example, a -100% initial flux is considered (worst condition).

Parameters

Parameters	
CT primary winding (A)	1200
CT secondary winding (A)	5
Knee Point Voltage Vk (V)	480
Initial Flux (%)	-100
Primary TC (s)	0.048

Update All data | Update Res & Var | Update Res Only | Update Var Only

Resistance number	Req	R1	R2	R3	Mounting 1=parallel 2=serial	Maximum secondary current (A)														
						Resistor + Varistor										Res only				
						9kJ					18kJ									
						.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s
1	495	165	165	165	2	34.0	34.0	15.6	9.4	4.5	48.9	48.9	28.9	13.9	6.4	7.9	3.5	1.9	1.8	1.6
2	330	165	165	0	2	34.7	20.4	4.9	4.4	3.3	49.5	36.9	7.7	6.9	4.8	5.9	3.2	1.8	1.8	1.6
3	83	165	165	0	1	14.2	7.1	3.9	3.9	3.4	17.6	8.1	4.2	4.1	3.6	7.1	5.1	3.5	3.5	3.1
4	55	165	165	165	1	18.4	9.9	5.7	5.6	5.0	22.6	11.0	6.0	5.9	5.1	10.6	7.7	5.1	5.2	4.6
5	1500	500	500	500	2	33.2	33.2	22.5	8.3	3.7	48.1	48.1	35.1	12.8	5.5	5.2	2.1	1.4	1.2	1.0
6	1000	500	500	0	2	33.3	33.3	22.9	8.6	3.9	48.3	48.3	35.4	13.1	5.7	3.3	1.5	1.1	1.0	0.9
7	250	500	500	0	1	25.0	6.9	4.1	3.8	2.9	44.5	10.6	5.7	5.2	3.9	4.2	2.7	2.1	2.0	1.8
8	167	500	500	500	1	27.7	8.5	5.2	4.8	3.9	47.2	12.4	6.9	6.3	4.8	6.4	3.9	3.1	3.0	2.7
9	3300	1100	1100	1100	2	33.0	33.0	22.0	8.1	3.4	47.8	47.8	34.5	12.6	5.3	5.3	1.9	1.6	1.6	1.2
10	2200	1100	1100	0	2	33.1	33.1	22.3	8.2	3.5	47.9	47.9	34.7	12.7	5.4	2.6	1.1	0.9	0.8	0.6
11	550	1100	1100	0	1	33.9	15.9	9.1	8.0	4.4	48.8	29.4	16.6	13.8	6.2	3.2	1.8	1.4	1.4	1.2
12	367	1100	1100	1100	1	34.5	16.9	10.0	8.8	4.9	49.3	30.5	17.4	14.5	6.8	4.7	2.6	2.1	2.0	1.8

Resistance number	Maximum primary current (kA)														
	Resistor + Varistor										Res only				
	9kJ					18kJ									
	.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s
1	8	8	4	2	1	12	12	7	3	2	2	1	0	0	0
2	8	5	1	1	1	12	9	2	2	1	1	1	0	0	0
3	3	2	1	1	1	4	2	1	1	1	2	1	1	1	1
4	4	2	1	1	1	5	3	1	1	1	3	2	1	1	1
5	8	8	5	2	1	12	12	8	3	1	1	1	0	0	0
6	8	8	5	2	1	12	12	8	3	1	1	0	0	0	0
7	6	2	1	1	1	11	3	1	1	1	1	1	1	0	0
8	7	2	1	1	1	11	3	2	2	1	2	1	1	1	1
9	8	8	5	2	1	11	11	8	3	1	1	0	0	0	0
10	8	8	5	2	1	11	11	8	3	1	1	0	0	0	0
11	8	4	2	2	1	12	7	4	3	1	1	0	0	0	0
12	8	4	2	2	1	12	7	4	3	2	1	1	1	0	0

Varistor Only										
	9kJ					18kJ				
	.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s
Maximum secondary current (A)	15.7	15.7	12.4	4.4	1.8	31.3	31.3	24.8	8.9	3.7
Maximum primary current (kA)	4	4	3	1	0	8	8	6	2	1

FIGURE 8: P790_LIMITS WORKSHEET – TRANSIENT CT SATURATION

From the results shown in FIGURE 7 and FIGURE 8, always choose the lowest current. For example, consider Req = 495 Ω, Resistor + Varistor 9 kJ and fault duration of 50ms. The transient CT saturation results in a maximum secondary current of 34 A. The steady state CT saturation results in a maximum secondary current of 58.8 A. The lower of the two currents should be considered. In this example, the P79x is suitable as long as the fault level current is below 34 A (transient CT saturation).

Now consider Req = 83 Ω and Resistor + Varistor 9 kJ. The transient CT saturation results in a maximum secondary current of 14.2 A. The steady state CT saturation results in a maximum secondary current of 10 A. The lower of the two currents should be considered. In this example, the P79x is suitable as long as the fault level current is below 10 A (steady state CT saturation).

As long as the current calculated by the P790_limits worksheet is below the current level calculated in a fault study, it is feasible to use the P79x.

3.2 Resistor Spec

The Resistor Spec worksheet considers the thermal withstand limit of the stabilizing resistance combinations in the P79x.

Option A = Based on 165 ohms resistors (5x 33ohms)
Option B = Based on 500 ohms resistors (5x 100ohms)
Option C = Based on 1100 ohms resistors (5x 220ohms)

											TOL		Maximum settings		Current rating (mA)				Ratio current rating / max settings		
	Option	Wiring	Req					Req	Rlim	Coef	Factor	Emax	Is (mA)	Vs (V)	Permanent	100 ms	1s	3s	100ms	1s	3s
1	A	1+2+3	495	165	165	165	2	495	165	1	1.05	100	364	180	364	2462	1784	1595	7	5	4
2	A	1+2	330	165	165		2	330	165	1	1.05	100	461	152	461	2462	1784	1595	5	4	3
3	A	1//2	83	165	165		1	82.5	165	0.5	1.05	100	921	76	921	4924	3568	3191	5	4	3
4	A	1//2//3	55	165	165	165	1	55	165	0.333	1.068	100	1382	76	1382	7385	5351	4786	5	4	3
5	B	1+2+3	1500	500	500	500	2	1500	500	1	1.05	65	120	180	120	1140	1025	917	10	9	8
6	B	1+2	1000	500	500		2	1000	500	1	1.05	65	180	180	180	1140	1025	917	6	6	5
7	B	1//2	250	500	500		1	250	500	0.5	1.05	65	529	132	529	2280	2049	1833	4	4	3
8	B	1//2//3	167	500	500	500	1	167	500	0.333	1.068	65	794	132	794	3421	3074	2750	4	4	3
9	C	1+2+3	3300	1100	1100	1100	2	3300	1100	1	1.05	55	55	180	55	707	691	618	13	13	11
10	C	1+2	2200	1100	1100		2	2200	1100	1	1.05	55	82	180	82	707	691	618	9	8	8
11	C	1//2	550	1100	1100		1	550	1100	0.5	1.05	55	327	180	327	1414	1382	1236	4	4	4
12	C	1//2//3	367	1100	1100	1100	1	367	1100	0.333	1.068	55	491	180	491	2121	2073	1854	4	4	4

FIGURE 9: RESISTOR SPEC WORKSHEET

As indicated in Section 2.1, three options of stabilizing resistance are available. The "Req" is the equivalent resistance and it may be equal to three resistors in parallel, three resistors in series, two resistors in parallel or two resistors in series.

The "Rlim" indicates the value of the resistor that will limit the current withstand of the equivalent resistance. The resistors connected in parallel or in series are equal. Therefore, "Rlim" is 165 Ω, 500 Ω or 1100 Ω depending on which option has been selected. Note that if the resistors were not equal, then "Rlim" is the lowest resistor for resistors in parallel. The reason is that more current will flow in the lower resistor. On the other hand, if the resistors are in series, the limiting resistor is the higher one. The reason is that the current through the series path is limited by the higher resistor value.

The "Coef" is the ratio of Req/Rlim when the resistors are in parallel. "Coef" is always 1 when the resistors are in series. If the resistors are connected in parallel, then the permanent power rating is increased by the "Coef" value. "Coef" is a measure of how much current flows through a resistor. Therefore, when the resistors are in series "Coef" = 1, whereas when the resistors are in parallel "Coef" = 0.5 or 0.3 with 2 or 3 resistors respectively. For example, consider that two or three 165 Ω resistors are connected in parallel. The permanent power rating of one 165 Ω resistor is 35 W. The permanent rating of the two resistors connected in parallel is 70 W (2 × 35 W), and the permanent rating of the three resistors connected in parallel is 105 W (3 × 35 W). The permanent power rating of two resistors connected is series is 70W and of three resistors connected in series is 105W.

For example, the permanent current rating of the 82.5 stabilizing resistance (line No. 3, Option A in Figure 9) is calculated as follows:

$$I = \frac{\sqrt{\dfrac{P}{R\lim}}}{coef} = \frac{\sqrt{\dfrac{35}{165}}}{0.5} \times 1000 = 921\,mA$$

The above is equivalent to:

$$I = \sqrt{\frac{P}{\mathrm{Re}\,q}} = \sqrt{\frac{70}{82.5}} \times 1000 = 921\,mA$$

The TOL Factor accounts for the tolerances of the equivalent resistances. Each resistor has a tolerance of ±5%. The spreadsheet tool considers the highest tolerance because this will result in the highest energy dissipation. When the resistors are in series, the highest TOL Factor is 1.05. When two resistors are in parallel the highest TOL Factor is 1.05. When three resistors are in parallel the highest TOL factor is 1.068 and it is obtained when two resistors are 1.05R and one resistor is 0.95R. R is the resistor nominal value. The TOL factor is used among other factors to calculate the energy dissipated in the resistor.

The maximum energy that can be withstood by Rlim is indicated as Emax. The 165Ω resistor can withstand a maximum of 100 J; the 500 Ω resistor can withstand a maximum of 65 J and the 1100 Ω resistor can withstand a maximum of 55 J.

In 1 A CT applications, the maximum current flowing through the varistor at the voltage setting must not exceed 30 mA. In 5 A CT applications, the maximum current flowing through the varistor at the voltage setting must not exceed 100 mA. These requirements must be fulfilled so that the differential protection is not desensitized significantly. Therefore, when calculating the maximum settings, make sure that the Vs maximum settings are as follows:

Maximum AC Voltage Setting		
	1 A CT	5 A CT
Option H (10 kJ)	150 V	210 V
Option F (20 kJ)	130 V	180 V

For example, if Option F is used with a 5 A CT secondary, the maximum voltage setting is 180 V. If the stabilizing resistance is equal to 495 Ω, the permanent current rating is calculated as:

$$I = \frac{\sqrt{\frac{P}{R\lim}}}{coef} = \frac{\sqrt{\frac{35}{165}}}{1} \times 1000 = 461\,mA$$

The Vs setting at the permanent current rating is as follows:

$$\mathrm{Vs} = \mathrm{I_r} \times \mathrm{R} = 0.461 \times 495 = 228\ \mathrm{V}$$

Where:

Vs = stability voltage

Ir = relay setting

Note that this setting is not suitable for this particular application; therefore, Vs should be limited to 180 V. As a result, the maximum Ir setting should be 180/495 *1000 = 364 mA approximately.

The power rating of each resistor (33 Ω, 100 Ω and 220 Ω) is as follows:

	Option A	Option B	Option C
Resistor value	33 Ω	100 Ω	220 Ω
Continuous power	7 W	7 W	7 W
Energy for one shot up to 100ms	20 J	13 J	11 J
Power for one shot 100ms and 1s	105 W	105 W	105 W
Power for one shot 3s	84 W	84 W	84 W
Power for one shot 5s	77 W	77 W	77 W
Power for one shot 8s	73.5 W	73.5 W	73.5 W
Power for one shot 10s	70 W	70 W	70 W

NOTE: To obtain the power rating of Rlim the values of energy and power in the table above must be multiplied by five.

