Electrical network protection

Sepam series 80

Protection, metering and control functions

User's manual

02/2016

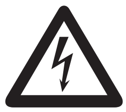
Schneider Electric

Safety instructions

Safety symbols and messages

Read these instructions carefully and look at the equipment to become familiar with the device before trying to install, operate, service or maintain it. The following special messages may appear throughout this bulletin or on the equipment to warn of potential hazards or to call attention to information that clarifies or simplifies a procedure.

ANSI symbol.



IEC symbol.

Risk of electric shock

The addition of either symbol to a Danger or Warning safety label indicates that an electrical hazard exists, which will result in personal injury if the instructions are not followed.

Safety alert

This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

Safety messages

⚠ DANGER
DANGER indicates an imminently hazardous situation which, if not avoided, **will result in** death or serious injury.

⚠ WARNING
WARNING indicates a potentially hazardous situation which, if not avoided, **can result in** death or serious injury.

⚠ CAUTION
CAUTION indicates a potentially hazardous situation which, if not avoided, **can result in** minor or moderate injury.

NOTICE
NOTICE, used without the safety alert symbol, indicates a potentially hazardous situation which, if not avoided, **can result in** equipment damages.

Important notes

Restricted liability

Electrical equipment should be serviced and maintained only by qualified personnel. No responsibility is assumed by Schneider Electric for any consequences arising out of the use of this manual. This document is not intended as an instruction manual for untrained persons.

Device operation

The user is responsible for checking that the rated characteristics of the device are suitable for its application. The user is responsible for reading and following the device's operating and installation instructions before attempting to commission or maintain it. Failure to follow these instructions can affect device operation and constitute a hazard for people and property.

Protective grounding

The user is responsible for compliance with all the existing international and national electrical codes concerning protective grounding of any device.

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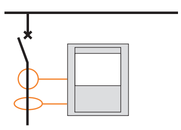
Selection guide by application

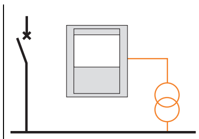
The selection guide by application suggests Sepam type(s) suitable for your protection requirements, based on your application characteristics. The most typical applications are presented along with the associated Sepam type.

Each application example is described:

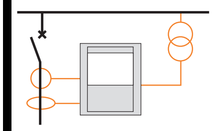
- ■ By a single-line diagram specifying
  - □ the device to be protected
  - □ the network configuration
  - □ the position of the metering sensors
- ■ By the standard and specific Sepam functions to be implemented to protect the application concerned.

Series 20





Series 40



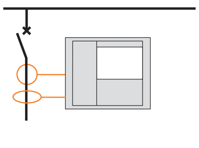
		Series 20				Series 40				
Protections										
	Current	■	■			■	■	■	■	■
	Voltage			■	■	■	■	■		■
	Frequency			■	■	■	■	■		■
	Specific		Breaker failure		Disconnection (ROCOF)		Directional earth fault	Directional earth fault and phase	Directional earth fault	
Applications										
Substation		S20	S24			S40 / S50 (4)	S41 / S51 (4)	S42 / S52 (4)	S43 / S53 (4)	S44 / S54
Busbar				B21	B22					
Transformer		T20	T24			T40 / T50 (5)		T42 / T52 (5)		
Motor		M20				M40	M41			
Generator						G40				
Capacitor										
Characteristics										
Logic inputs/outputs	Inputs	0 to 10		0 to 10		0 to 10				
	Outputs	4 to 8		4 to 8		4 to 8				
Temperature sensors		0 to 8		0 to 8		0 to 16				
Channel	Current	3I + I0		–		3I + I0				
	Voltage	–		3V + V0		3V				
	LPCT (1)	Yes		–		Yes				
Communication ports		1 to 2		1 to 2		1 to 2				
Control	Matrix (2)	Yes		Yes		Yes				
	Logic equation editor	–		–		Yes				
	Logipam (3)	–		–		–				
Other	Memory cartridge with settings	–		–		–				
	Backup battery	–		–		–				

(1) LPCT: Low-Power Current Transducer conforming to standard IEC 60044-8.
(2) Control matrix used for simple assignment of data from the protection, control and monitoring functions.
(3) Logipam: Ladder language PC programming environment for extended use of Sepam series 80 functions.
(4) S5X applications are identical to S4X applications with the following additional functions:
- *■ earth fault and phase overcurrent cold load pick-up*
- *■ broken conductor detection*
- *■ fault locator*

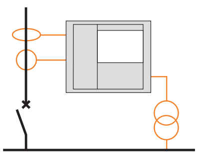
(5) T5X applications are identical to T4X applications with the following additional functions:
- *■ earth fault and phase overcurrent cold load pick-up*
- *■ broken conductor detection*

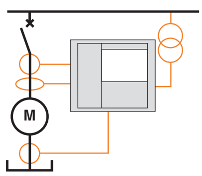
The list of protection functions is given for information only.
Direct earthing or impedance earthing have been represented by the same pictogram, i.e. by a direct earthing system.

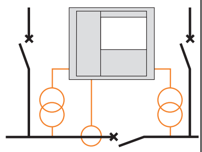
Series 60

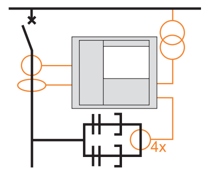


Series 80









Series 60			Series 80							
■	■	■	■	■	■	■	■	■	■	■
■	■	■	■	■	■	■	■	■	■	■
■	■	■	■	■	■	■	■	■	■	■
	Directional earth fault	Directional earth fault and phase		Directional earth fault	Directional earth fault and phase	Disconnection (ROCOF)	Transformer or machine-transformer unit differential	Machine differential	Busbar voltage and frequency protection	Capacitor bank unbalance
S60		S62	S80	S81	S82	S84				
			B80						B83	
T60		T62		T81	T82		T87			
	M61			M81			M88	M87		
G60		G62			G82		G88	G87		
C60										C86
0 to 28			0 to 42				0 to 42		0 to 42	0 to 42
4 to 16			5 to 23				5 to 23		5 to 23	5 to 23
0 to 16			0 to 16				0 to 16		0 to 16	0 to 16
3I + I0			3I + 2 x I0				2 x 3I + 2 x I0		3I + I0	2 x 3I + 2 x I0
3V, 2U + V0 or Vnt			3V + V0				3V + V0		2 x 3V + 2 x V0	3V + V0
Yes			Yes				Yes		Yes	Yes
1 to 2			2 to 4				2 to 4		2 to 4	2 to 4
Yes			Yes				Yes		Yes	Yes
Yes			Yes				Yes		Yes	Yes
–			Yes				Yes		Yes	Yes
Yes			Yes				Yes		Yes	Yes
Yes			Yes				Yes		Yes	Yes

All the information relating to the Sepam range can be found in the following documents:
- *Sepam catalog, reference SEPED303005EN*
- *Sepam series 20 user's manual, reference PCRED301005EN*
- *Sepam series 40 user's manual, reference PCRED301006EN*
- *Sepam series 60 user's manual, reference SEPED310017EN*
- *Sepam series 80 functions user's manual, reference SEPED303001EN*
- *Sepam series 80 Modbus communication user's manual, reference SEPED303002EN*
- *Sepam series 80 operation manual, reference SEPED303003EN*
- *Sepam DNP3 communication user's manual, reference SEPED305001EN*
- *Sepam IEC 60870-5-103 communication user's manual, reference SEPED305002EN*
- *Sepam IEC 61850 communication user's manual, reference SEPED306024EN*

Protection functions suitable for low voltage

Low voltage earthing systems

There are 4 low voltage (LV) earthing systems designated by a 2 or 3-letter acronym:
- TN-S
- TN-C
- TT
- IT

The letters making up the acronym have the following meanings:

Letter		Meaning
First letter		**Transformer neutral point**
	I	Earthed with an impedance
	T	Directly earthed
Second letter		**Electrical exposed conductive parts of the consumer**
	T	Earthed
	N	Connected to the neutral conductor
Third letter (optional)		**Protective Earth conductor**
	S	Separate N neutral conductor and PE Protective Earth conductor
	C	Combined N neutral conductor and PE Protective Earth conductor (PEN)

Protection functions suitable for low voltage

Compatibility of Sepam low voltage protection functions

Sepam protection functions can be used with low voltage (LV) as long as the conditions below are met:
■ The distribution circuit must be rated higher than 32 A.
■ The installation must comply with standard IEC 60364.
For additional information about the compatibility of Sepam protection functions with low voltage, please contact Schneider Electric technical support.

The table below lists the Sepam protection functions suitable for low voltage according to the earthing system used. Sepam protection functions not listed in this table are not suitable for low voltage. The protection functions listed in this table are available according to the Sepam type.

Protection	ANSI code	Earthing system				Comments
		TN-S	TN-C	TT	IT	
Phase overcurrent	50/51	■	■	■	■	Neutral conductor not protected
Earth fault/Sensitive earth fault	50N/51N	■	■	■	(1)	
Earth fault/Sensitive earth fault	50G/51G	■	■	■	(3)	
Negative sequence/unbalance	46	■	■	■	■	Threshold to be adapted to the phase unbalance
Thermal overload for cables/capacitor/ transformer/motor/generic	49RMS	■	■	■	■	Neutral conductor not protected
Restricted earth fault	64REF	■	■	■	(3)	
Two-winding transformer differential	87T	■	■	■	■	
Directional phase overcurrent	67	■	■	■ (4)	■ (4)	
Directional earth fault	67N/67NC					Incompatible with LV diagrams (4-wire)
Directional active overpower	32P	■	■	(2)	(2)	
Directional reactive overpower	32Q	■	■	(2)	(2)	
Undervoltage (L-L or L-N)	27	■	■	■	■	
Remanent undervoltage	27R	■	■	■	■	
Overvoltage (L-L or L-N)	59	■	■	■	■	
Neutral voltage displacement	59N	■	■	(4)	(4)	Residual voltage not available with 2 VTs
Negative sequence overvoltage	47	■	■	■	■	
Overfrequency	81H	■	■	■	■	
Underfrequency	81L	■	■	■	■	
Rate of change of frequency	81R	■	■	■	■	
Synchro-check	25	■	■	■	■	

■ : Protection function suitable for low voltage (according to Sepam)
(1) *Not recommended even on the second fault.*
(2) *2-wattmeter method not suitable for unbalanced loads.*
(3) *Residual current too low in IT.*
(4) *2 phase-to-phase VTs.*

1

The Sepam range of protection relays is designed for the operation of machines and electrical distribution networks of industrial installations and utility substations at all levels of voltage.
It includes 4 families
- *Sepam series 20*
- *Sepam series 40*
- *Sepam series 60*
- *Sepam series 80*

to cover all needs, from the simplest to the most complete.

PE80324

Sepam series 80 with integrated advanced UMI.

Sepam series 80, intelligent solutions for custom applications

Specially designed for demanding customers on large industrial sites,
Sepam series 80 provides proven solutions for electrical distribution and machine protection.

Main characteristics

■ protection of closed ring networks or networks with parallel incomers by directional protection and logic discrimination
■ directional earth fault protection for impedance-earthed and isolated or compensated neutral systems
■ complete protection of transformers and machine-transformer units
□ stable, sensitive differential protection with neural network restraint
□ linked to all necessary backup protection functions
■ complete protection of motors and generators
□ against internal faults:
- stable, sensitive machine differential protection, with starting and sensor loss restraint
- field loss, stator earth fault, etc.
□ against network and process faults: pole slip, speed control, inadvertent energization, etc.
■ synchro-check between 2 networks before coupling
■ measurement of harmonic distortion, current and voltage, to assess network power quality
■ 42 inputs / 23 outputs for comprehensive equipment control
■ mimic-based UMI for local switchgear control
■ SFT2841 parameter setting and operating software, a simple and complete tool that is indispensable for all Sepam users:
□ assisted preparation of parameter and protection settings
□ complete information during commissioning
□ remote equipment management and diagnostics during operation
■ logic equation editor built into the SFT2841 software to adapt the predefined control functions
■ optional SFT2885 programming software (Logipam), to program specific control and monitoring functions
■ 2 communication ports to integrate Sepam in 2 different networks or redundant architectures
■ removable memory cartridge to get equipment in operation again quickly after the replacement of a faulty base unit
■ battery backup to save historical and disturbance recording data.

Selection guide

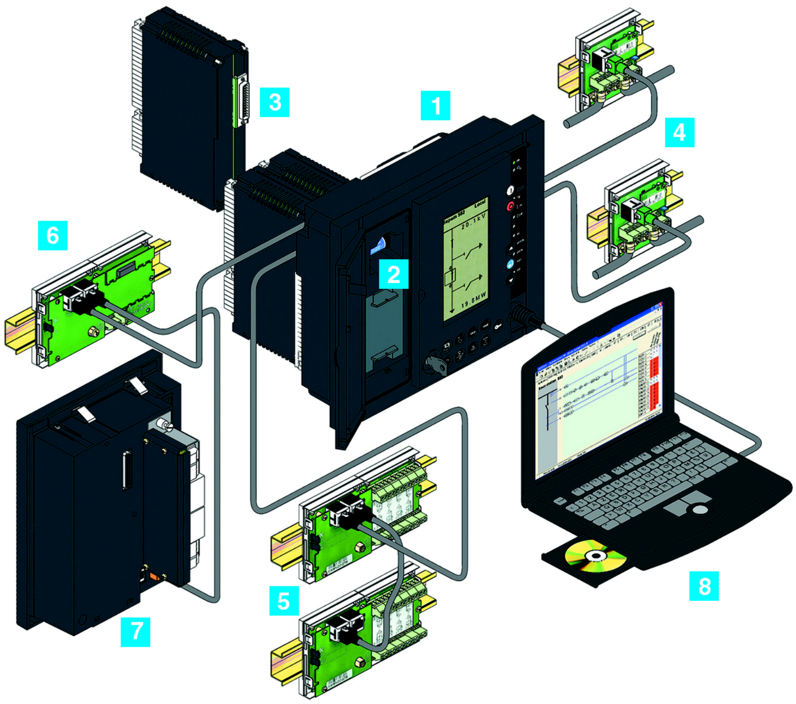
The Sepam series 80 family includes 16 types to offer the right solution for each application.

Specific protection functions available	Applications					
	Substation	**Transformer**	**Motor**	**Generator**	**Busbar**	**Capacitor**
	S80				B80	
Directional earth fault	S81	T81	M81			
Directional earth fault and phase overcurrent	S82	T82		G82		
Check on 3 phase voltages on 2 sets of busbars					B83	
Rate of change of frequency	S84					
Capacitor bank unbalance						C86
Transformer or machine differential		T87	M87	G87		
Machine-transformer unit differential			M88	G88		

Flexibility and upgrading capability

To adapt to as many situations as possible, and allow for future installation upgrading, optional modules may be added to Sepam at any time for new functions.

PE50286



1 **Base unit, with different types of User-Machine Interface (UMI):**
■ Integrated mimic-based UMI
■ Integrated or remote advanced UMI

2 **Parameter and protection settings saved on removable memory cartridge**

3 **42 logic inputs and 23 relay outputs**
with 3 optional modules providing 14 inputs and 6 outputs

4 **2 independent communication ports**
■ Connection:
□ direct, to 2-wire RS 485, 4-wire RS 485 or fiber optic networks
□ to Ethernet TCP/IP network via PowerLogic Ethernet server (Transparent Ready™)
■ Protocols:
□ DNP3 and IEC 60870-5-103 with ACE969 communication interface
□ IEC 61850 and Modbus TCP with ACE850 communication interface

5 **Processing of data from 16 temperature sensors**
Pt100, Ni100 or Ni120

6 **1 low level analog output**
0-10 mA, 0-10 mA, 4-20 mA or 0-20 mA

7 **Synchro-check module**

8 **Software tools:**
■ Sepam parameter and protection setting and adaptation of the predefined functions
■ Local or remote installation operation
■ Programming of specific functions (Logipam)
■ Retrieval and display of disturbance recording data

Ease of installation

■ Light, compact base unit
■ Easy to integrate due to Sepam's adaptation capabilities:
□ universal supply voltage for Sepam and its logic inputs: 24 to 250 V DC
□ phase currents can be measured by 1 A or 5 A current transformers, or LPCT (Low Power Current Transducer) type sensors
□ residual current calculated or measured by a choice of methods to fit requirements
■ The same, easy-to-install remote modules for all Sepam units:
□ mounted on DIN rail
□ connected to the Sepam base unit by prefabricated cords

Commissioning assistance

■ Predefined functions implemented by simple parameter setting
■ User-friendly, powerful SFT2841 PC setting software tool used on all Sepam units to provide users with all the possibilities offered by Sepam

Intuitive use

■ Integrated or remote advanced User Machine Interface (UMI) installed in the most convenient place for the facility manager
■ Integrated mimic-based User Machine Interface for local control of switchgear
■ User-friendly User Machine Interface, with direct access to data
■ Clear graphic LCD display of all data required for local operation and installation diagnosis
■ Working language can be customized to be understood by all users.

Selection table

		Substation				Transformer			Motor			Generator			Busbar		Cap.
Protection	**ANSI code**	**S80**	**S81**	**S82**	**S84**	**T81**	**T82**	**T87**	**M81**	**M87**	**M88**	**G82**	**G87**	**G88**	**B80**	**B83**	**C86**
Phase overcurrent (1)	50/51	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Earth fault / Sensitive earth fault (1)	50N/51N 50G/51G	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Breaker failure	50BF	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Negative sequence / unbalance	46	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Thermal overload for cables	49RMS		1	1	1												
Generic thermal overload (1) or	49RMS					2	2	2	2	2	2	2	2	2			
Thermal overload for motors/transformers						2	2	2	1	1	1						
Thermal overload for capacitors	49RMS																1
Capacitor bank unbalance	51C																8
Restricted earth fault	64REF					2	2	2				2		2			
Two-winding transformer differential	87T							1			1			1			
Machine differential	87M									1			1				
Directional phase overcurrent (1)	67			2	2		2	2				2	2	2			
Directional earth fault (1)	67N/67NC		2	2	2	2	2	2	2	2	2	2	2	2			
Directional active overpower	32P		2	2	2	2	2	2	2	2	2	2	2	2			
Directional reactive overpower	32Q								1	1	1	1	1	1			
Directional active underpower	37P				2							2					
Phase undercurrent	37								1	1	1						
Excessive starting time, locked rotor	48/51LR								1	1	1						
Starts per hour	66								1	1	1						
Field loss (underimpedance)	40								1	1	1	1	1	1			
Pole slip	78PS								1	1	1	1	1	1			
Overspeed (2 set points) (2)	12								□	□	□	□	□	□			
Underspeed (2 set points) (2)	14								□	□	□	□	□	□			
Voltage-restrained overcurrent	50V/51V											2	2	2			
Underimpedance	21B											1	1	1			
Inadvertent energization	50/27											1	1	1			
Third harmonic undervoltage / 100 % stator earth fault	27TN/64G2 64G											2	2	2			
Overfluxing (V / Hz)	24							2				2	2	2			
Undervoltage (L-L or L-N)	27	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Positive sequence undervoltage	27D	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Remanent undervoltage	27R	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Overvoltage (L-L or L-N)	59	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Neutral voltage displacement	59N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Negative sequence overvoltage	47	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Overfrequency	81H	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Underfrequency	81L	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Rate of change of frequency	81R				2												
Recloser (4 cycles) (2)	79	□	□	□	□												
Thermostat / Buchholz (2)	26/63					□	□	□	□		□	□		□			
Temperature monitoring (16 RTDs) (3)	38/49T					□	□	□	□	□	□	□	□	□			□
Synchro-check (4)	25	□	□	□	□	□	□	□				□	□	□	□	□	

The figures indicate the number of relays available for each protection function.
■ standard, □ optional
***(1)** Protection functions with 2 groups of settings*
***(2)** According to parameter setting and optional MES120 input/output modules*
***(3)** With optional MET148-2 temperature input module*
***(4)** With optional MCS025 synchro-check module*

Selection table

	Substation				Transformer			Motor			Generator			Busbar		Cap.
Metering	**S80**	**S81**	**S82**	**S84**	**T81**	**T82**	**T87**	**M81**	**M87**	**M88**	**G82**	**G87**	**G88**	**B80**	**B83**	**C86**
Phase current I1, I2, I3 RMS	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Measured residual current I0, calculated I0Σ	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Demand current I1, I2, I3	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Peak demand current IM1, IM2, IM3	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Measured residual current I'0	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■
Voltage U21, U32, U13, V1, V2, V3	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Residual voltage V0	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Positive sequence voltage Vd / rotation direction	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Negative sequence voltage Vi	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Frequency	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Active power P, P1, P2, P3	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Reactive power Q, Q1, Q2, Q3	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Apparent power S, S1, S2, S3	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Peak demand power PM, QM	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Power factor	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Calculated active and reactive energy (±Wh, ±VARh)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Active and reactive energy by pulse counting (1) (± Wh, ± VARh)	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Phase current I'1, I'2, I'3 RMS							■		■	■		■	■			
Calculated residual current I'0Σ							■		■	■		■	■			
Voltage U'21, V'1 and frequency														■		
Voltage U'21, U'32, U'13, V'1, V'2, V'3, V'd, V'i and frequency															■	
Residual voltage V'0															■	
Temperature (16 RTDs) (2)					□	□	□	□	□	□	□	□	□			□
Rotation speed (1)								□	□	□	□	□	□			
Neutral point voltage Vnt								■	■	■	■	■	■			

Control and monitoring		**S80**	**S81**	**S82**	**S84**	**T81**	**T82**	**T87**	**M81**	**M87**	**M88**	**G82**	**G87**	**G88**	**B80**	**B83**	**C86**
Circuit breaker / contactor control	94/69	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Automatic transfer (AT) (1)		□	□	□	□	□	□	□				□	□	□	□	□	
Load shedding / automatic restart									■	■	■						
De-excitation												■	■	■			
Genset shutdown												■	■	■			
Capacitor step control (1)																	□
Logic discrimination (1)	68	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Latching / acknowledgement	86	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Annunciation	30	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Triggering a Motor start report									■	■	■						
Activating/Deactivating a Data log		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Change of phase rotation direction		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Switching of groups of settings		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Adaptation using logic equations		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Logipam programming (Ladder language)		□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□

The figures indicate the number of relays available for each protection function.
■ standard, □ optional
***(1)** According to parameter setting and optional MES120 input/output modules*
***(2)** With optional MET148-2 temperature input module*

Selection table

	Substation				Transformer			Motor			Generator			Busbar		Cap.
Network and machine diagnosis	**S80**	**S81**	**S82**	**S84**	**T81**	**T82**	**T87**	**M81**	**M87**	**M88**	**G82**	**G87**	**G88**	**B80**	**B83**	**C86**
Tripping context	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Tripping current TripI1, TripI2, TripI3	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Phase fault and earth fault trip counters	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Unbalance ratio / negative sequence current Ii	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Harmonic distortion (THD), current and voltage Ithd, Uthd	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Phase displacement φ0, φ'0, φ0Σ	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Phase displacement φ1, φ2, φ3	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Disturbance recording	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Motor start report (MSR)								■	■	■						
Motor start trend (MST)								■	■	■						
Data log (DLG)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Thermal capacity used		■	■	■	■	■	■	■	■	■	■	■	■			■
Remaining operating time before overload tripping		■	■	■	■	■	■	■	■	■	■	■	■			■
Waiting time before closing authorization								■	■	■						
Running hours counter / operating time					■	■	■	■	■	■	■	■	■			■
Starting current and time								■	■	■						
Start inhibit time								■	■	■						
Number of starts before inhibition								■	■	■						
Unbalance ratio / negative sequence current I'i							■		■	■		■	■			
Differential current Idiff1, Idiff2, Idiff3							■		■	■		■	■			
Through current It1, It2, It3							■		■	■		■	■			
Current I and I' phase displacement θ							■		■	■		■	■			
Apparent positive sequence impedance Zd		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Apparent phase-to-phase impedances Z21, Z32, Z13		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Third harmonic voltage, neutral point or residual											■	■	■			
Difference in amplitude, frequency and phase of voltages compared for synchro-check (1)	□	□	□	□	□	□	□				□	□	□	□	□	
Capacitor unbalance current and capacitance																■