Consider option A, the 100 ms current rating in mA uses the 100 J rating (20 × 5 = 100 J), and it is calculated as follows:

$$I = \frac{\sqrt{\dfrac{energy}{time \times R\lim}}}{coef} \times 1000$$

Consider that two or three 165 Ω resistors are connected in series, the 100 ms current withstand limit is as follows:

$$I = \frac{\sqrt{\dfrac{energy}{time \times R\lim}}}{coef} \times 1000 = \frac{\sqrt{\dfrac{100}{0.1 \times 165}}}{1} \times 1000 = 2462\ mA$$

Consider that two165 Ω resistors are connected in parallel, the 100 ms current withstand limit is as follows:

$$\mathrm{I} = \frac{\sqrt{\dfrac{\mathrm{energy}}{\mathrm{time} \times \mathrm{R\lim}}}}{\mathrm{coef}} \times 1000 = \frac{\sqrt{\dfrac{100}{0.1 \times 165}}}{0.5} \times 1000 = 4924\ \mathrm{mA}$$

The above is equivalent to:

$$\mathrm{I} = \sqrt{\frac{\mathrm{energy}}{\mathrm{time} \times \mathrm{Req}}} \times 1000 = \sqrt{\frac{200}{0.1 \times 82.5}} \times 1000 = 4924\ \mathrm{mA}$$

Consider that two 500 Ω resistors are connected in parallel, the 1 s current withstand limit is as follows:

$$\mathrm{I} = \frac{\sqrt{\dfrac{\mathrm{P}}{\mathrm{R\lim}}}}{\mathrm{coef}} \times 1000 = \frac{\sqrt{\dfrac{525}{500}}}{0.5} \times 1000 = 2049\ \mathrm{mA}$$

The above is equivalent to:

$$\mathrm{I} = \sqrt{\frac{\mathrm{P}}{\mathrm{Req}}} \times 1000 = \sqrt{\frac{1050}{250}} \times 1000 = 2049\ \mathrm{mA}$$

Consider that three or two 500 Ω resistors are connected in series, the 1 s current withstand limit is as follows:

$$\mathrm{I} = \frac{\sqrt{\dfrac{\mathrm{P}}{\mathrm{R\lim}}}}{\mathrm{coef}} \times 1000 = \frac{\sqrt{\dfrac{525}{500}}}{1} \times 1000 = 1025\ \mathrm{mA}$$

The 3 s current withstand limit is calculated similarly to the 1 s current withstand limit.

3.3 Varistor Spec

In the varistor spec worksheet, the varistor characteristics are given.

U = 270V

A = 1.73×10^{-11}

k = 3.8

Imax = 40A

I = 15-30 mA at the rated DC voltage

Umax = 2200V

P = 9 W

E = 3000J

Where:

U = rated dc voltage

A = varistor constant

k = varistor non-linearity constant

I = continuous current (A DC) at the rated dc voltage

Umax = maximum clamping voltage

P = continuous rated power per varistor

E = maximum energy per varistor

The maximum amount of voltage that a surge protector will allow through itself before it will suppress the power surge. When the device reaches its clamping voltage, it blocks any further current from flowing through the device and into a computer system or other electronic device.

4. P79x APPLICATION

In this section, a list of advice is given so that the user can determined if the P79x may be used in any particular application.

The first step is to verify how much current the varistors may conduct at the voltage setting. It is important to verify that the current drawn by the varistors at the voltage setting does not desensitise the relay significantly. Therefore, check that in 1 A CT applications, the maximum current flowing through the varistor at the voltage setting does not exceed 30 mA. Verify that in 5 A CT applications, the maximum current flowing through the varistor at the voltage setting does not exceed 100 mA. To comply with this requirement, the maximum voltage settings are as follows:

Maximum AC Voltage Setting		
	1A CT	5A CT
Option H (10 kJ)	150 V	210 V
Option F (20 kJ)	130 V	180 V

If the voltage setting required is equal or less than the voltages given in the table above, then it is possible to use the P79x.

Consider an internal fault and that the CT does not saturate. Figure 10 shows a 1 A rms sinusoidal current waveform, and it is the total secondary internal fault current that is distributed between the stabilizing resistor and varistor. The voltage waveform and the current distribution between the stabilizing resistor and varistor are given in Figure 10. A stabilizing resistor of 1000 Ω is used in this example.

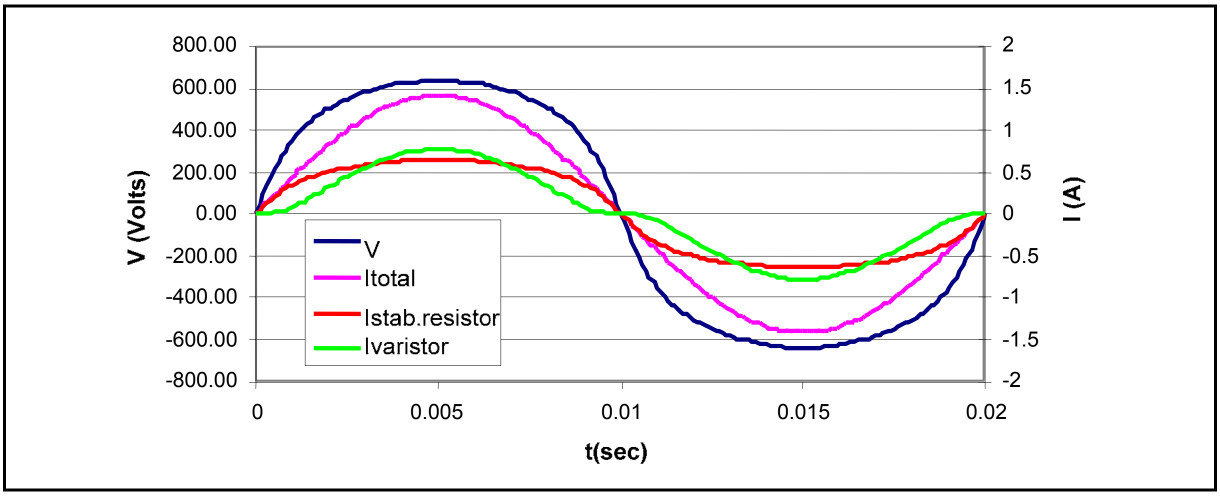


FIGURE 10: CURRENT DISTRIBUTION: STABILIZING RESISTOR-VARISTOR

The following equation describes the relationship between flux and voltage: $\phi = \frac{1}{N}\int e dt$.

Where:

ϕ	=	flux
N	=	number of turns
e	=	voltage

The flux waveform is the area below the voltage waveform divided by the number of turns. It has been assumed that the number of turns is 100. When no saturation occurs, the flux in the CT core is as follows:

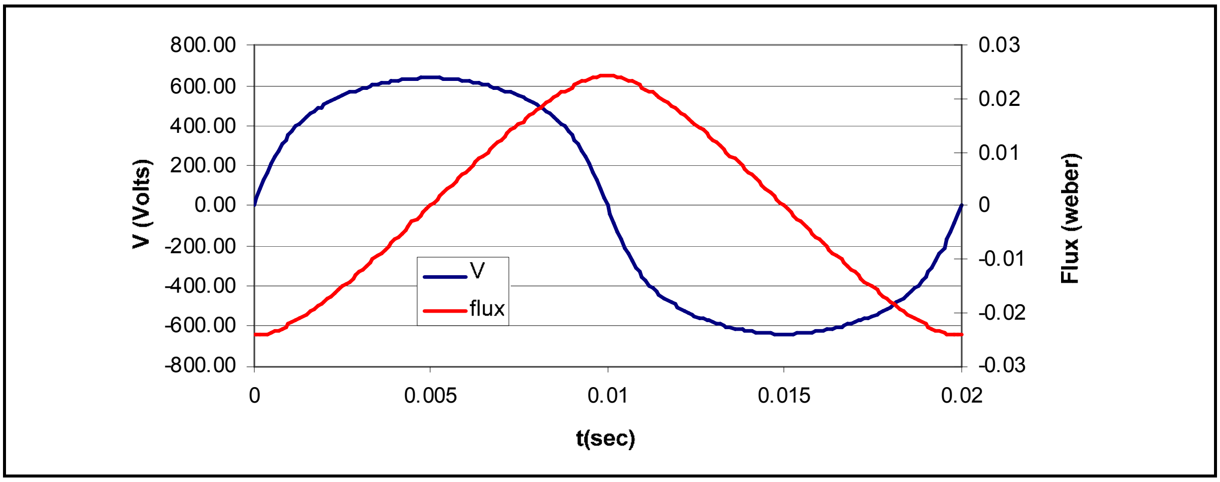


FIGURE 11: FLUX IN THE CT CORE

Now assume a CT knee point voltage equal to 200 V and that the secondary winding turns is 100. Then the steady state voltage and flux waveforms are as shown in Figure 12. Note that the maximum change in flux is 0.018 webers.

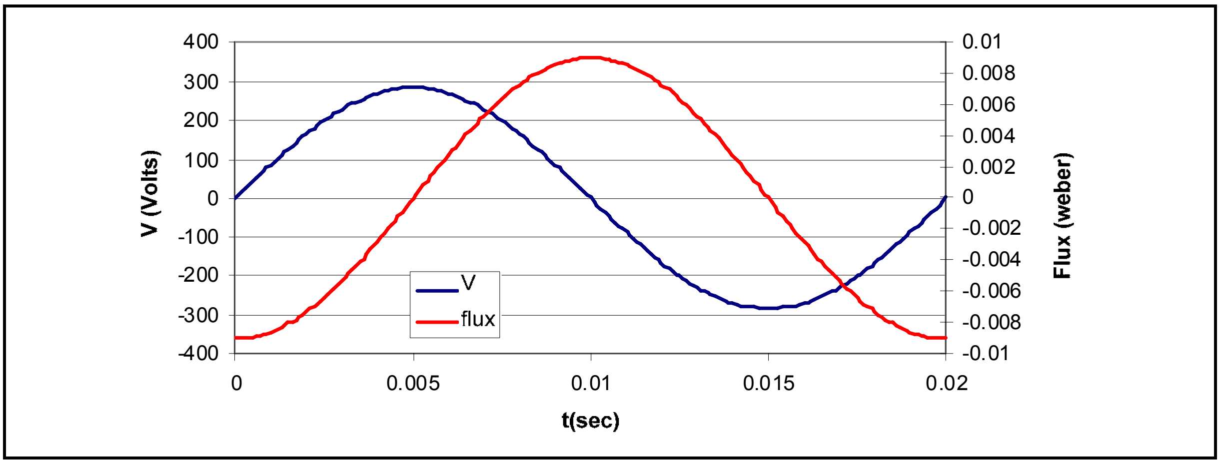


FIGURE 12: CT VOLTAGE AND FLUX WAVEFORM AT THE KNEE POINT VOLTAGE

If the voltage and flux waveforms given in Figure 11 are applied to the CT described in Figure 12, then this CT would saturate. Note that in this example only steady state saturation is considered. The voltage and flux waveforms during saturation are shown in Figure 13. Note that during each half cycle the CT conducts approximately during 4 ms.

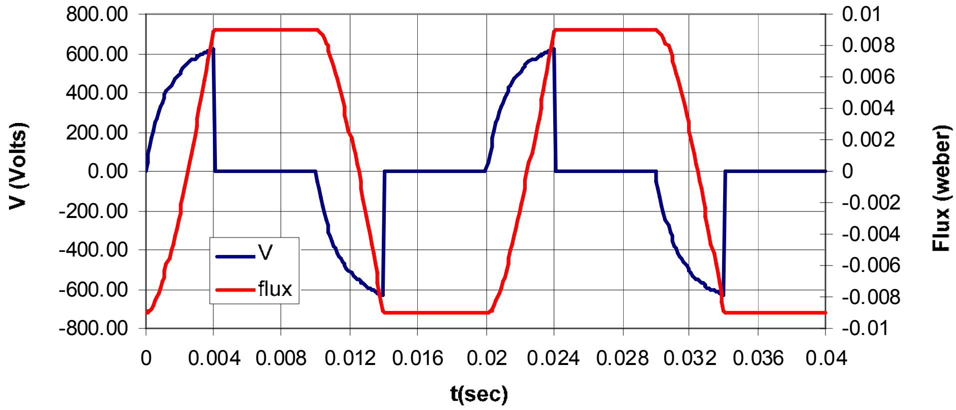


FIGURE 13: FLUX AND VOLTAGE WAVEFORMS UNDER SATURATION

The current waveforms during saturation are shown in Figure 14.