Switchgear diagnosis	**ANSI code**	S80	S81	S82	S84	T81	T82	T87	M81	M87	M88	G82	G87	G88	B80	B83	C86
CT / VT supervision	60/60FL	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Trip circuit supervision (2)	74	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Auxiliary power supply monitoring		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Cumulative breaking current		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Number of operations, operating time, charging time, number of racking out operations (2)		□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□

Modbus, IEC 60870-5-103, DNP3 communication or IEC 61850 (Editions 1 and 2)	S80	S81	S82	S84	T81	T82	T87	M81	M87	M88	G82	G87	G88	B80	B83	C86
Measurement readout (3) (4)	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Remote indication and time tagging of events (3) (4)	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Remote control orders (3) (4)	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Remote protection setting (3) (4)	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Transfer of disturbance recording data (3) (4)	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
IEC 61850 GOOSE message (4)	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□

The figures indicate the number of relays available for each protection function.
■ *standard,* □ *optional*
(1) *With optional MCS025 synchro-check module*
(2) *According to parameter setting and optional MES120 input/output modules*
(3) *With ACE949-2, ACE959, ACE937, ACE969TP-2 or ACE969FO-2 communication interface*
(4) *With ACE850TP or ACE850FO communication interface*

Technical characteristics

Weight

	Base unit with advanced UMI	Base unit with mimic-based UMI
Minimum weight (base unit without MES120)	2.4 kg (5.29 lb)	3.0 kg (6.61 lb)
Maximum weight (base unit with 3 MES120)	4.0 kg (8.82 lb)	4.6 kg (10.1 lb)

Sensor inputs

Phase current inputs	1 A or 5 A CT
Input impedance	< 0.02 Ω
Consumption	< 0.02 VA (1 A CT) < 0.5 VA (5 A CT)
Continuous thermal withstand	4 In
1 second overload	100 In (500 A)

Voltage inputs	Phase	Residual
Input impedance	> 100 kΩ	> 100 kΩ
Consumption	< 0.015 VA (100 V VT)	< 0.015 VA (100 V VT)
Continuous thermal withstand	240 V	240 V
1-second overload	480 V	480 V
Isolation of inputs from other isolated groups	Enhanced	Enhanced

Relay outputs

Control relay outputs O1 to O4 and Ox01 (1)

Voltage	DC	24/48 V DC	127 V DC	220 V DC	250 V DC	-
	AC (47.5 to 63 Hz)	-	-	-	-	100 to 240 V AC
Continuous current		8 A	8 A	8 A	8 A	8 A
Breaking capacity	Resistive load	8 A / 4 A	0.7 A	0.3 A	0.2 A	-
	L/R Load < 20 ms	6 A / 2 A	0.5 A	0.2 A	-	-
	L/R Load < 40 ms	4 A / 1 A	0.2 A	0.1 A	-	-
	Resistive load	-	-	-	-	8 A
	p.f. load > 0.3	-	-	-	-	5 A
Making capacity		< 15 A for 200 ms				
Isolation of outputs from other isolated groups		Enhanced				

Annunciation relay output O5 and Ox02 to Ox06

Voltage	DC	24/48 V DC	127 V DC	220 V DC	250 V DC	-
	AC (47.5 to 63 Hz)	-	-	-	-	100 to 240 V AC
Continuous current		2 A	2 A	2 A	2 A	2 A
Breaking capacity	Resistive load	2 A / 1 A	0.6 A	0.3 A	0.2 A	-
	L/R Load < 20 ms	2 A / 1 A	0.5 A	0.15 A	-	-
	p.f. load > 0.3	-	-	-	-	1 A
Isolation of outputs from other isolated groups		Enhanced				

Power supply

Voltage	24 to 250 V DC	-20 % / +10 %
Maximum consumption	< 16 W	
Inrush current	< 10 A 10 ms	
Acceptable ripple content	12%	
Acceptable momentary outages	100 ms	

Battery

Format	1/2 AA lithium 3.6 V
Service life	10 years Sepam energized
	MMS020 standard memory cartridge: 3 years minimum, typically 6 years with the Sepam de-energized MMR020 extended memory cartridge: 1.5 years minimum, typically 3 years with the Sepam de-energized

Analog output (MSA141 module)

Current	4 - 20 mA, 0 - 20 mA, 0 - 10 mA, 0 - 1 mA
Load impedance	< 600 Ω (including wiring)
Accuracy	0.50% full scale or 0.01 mA

***(1)** Relay outputs complying with clause 6.7 of standard C37.90 (30 A, 200 ms, 2000 operations).*

Environmental characteristics

Electromagnetic compatibility	Standard	Level/Class	Value
Emission tests			
Disturbing field emission	IEC 60255-25		
	EN 55022	A	
Conducted disturbance emission	IEC 60255-25		
	EN 55022	A	
Immunity tests - Radiated disturbances			
Immunity to radiated fields	IEC 60255-22-3		10 V/m; 80 MHz - 1 GHz
	IEC 61000-4-3	III	10 V/m; 80 MHz - 2 GHz
			30 V/m non-modulated; 800MHz - 2GHz (1)
	ANSI C37.90.2 (2004)		20 V/m; 80 MHz - 1 GHz
Electrostatic discharge	IEC 61000-4-2 (1)	IV	15 kV air ; 8 kV contact
	IEC 60255-22-2		8 kV air; 6 kV contact
	ANSI C37.90.3		8 kV air; 4 kV contact
Immunity to magnetic fields at network frequency (2)	IEC 61000-4-8	4	30 A/m (continuous) - 300 A/m (1-3 s)
Immunity to pulsed magnetic fields (1)	IEC 61000-4-9	IV	600 A/m
Immunity to magnetic fields with damped oscillating waves (1)	IIEC 61000-4-10	5	100 A/m
Immunity tests - Conducted disturbances			
Immunity to conducted RF disturbances	IEC 60255-22-6	III	10 V
Electrical fast transients/burst	IEC 60255-22-4	A and B	4 kV; 2.5 kHz/2 kV; 5 kHz
	IEC 61000-4-4	IV	4 kV; 2.5 kHz
	ANSI C37.90.1		4 kV; 2.5 kHz
1 MHz damped oscillating wave	IEC 60255-22-1		2.5 kV CM; 1 kV DM
	ANSI C37.90.1		2.5 kV CM; 2.5 kV DM
100 kHz damped sinusoidal wave	IEC 61000-4-12	III	2 kV MC
		IV (1)	4 kV MC ; 2,5 kV DM
Slow damped oscillating wave (100 kHz to 1 MHz)	IEC 61000-4-18	III	
Fast damped oscillating wave (3 MHz, 10 MHz, 30 MHz)	IEC 61000-4-18	III	
Surges	IEC 61000-4-5	III	2 kV CM; 1 kV DM
	GOST R 50746-2000 (1)	4	200 A
Immunity to conducted disturbances in common mode from 0 Hz to 150 kHz	IEC 61000-4-16	III	
Voltage interruptions	IEC 60255-11		100% for 100 ms
Mechanical robustness	**Standard**	**Level/Class**	**Value**
Energized			
Vibrations	IEC 60255-21-1	2	1 Gn; 10 Hz - 150 Hz
	IEC 60068-2-6	Fc	3 Hz - 13.2 Hz; a = ±1 mm
	IEC 60068-2-64	2M1	
Shocks	IEC 60255-21-2	2	10 Gn/11 ms
Earthquakes	IEC 60255-21-3	2	2 Gn (horizontal)
			1 Gn (vertical)
De-energized			
Vibrations	IEC 60255-21-1	2	2 Gn; 10 Hz - 150 Hz
Shocks	IEC 60255-21-2	2	27 Gn/11 ms
Jolts	IEC 60255-21-2	2	20 Gn/16 ms

***(1)** Test conducted with a mimic-based HMI in the case of GOST performance testing.*
***(2)** When protection functions 50N/51N or 67N are used and I0 is calculated on the sum of the phase currents, Is0 must be higher than 0.1In0.*

Climatic withstand	Standard	Level/Class	Value
During operation			
Exposure to cold	IEC 60068-2-1	Ad	-25°C (-13°F)
Exposure to dry heat	IEC 60068-2-2	Bd	+70°C (+158°F)
Continuous exposure to damp heat	IEC 60068-2-78	Cab	10 days; 93% RH; 40°C (104°F)
Salt mist	IEC 60068-2-52	Kb/2	3 days
Influence of corrosion/2-gas test	IEC 60068-2-60	Method 1	21 days; 75% RH; 25°C (77°F); 0.1 ppm H_2S; 0.5 ppm SO_2
Influence of corrosion/4-gas test	IEC 60068-2-60	Method 4	21 days; 75% RH; 25°C (77°F); 0.01 ppm H_2S; 0.2 ppm SO_2; 0.2 ppm NO_2; 0.01 ppm Cl_2
	EIA 364-65A	IIIA	42 days ; 75% RH ; 30 °C (86 °F) ; 0.1 ppm H_2S ; 0.2 ppm SO_2 ; 0.2 ppm NO_2 ; 0.02 ppm Cl_2
In storage (1)			
Temperature variation with specified variation rate	IEC 60068-2-14	Nb	-25°C to +70°C (-13°F to +158°F) 5°C/min
Exposure to cold	IEC 60068-2-1	Ab	-25°C (-13°F)
Exposure to dry heat	IEC 60068-2-2	Bb	+70°C (+158°F)
Continuous exposure to damp heat	IEC 60068-2-78	Cab	56 days; 93% RH; 40°C (104°F)
	IEC 60068-2-30	Db	6 days; 95% RH; 55°C (131°F)

Safety	Standard	Level/Class	Value
Enclosure safety tests			
Front panel tightness	IEC 60529	IP52	Other panels IP20
	NEMA	Type 12	
Fire withstand	IEC 60695-2-11		650°C (1200°F) with glow wire
Electrical safety tests			
1.2/50 µs impulse wave	IEC 60255-5		5 kV (2)
Power frequency dielectric withstand	IEC 60255-5		2 kV 1min (3)
	ANSI C37.90		1 kV 1 min (annunciation output) 1.5 kV 1 min (control output)
Functional safety			
Functional safety of electrical/electronic/programmable electronic safety-related systems	IEC 61508, EN 61508	SIL2(1)	System architecture evaluation Hardware evaluation Software evaluation

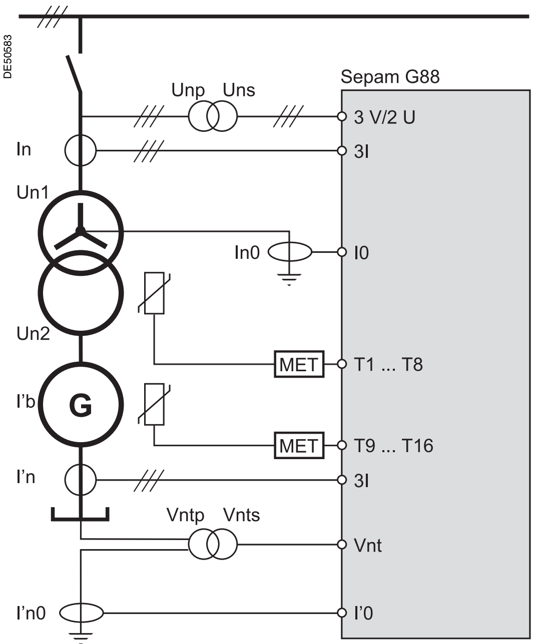
Certification	Standard		Value
	EN 50263 harmonized standard	**European directives:** ■ EMC European Directive 2004/108/EC dated 15 December 2004 ■ Low Voltage European Directive 2006/95/EC dated 12 December 2006 ■ ATEX Directive 94/9/EC(1)	
UL	UL508 - CSA C22.2 no. 14-95		File E212533
CSA	CSA C22.2 no. 14-95/no. 94-M91/no. 0.17-00		File 210625

(1) Sepam must be stored in its original packaging.
(2) Except for communication: 3 kV in common mode and 1 kV in differential mode.
(3) Except for communication: 1 kVrms.
(4) See the appendix in "Installation and operation" manual SEPED303003EN, "Functional Safety" section

Contents

Contents

Sensor inputs



Sepam G88 sensor inputs.