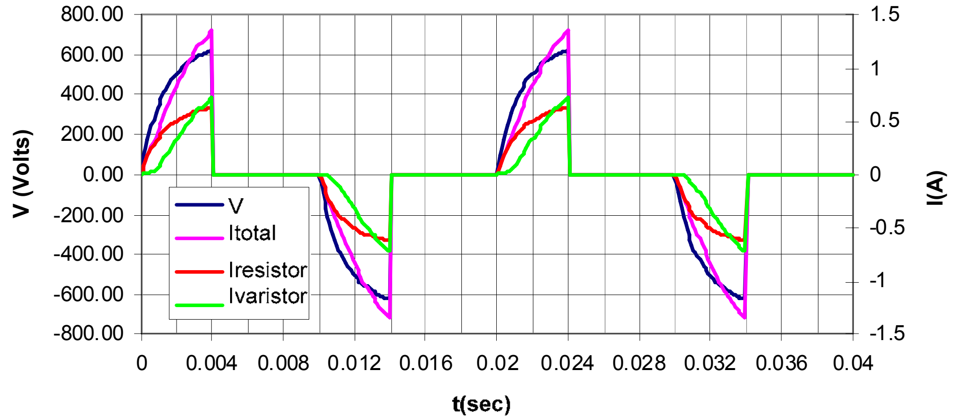


FIGURE 14: CURRENT, FLUX AND VOLTAGE WAVEFORMS
UNDER STEADY STATE SATURATION

From the waveforms given above, it can be deduced that complex analysis is required to establish whether each component is adequately rated for the application. Schneider Electric have developed a spreadsheet to assist in determining the suitability of the P79x for your application. This can be downloaded from our website www.schneider-electric.com.

Different scenarios should be studied to ensure that the P79x will be safely applied. It is important to consider the thermal withstand of the elements constituting the P79x under different conditions. The conditions to be considered must include successful and failure scenarios.

The conditions given in sections 4.1 to 4.6 should be verified using the P79x Energy Limit Tool provided by Schneider Electric. The calculation of the maximum current that the resistor may withstand considers that the transient energy is 20 Joules per resistor, and the transient duration is <100 ms. Since each equivalent resistance is formed by 5 resistors in series, the total transient energy is 100 Joules. The following thermal withstand coefficients are also considered:

Pulse duration (sec)	**K (thermal coefficient)**
0.1-1	15
3	12
5	11
8	10.5
10	10

The calculation of the maximum current that the varistor may withstand considers the maximum transient energy. Two options are available: in the half-power option three varistors are connected in parallel and the transient energy is 10 kJ; in the full-power option, six varistors are in parallel and the transient energy is 20 kJ.

The current level calculated by this tool is the maximum propective current that the resistors and varistors may withstand. The prospective current is the rms quantity of a sinusoidal current waveform. Note that even though the tool output is the prospective current, the spreadsheet tool accounts for steady state CT saturation and transient CT saturation to calculate the thermal withstands (maximum secondary currents).

The following example shows the calculation of the energy dissipated across the 367 Ω stabilizing resistance. Consider an internal fault in the 50 Hz system shown in FIGURE 15. The fault is only fed from one end, the CT's are 1000:1, the Vk is 1000V. To make the calculations easier, consider steady state saturation (note that for internal faults transient CT saturation must be considered) and that no varistors are required.

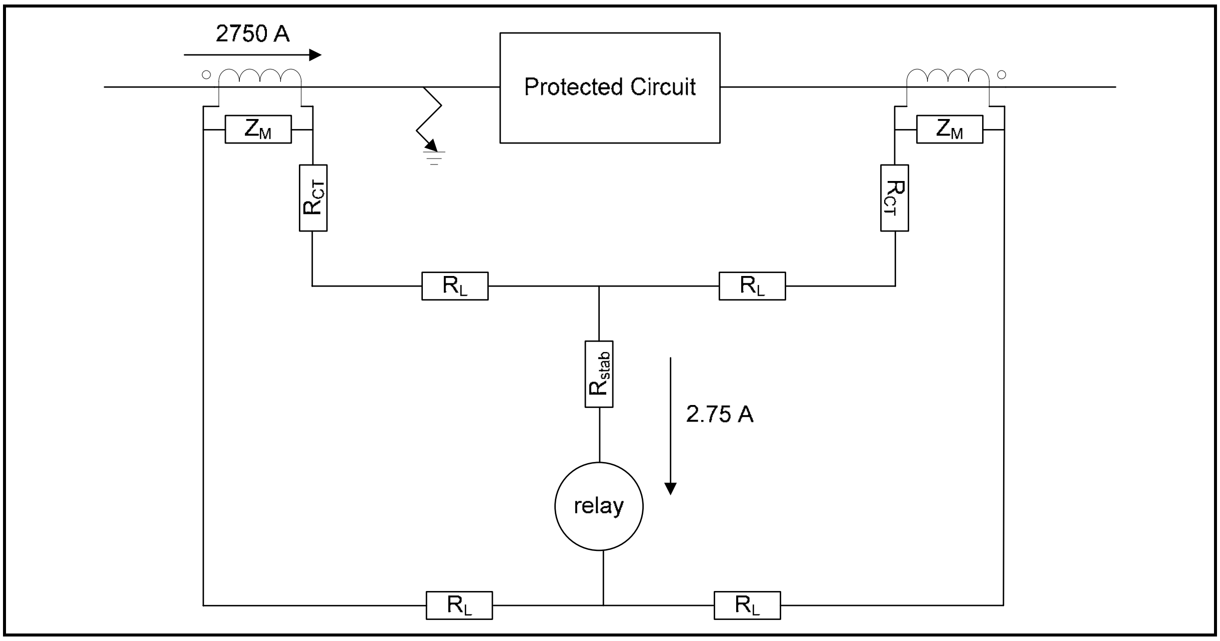


FIGURE 15: HIGH IMPEDANCE DIFFERENTIAL SCHEME – INTERNAL FAULT

The voltage and current waveforms for this example are shown in FIGURE 16.

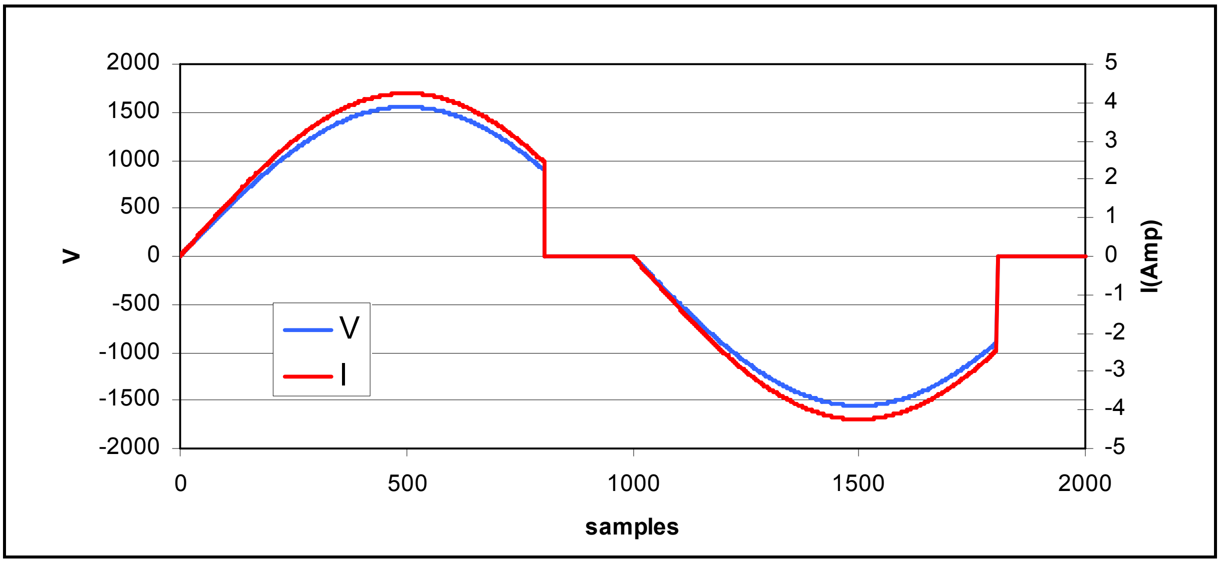


FIGURE 16: VOLTAGE AND CURRENT WAVEFORMS – INTERNAL FAULT

The total current flowing through the stabilizing resistance is:

$$I_{stab} = \frac{\sqrt{\dfrac{P}{R\lim}}}{coef}$$

Therefore, the energy dissipated across the 367Ω is calculated using the following formula:

$$Energy = (I_{stab} \times coef)^2 \times R\lim \times TOL\_factor \times time$$

The total energy is calculated by adding the energy at each sample. The total energy at sample 'n+1' is equal to the energy at sample 'n' plus the energy at sample 'n+1'. In this example, at the end of 1 cycle the energy dissipated across the stabilising resistance is 19.7 J.

In the spreadsheet tool the permanent, 100 ms, 1 s and 3 s energy or power ratings are known. Iterative calculations are performed to work out the maximum current that the P79x resistors/varistors can withstand. The calculations end, and the maximum current is displayed when the energy or power rating is reached. Iterative calculations are performed until the maximum energy/power withstand is reached. If this maximum power/energy withstand is not reached, then the P790_limits tool displays 399.60 A as the maximum secondary current.

4.1 Internal fault – high impedance scheme successful operation

It is expected that during internal faults the P79x elements are short-circuited as soon as the protection trips. If the relay trips in 40 ms and the auxiliary relay in the P79x case is released in 10 ms, then the stabilizing resistor and varistors will be subjected to the fault current for at least 50 ms. Whenever the relay is short circuited, the trip contact should be configured as latched, so that the 86 relay is effectively energised.

Assume that a C800 MR2000:5 current transformer is used, and that the CT ratio is 1200:5. In this application, the Knee point voltage is 480V. Also assume that the P79x elements should withstand the current for at least 50 ms. Transient CT saturation must be considered. The current calculated by the spreadsheet tool should be compared against the actual fault current level. The P79x is suitable for the application only if the actual fault current level is below the prospective current calculated by the spreadsheet tool. When considering transient CT saturation, the **Primary T C (s)** should be indicated. It is recommended to leave the **Initial Flux (%)** as -100% to consider the worst condition. The primary time constant is 0.048 sec which corresponds to an X/R = 15 for a 50 Hz system.

In the spreadsheet tool, the Parameters table should be updated with the required data: CT primary winding (A), CT secondary winding (A), Knee point voltage Vk (V), Initial Flux (%) and Primary T C (s). Click the **Update all data** button to update the maximum currents. The short circuit fault current calculated by the customer should be less than the maximum current level calculated by this spreadsheet tool. In this case the “Resistor + Varistor” maximum current levels should be considered.

As shown in Figure 17, during transient CT saturation if the 495 Ω equivalent resistor is used, the maximum current that the P79x may withstand during 50 ms is 34 A for the half-power option and 48.9 A for the full-power option.

Parameters	
CT primary winding (A)	1200
CT secondary winding (A)	5
Knee Point Voltage Vk (V)	480
Initial Flux (%)	-100
Primary TC (s)	0.048

Update All data | Update Res & Var | Update Res Only | Update Var Only

Resistance number	Req	R1	R2	R3	Mounting 1=parallel 2=serial	Maximum secondary current (A) Resistor + Varistor 9kJ .05s	.1s	.3s	1s	3s	18kJ .05s	.1s	.3s	1s	3s	Res only .05s	.1s	.3s	1s	3s
1	495	165	165	165	2	34.0	34.0	15.6	9.4	4.5	48.9	48.9	28.9	13.9	6.4	7.9	3.5	1.9	1.8	1.6
2	330	165	165	0	2	34.7	20.4	4.9	4.4	3.3	49.5	36.9	7.7	6.9	4.8	5.9	3.2	1.8	1.8	1.6
3	83	165	165	0	1	14.2	7.1	3.9	3.9	3.4	17.6	8.1	4.2	4.1	3.6	7.1	5.1	3.5	3.5	3.1
4	55	165	165	165	1	18.4	9.9	5.7	5.6	5.0	22.6	11.0	6.0	5.9	5.1	10.6	7.7	5.1	5.2	4.6
5	1500	500	500	500	2	33.2	33.2	22.5	8.3	3.7	48.1	48.1	35.1	12.8	5.5	5.2	2.1	1.4	1.2	1.0
6	1000	500	500	0	2	33.3	33.3	22.9	8.6	3.9	48.3	48.3	35.4	13.1	5.7	3.3	1.5	1.1	1.0	0.9
7	250	500	500	0	1	25.0	6.9	4.1	3.8	2.9	44.5	10.6	5.7	5.2	3.9	4.2	2.7	2.1	2.0	1.8
8	167	500	500	500	1	27.7	8.5	5.2	4.8	3.9	47.2	12.4	6.9	6.3	4.8	6.4	3.9	3.1	3.0	2.7
9	3300	1100	1100	1100	2	33.0	33.0	22.0	8.1	3.4	47.8	47.8	34.5	12.6	5.3	5.3	1.9	1.6	1.6	1.2
10	2200	1100	1100	0	2	33.1	33.1	22.3	8.2	3.5	47.9	47.9	34.7	12.7	5.4	2.6	1.1	0.9	0.8	0.6
11	550	1100	1100	0	1	33.9	15.9	9.1	8.0	4.4	48.8	29.4	16.6	13.8	6.2	3.2	1.8	1.4	1.4	1.2
12	367	1100	1100	1100	1	34.5	16.9	10.0	8.8	4.9	49.3	30.5	17.4	14.5	6.8	4.7	2.6	2.1	2.0	1.8