Sepam series 80 has analog inputs that are connected to the measurement sensors required for applications:

- ■ main analog inputs, available on all types of Sepam series 80:
  - □ 3 phase current inputs I1, I2, I3
  - □ 1 residual current input I0
  - □ 3 phase voltage inputs V1, V2, V3
  - □ 1 residual voltage input V0
- ■ additional analog inputs, dependent on the type of Sepam:
  - □ 3 additional phase current inputs I'1, I'2, I'3
  - □ 1 additional residual current input I'0
  - □ 3 additional phase voltage inputs V'1, V'2, V'3
  - □ 1 additional residual voltage input V'0.

The table below lists the analog inputs available according to the type of Sepam series 80.

		S80, S81, S82, S84	T81, T82, M81, G82	T87, M87, M88, G87, G88	B80	B83	C86
Phase current inputs	Main channel	I1, I2, I3	I1, I2, I3	I1, I2, I3	I1, I2, I3	I1, I2, I3	I1, I2, I3
	Additional channels			I'1, I'2, I'3			
Residual current inputs	Main channel	I0	I0	I0	I0	I0	I0
	Additional channels	I'0	I'0	I'0	I'0		
Unbalance current inputs for capacitor steps							I'1, I'2, I'3, I'0
Phase voltage inputs	Main channel	V1, V2, V3 or U21, U32	V1, V2, V3 or U21, U32	V1, V2, V3 or U21, U32	V1, V2, V3 or U21, U32	V1, V2, V3 or U21, U32	V1, V2, V3 or U21, U32
	Additional channels				V'1 or U'21	V'1, V'2, V'3 or U'21, U'32	
Residual voltage inputs	Main channel	V0	V0	V0	V0 (1)	V0	V0
	Additional channel					V'0	
Temperature inputs (on MET148-2 module)			T1 to T16	T1 to T16			T1 to T16

Note: *by extension, an additional measurement (current or voltage) is a value measured via an additional analog channel.*
(1) *Available with phase voltage U21, U32.*

General settings

The general settings define the characteristics of the measurement sensors connected to Sepam and determine the performance of the metering and protection functions used. They are accessed via the SFT2841 setting software "General Characteristics", "CT-VT Sensors" and "Particular characteristics" tabs.

General settings		Selection	Value
In, I'n	Rated phase current (sensor primary current)	2 or 3 1 A / 5 A CTs	1 A to 15 kA
		3 LPCTs sensors	25 A to 3150 A (1)
I'n	Unbalance current sensor rating (capacitor application)	CT 1 A / 2 A / 5 A	1 A to 30 A
Ib	Base current, according to rated power of equipment (2)		0.2 to 1.3 In
I'b	Base current on additional channels (not adjustable)	Applications with transformer	I'b = Ib x Un1/Un2
		Other applications	I'b = Ib
In0, I'n0	Rated residual current	Sum of 3 phase currents	See In(I'n) rated phase current
		CSH120 or CSH200 core balance CT	2 A or 20 A rating
		1 A/5 A CT	1 A to 15 kA
		Core balance CT + ACE990 (the core balance CT ratio 1/n must be such that 50 ⩽ n ⩽ 1500)	According to current monitored and use of ACE990
Unp, U'np	Rated primary phase-to-phase voltage (Vnp: rated primary phase-to-neutral voltage Vnp = Unp/$\sqrt{3}$)		0 A<In≤6.25 kA: 220 V ≤ Unp ≤ 250 kV 6.25 kA<In≤15 kA: 220V≤ Unp ≤ 20 kV (Idem for U'np)
Uns, U'ns	Rated secondary phase-to-phase voltage	3 VTs: V1, V2, V3	90 to 230 V
		2 VTs: U21, U32	90 to 120 V
		1 VT: U21	90 to 120 V
		1 VT: V1	90 to 230 V
Uns0, U'nso	Secondary zero sequence voltage for primary zero sequence voltage Unp/$\sqrt{3}$		Uns/3 or Uns/$\sqrt{3}$
Vntp	Neutral point voltage transformer primary voltage (generator application)		220 V to 250 kV
Vnts	Neutral point voltage transformer secondary voltage (generator application)		57.7 V to 133 V
fn	Rated frequency		50 Hz or 60 Hz
	Phase rotation direction		1-2-3 or 1-3-2
	Integration period (for demand current and peak demand current and power)		5, 10, 15, 30, 60 min
	Pulse-type accumulated energy meter	Increments active energy	0.1 kWh to 5 MWh
		Increments reactive energy	0.1 kVARh to 5 MVARh
S	Transformer rated apparent power		100 kVA to 999 MVA
Un1	Rated winding 1 voltage (main channels: I)		220 V to 250 kV
Un2	Rated winding 2 voltage (additional channels: I')		220 V to 400 kV
In1	Rated winding 1 current (not adjustable)		In1 = P/($\sqrt{3}$ Un1)
In2	Rated winding 2 current (not adjustable)		In2 = P/($\sqrt{3}$ Un2)
	Transformer vector shift		0 to 11
Ωn	Rated speed (motor, generator)		100 to 3600 rpm
R	Number of pulses per rotation (for speed acquisition)		1 to 1800 (Ωn x R/60⩽1500)
	Zero speed set point		5 to 20 % of Ωn
	Number of capacitor steps		1 to 4
	Connection of capacitor steps		Star / Delta
	Capacitor step ratio	Step 1	1
		Step 2	1, 2
		Step 3	1, 2, 3, 4
		Step 4	1, 2, 3, 4, 6, 8

(1) *In values for LPCT, in Amps: 25, 50, 100, 125, 133, 200, 250, 320, 400, 500, 630, 666, 1000, 1600, 2000, 3150.*

(2) *Even if the value is within the range, it has to be rounded according to the setting step of 1 or 10A (i.e.: Ib = 12.2A → 13A).*

Characteristics

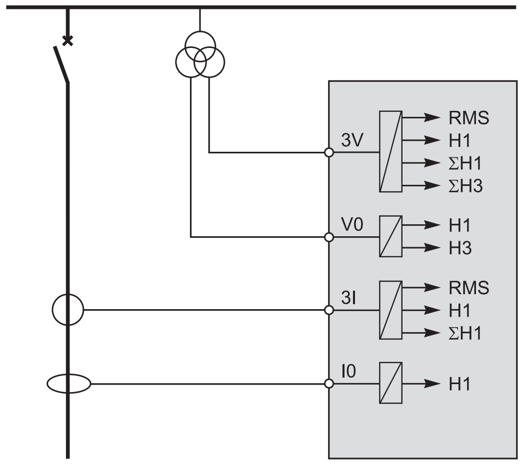
Functions		Measurement range	Accuracy (1)	MSA141	Saving
Metering					
Phase current		0.02 to 40 In	±0.5 %	■	
Residual current	Calculated	0.005 to 40 In	±1 %	■	
	Measured	0.005 to 20 In0	±1 %	■	
Demand current		0.02 to 40 In	±0.5 %		
Peak demand current		0.02 to 40 In	±0.5 %		□
Phase-to-phase voltage	Main channels (U)	0.05 to 1.2 Unp	±0.5 %	■	
	Additional channels (U')	0.05 to 1.2 Unp	±1 %		
Phase-to-neutral voltage	Main channels (V)	0.05 to 1.2 Vnp	±0.5 %	■	
	Additional channels (V')	0.05 to 1.2 Vnp	±1 %		
Residual voltage		0.015 to 3 Vnp	±1 %		
Neutral point voltage		0.015 to 3 Vntp	±1 %		
Positive sequence voltage		0.05 to 1.2 Vnp	±2 %		
Negative sequence voltage		0.05 to 1.2 Vnp	±2 %		
Frequency	Main channels (f)	25 to 65 Hz	±0.01 Hz	■	
	Additional channels (f')	45 to 55 Hz (fn = 50 Hz) 55 to 65 Hz (fn = 60 Hz)	±0.05 Hz		
Active power (total or per phase)		0.008 Sn to 999 MW	±1 %	■	
Reactive power (total or per phase)		0.008 Sn to 999 MVAR	±1 %	■	
Apparent power (total or per phase)		0.008 Sn to 999 MVA	±1 %	■	
Peak demand active power		0.008 Sn to 999 MW	±1 %		□
Peak demand reactive power		0.008 Sn to 999 MVAR	±1 %		□
Power factor		-1 to + 1 (CAP/IND)	±0.01	■	
Calculated active energy		0 to 2.1 x 10^8 MWh	±1 % ±1 digit		□ □
Calculated reactive energy		0 to 2.1 x 10^8 MVARh	±1 % ±1 digit		□ □
Temperature		-30 °C to +200 °C or -22 °F to +392 °F	±1 °C from +20 to +140 °C	■	
Rotation speed		0 to 7200 rpm	±1 rpm		
Network diagnosis assistance					
Tripping context					□
Tripping current		0.02 to 40 In	±5 %		□
Number of trips		0 to 65535	-		□ □
Negative sequence / unbalance		1 to 500 % of Ib	±2 %		
Total harmonic distortion, current		0 to 100 %	±1 %		
Total harmonic distortion, voltage		0 to 100 %	±1 %		
Phase displacement φ0 (between V0 and I0)		0 to 359°	±2°		
Phase displacement φ1, φ2, φ3 (between V and I)		0 to 359°	±2°		
Disturbance recording					□
Amplitude difference		0 to 1.2 Usync1	±1 %		
Frequency difference		0 to 10 Hz	±0.5 Hz		
Phase difference		0 to 359°	±2°		
Out-of-sync context					□

■ *available on MSA141 analog output module, according to setup*
□ □ *saved in the event of auxiliary supply outage, even without battery*
□ *saved by battery in the event of auxiliary supply outage.*
***(1)** Typical accuracy, see details on subsequent pages.*

Functions	Measurement range	Accuracy (1)	MSA141	Saving
Machine operating assistance				
Thermal capacity used	0 to 800 % (100 % for phase I = Ib)	±1 %	■	□ □
Remaining operating time before overload tripping	0 to 999 min	±1 min		
Waiting time after overload tripping	0 to 999 min	±1 min		
Running hours counter / operating time	0 to 65535 hours	±1 % or ±0.5 h		□ □
Starting current	1.2 Ib to 40 In	±5 %		□
Starting time	0 to 300 s	±300 ms		□
Number of starts before inhibition	0 to 60			
Start inhibit time	0 to 360 min	±1 min		
Differential current	0.015 to 40 In	±1 %		
Through current	0.015 to 40 In	±1 %		
Phase displacement θ1, θ2, θ3 (between I and I')	0 to 359°	±2°		
Apparent impedance Zd, Z21, Z32, Z13	0 to 200 kΩ	±5 %		
Third harmonic neutral point voltage	0.2 to 30 % of Vnp	±1 %		
Third harmonic residual voltage	0.2 to 90 % of Vnp	±1 %		
Capacitance	0 to 30 F	±5 %		
Capacitor unbalance current	0.02 to 40 I'n	±5 %		
Switchgear diagnosis assistance				
Cumulative breaking current	0 to 65535 kA²	±10 %		□ □
Number of operations	0 to 4 x 10^9	-		□ □
Operating time	20 to 100 s	±1 ms		□ □
Charging time	1 to 20 s	±0.5 s		□ □
Number of rackouts	0 to 65535	-		□ □
Auxiliary supply supervision	20 to 275V CC	±10 % or ±4 V		

■ *available on MSA141 analog output module, according to setup*
□ □ *saved in the event of auxiliary supply outage, even without battery*
□ *saved by battery in the event of auxiliary supply outage.*
***(1)** Typical accuracy, see details on subsequent pages.*

Processing of measured signals



Values produced by Sepam from the signals measured.