Resistance number	Maximum primary current (kA) Resistor + Varistor 9kJ .05s	.1s	.3s	1s	3s	18kJ .05s	.1s	.3s	1s	3s	Res only .05s	.1s	.3s	1s	3s
1	8	8	4	2	1	12	12	7	3	2	2	1	0	0	0
2	8	5	1	1	1	12	9	2	2	1	1	1	0	0	0
3	3	2	1	1	1	4	2	1	1	1	2	1	1	1	1
4	4	2	1	1	1	5	3	1	1	1	3	2	1	1	1
5	8	8	5	2	1	12	12	8	3	1	1	1	0	0	0
6	8	8	5	2	1	12	12	8	3	1	1	0	0	0	0
7	6	2	1	1	1	11	3	1	1	1	1	1	1	0	0
8	7	2	1	1	1	11	3	2	2	1	2	1	1	1	1
9	8	8	5	2	1	11	11	8	3	1	1	0	0	0	0
10	8	8	5	2	1	11	11	8	3	1	1	0	0	0	0
11	8	4	2	2	1	12	7	4	3	1	1	0	0	0	0
12	8	4	2	2	1	12	7	4	3	2	1	1	1	0	0

	Varistor Only 9kJ .05s	.1s	.3s	1s	3s	18kJ .05s	.1s	.3s	1s	3s
Maximum secondary current (A)	15.7	15.7	12.4	4.4	1.8	31.3	31.3	24.8	8.9	3.7
Maximum primary current (kA)	4	4	3	1	0	8	8	6	2	1

FIGURE 17: P79X CURRENT WITHSTAND – INTERNAL FAULT – TRANSIENT CT SATURATION– HIGH IMPEDANCE SCHEME SUCCESSFUL OPERATION

If the half-power option is used, then 34 A is the maximum current the P79x may withstand. If the maximum fault current is below 34 A, then the P79x is suitable for the application.

Note that the transient energy during internal faults may be too high. If this energy is higher than the maximum ratings given by the manufacturer, then the varistor/resistor may burn or melt. It is important to check the P79x current withstand limits using the spreadsheet tool to assure that the energy withstands are not exceeded. Note that the life expectancy of a varistor is affected by the current level, the time and the number of transient energy pulses. A varistor is fully degraded when its “clamping voltage” has changed by 10%. Beware that a fully degraded varistor is not visually damaged and it remains functional, but the amount of current that it may conduct for a given voltage increases. This means that during an internal fault, for example, the current flowing through the relay decreases due to an increase in current through the varistor. As a result, the sensitivity of the high impedance differential scheme is decreased.

4.2 Internal Fault – P79x shorting contact failure

If the P79x contacts fail to short-circuit the high impedance path, then the resistors and varistors should withstand the fault current for up to 100 ms (this includes the relay operating time plus the circuit breaker tripping time).

Assume that a C800 MR2000:5 current transformer is used, and that the CT ratio is 1200:5. In this application, the Knee point voltage is 480. Also assume that the P79x elements should withstand the current for at least 100 ms.

Transient CT saturation must be considered. The current calculated by the spreadsheet tool should be compared against the actual fault current level. The P79x is suitable for the application only if the fault current level is below the prospective current calculated by the spreadsheet tool. When considering transient CT saturation, the **Primary T C (s)** should be indicated. It is recommended to leave the **Initial Flux (%)** as -100% to consider the worst condition. The primary time constant is 0.048sec which corresponds to an X/R = 15 for a 50 Hz system.

In the spreadsheet tool, the Parameters table should be updated with the required data: CT primary winding (A), CT secondary winding (A), Knee point voltage Vk (V), Initial flux (%) and Primary T C (s). Click the **Update all data** button to update the maximum currents. The short circuit fault current calculated by the customer should be less than the maximum current level calculated by this Spreadsheet tool. In this case the "Resistor + Varistor" maximum current levels should be considered

As shown in Figure 18, during transient CT saturation if the 495 Ω equivalent resistor is used, the maximum current that the P79x may withstand during 100 ms is 34 A for the half-power option and 48.9 A for the full-power option.

Parameters

CT primary winding (A)	1200
CT secondary winding (A)	5
Knee Point Voltage Vk (V)	480
Initial Flux (%)	-100
Primary TC (s)	0.048

Update All data | Update Res & Var | Update Res Only | Update Var Only

Resistance number	Req	R1	R2	R3	Mounting 1=parallel 2=serial	Maximum secondary current (A)														
						Resistor + Varistor										Res only				
						9kJ					18kJ									
						.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s
1	495	165	165	165	2	34.0	34.0	15.6	9.4	4.5	48.9	48.9	28.9	13.9	6.4	7.9	3.5	1.9	1.8	1.6
2	330	165	165	0	2	34.7	20.4	4.9	4.4	3.3	49.5	36.9	7.7	6.9	4.8	5.9	3.2	1.8	1.8	1.6
3	83	165	165	0	1	14.2	7.1	3.9	3.9	3.4	17.6	8.1	4.2	4.1	3.6	7.1	5.1	3.5	3.5	3.1
4	55	165	165	165	1	18.4	9.9	5.7	5.6	5.0	22.6	11.0	6.0	5.9	5.1	10.6	7.7	5.1	5.2	4.6
5	1500	500	500	500	2	33.2	33.2	22.5	8.3	3.7	48.1	48.1	35.1	12.8	5.5	5.2	2.1	1.4	1.2	1.0
6	1000	500	500	0	2	33.3	33.3	22.9	8.6	3.9	48.3	48.3	35.4	13.1	5.7	3.3	1.5	1.1	1.0	0.9
7	250	500	500	0	1	25.0	6.9	4.1	3.8	2.9	44.5	10.6	5.7	5.2	3.9	4.2	2.7	2.1	2.0	1.8
8	167	500	500	500	1	27.7	8.5	5.2	4.8	3.9	47.2	12.4	6.9	6.3	4.8	6.4	3.9	3.1	3.0	2.7
9	3300	1100	1100	1100	2	33.0	33.0	22.0	8.1	3.4	47.8	47.8	34.5	12.6	5.3	5.3	1.9	1.6	1.6	1.2
10	2200	1100	1100	0	2	33.1	33.1	22.3	8.2	3.5	47.9	47.9	34.7	12.7	5.4	2.6	1.1	0.9	0.8	0.6
11	550	1100	1100	0	1	33.9	15.9	9.1	8.0	4.4	48.8	29.4	16.6	13.8	6.2	3.2	1.8	1.4	1.4	1.2
12	367	1100	1100	1100	1	34.5	16.9	10.0	8.8	4.9	49.3	30.5	17.4	14.5	6.8	4.7	2.6	2.1	2.0	1.8

Varistor Only									
9kJ					18kJ				
.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s
15.7	15.7	12.4	4.4	1.8	31.3	31.3	24.8	8.9	3.7

Resistance number	Maximum primary current (kA)														
	Resistor + Varistor										Res only				
	9kJ					18kJ									
	.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s
1	8	8	4	2	1	12	12	7	3	2	2	1	0	0	0
2	8	5	1	1	1	12	9	2	2	1	1	1	0	0	0
3	3	2	1	1	1	4	2	1	1	1	2	1	1	1	1
4	4	2	1	1	1	5	3	1	1	1	3	2	1	1	1
5	8	8	5	2	1	12	12	8	3	1	1	1	0	0	0
6	8	8	5	2	1	12	12	8	3	1	1	0	0	0	0
7	6	2	1	1	1	11	3	1	1	1	1	1	1	0	0
8	7	2	1	1	1	11	3	2	2	1	2	1	1	1	1
9	8	8	5	2	1	11	11	8	3	1	1	0	0	0	0
10	8	8	5	2	1	11	11	8	3	1	1	0	0	0	0
11	8	4	2	2	1	12	7	4	3	1	1	0	0	0	0
12	8	4	2	2	1	12	7	4	3	2	1	1	1	0	0

Varistor Only									
9kJ					18kJ				
.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s
4	4	3	1	0	8	8	6	2	1

FIGURE 18: P79X CURRENT WITHSTAND – INTERNAL FAULT – TRANSIENT CT SATURATION – P79X SHORTING CONTACT FAILURE

The lowest of the currents should be considered. If the half-power option is used, then 34 A is the maximum current the P79x may withstand. If the maximum fault current is below 34 A, then the P79x is suitable for the application.

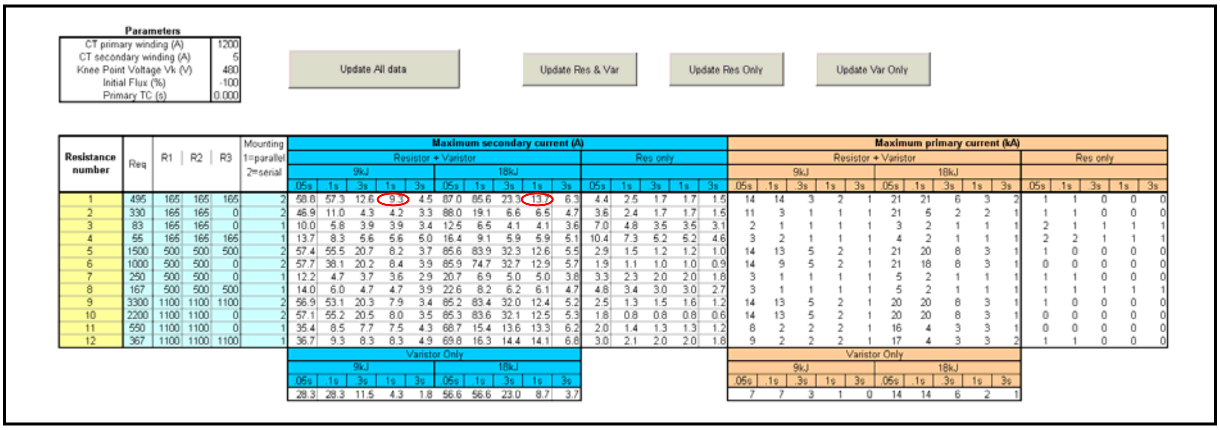
4.3 Internal fault - Failure to trip the circuit breakers

Busbars are usually rated 1 or 3 seconds. Backup protection may operate as slow as 3 seconds in distribution systems. The fault levels can be as high as 40 A secondary in 1 A CT applications. The varistors and resistors 1 and 3 seconds withstand limits should be considered.

Assume that a C800 MR2000:5 current transformer is used, and that the CT ratio is 1200:5. In this application, the Knee point voltage is 480V. Also assume that the P79x elements should withstand the current for at least 1 s. Steady state CT saturation should be considered. Therefore, set Primary T C (s) to 1e-100.

In the spreadsheet tool, the Parameters table should be updated with the required data: CT primary winding (A), CT secondary winding (A), Knee point voltage Vk (V) and Primary T C (s). In addition, the Initial Flux (%) can also be set; a setting of -100% is recommended to consider the worst case. Click the **Update all data** button to update the maximum currents. The short circuit fault current calculated by the customer should be less than the maximum current level calculated by this spreadsheet tool. In this case the "Resistor + Varistor" maximum current levels should be considered.

As shown in Figure 19, if the 495 Ω equivalent resistor is used, the maximum current that the P79x may withstand for 1 s is 9.3 A for the half power option and 13.7 A for the full power option.