Measured physical values

Sepam measures the following physical values:
- phase currents (3I)
- residual current (I0)
- phase voltages (3V)
- residual voltage (V0).

Each measured signal is processed by Sepam to produce all the values necessary for the metering, diagnosis and protection functions.

The charts below indicate, for the various functions, the values produced from the signals measured, with:
- RMS = RMS value up to the 13th harmonic
- H1 = fundamental 50 Hz or 60 Hz component
- ΣH1 = vector sum of the fundamental components of the three phases
- H3 = 3rd harmonic component
- ΣH3 = vector sum of the 3rd harmonic components of the three phases.

Values used by the metering and diagnosis functions

		3I			I0	3V				V0	
Metering		**RMS**	**H1**	**ΣH1**	**H1**	**RMS**	**H1**	**ΣH1**	**ΣH3**	**H1**	**H3**
RMS phase current I1, I2, I3		■									
Calculated residual current I0Σ				■							
Demand current I1, I2, I3		■									
Peak demand current IM1, IM2, IM3		■									
Measured residual current I0, I'0					■						
Voltage U21, U32, U13, V1, V2, V3, U'21, U'32, U'13, V'1, V2', V'3							■				
Residual voltage V0								□		□	
Positive sequence voltage Vd / rotation direction							■				
Negative sequence voltage Vi							■				
Frequency f							■				
Active power P, P1, P2, P3			■				■				
Reactive power Q, Q1, Q2, Q3			■				■				
Apparent power S, S1, S2, S3			■				■				
Peak demand power PM, QM			■				■				
Power factor			■				■				
Calculated active and reactive energy (±Wh, ±VARh)			■				■				
Phase current I'1, I'2, I'3 RMS		■									
Calculated residual current I'0Σ				■							
Neutral point voltage Vnt										■	
Network and machine diagnosis											
Tripping current TripI1, TripI2, TripI3			■								
Unbalance ratio / negative sequence current Ii			■								
Harmonic distortion (THD), current Ithd		■	■								
Harmonic distortion (THD), voltage Uthd						■	■				
Phase displacement φ0, φ'0, φ0Σ				■	■			□		□	
Phase displacement φ1, φ2, φ3			■				■				
Thermal capacity used		■									
Unbalance ratio / negative sequence current I'i			■								
Differential current Idiff1, Idiff2, Idiff3			■								
Through current It1, It2, It3			■								
Angle between currents I and I'			■								
Starting current			■								
Third harmonic voltage, neutral point or residual									■		■
Switchgear diagnosis	**ANSI code**										
CT / VT supervision	60/60FL		■				■				
Cumulative breaking current			■								

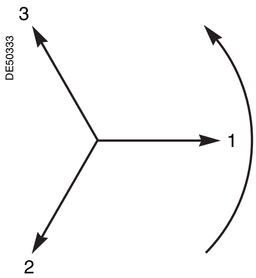
■ *standard*
□ *according to measurement sensors connected.*

Values used by the protection functions

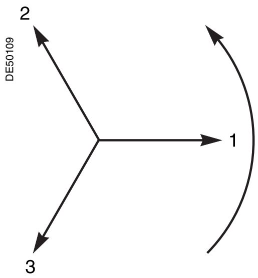
		3I			I0	3V				V0	
Protections	**ANSI code**	**RMS**	**H1**	**ΣH1**	**H1**	**RMS**	**H1**	**ΣH1**	**ΣH3**	**H1**	**H3**
Phase overcurrent	50/51		■								
Earth fault Sensitive earth fault	50N/51N 50G/51G			□	□						
Breaker failure	50BF		■								
Negative sequence / unbalance	46		■								
Thermal overload for cables	49RMS	■									
Generic thermal overload	49RMS	■									
Thermal overload for capacitors	49RMS	■									
Thermal overload for motors	49RMS	■									
Thermal overload for transformers	49RMS	■									
Capacitor bank unbalance	51C		■								
Restricted earth fault	64REF			■	■						
Two-winding transformer differential	87T		■								
Machine differential	87M		■								
Directional phase overcurrent	67		■				■				
Directional earth fault	67N/67NC			□	□			□		□	
Directional active overpower	32P		■				■				
Directional reactive overpower	32Q		■				■				
Directional active underpower	37P		■				■				
Phase undercurrent	37		■								
Excessive starting time, locked rotor	48/51LR		■								
Starts per hour	66		■								
Field loss (underimpedance)	40		■				■				
Pole slip	78 PS		■				■				
Voltage-restrained overcurrent	50V/51V		■				■				
Underimpedance	21B		■				■				
Inadvertent energization	50/27		■				■				
Third harmonic undervoltage / 100 % stator earth fault	27TN/64G2 64G								□		■
Overfluxing (V / Hz)	24						■				
Positive sequence undercurrent	27D						■				
Remanent undervoltage	27R						■				
Undervoltage (L-L or L-N)	27						■				
Overvoltage (L-L or L-N)	59						■				
Neutral voltage displacement	59N							□		□	
Negative sequence overvoltage	47						■				
Overfrequency	81H						■				
Underfrequency	81L						■				
Rate of change of frequency	81R						■				

■ *standard*
□ *according to measurement sensors connected.*

Phase rotation direction



Phase rotation direction 1-2-3.



Phase rotation direction 1-3-2.

The rotation direction of the 3 phases of the network may be 1-2-3, or 1-3-2, the phase order in the trigonometric (counter-clockwise) direction.
The phase rotation direction needs to be set for correct calculation of the symmetrical components (Vd, Vi, Id, Ii).
The phase rotation direction directly affects:

- the direction of energy flow measured in the Sepam relay
- the sign and calculation of the powers and directional functions.

Phase current
Residual current

Phase current

Operation

This function gives the RMS value of the phase currents:
- I1: phase 1 current, main channels
- I2: phase 2 current, main channels
- I3: phase 3 current, main channels
- I’1: phase 1 current, additional channels
- I’2: phase 2 current, additional channels
- I’3: phase 3 current, additional channels.

It is based on RMS current measurement and takes into account harmonics up to the 13th.
Different types of sensors may be used to meter phase current:
- 1 A or 5 A current transformers
- LPCT (Low Power Current Transducer) type current sensors.

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link
- an analog converter with the MSA141 option.

Characteristics

Measurement range	0.02 to 40 In (1)
Units	A or kA
Resolution	0.1 A
Accuracy	±0.5 % typical (2) ±1 % from 0.3 to 1.5 In ±2 % from 0.1 to 0.3 In
Display format	3 significant digits
Refresh interval	1 second (typical)

(1) *In rated current set in the general settings.*
(2) *At In, under reference conditions (IEC 60255-6).*

Residual current

Operation

This operation gives the RMS value of the residual current.
It is based on measurement of the fundamental component.
Four types of residual current values are available depending on the type of Sepam and sensors connected to it:
- 2 residual currents I0Σ and I'0Σ, calculated by the vector sum of the 3 phase currents
- 2 measured residual currents I0 and I'0.

Different types of sensors may be used to measure residual current:
- CSH120 or CSH200 specific core balance CT
- conventional 1 A or 5 A current transformer
- any core balance CT with an ACE990 interface.

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link
- an analog converter with the MSA141 option.

Characteristics

Measurement range	I0Σ or I’0Σ			0.005 to 40 In (1)
	I0 or I’0 measured by CSH core balance CT	Rating	In0 = 2 A	0.005 to 20 In0 (1)
			In0 = 20 A	0.005 to 20 In0 (1)
	I0 or I’0 measured by core balance CT with ACE990			0.005 to 20 In0 (1)
	I0 or I’0 measured by CT			0.005 to 20 In0 (1)
Units				A or kA
Resolution				0.1 A or 1 digit
Accuracy (2)				±1 % typical at In0 ±2 % from 0.3 to 1.5 In0 ±5 % from 0.1 to 0.3 In0
Display format				3 significant digits
Refresh interval				1 second (typical)

(1) *In, In0: nominal rating set in the general settings.*
(2) *Under reference conditions (IEC 60255-6), excluding sensor accuracy.*

Demand current and peak demand currents

Operation

Demand current and peak demand currents are calculated according to the 3 phase currents I1, I2 and I3:
- demand current is calculated over an adjustable period of 5 to 60 minutes
- peak demand current is the greatest demand current and indicates the current drawn by peak loads.

Peak demand currents may be cleared. They are saved in the event of a power failure.

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Resetting to zero

- via the clear key on the Sepam display if a peak demand is displayed
- via the clear command in the SFT2841 software
- via the communication link (remote control order TC4).

Characteristics

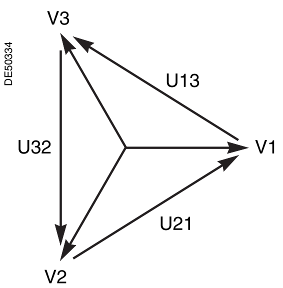
Measurement range	0.02 to 40 In (1)
Units	A or kA
Resolution	0.1 A
Accuracy	±0.5 % typical (2) ±1 % from 0.3 to 1.5 In ±2 % from 0.1 to 0.3 In
Display format	3 significant digits
Integration period	5, 10, 15, 30, 60 min

(1) *In rated current set in the general settings.*
(2) *At In, under reference conditions (IEC 60255-6).*

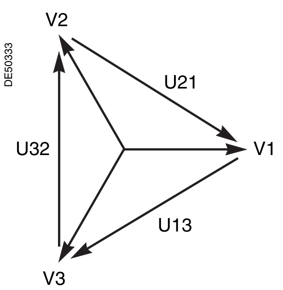
TS/TC equivalence for each protocol

Modbus	DNP3	IEC 60870-5-103	IEC 61850
TC	**Binary Output**	**ASDU, FUN, INF**	**LN.DO.DA**
TC4	BO12	-	MSTA1.RsMaxA.ctlVal

Phase-to-phase voltage



1-2-3 network: phase-to-neutral and phase-to-phase voltages.



1-3-2 network: phase-to-neutral and phase-to-phase voltages.

Operation

This function gives the RMS value of the fundamental 50 Hz or 60 Hz component of:
- the main phase-to-phase voltages:
  - □ $(\vec{\mathbf{U21}} = \vec{\mathbf{V1}} - \vec{\mathbf{V2}})$, voltage between phases 2 and 1
  - □ $(\vec{\mathbf{U32}} = \vec{\mathbf{V2}} - \vec{\mathbf{V3}})$, voltage between phases 3 and 2
  - □ $(\vec{\mathbf{U13}} = \vec{\mathbf{V3}} - \vec{\mathbf{V1}})$, voltage between phases 1 and 3.
- the additional phase-to-phase voltages:
  - □ $\vec{\mathbf{U}}'\,\mathbf{21} = \vec{\mathbf{V}}'\,\mathbf{1} - \overrightarrow{\mathbf{V}'\,\mathbf{2}}$, voltage between phases 2 and 1
  - □ $\vec{\mathbf{U}}'\,\mathbf{32} = \vec{\mathbf{V}}'\,\mathbf{2} - \overrightarrow{\mathbf{V}'\,\mathbf{3}})$, voltage between phases 3 and 2
  - □ $\vec{\mathbf{U}}'\,\mathbf{13} = \overrightarrow{\mathbf{V}'\,\mathbf{3}} - \vec{\mathbf{V}}'\,\mathbf{1})$, voltage between phases 1 and 3.

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link
- an analog converter with the MSA141 option.

Characteristics

Measurement range	0.05 to 1.2 Unp (1)
Units	V or kV
Resolution	1 V
Accuracy	±0.5 % typical (2) main channels ±1 % typical (2) additional channels ±1 % from 0.5 to 1.2 Unp ±2 % from 0.06 to 0.5 Unp
Display format	3 significant digits
Refresh interval	1 second (typical)

***(1)** Un rated current set in the general settings.*
***(2)** At Unp, under reference conditions (IEC 60255-6).*

Operation

This function gives the RMS value of the fundamental 50 Hz or 60 Hz component of:

- the main phase-to-neutral voltages V1, V2, V3 measured on phases 1, 2 and 3
- the additional phase-to-neutral voltages V'1, V'2 and V'3 measured on phases 1, 2 and 3.