Parameters

CT primary winding (A)	1200
CT secondary winding (A)	5
Knee Point Voltage Vk (V)	480
Initial Flux (%)	-100
Primary TC (s)	0.000

Update All data | Update Res & Var | Update Res Only | Update Var Only

Resistance number	Req	R1	R2	R3	Mounting 1=parallel 2=serial	Maximum secondary current (A)														
						Resistor + Varistor										Res only				
						9kJ					18kJ									
						.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s
1	495	165	165	165	2	58.8	57.3	12.6	9.3	4.5	87.0	85.6	23.3	13.7	6.3	4.4	2.5	1.7	1.7	1.5
2	330	165	165	0	2	46.9	11.0	4.3	4.2	3.3	88.0	19.1	6.6	6.5	4.7	3.6	2.4	1.7	1.7	1.5
3	83	165	165	0	1	10.0	5.8	3.9	3.9	3.4	12.5	6.5	4.1	4.1	3.6	7.0	4.8	3.5	3.5	3.1
4	55	165	165	165	1	13.7	8.3	5.6	5.6	5.0	16.4	9.1	5.9	5.9	5.1	10.4	7.3	5.2	5.2	4.6
5	1500	500	500	500	2	57.4	55.5	20.7	8.2	3.7	85.6	83.9	32.3	12.6	5.5	2.9	1.5	1.2	1.2	1.0
6	1000	500	500	0	2	57.7	38.1	20.2	8.4	3.9	85.9	74.7	32.7	12.9	5.7	1.9	1.1	1.0	1.0	0.9
7	250	500	500	0	1	12.2	4.7	3.7	3.6	2.9	20.7	6.9	5.0	5.0	3.8	3.3	2.3	2.0	2.0	1.8
8	167	500	500	500	1	14.0	6.0	4.7	4.7	3.9	22.6	8.2	6.2	6.1	4.7	4.8	3.4	3.0	3.0	2.7
9	3300	1100	1100	1100	2	56.9	53.1	20.3	7.9	3.4	85.2	83.4	32.0	12.4	5.2	2.5	1.3	1.5	1.6	1.2
10	2200	1100	1100	0	2	57.1	55.2	20.5	8.0	3.5	85.3	83.6	32.1	12.5	5.3	1.8	0.8	0.8	0.8	0.6
11	550	1100	1100	0	1	35.4	8.5	7.7	7.5	4.3	68.7	15.4	13.6	13.3	6.2	2.0	1.4	1.3	1.3	1.2
12	367	1100	1100	1100	1	36.7	9.3	8.3	8.3	4.9	69.8	16.3	14.4	14.1	6.8	3.0	2.1	2.0	2.0	1.8

Resistance number	Maximum primary current (kA)														
	Resistor + Varistor										Res only				
	9kJ					18kJ									
	.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s
1	14	14	3	2	1	21	21	6	3	2	1	1	0	0	0
2	11	3	1	1	1	21	5	2	2	1	1	1	0	0	0
3	2	1	1	1	1	3	2	1	1	1	2	1	1	1	1
4	3	2	1	1	1	4	2	1	1	1	2	2	1	1	1
5	14	13	5	2	1	21	20	8	3	1	1	0	0	0	0
6	14	9	5	2	1	21	18	8	3	1	0	0	0	0	0
7	3	1	1	1	1	5	2	1	1	1	1	1	0	0	0
8	3	1	1	1	1	5	2	1	1	1	1	1	1	1	1
9	14	13	5	2	1	20	20	8	3	1	1	0	0	0	0
10	14	13	5	2	1	20	20	8	3	1	0	0	0	0	0
11	8	2	2	2	1	16	4	3	3	1	0	0	0	0	0
12	9	2	2	2	1	17	4	3	3	2	1	1	0	0	0

	Varistor Only									
	9kJ					18kJ				
	.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s
Maximum secondary current (A)	28.3	28.3	11.5	4.3	1.8	56.6	56.6	23.0	8.7	3.7
Maximum primary current (kA)	7	7	3	1	0	14	14	6	2	1

FIGURE 19: P79X CURRENT WITHSTAND – INTERNAL FAULT – FAILURE TO TRIP THE CIRCUIT BREAKERS

4.4 Bus-wire supervision operation

Under certain conditions, a transformer may operate at 1.5 times the rated current. Therefore, it may be assumed that the associated busbar may also operate at 1.5 times the rated current. During a CT wiring fault, such as an open CT, at least 1.5 times the rated current may flow through the combined relay, stabilizing resistor, and varistor path. As a result, significant current may be passed through the varistor or resistor for a considerable time. It is recommended to set the supervision time delay to 3 seconds; therefore, this time should be considered to calculate the P79x current withstand. Note that after 3 seconds that the bus-wire supervision element has picked up, the contacts configured as bus-wire supervision would short circuit the high impedance differential path. In this case, the varistors and resistors should be able to withstand 1.5 times the rated current for at least 3 seconds.

Assume that a C800 MR2000:5 current transformer is used, and that the CT ratio is 1200:5. In this application, the Knee point voltage is 480V. Also assume that the P79x elements should withstand the current for at least 3 s. Steady state CT saturation should be considered. Therefore, set Primary T C (s) to 1e-100.

In the spreadsheet tool, the Parameters table should be updated with the required data: CT primary winding (A), CT secondary winding (A), Knee point voltage Vk (V) and Primary T C (s). In addition, the Initial Flux (%) can also be set; a setting of -100% is recommended. Click the **Update all data** button to update the maximum currents. Consider that the ac secondary circuit of the feeder with the highest load is open circuited. As a result, a differential current will flow through the high impedance path. This current will split between the varistor and the stabilizing resistor. The highest load current calculated by the customer should be less than the maximum current level calculated by the Spreadsheet tool under the "Resistor + Varistor" column.

As shown in Figure 20, if the 495 Ω equivalent resistor is used, the maximum current that the P79x may withstand during 3 sec is 4.5 A for the half power option and 6.3 A for the full power option.

Parameters

CT primary winding (A)	1200
CT secondary winding (A)	5
Knee Point Voltage Vk (V)	480
Initial Flux (%)	-100
Primary TC (s)	0.000

Update All data | Update Res & Var | Update Res Only | Update Var Only

Resistance number	Req	R1	R2	R3	Mounting 1=parallel 2=serial	Maximum secondary current (A)														
						Resistor + Varistor										Res only				
						9kJ					18kJ									
						.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s
1	495	165	165	165	2	58.8	57.3	12.6	9.3	4.5	87.0	85.6	23.3	13.7	6.3	4.4	2.5	1.7	1.7	1.5
2	330	165	165	0	2	46.9	11.0	4.3	4.2	3.3	88.0	19.1	6.6	6.5	4.7	3.6	2.4	1.7	1.7	1.5
3	83	165	165	0	1	10.0	5.8	3.9	3.9	3.4	12.5	6.5	4.1	4.1	3.6	7.0	4.8	3.5	3.5	3.1
4	55	165	165	165	1	13.7	8.3	5.6	5.6	6.0	16.4	9.1	5.9	5.9	6.1	10.4	7.3	5.2	5.2	4.6
5	1500	500	500	500	2	57.4	55.5	20.7	8.2	3.7	85.6	83.9	32.3	12.6	5.5	2.9	1.5	1.2	1.2	1.0
6	1000	500	500	0	2	57.7	38.1	20.2	8.4	3.9	85.9	74.7	32.7	12.9	5.7	1.9	1.1	1.0	1.0	0.9
7	250	500	500	0	1	12.2	4.7	3.7	3.6	2.9	20.7	6.9	5.0	5.0	3.8	3.3	2.3	2.0	2.0	1.8
8	167	500	500	500	1	14.0	6.0	4.7	4.7	3.9	22.6	8.2	6.2	6.1	4.7	4.8	3.4	3.0	3.0	2.7
9	3300	1100	1100	1100	2	56.9	53.1	20.3	7.9	3.4	85.2	83.4	32.0	12.4	5.2	2.5	1.3	1.5	1.6	1.2
10	2200	1100	1100	0	2	57.1	55.2	20.5	8.0	3.5	85.3	83.6	32.1	12.5	5.3	1.8	0.8	0.8	0.8	0.6
11	550	1100	1100	0	1	35.4	8.5	7.7	7.5	4.3	68.7	15.4	13.6	13.3	6.2	2.0	1.4	1.3	1.3	1.2
12	367	1100	1100	1100	1	36.7	9.3	8.3	8.3	4.9	69.8	16.3	14.4	14.1	6.8	3.0	2.1	2.0	2.0	1.8
						Varistor Only														
						9kJ					18kJ									
						.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s					
						28.3	28.3	11.5	4.3	1.8	56.6	56.6	23.0	8.7	3.7					

Resistance number	Maximum primary current (kA)														
	Resistor + Varistor										Res only				
	9kJ					18kJ									
	.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s
1	14	14	3	2	1	21	21	6	3	2	1	1	0	0	0
2	11	3	1	1	1	21	5	2	2	1	1	1	0	0	0
3	2	1	1	1	1	3	2	1	1	1	2	1	1	1	1
4	3	2	1	1	1	4	2	1	1	1	2	2	1	1	1
5	14	13	5	2	1	21	20	8	3	1	1	0	0	0	0
6	14	9	5	2	1	21	18	8	3	1	0	0	0	0	0
7	3	1	1	1	1	5	2	1	1	1	1	1	0	0	0
8	3	1	1	1	1	5	2	1	1	1	1	1	1	1	1
9	14	13	5	2	1	20	20	8	3	1	1	0	0	0	0
10	14	13	5	2	1	20	20	8	3	1	0	0	0	0	0
11	8	2	2	2	1	16	4	3	3	1	0	0	0	0	0
12	9	2	2	2	1	17	4	3	3	2	1	1	0	0	0
	Varistor Only														
	9kJ					18kJ									
	.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s					
	7	7	3	1	0	14	14	6	2	1					

FIGURE 20: P79X CURRENT WITHSTAND – BUS-WIRE SUPERVISION OPERATION

4.5 Relay failure

If the relay fails, the varistors and resistors will no longer be protected against any differential current flow. Therefore, normally closed contacts should be connected across the differential circuit (check section 2.3 Auxiliary relays). These contacts will open once the relay is considered healthy. This in effect inhibits the differential protection, and an appropriate alarm should be raised by the watchdog contact.

4.6 Open circuited differential path

If the differential path is open circuited, for example, an open resistor, then the differential protection can not trip for internal faults. The fault may be cleared in as long as 3 seconds when the backup protection in a distribution system operates. In a transmission system the backup protection operating time might be as low as 1 s, when the line distance protection reverse looking zone is used as busbar backup protection.

Let's consider that the stabilizing resistor is open circuited, and that the varistor shall withstand the fault current during 1 s. Assume that a C800 MR2000:5 current transformer is used, and that the CT ratio is 1200:5. Therefore, in this application the Knee point voltage is 480V.

In the spreadsheet tool, the Parameters table should be updated with the required data: CT primary winding (A), CT secondary winding (A), Knee point voltage Vk (V) and Primary T C (s). In addition, the Initial Flux (%) can also be set; a setting of -100% is recommended. Click the **Update this table** button to update the maximum currents. The maximum fault current calculated by the customer should be less than the maximum current level calculated by the spreadsheet tool. In this case the "Varistor only" maximum current levels should be considered.

As shown in Figure 21, if the 495 Ω equivalent resistor is used, then the maximum current that the P79x may withstand for 1 s is 4.3 A for the half-power option and 8.7 A for the full-power option.

Parameters

CT primary winding (A)	1200
CT secondary winding (A)	5
Knee Point Voltage Vk (V)	480
Initial Flux (%)	-100
Primary TC (s)	0.000

Update All data | Update Res & Var | Update Res Only | Update Var Only

Resistance number	Req	R1	R2	R3	Mounting 1=parallel 2=serial
1	495	165	165	165	2
2	330	165	165	0	2
3	83	165	165	0	1
4	55	165	165	165	1
5	1500	500	500	500	2
6	1000	500	500	0	2
7	250	500	500	0	1
8	167	500	500	500	1
9	3300	1100	1100	1100	2
10	2200	1100	1100	0	2
11	550	1100	1100	0	1
12	367	1100	1100	1100	1

Maximum secondary current (A)

	Resistor + Varistor										Res only				
	9kJ					18kJ									
Resistance number	.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s
1	58.8	57.3	12.6	9.3	4.5	87.0	85.6	23.3	13.7	6.3	4.4	2.5	1.7	1.7	1.5
2	46.9	11.0	4.3	4.2	3.3	88.0	19.1	6.6	6.5	4.7	3.6	2.4	1.7	1.7	1.5
3	10.0	5.8	3.9	3.9	3.4	12.5	6.5	4.1	4.1	3.6	7.0	4.8	3.5	3.5	3.1
4	13.7	8.3	5.6	5.6	5.0	16.4	9.1	5.9	5.9	5.1	10.4	7.3	5.2	5.2	4.6
5	57.4	55.5	20.7	8.2	3.7	85.6	83.9	32.3	12.6	5.5	2.9	1.5	1.2	1.2	1.0
6	57.7	38.1	20.2	8.4	3.9	85.9	74.7	32.7	12.9	5.7	1.9	1.1	1.0	1.0	0.9
7	12.2	4.7	3.7	3.6	2.9	20.7	6.9	5.0	5.0	3.8	3.3	2.3	2.0	2.0	1.8
8	14.0	6.0	4.7	4.7	3.9	22.6	8.2	6.2	6.1	4.7	4.8	3.4	3.0	3.0	2.7
9	56.9	53.1	20.3	7.9	3.4	85.2	83.4	32.0	12.4	5.2	2.5	1.3	1.5	1.6	1.2
10	57.1	55.2	20.5	8.0	3.5	85.3	83.6	32.1	12.5	5.3	1.8	0.8	0.8	0.8	0.6
11	35.4	8.5	7.7	7.5	4.3	68.7	15.4	13.6	13.3	6.2	2.0	1.4	1.3	1.3	1.2
12	36.7	9.3	8.3	8.3	4.9	69.8	16.3	14.4	14.1	6.8	3.0	2.1	2.0	2.0	1.8

Varistor Only									
9kJ					18kJ				
.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s
28.3	28.3	11.5	4.3	1.8	56.6	56.6	23.0	8.7	3.7

Maximum primary current (kA)

	Resistor + Varistor										Res only				
	9kJ					18kJ									
Resistance number	.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s
1	14	14	3	2	1	21	21	6	3	2	1	1	0	0	0
2	11	3	1	1	1	21	5	2	2	1	1	1	0	0	0
3	2	1	1	1	1	3	2	1	1	1	2	1	1	1	1
4	3	2	1	1	1	4	2	1	1	1	2	2	1	1	1
5	14	13	5	2	1	21	20	8	3	1	1	0	0	0	0
6	14	9	5	2	1	21	18	8	3	1	0	0	0	0	0
7	3	1	1	1	1	5	2	1	1	1	1	1	0	0	0
8	3	1	1	1	1	5	2	1	1	1	1	1	1	1	1
9	14	13	5	2	1	20	20	8	3	1	1	0	0	0	0
10	14	13	5	2	1	20	20	8	3	1	0	0	0	0	0
11	8	2	2	2	1	16	4	3	3	1	0	0	0	0	0
12	9	2	2	2	1	17	4	3	3	2	1	1	0	0	0

Varistor Only									
9kJ					18kJ				
.05s	.1s	.3s	1s	3s	.05s	.1s	.3s	1s	3s
7	7	3	1	0	14	14	6	2	1

FIGURE 21: P79X CURRENT WITHSTAND – OPEN CIRCUITED DIFFERENTIAL PATH

4.7 Results summary

The following table shows the maximum current that the P79x might withstand under the conditions explained above.

Conditions	Half-power (A)	Full-power (A)
Internal fault – high impedance scheme successful operation	34	48.9
Internal Fault – P79x shorting contact failure	34	48.9
Internal fault - Failure to trip the circuit breakers	9.3	13.7
Bus-wire supervision operation	4.5	6.3
Open circuited differential path	4.3	8.7

For this particular application, if the currents calculated by the customer under the different conditions described earlier are equal to or below the currents given in the table, then the P79x is suitable for the application.

TECHNICAL DATA

CONTENT

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1. RATINGS

1.1 Power supply

Nominal voltage (V)	24Vdc 48Vdc,110Vac/Vdc, 125Vdc 220Vac/Vdc, 250Vdc
Operating range	dc: ± 20% ac: ± 10%
Residual ripple	Up to 12%
Stored energy time	<20 ms for interruption of Vx
Burden (coil)	24 V dc: 2.7 W permanent 48 V dc : 2.7 W permanent 110 V dc : 6.2 W permanent 125 V dc : 6.2 W permanent 220 V dc: 4.2 W permanent 250 V dc: 4.2 W permanent

1.2 Contact rating

Rated load (approved standards UL / CSA)	NO contact 30 A/ NC contact 30 A, 250 Vac (Res)
Contact material	AgCdO
Rated carry current	30 A
Maximum switching voltage	250 Vac, 28 Vdc
Maximum switching current	30 Aac, 20 Adc
Maximum switching capacity	7500 VA, 560 W
Maximum operate time	15 ms
Maximum release time	10 ms
Insulation strength between contacts and coil	Dielectric 2500 Vrms; 6 kV surge 1.2/50 us impulse wave
Dielectric strength between open contacts	1500 Vrms 50/50 Hz for 1 min
Life expectancy	Mechanical: 10,000,000 operations minimum Electrical: 100,000 operations minimum

1.3 Resistor specification

The following table indicates the specification of each basic resistor unit.

Resistor Values	33 Ω, 100 Ω, 220 Ω
Power rating at +25°C	7 W
Surface temperature +450°C	10 W
Transient energy (100msec)	20 Joules
1sec power rating	105 W
3sec power rating	84 W
5sec power rating	77 W
8sec power rating	73.5 W
10sec power rating	70 W

The following tables indicate the power rating per stabilising resistance.

Option A (basic resistor unit = 33Ω)							
Resistor Values	Continuous	100msec	1sec	3sec	5sec	8sec	10sec
495 Ω	105 W	300 J	1575 W	1260 W	1155 W	1103 W	1050 W
330 Ω	70 W	200 J	1050 W	840 W	770 W	735 W	700 W
82.5 Ω	70 W	200 J	1050 W	840 W	770 W	735 W	700 W
55 Ω	105 W	300 J	1575 W	1260 W	1155 W	1103 W	1050 W

Option B (basic resistor unit = 100Ω)							
Resistor Values	Continuous	100 msec	1 sec	3 sec	5 sec	8 sec	10 sec
1500 Ω	105 W	195 J	1575 W	1260 W	1155 W	1103 W	1050 W
1000 Ω	70 W	130 J	1050 W	840 W	770 W	735 W	700 W
250 Ω	70 W	130 J	1050 W	840 W	770 W	735 W	700 W
166 Ω	105 W	195 J	1575 W	1260 W	1155 W	1103 W	1050 W

Option C (basic resistor unit = 220Ω)							
Resistor Values	Continuous	100 msec	1 sec	3 sec	5 sec	8 sec	10 sec
3300 Ω	105 W	165 J	1575 W	1260 W	1155 W	1103 W	1050 W
2200 Ω	70 W	110 J	1050 W	840 W	770 W	735 W	700 W
550 Ω	70 W	110 J	1050 W	840 W	770 W	735 W	700 W
366 Ω	105 W	165 J	1575 W	1260 W	1155 W	1103 W	1050 W

Heavy overloads can be endured in the form of short pulses <0.1 sec.

1.4 Varistor specification

DC rated voltage	270
Non-linearity coefficient	3.8
Constant	1.73×10^{-11}
Clamping voltage	2200
Rated power	9 W
Transient energy	4800 J

Varistor options	Transient energy
Option H	10 kJ
Option F	20 kJ

2. TYPE TESTS

2.1 Insulation

According to EN 60255-27: 2005

Insulation resistance > 100 MΩ at 500 Vdc (Using only electronic/brushless insulation tester).

2.2 Creepage Distances and Clearances

According to EN 60255-27: 2005

Pollution degree 2,

Overvoltage category III,

Impulse test voltage 5 kV.

2.3 High Voltage Dielectric (Dielectric) Withstand

According to EN 60255-27: 2005, 2 kV rms

AC, 1 minute:

Between all independent circuits.

Between independent circuits and protective (earth) conductor terminal.

1 kV rms ac for 1 minute, across open contacts of changeover output relays.

2.4 Impulse Voltage Withstand Test

According to EN 60255-27: 2005

Front time: 1.2 µs, Time to half-value: 50 µs,

Peak value: 5 kV, 0.5J

Between all independent circuits.

Between all independent circuits and protective (earth) conductor terminal.

Between the terminals of independent circuits (open contacts of output relays excepted).

3. EMC TESTS

High Frequency Disturbance	
EN 60255-22-1:2008	2.5 kV common mode,Class III 1kV differential mode Class III
Electrostatic Discharge	
EN 61000-4-2: 1995 EN 60255-22-2: 1997	8 kV contact discharge, Class 4 15 kV air discharge, Class 4
Fast Transient	
EN 61000-4-4: 2004 Level 4	4 kV 5 kHz, power supply 2 kV 5 kHz all other circuits
EN 60255-22-4: 2002 Class A	4 kV 2.5 kHz all other circuits
Surge	
EN 61000-4-5: 2006 and EN 60255-22-5: 2002	4 kV common mode, Level 4 2 kV differential mode, Level 4

4. ENVIRONMENT

Temperature	EN 60068-2-1: 2007 EN 60068-2-2: 2007	Storage: –25 °C to +70 °C Operation: –25 °C to + 55 °C
Humidity damp heat	EN 60068-2-78: 2001	56 days at 93% RH and 40 °C
Enclosure protection	EN 60529: 2001	IP2X (front face only) IP3X (case enclosure)
Sinusoidal Vibrations	EN 60255-21-1:1988	Response and endurance, class 2
Shocks	EN 60255-21-2:1988	Response and withstand, class 2
Shock withstand & Bump	EN 60255-21-2:1988	Response and withstand, class 1
Seismic	EN 60255-21-3:1993	Class 2
Corrosive Environments	EN 60068-2-30: 2005	25°C to 55°C, 50% relative humidity

5. EU DIRECTIVE

5.1 EMC compliance

2004/108/EC

Compliance with European Commission Directive on EMC is demonstrated using a Technical File. Product Specific Standards were used to establish conformity:

– EN50263: 2000

5.2 Product safety

2006/95/EC
(replacing 73/23/EEC from 01/2007)

Compliance with European Commission Low Voltage Directive. Compliance is demonstrated by reference to generic safety standards:

– EN61010-1: 1993/A2: 1995

– EN60950: 1992/A11: 1997

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COMMISSIONING AND RECORDS SHEETS

CONTENTS

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1. REQUIREMENTS PRIOR TO COMMISSIONING

The P79x is an accessory to be used in high impedance differential schemes. It includes the stabilising resistance, the varistor(s) and auxiliary relays.

Blank commissioning test sheets are provided in APPENDIX 2 of the Technical Guide for completion as required.

BEFORE CARRYING OUT ANY WORK ON THE EQUIPMENT, THE USER SHOULD BE FAMILIAR WITH THE CONTENTS OF THE SAFETY GUIDE SFTY/4LM/G11-S OR LATER ISSUE, OR THE SAFETY AND TECHNICAL DATA SECTION OF THE TECHNICAL MANUAL AND ALSO THE RATINGS ON THE EQUIPMENT RATING LABEL.

2. COMMISSIONING TEST ENVIRONMENT

2.1 Important notes

2.1.1 Commissioning test equipment

- 1 multimeter (precision 1%),
- A dc supply source (55 VA minimum) is required to apply 270 Vdc across the varistor.

2.2 Commissioning test sheets

Commissioning test sheets are available in the *Commissioning Test & Record Sheets,* section *P79x/EN RS*.

The presentation of the Commissioning test sheets follows the tests described in this chapter.

The contents of these Commissioning test sheets enable you to log:

- The name of the unit, station and circuit
- The characteristics of the **MiCOM P791** and **P793** units
- The result of the test records after commissioning.

3. PRODUCT VERIFICATION TESTS

BEFORE CARRYING OUT ANY WORK ON THE EQUIPMENT, THE USER SHOULD BE FAMILIAR WITH THE CONTENTS OF THE SAFETY GUIDE SFTY/4LM/G11-S OR LATER ISSUE, OR THE SAFETY AND TECHNICAL DATA SECTIONS OF THE TECHNICAL MANUAL AND ALSO THE RATINGS ON THE EQUIPMENT RATING LABEL.

3.1 Allocation of terminals

It is necessary to consult the appropriate wiring diagram provided in the “Connection diagrams” section (P79x/EN CO) whilst observing the various polarities and ground/earth connection.

3.2 Electrostatic discharge (ESD)

Before any handling of the module, please refer to the recommendations in “Handling, Installation and Case Dimensions” section (P79x/EN IN).

3.3 Visual inspection

Carefully examine the unit to see if there has been any possible deterioration following installation.

Check if the external wiring corresponds to the appropriate unit diagram or the assembly diagram. The reference number of the P79x diagram is indicated on a label situated under the upper flap of the front panel.

3.4 Earthing

Check if the earth connection of the case situated above the rear terminal block is used to connect the unit to a local earth bar. With several units present, make sure that the copper earth bar is properly installed for solidly connecting the earthing terminals of each case.

3.5 Auxiliary relays

This test checks that all relays are functioning correctly.

For all MiCOM units, relays are change-over relays. The general power supply energizes each relay.

When the auxiliary relay is de-energised, check that the NC contacts are closed and that the NO contacts are open. Afterwards, energize the auxiliary relay and check that the NC contacts are open and the NO contacts are closed. Make sure that the appropriate voltage level is used to energize the auxiliary relay. Verify the voltage level required to energize the auxiliary relay; this voltage is on the label under the upper flap of the front panel.