Readout

The measurements may be accessed via:

- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link
- an analog converter with the MSA141 option.

Characteristics

Measurement range	0.05 to 1.2 Vnp (1)
Units	V or kV
Resolution	1 V
Accuracy	±0.5 % typical (2) main channels ±1 % typical (2) additional channels ±1 % from 0.5 to 1.2 Vnp ±2 % from 0.06 to 0.5 Vnp
Display format	3 significant digits
Refresh interval	1 second (typical)

(1) *Vnp: primary rated phase-to-neutral voltage (Vnp = Unp/$\sqrt{3}$).*
(2) *At Vnp, under reference conditions (IEC 60255-6).*

Residual voltage
Neutral point voltage

Residual voltage

Operation

This function gives the following values:

- main residual voltage $\vec{V0} = \vec{V1} + \vec{V2} + \vec{V3}$
- additional residual voltage $\overrightarrow{V'0} = \vec{V'1} + \vec{V'2} + \overrightarrow{V'3}$

The residual voltage value may be:
- calculated by an open star/delta VT
- or calculated by taking the internal sum of the 3 phase voltages.

It is based on the measurement of the fundamental 50 Hz or 60 Hz component of the voltages.

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0.015 to 3 Vnp (1)
Units	V or kV
Resolution	1 V
Accuracy	±1 % from 0.5 to 3 Vnp ±2 % from 0.05 to 0.5 Vnp ±5 % from 0.02 to 0.05 Vnp
Display format	3 significant digits
Refresh interval	1 second (typical)

(1) Vnp: primary rated phase-to-neutral voltage (Vnp = Unp/$\sqrt{3}$).

Neutral point voltage

Operation

This function gives the value of the zero sequence voltage Vnt, measured at the neutral point of a generator or motor by a dedicated VT:

$$\vec{Vnt} = (\vec{V1} + \vec{V2} + \vec{V3}) / 3$$

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0.015 Vnp to 3 Vntp (1)
Units	V or kV
Resolution	1 V
Accuracy	±1 % from 0.5 to 3 Vntp ±2 % from 0.05 to 0.5 Vntp ±5 % from 0.02 to 0.05 Vntp
Display format	3 significant digits
Refresh interval	1 second (typical)

(1) Vntp: neutral point voltage transformer primary voltage.

2

Operation

This function calculates the value of the main positive sequence voltage Vd:

- from the 3 main phase-to-neutral voltages:
  - phase rotation direction 1-2-3: $\vec{Vd} = \frac{1}{3} \times (\vec{V1} + a\vec{V2} + a^2\vec{V3})$
  - phase rotation direction 1-3-2: $\vec{Vd} = \frac{1}{3} \times (\vec{V1} + a^2\vec{V2} + a\vec{V3})$
- or from the 2 main phase-to-phase voltages:
  - phase rotation direction 1-2-3: $\vec{Vd} = \frac{1}{3} \times (\vec{U21} - a^2\vec{U32})$
  - phase rotation direction 1-3-2: $\vec{Vd} = \frac{1}{3} \times (\vec{U21} - a\vec{U32})$

with $a = e^{j\frac{2\pi}{3}}$

The additional positive sequence voltage V'd is calculated in the same way:

- from the 3 additional phase-to-neutral voltages V'1, V'2 and V'3
- or from the 2 additional phase-to-phase voltages U'21 and U'32.

Readout

The measurements may be accessed via:

- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0.05 to 1.2 Vnp (1)
Units	V or kV
Resolution	1 V
Accuracy	±2 % at Vnp
Display format	3 significant digits
Refresh interval	1 second (typical)

(1) *Vnp: primary rated phase-to-neutral voltage (Vnp = Unp/√3).*

Negative sequence voltage

Operation

This function calculates the value of the main negative sequence voltage Vi:

- from the 3 main phase-to-neutral voltages:
  - phase rotation direction 1-2-3: $\vec{Vi} = \frac{1}{3} \times (\vec{V1} + a^2\vec{V2} + a\vec{V3})$
  - phase rotation direction 1-3-2: $\vec{Vi} = \frac{1}{3} \times (\vec{V1} + a\vec{V2} + a^2\vec{V3})$
- or from the 2 main phase-to-phase voltages:
  - phase rotation direction 1-2-3: $\vec{Vi} = \frac{1}{3} \times (\vec{U21} - a\vec{U32})$
  - phase rotation direction 1-3-2: $\vec{Vi} = \frac{1}{3} \times (\vec{U21} - a^2\vec{U32})$

with $a = e^{j\frac{2\pi}{3}}$

The additional negative sequence voltage V'i is calculated in the same way:

- from the 3 additional phase-to-neutral voltages V'1, V'2 and V'3
- or from the 2 additional phase-to-phase voltages U'21 and U'32.

Readout

The measurements may be accessed via:

- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0.05 to 1.2 Vnp (1)
Units	V or kV
Resolution	1 V
Accuracy	±2 % at Vnp
Display format	3 significant digits
Refresh interval	1 second (typical)

***(1)** Vnp: primary rated phase-to-neutral voltage (Vnp = Unp/$\sqrt{3}$).*

Frequency

Operation

This function gives the frequency value.
Frequency is measured via the following:
- based on U21 or V1, if only one phase-to-phase voltage is connected to the Sepam
- based on positive sequence voltage in other cases.

Frequency is not measured if:
- the voltage U21 (or V1) or positive sequence voltage Vd is less than 40 % of Un
- the frequency f is outside the measurment range.

The measurement of the frequency f' is calculated according to the same principle, from V'd or U'21 or V'1

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link
- an analog converter with the MSA141 option.

Characteristics

Main channels	
Rated frequency	50 Hz, 60 Hz
Range	25 to 65 Hz
Resolution	0.01 Hz (1)
Accuracy (2)	±0.01 Hz
Display format	3 significant digits
Refresh interval	1 second (typical)
Additional channels	
Rated frequency fn	50 Hz, 60 Hz
Range	45 to 55 Hz (fn = 50 Hz)
	55 to 65 Hz (fn = 60 Hz)
Resolution (1)	0.01 Hz
Accuracy (2)	±0.05 Hz
Display format	3 significant digits
Refresh interval	1 second (typical)

***(1)** On SFT2841.*
***(2)** At Unp, under reference conditions (IEC 60255-6).*

Active, reactive and apparent power

Operation

Power values are calculated from the phase currents I1, I2 and I3:
- active power = $\sqrt{3}$.U.I cos φ
- reactive power = $\sqrt{3}$.U.I.sin φ
- apparent power = $\sqrt{3}$.U.I.

According to the sensors used, power calculations may be based on the 2 or 3 wattmeter method (see table below).
The 2 wattmeter method is only accurate when there is no residual current, but it is not applicable if the neutral is distributed.
The 3 wattmeter method gives an accurate calculation of 3-phase and phase by phase powers in all cases, regardless of whether or not the neutral is distributed.

Connection of voltage channels	Connection of main current channels	P, Q, S calculation method	Power per phase P1, P2, P3 Q1, Q2, Q3 S1, S2, S3
3 V	I1, I2, I3	3 wattmeters	Available
	I1, I3	2 wattmeters	Not available
U32, U21 + V0	I1, I2, I3	3 wattmeters	Available
	I1, I3	2 wattmeters	Not available
U32, U21 without V0	I1, I2, I3 or I1, I3	2 wattmeters	Not available
U21	I1, I2, I3 or I1, I3	2 wattmeters The system voltage is considered to be balanced	Not available
V1	I1, I2, I3 or I1, I3	No calculation	P1, Q1, S1 only

Power calculation
- by 3 wattmeter method:

$$P = \vec{V1}\,\vec{I1}\cos(\vec{V1},\vec{I1}) + \vec{V2}\,\vec{I2}\cos(\vec{V2},\vec{I2}) + \vec{V3}\,\vec{I3}\cos(\vec{V3},\vec{I3})$$

$$Q = \vec{V1}\,\vec{I1}\sin(\vec{V1},\vec{I1}) + \vec{V2}\,\vec{I2}\sin(\vec{V2},\vec{I2}) + \vec{V3}\,\vec{I3}\sin(\vec{V3},\vec{I3})$$

- by 2 wattmeter method:

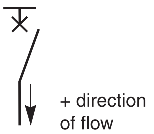
$$P = \vec{U21}\,\vec{I1}\cos(\vec{U21},\vec{I1}) - \vec{U32}\,\vec{I3}\cos(\vec{U32},\vec{I3})$$

$$Q = \vec{U21}\,\vec{I1}\sin(\vec{U21},\vec{I1}) - \vec{U32}\,\vec{I3}\sin(\vec{U32},\vec{I3})$$

- $S = \sqrt{P^2 + Q^2}$.

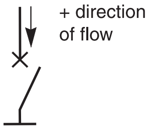
According to standard practice, it is considered that:
- for the outgoing circuit (1):
  - □ power supplied by the busbars is positive
  - □ power supplied to the busbars is negative

DE50646



- for the incoming circuit (1):
  - □ power supplied to the busbars is positive
  - □ power supplied by the busbars is negative.

DE50647



(1) Choice to be set in the general settings.

Active, reactive and apparent power

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link
- an analog converter with the MSA141 option.

Characteristics

	Active power P, P1, P2, P3	**Reactive power Q, Q1, Q2, Q3**	**Apparent power S, S1, S2, S3**
Measurement range	±(0.8 % Sn at 999 MW) (1)	±(0.8 % Sn at 999 Mvar) (1)	0.8 % Sn at 999 MVA (1)
Units	kW, MW	kvar, Mvar	kVA, MVA
Resolution	0.1 kW	0.1 kvar	0.1 kVA
Accuracy	±1 % from 0.3 to 1.5 Sn (2) ±3 % from 0.1 to 0.3 Sn (2)	±1 % from 0.3 to 1.5 Sn (3) ±3 % from 0.1 to 0.3 Sn (3)	±1 % from 0.3 to 1.5 Sn ±3 % from 0.1 to 0.3 Sn
Display format	3 significant digits	3 significant digits	3 significant digits
Refresh interval	1 second (typical)	1 second (typical)	1 second (typical)

(1) *Sn =* $\sqrt{3}$ *Unp.In.*
(2) *In, Unp, Cos φ > 0.8 under reference conditions (IEC 60255-6).*
(3) *In, Unp, Cos φ < 0.6 under reference conditions (IEC 60255-6).*

Peak demand active and reactive power Power factor (cos φ)

Peak demand active and reactive power

Operation

This function gives the greatest demand active or reactive power value since the last reset.
The values are refreshed after each "integration interval", an interval that may be set from 5 to 60 min (common interval with peak demand phase currents). The values are saved in the event of a power failure.

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Resetting to zero

- via the clear key on the Sepam display if a peak demand is displayed
- via the clear command in the SFT2841 software
- via the communication link (remote control order TC5).

Characteristics

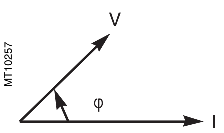
	Demand active power	Demand reactive power
Measurement range	±(1.5 % Sn at 999 MW) (1)	±(1.5 % Sn at 999 Mvar) (1)
Units	kW, MW	kvar, Mvar
Resolution	0.1 kW	0.1 kvar
Accuracy	±1 %, typical (2)	±1 % typical (3)
Display format	3 significant digits	3 significant digits
Integration period	5, 10, 15, 30, 60 min	5, 10, 15, 30, 60 min

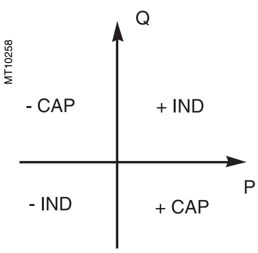
(1) Sn = $\sqrt{3}$ Unp.In.
(2) At In, Unp, cos φ > 0.8 under reference conditions (IEC 60255-6).
(3) At In, Unp, cos φ < 0.6 under reference conditions (IEC 60255-6).