	P791 Unit	**P793 Unit**
	1 relay	3 relays
Normally closed contacts (NC) when power supply is off	31-32	31-32 41-42 51-52
Normally opened contacts (NO) when power supply is off	31-30	31-30 41-40 51-50
+250 Vdc or +220 Vac	2	2
-250 Vdc or -220 Vac	4	4
+220 Vdc	8	8
-220 Vdc	10	10
+125 Vdc or +110 Vac	14	14

	P791 Unit	P793 Unit
-125 Vdc or -110 Vac	16	16
+110 Vdc	20	20
-110 Vdc	22	22
+48 Vdc or +24 Vdc	26	26
-48 Vdc or -24 Vdc	28	28

3.6 Integrated resistors

This test checks that all the integrated resistors are not short circuited or open circuited.

The following table shows the resistors' nominal values. Measure the resistance across the terminals shown in the table below. The measured resistance should be within ±10% of the nominal value.

Terminals	Unit	Model A	Model B	Model C
1-7	P791 – P793	495 Ω	1500 Ω	3300 Ω
11-17	P793	495 Ω	1500 Ω	3300 Ω
21-27	P793	495 Ω	1500 Ω	3300 Ω

3.7 Varistors

In this test, the nominal DC voltage is applied across the varistor and the current flowing through it is measured. 270V dc should be applied across the varistor. The current flowing through the varistor should be 45-90 mA if the half-power option is used. If the full-power option is used, the current should be 90-180 mA.

Current through the varistor at rated dc voltage			
Terminals	**Unit**	**Half Power**	**Full Power**
35-36	P791 – P793	45-90 mA	90-180 mA
45-46	P793	45-90 mA	90-180 mA
55-56	P793	45-90 mA	90-180 mA

3.8 Final checks

The tests are now complete. Remove all test or temporary shorting leads. If it is necessary to disconnect any of the external wiring from the P79x to perform the wiring verification tests, ensure that all connections are replaced according to the relevant external connection or scheme diagram.

If a MMLG test block is installed, remove the MMLB01 test plug and replace the MMLG cover so that the P79x is put into service.

4. MAINTENANCE

4.1 Method of repair

4.1.1 Replacing the active part

BEFORE CARRYING OUT ANY WORK ON THE EQUIPMENT, THE USER SHOULD BE FAMILIAR WITH THE CONTENTS OF THE SAFETY GUIDE SFTY/4LM/G11-S OR LATER ISSUE, OR THE SAFETY AND TECHNICAL DATA SECTIONS OF THE TECHNICAL MANUAL AND ALSO THE RATINGS ON THE EQUIPMENT RATING LABEL.

If replacement or repair becomes necessary, the case and the rear terminal blocks are designed to ease removal of the MiCOM P79x unit, without disconnecting the scheme wiring.

NOTE: The MiCOM range of relays have integral current transformer shorting switches which close when the active part is removed from the case.

Remove the upper and lower flap without exerting excessive force. Remove the external screws. Under the upper flap, turn the extractor with a 3 mm screwdriver and extract the active part of the relay by pulling from the upper and lower notches on the front panel of the MiCOM P79x.

To reinstall the repaired relay or replace it, follow the above instructions in reverse, ensuring that no modifications have been made to the scheme wiring.

On completion of any operations which require the unit to be removed from its case, verify that the four fixing screws are fitted at the corners of the front panel, under the flaps. These screws secure the chassis (removable part) to the case, ensuring good seating/contact.

4.1.2 Replacing the complete unit

To remove the complete unit (active part and case), the entire wiring must be removed from the rear connector.

Before working at the rear of the unit, isolate all current supplies to the MiCOM P79x and ensure that the relay is not powered.

DANGER: NEVER OPEN THE SECONDARY CIRCUIT OF A CURRENT TRANSFORMER SINCE THE HIGH VOLTAGE PRODUCED MAY BE LETHAL AND COULD DAMAGE THE INSULATION.

Remove all wiring. Disconnect the relay earth connection from the rear of the relay.

Remove the screws used to fasten the unit to the panel, rack, etc. These are the screws with the larger diameter heads that are accessible when the upper and lower flaps are installed.

Carefully withdraw the unit from the panel or rack because it will be heavy.

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 that the case earth and communications connections are refitted.

Once reinstallation is complete the relay should be re-commissioned using the instructions in sections 1 to 3 inclusive of this chapter.

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CONNECTION DIAGRAMS

BEFORE CARRYING OUT ANY WORK ON THE EQUIPMENT, THE USER SHOULD BE FAMILIAR WITH THE CONTENTS OF THE SAFETY GUIDE SFTY/4LM/G11-S OR LATER ISSUE, OR THE SAFETY AND TECHNICAL DATA SECTION OF THE TECHNICAL MANUAL AND ALSO THE RATINGS ON THE EQUIPMENT RATING LABEL."

In the following schemes, the auxiliary relays within the P79x case are off.

Resistance values are obtained according to the connection and model option (A, B or C code).

NOTE THAT IT IS NOT ALLOWED TO USE RESISTANCES 1, 2 OR 3 ALONE DUE TO ENERGY DISSIPATION CONSTRAINTS.

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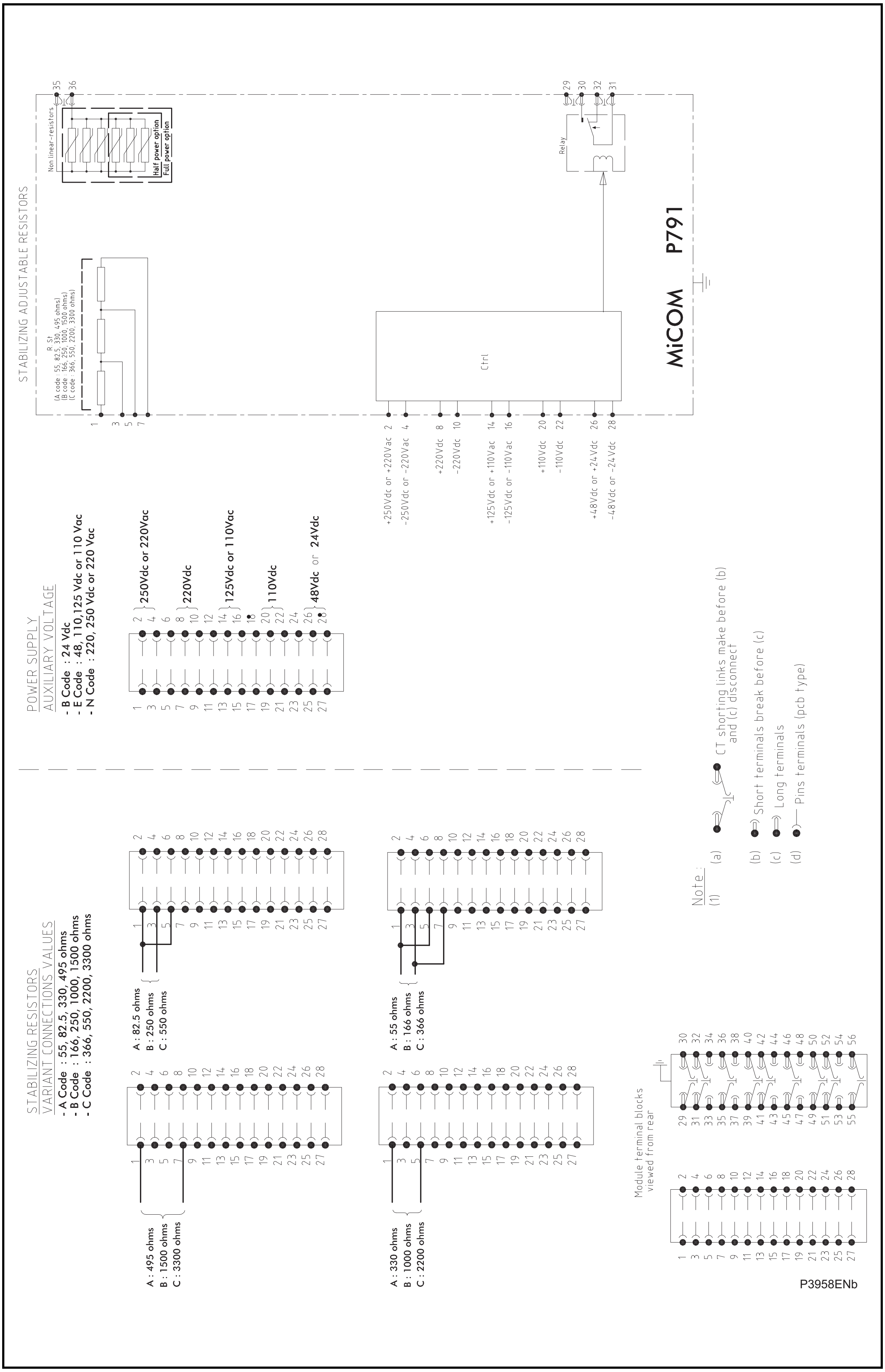

FIGURE 1: INTEGRATED RESISTOR OR VARISTOR UNIT P791 (1/2)

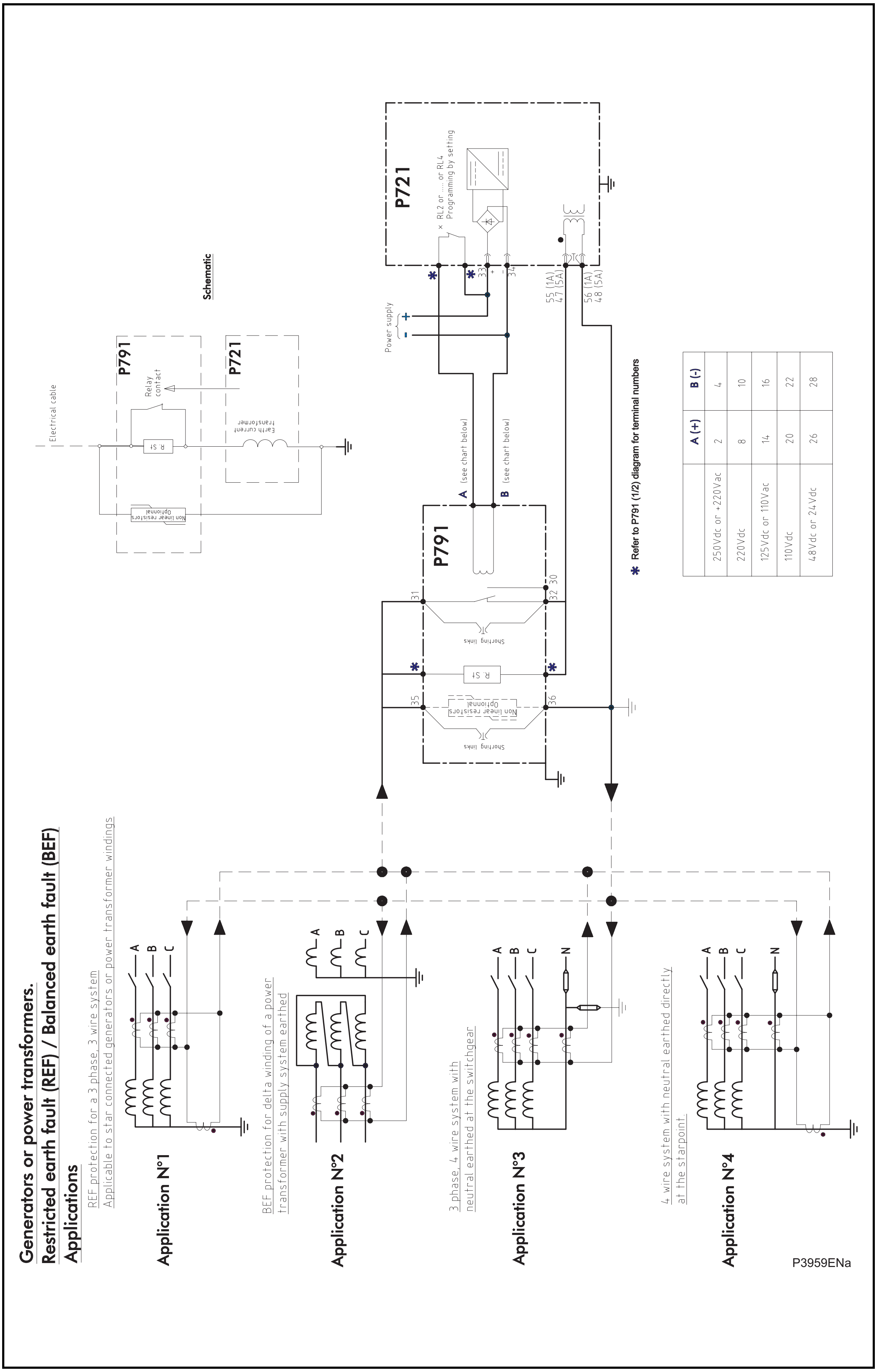

FIGURE 2: INTEGRATED RESISTOR OR VARISTOR UNIT P791 (2/2)

Note: The relay contact positions shown are not the positions when in normal condition.

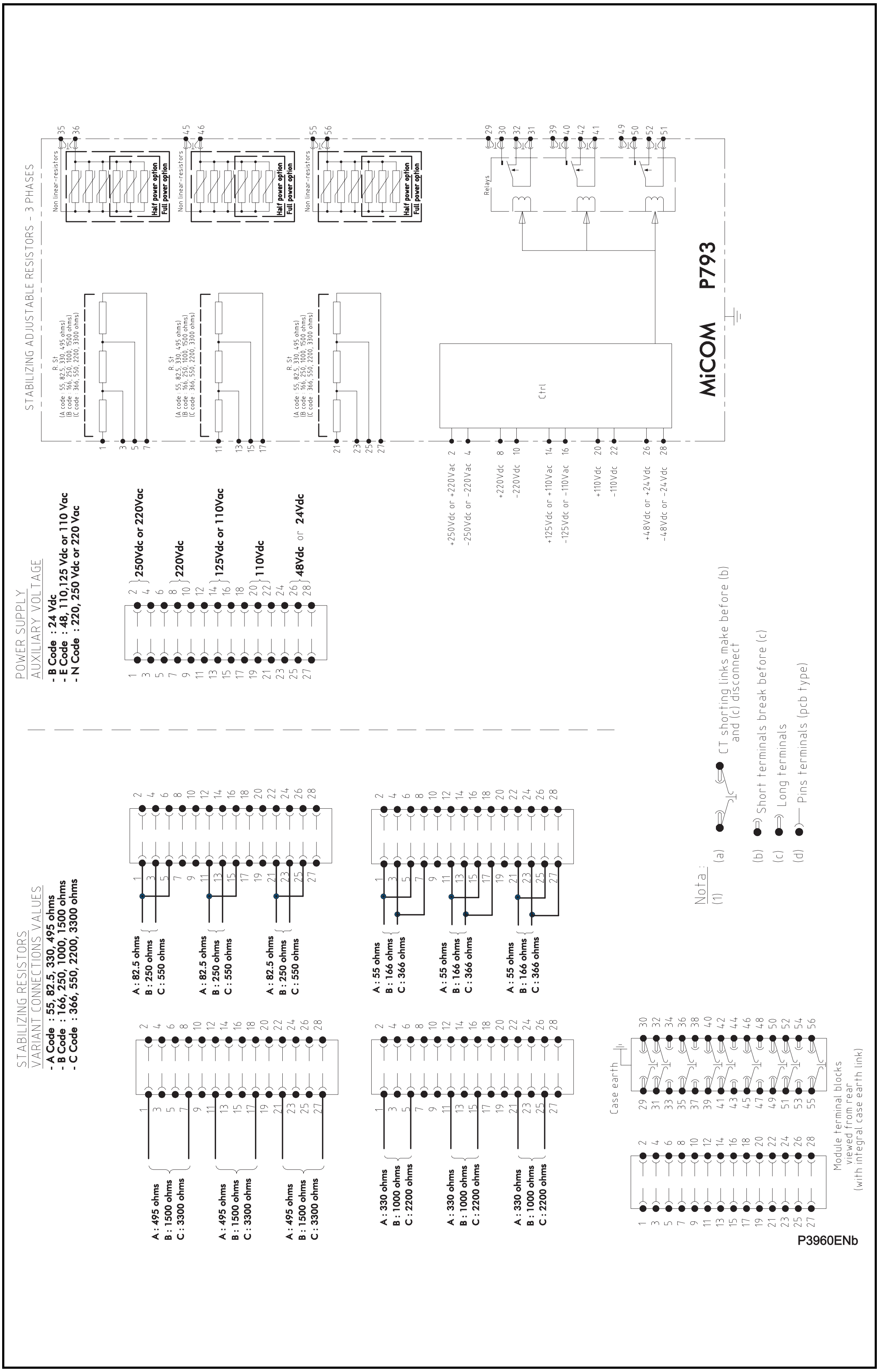

FIGURE 3: INTEGRATED RESISTOR OR VARISTOR UNIT P793 (1/2)

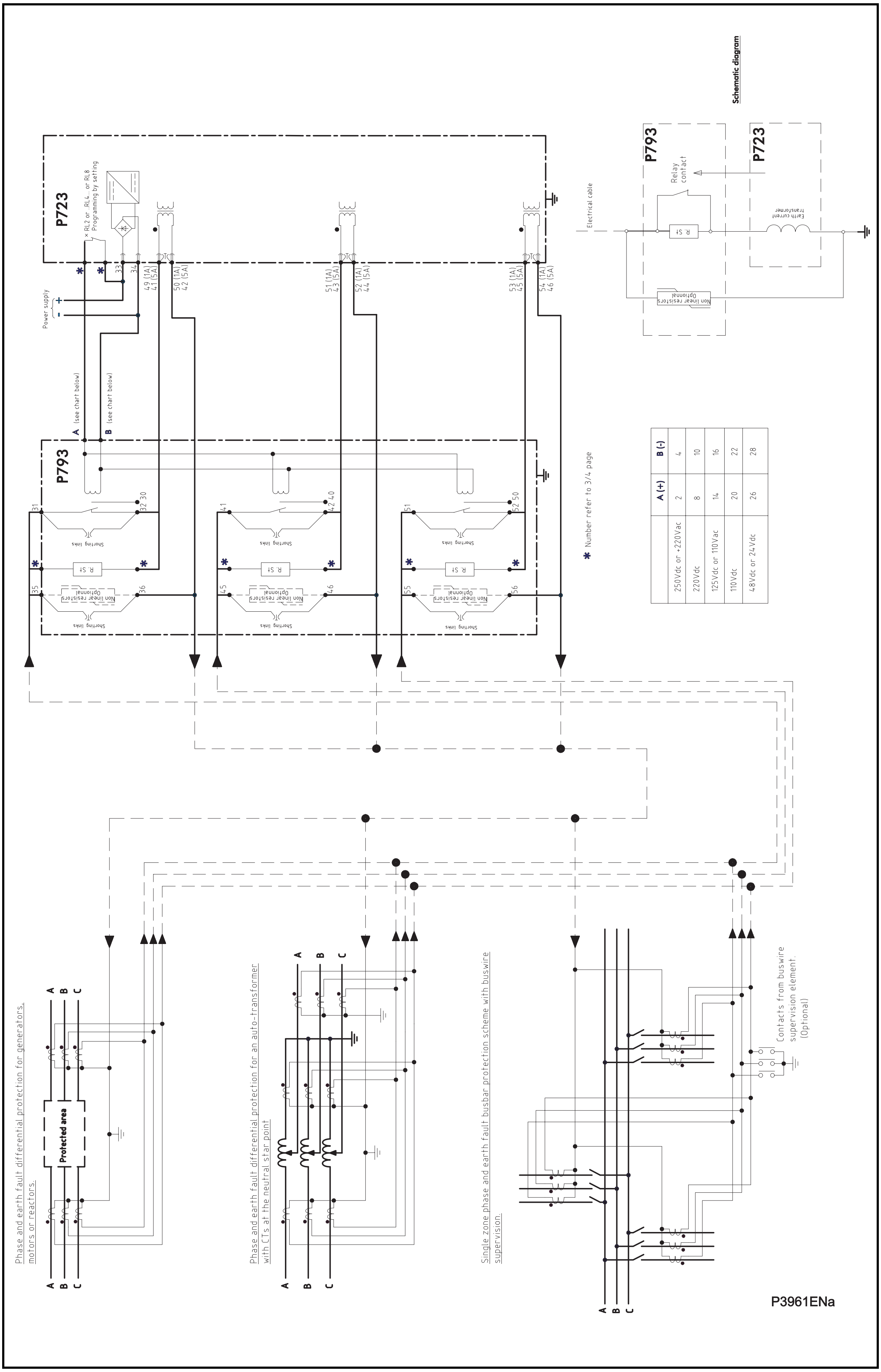

FIGURE 4: INTEGRATED RESISTOR OR VARISTOR UNIT P793 (2/2)

Note: The relay contact positions shown are not the positions when in normal condition.

COMMISSIONING TEST & RECORD SHEETS

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1. COMMISSIONING TEST SHEETS

BEFORE CARRYING OUT ANY WORK ON THE EQUIPMENT, THE USER SHOULD BE FAMILIAR WITH THE CONTENTS OF THE SAFETY GUIDE SFTY/4LM/G11-S OR LATER ISSUE, OR THE SAFETY AND TECHNICAL DATA SECTION OF THE TECHNICAL MANUAL AND ALSO THE RATINGS ON THE EQUIPMENT RATING LABEL.

1.1 Relay identification

Commissioning date : ______________________

Engineer : ______________________

Substation : ______________________

Circuit : ______________________

Network nominal frequency: ______________________

MiCOM P79x high impedance accesory : ☐ **P791** ☐ **P793**

Serial number :

1.2 Commissioning test record

(put a cross after each checked stage)

Serial number check ?	☐
All current transformer shorting switches closed ?	☐
Wiring checked against diagram (if available) ?	☐
Case earth installed ?	☐
Test block connections checked (if installed) ?	☐
Insulation tested ?	☐

1.3 Relays

Unit not energized

	Close	Open
Relay 1		
Contact 31-32	❑	❑
Contact 31-30	❑	❑
Relay 2 (P793 only)		
Contact 41-42	❑	❑
Contact 41-40	❑	❑
Relay 3 (P793 only)		
Contact 51-52	❑	❑
Contact 51-50	❑	❑

Unit energized

	Close	Open
Relay 1		
Contact 31-32	❑	❑
Contact 31-30	❑	❑
Relay 2 (P793 only)		
Contact 41-42	❑	❑
Contact 41-40	❑	❑
Relay 3 (P793 only)		
Contact 51-52	❑	❑
Contact 51-50	❑	❑

Note: Contacts 31-32, 41-42 and 51-52 are normally closed contacts. Contacts 31-30, 41-40 and 51-50 are normally open contacts. If the relay is deenergized, then the normally closed contacts are closed and the normally open contacts are open. If the relay is energized, then the normally closed contacts open and the normally open contacts close.

1.4 Integrated resistors

Take note of the resistance measured between the terminals. Depending on the option, the resistance value might be:

Terminals	Model A	Model B	Model C
1-3, 11-13, 21-23	165	500	1100
1-5, 11-15, 21-25	330	1000	2200
1-7, 11-17, 21-27	495 Ω	1500 Ω	3300 Ω

The purpose of this test is to verify the continuity between terminals, ensuring that the resistors chain in the P79x is not open.

Terminals	Measured resistance
1-3 (P791 and P793)	__________ Ω
1-5 (P791 and P793)	__________ Ω
1-7 (P791 and P793)	__________ Ω
11-13 (P793)	__________ Ω
11-15 (P793)	__________ Ω
11-17 (P793)	__________ Ω
21-23 (P793)	__________ Ω
21-25 (P793)	__________ Ω
21-27 (P793)	__________ Ω

The next step is to measure the actual resistance required by the application.

Phase	Terminals	Measured resistance
A		__________ Ω
B		__________ Ω
C		__________ Ω
Neutral		__________ Ω

1.5 Varistors

This test should be performed only if the P79x includes the simple or dual non linear resistors. Apply 270 Vdc across the following terminals and verify that the current flowing through the varistor is within the following limits:

$45 \leq \mathbf{I} \leq 90$ mA half power option

$90 \leq \mathbf{I} \leq 180$ mA full power option

Terminals	Measured current
Contact 35-36 (P791 and P793)	______________ mA
Contact 45-46 (P793 only)	______________ mA
Contact 55-56 (P793 only)	______________ mA

1.6 Notes

HARDWARE VERSION HISTORY AND COMPATIBILITY

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1. MiCOM P791

MiCOM P791		
Hardware Version	Date of Issue	Full Description of Changes
Phase II	02/02/2010	Phase II is the first issue for the P791 hardware

2. MiCOM P793

MiCOM P793		
Hardware Version	Date of Issue	Full Description of Changes
Phase II	02/02/2010	Phase II is the first issue for the P793 hardware

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Publication: P79x/EN T/B11

Publishing: Schneider Electric

01/2012