TS/TC equivalence for each protocol

Modbus	DNP3	IEC 60870-5-103	IEC 61850
TC	**Binary Output**	**ASDU, FUN, INF**	**LN.DO.DA**
TC5	BO14	-	MSTA1.RsMaxPwr.ctlVal

Power factor (cos φ)





CEI Convention.

Operation

The power factor is defined by: $\cos\varphi = P / \sqrt{P^2 + Q^2}$.

It expresses the phase displacement between the phase currents and phase-to-neutral voltages.
The + and - signs and **IND** (inductive) and **CAP** (capacitive) indications give the direction of power flow and the type of load.

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	-1 at 1 IND/CAP
Resolution	0.01
Accuracy (1)	0.01 typical
Display format	3 significant digits
Refresh interval	1 second (typical)

(1) At In, Unp, cos φ > 0.8 under reference conditions (IEC 60255-6).

2

Accumulated active and reactive energy

Operation

This function gives the following for the active and reactive energy values, calculated according to voltages and phase currents I1, I2 and I3:
- accumulated energy conveyed in one direction
- accumulated energy conveyed in the other direction.

It is based on measurement of the fundamental component.
The accumulated energy values are saved in the event of a power failure.

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

	Active energy	Reactive energy
Metering capacity	0 to 2.1 10^8 MW.h	0 to 2.1 10^8 Mvar.h
Units	MW.h	Mvar.h
Resolution	0.1 MW.h	0.1 Mvar.h
Accuracy	±1 % typical (1)	±1 % typical (1)
Display format	10 significant digits	10 significant digits

(1) At In, Unp, cos φ > 0.8 under reference conditions (IEC 60255-6).

Accumulated active and reactive energy by pulse metering

Operation

This function is used for energy metering via logic inputs. Energy incrementing is associated with each input (one of the general parameters to be set). Each input pulse increments the meter. 4 inputs and 4 accumulated energy metering options are available:
- positive and negative active energy
- positive and negative reactive energy.

The accumulated active and reactive energy values are saved in the event of a power failure.

Readout

- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

	Active energy	Reactive energy
Metering capacity	0 to 2.1 10^8 MW.h	0 to 2.1 10^8 Mvar.h
Units	MW.h	Mvar.h
Resolution	0.1 MW.h	0.1 Mvar.h
Display format	10 significant digits	10 significant digits
Increment	0.1 kW.h to 5 MW	0.1 kvar.h to 5 Mvar.h
Pulse	15 ms min.	15 ms min.

Operation

This function gives the temperature value measured by resistance temperature detectors (RTDs):
■ platinum Pt100 (100 Ω at 0 °C or 32 °F) in accordance with the IEC 60751 and DIN 43760 standards
■ nickel 100 Ω or 120 Ω (at 0 °C or 32 °F).
Each RTD channel gives one measurement:
tx = RTD x temperature.
The function also indicates RTD faults:
■ RTD disconnected (t > 205 °C or t > 401 °F)
■ RTD shorted (t < -35 °C or t < -31 °F).
In the event of a fault, display of the value is inhibited.
The associated monitoring function generates a maintenance alarm.

Readout

The measurements may be accessed via:
■ the Sepam display via the key, in °C or °F
■ the display of a PC with the SFT2841 software
■ the communication link
■ an analog converter with the MSA141 option.

Characteristics

Range	-30 °C to +200 °C	-22 °F to +392 °F
Resolution	1 °C	1 °F
Accuracy	±1 °C from +20 °C to +140 °C ±2 °C from -30 °C to +20 °C ±2 °C from +140 °C to +200 °C	±1.8 °F from +68 °F to +284 °F ±3.6 °F from -22 °F to +68 °F ±3.6 °F from +284 °F to +392 °F
Refresh interval	5 seconds (typical)	

Accuracy derating according to wiring

■ connection in 3-wire mode: the error Δt is proportional to the length of the connector and inversely proportional to the connector cross-section:

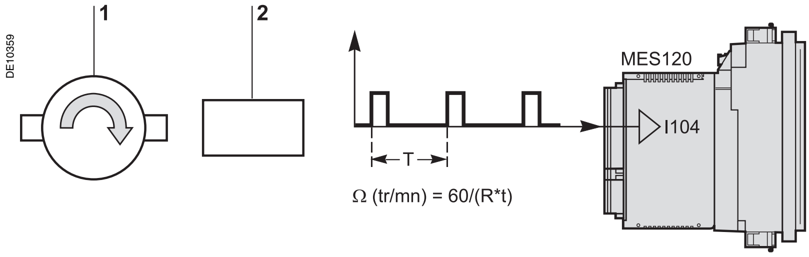
$$\Delta t(°C) = 2 \times \frac{l(km)}{S(mm^2)}$$

□ ±2.1 °C/km for a cross-section of 0.93 mm^2 (AWG 18)
□ ±1 °C/km for a cross-section of 1.92 mm^2 (AWG 14).

2

Operation

This function gives the rotation speed of a motor or generator rotor. It is calculated by measurement of the time between two pulses transmitted by a proximity sensor at each passage of a cam driven by the rotation of the motor or generator shaft. The number of pulses per rotation is set in the "particular characteristics" screen of the SFT2841 software. The proximity sensor is connected to logic input I104.



1 Rotor with 2 cams.
2 Proximity sensor.

Readout

The measurements may be accessed via:
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Range		0 to 7200 rpm
Resolution		1 rpm
Accuracy		±1 rpm
Refresh interval		1 second (typical)
Pulses per rotation (R)		1 to 1800 with Ωn R/60 ≤1500 (Ωn: rated speed in rpm)
Proximity sensor	Pass-band (in Hz)	> 2.Ωn R/60
	Output	24 to 250 V DC, 3 mA minimum
	Leakage current in open status	< 0.5 mA
	Voltage dip in closed status	< 4 V (with 24 V DC power supply)
	Pulse duration	0 status > 120 µs
		1 status > 200 µs

Phasor diagram

Operation

This function displays a phasor diagram of the fundamental component of the current and voltage measurements as acquired by Sepam without any correction. It provides effective assistance in the checking of cables and the implementation of directional and differential protection functions.
It is fully parameterizable and the following choices are proposed to adapt the phasor diagram according to requirements:
- choice of measurements to be displayed in the phasor diagram
- choice of reference phasor
- choice of display mode.

Measurements to be displayed
- phase currents on main and additional channel
- residual currents measured or with sum on main and additional channels
- symmetrical components of current Id, Ii, I0Σ/3
- phase-to-neutral voltages on main and additional channels
- phase-to-phase voltages on main and additional channels
- residual voltages on main and additional channels
- symmetrical components of voltage Vd, Vi, V0/3.

Reference phasor
The reference phasor according to which the phase shifts of the other phasors displayed are calculated may be chosen from the phase or residual current or voltage phasors. When the reference phasor is too small (< 2 % In for currents or 5 % Un for voltages), display is impossible.

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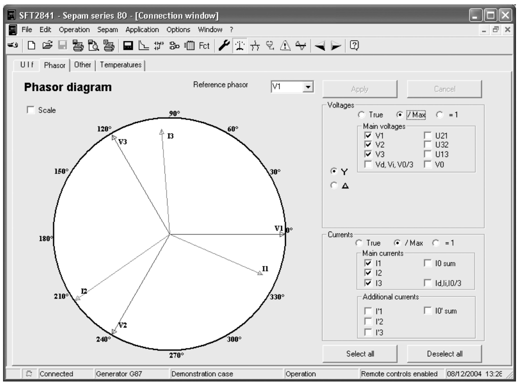


Phasor diagram on SFT2841

Display mode
- Display as true values: the measurements are displayed without any modification in a scale chosen in relation to the respective rated values:
  - 0 to 2 Max (In, I'n) for currents
  - 0 to 2 Max (Unp, U'np) for voltages.
- Display as values normalized in relation to the maximum, i.e. the measurements are normalized in relation to the greatest measurement of the same type. The greatest measurement is displayed full scale with a modulus equal to 1, and the others are displayed as relative values compared to the modulus 1 value. This display provides maximum angular resolution, regardless of the measured values, while maintaining the relative values between measurements.
- Display as values normalized to 1: all the measurements are normalized in relation to themselves and displayed with a modulus of 1, equal to full scale. This mode provides optimal display of the angles between phasors but does not allow moduli to be compared.
- Display of phase-to-phase voltage values in a triangle arrangement: for a more common display of phase-to-phase voltage phasors.
- Display / elimination of the scale: for more convenient reading of the displayed phasors.

Readout

All of the possibilities described above may be accessed via the SFT2841 setting and operating software.
Two predefined displays are available on the mimic-based UMI:
- display of the three phase currents and three phase-to-neutral voltages of the main channels
- display of the three phase currents of the main channels and the three phase currents of the additional channels

Characteristics

Diagram display options of an SFT2841 phasor diagram	
Measurements to be displayed	
Multiple selection from:	I1, I2, I3, I0, I0Σ, Id, Ii, I0Σ/3, I'1, I'2, I'3, I'0, I'0Σ V1, V2, V3, V0, U21, U32Σ, U13, Vd, Vi, V0/3 V'1, V'2, V'3, V'0, U'21, U'32, U'13
Reference phasor	
Single choice from:	I1, I2, I3, I0, I0Σ, I'0, I'0Σ V1, V2, V3, V0, U21, U32, U13, V'1, V'2, V'3, V'0, U'21, U'32, U'13
Display mode	
Current display	true (true value) / max (value normalized in relation to maximum) = 1 (normalized to 1)
Voltage display	true (true value) / max (value normalized in relation to maximum) = 1 (normalized to 1)
Phase-to-phase voltage	star/delta
Display of scale	yes/no

Tripping context

Operation

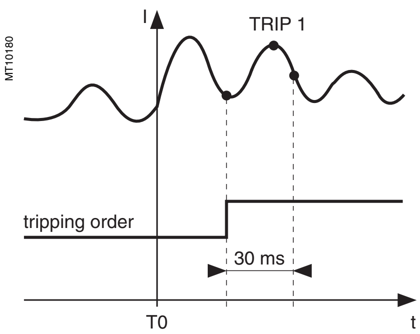
This function gives the values at the time of tripping (activation of the tripping contact on output O1) to enable analysis of the cause of the fault.
Values available on the Sepam display:
- tripping currents TRIPI et TRIPI’
- residual currents I0, I’0, I0Σ and I’0Σ
- differential and through currents
- phase-to-phase voltages
- residual voltage
- neutral point voltage
- third harmonic neutral point or residual voltage
- frequency
- active power
- reactive power
- apparent power.
- phase rotation direction 1-2-3/1-3-2

In addition to the values available on the Sepam display, the following values are available with the SFT2841 software:
- phase-to-neutral voltages
- negative sequence voltage
- positive sequence voltage.

The values for the last five trips are stored with the date and time of tripping.
They are saved in the event of a power failure.
Once 5 tripping contexts have been stored, the following new tripping value overwrites the oldest tripping context in the memory.

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.



Tripping current (TRIPI1) acquisition.

Tripping current

Operation

This function gives the RMS value of currents at the prospective time of the last trip:
- TRIPI1: phase 1 current (main channels)
- TRIPI2: phase 2 current (main channels)
- TRIPI3: phase 3 current (main channels)
- TRIPI’1: phase 1 current (additional channels)
- TRIPI’2: phase 2 current (additional channels)
- TRIPI’3: phase 3 current (additional channels).

It is based on measurement of the fundamental component.
This measurement is defined as the maximum RMS value measured during a 30 ms interval after the activation of the tripping contact on output O1.

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0.1 to 40 In (1)
Units	A or kA
Resolution	0.1 A
Accuracy	±5 % ±1 digit
Display format	3 significant digits

***(1)** In, rated current set in the general settings.*

Number of phase fault trips
Number of earth fault trips

Number of phase fault trips

Operation
This function counts the network phase faults that have caused circuit breaker tripping.
It counts only trips triggered by protection functions 50/51, 50V/51V and 67 when the circuit breaker is closed.
If there is discrimination between several circuit breakers, the fault is only counted by the Sepam that issues the trip order.
Transient faults cleared by the recloser are counted.

The number of phase fault trips is saved in the event of an auxiliary power failure.
It may be reinitialized using the SFT2841 software.

Readout
The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0 to 65535
Units	None
Resolution	1
Refresh interval	1 second (typical)

Number of earth fault trips

Operation
This function counts earth faults on the network that have caused circuit breaker tripping.
It counts only trips triggered by protection functions 50N/51N and 67N when the circuit breaker is closed.
If there is discrimination between several circuit breakers, the fault is only counted by the Sepam that issues the trip order.
Transient faults cleared by the recloser are counted.

The number of earth fault trips is saved in the event of an auxiliary power failure.
It may be reinitialized using the SFT2841 software.

Readout
The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0 to 65535
Units	None
Resolution	1
Refresh interval	1 second (typical)

Negative sequence / unbalance

Operation

This function gives the negative sequence component: **T = Ii/Ib** or **T' = I'i/I'b**.
The negative sequence current is determined based on the phase currents:

- 3 phases:
  - phase rotation direction 1-2-3: $\vec{Ii} = \frac{1}{3} \times \left(\vec{I1} + a^2\vec{I2} + a\vec{I3}\right)$
  - phase rotation direction 1-3-2: $\vec{Ii} = \frac{1}{3} \times \left(\vec{I1} + a\vec{I2} + a^2\vec{I3}\right)$
- 2 phases:
  - phase rotation direction 1-2-3: $\left|\vec{Ii}\right| = \frac{1}{\sqrt{3}} \times \left|\vec{I1} - a^2\vec{I3}\right|$
  - phase rotation direction 1-3-2: $\left|\vec{Ii}\right| = \frac{1}{\sqrt{3}} \times \left|\vec{I1} - a\vec{I3}\right|$

with $a = e^{j\frac{2\pi}{3}}$

When there are no earth faults, the formulas for 2 phase currents are equivalent to those for 3 phase currents.

Readout

The measurements may be accessed via:

- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	10 to 500 %
Units	% Ib or % I'b
Resolution	1 %
Accuracy	±2 %
Display format	3 significant digits
Refresh interval	1 second (typical)

Current total harmonic distortion Voltage total harmonic distortion

Current total harmonic distortion

Operation

Current total harmonic distortion Ithd may be used to assess the quality of the current. It is calculated based on phase I1, taking into account harmonics up to the 13th.

Ithd is calculated over 50 periods using the following formula:

$$\textbf{Ithd} = 100\ \% \sqrt{\left(\frac{\textbf{RMS}}{\textbf{H1}}\right)^2 - 1}$$

with:
RMS = RMS value of current I1 up to the 13th harmonic
H1 = value of the fundamental of current I1

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0 to 100 %
Units	%
Resolution	0.1 %
Accuracy (1)	±1 % at In for Ithd > 2 %
Display format	3 significant digits
Refresh interval	1 second (typical)

***(1)** Under reference conditions (IEC 60255-6).*

Voltage total harmonic distortion

Operation

Voltage total harmonic distortion Uthd may be used to assess the quality of the voltage. It is calculated based on the measurement of U21 or V1 according to the configuration, taking into account harmonics up to the 13th.

Uthd is calculated over 50 periods using the following formula:

$$\textbf{Uthd} = 100\ \% \sqrt{\left(\frac{\textbf{RMS}}{\textbf{H1}}\right)^2 - 1}$$

with:
RMS = RMS value of voltage U21 or V1 up to the 13th harmonic
H1 = value of the fundamental of voltage U21 or V1

Readout

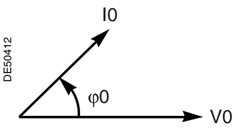
The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0 to 100 %
Units	%
Resolution	0.1 %
Accuracy (1)	±1 % at Un or Vn for Uthd > 2 %
Display format	3 significant digits
Refresh interval	1 second (typical)

***(1)** Under reference conditions (IEC 60255-6).*

Phase displacement φ0, φ'0, φ0Σ
Phase displacement φ1, φ2, φ3



Phase displacement φo.

Phase displacement φ0, φ'0, φ0Σ

Operation

This function gives the phase displacement measured between the residual voltage and residual current in the trigonometric (counter-clockwise) direction (see diagram).
The measurement is useful during commissioning to check that the directional earth fault protection unit is connected correctly.
Three values are available:

- φ0, angle between V0 and measured I0
- φ'0, angle between V0 and measured I'0
- φ0Σ, angle between V0 and I0Σ calculated as the sum of the phase currents.

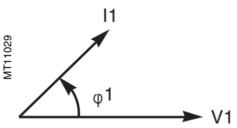
Readout

The measurements may be accessed via:

- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0 to 359°
Resolution	1°
Accuracy	±2°
Refresh interval	2 seconds (typical)



Phase displacement φ1.

Phase displacement φ1, φ2, φ3

Operation

This function gives the phase displacement between the V1, V2, V3 voltages and I1, I2, I3 currents respectively, in the trigonometric (counter-clockwise) direction (see diagram).
The measurements are used when Sepam is commissioned to check that the voltage and current inputs are wired correctly. When the phase-to-phase voltages U21 and U32 are connected to Sepam and there is no measurement of residual voltage V0, the residual voltage is presumed to be zero. The function does not operate when only the voltage U21 or V1 is connected to Sepam.
This function takes into account the convention regarding the direction of flow of energy in the outgoing and incoming circuits (see "Power measurements").
Therefore, the angles φ1, φ2 and φ3 are adjusted by 180° with respect to the values acquired by Sepam for the incoming circuits.

Readout

The measurements may be accessed via:

- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0 to 359°
Resolution	1°
Accuracy	±2°
Refresh interval	2 seconds (typical)

Disturbance recording

Operation

This function is used to record analog signals and logical states.
The storage of recordings is activated by one or more events set using the SFT2841 software.
The stored event begins before the event and continues afterwards.
Recordings comprise the following information:

- values sampled from the different signals
- date
- characteristics of the recorded channels.

The names of the logic input and output data used in Logipam are also used in disturbance recording for ease of reading.
The duration and number of recordings may be set using the SFT2841 software tool.
The files are recorded in FIFO (First In First Out) type shift storage: when the maximum number of recordings is reached, the oldest recording is erased when a new recording is triggered.

Transfer

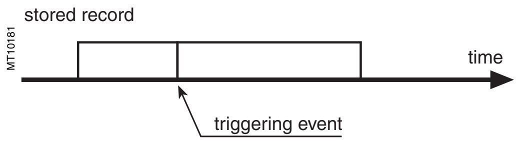
Files may be transferred locally or remotely:

- locally: using a PC which is connected to the front panel and includes the SFT2841 software tool
- remotely: using a software tool specific to the remote monitoring and control system.

Recovery

The signals are recovered from a recording by means of the Wavewin-SE software tool.

Block diagram



Characteristics

Recording content	Set-up file: date, channel characteristics, measuring chain transformer ratio Sample file: recorded signals
Sampling frequency (1)	12 or 36 samples per network period
Analog signals recorded (2)	I1, I2, I3, I0, I'1, I'2, I'3, I'0 current channels V1, V2, V3 or U21, U32, V'1, V'2, V'3, U'21, U'32 phase voltage channels V0, Vnt or V'0 residual voltage channels
Logical states recorded (1) (3)	Some or all of the following data is recorded: ■ all logic inputs / outputs ■ all GOOSE logic inputs G401 to G416 and G501 to G516 (if recording configured in SFT2841 software disturbance recording screen) ■ pick-up signal ■ 1 data item configurable by the logic equation editor (V_FLAGREC) or 15 data items configurable by Logipam (V_FLAGREC, V_FLAGREC2 to V_FLAGREC15)
Number of recordings stored (1)	1 to 19
Total duration of a recording (1)	1 s to 20 s if using a standard cartridge
	1 s to 32 s if using an extended cartridge
Maximum recording capacity (dist. rec. memory usage = 100 %)	With an MMS020 standard memory cartridge: ■ 22 s at 50 Hz, 12 samples per period ■ 18 s at 60 Hz, 12 samples per period ■ 7 s at 50 Hz, 36 samples per period ■ 6 s at 60 Hz, 36 samples per period With an MMR020 extended memory cartridge: ■ 35 s at 50 Hz, 12 samples per period ■ 28 s at 60 Hz, 12 samples per period ■ 11 s at 50 Hz, 36 samples per period ■ 9 s at 60 Hz, 36 samples per period
Periods recorded before triggering event (1)	0 to 99 periods
File format	COMTRADE - IEC60255-24 Ed 1 - 2001

***(1)** To be set using the SFT2841 software.*
***(2)** According to type and connection of sensors.*
***(3)** According to Sepam hardware configuration.*

Data log (DLG)

■ Back up any existing files before changing the DLG function parameter settings as this will result in loss of the existing files.
■ Any change to the Sepam time affects the Data logs because the time system in which they operate will have changed.
If a Data log (in Circular or Limited mode) is in progress, the corresponding operating mode is as follows:
□ the Data log is stopped
□ the user must explicitly reset the command he has triggered before being able to trigger another one.

Operation

This function is used to record and back up a set of measurements available in the Sepam relay, in the form of a COMTRADE file. The number of backed-up files and the number of measurements per file depend on the type of cartridge installed. The recording mode and selection of measurements can be configured by the user via the SFT2841 software.
The files are saved in a FIFO memory (First In First Out): when the maximum number of files is reached, a new file replaces the oldest.
Using the DLG function does not affect the quality of service of Sepam's active protection functions.

Transfer

The files can be retrieved on a medium external to the Sepam locally or remotely:
■ Locally: using a PC connected to the programming port and running the SFT2841 software
■ Remotely: when the Sepam has the ACE850 and ACE969 communication modules (TP and FO) and a dedicated supervision system program.
Only completed files can be transferred. A remote indication data item is created at the end of recording.

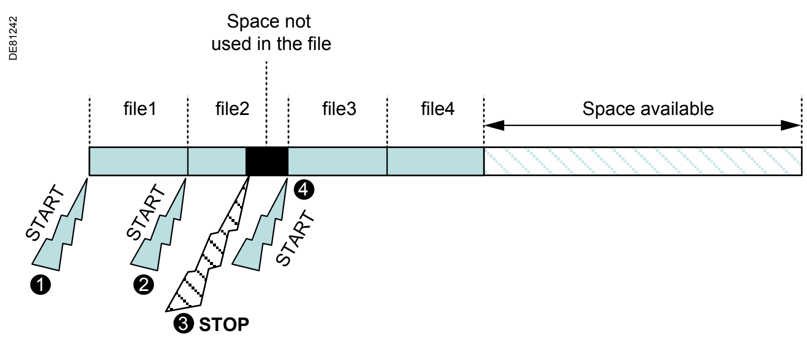
Read

The files can be viewed after being transferred to a PC using software compatible with the COMTRADE format.

Operating modes

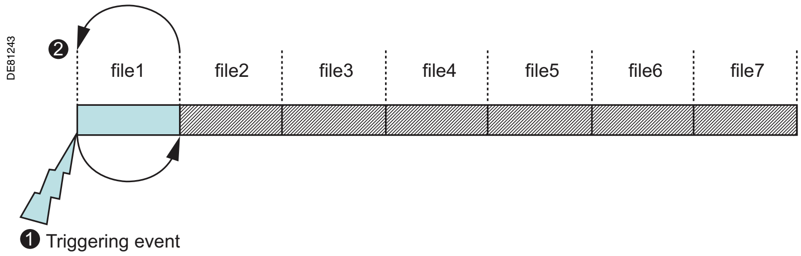
After starting up the DLG function, the measurements are captured continuously. The stop condition and file management differ according to which of the following 2 modes is used:
■ Limited (default mode): the DLG function stops automatically when the end of recording time is reached or on receipt of an external event (a logic input for example). However, the method used to stop must be the same as that used for start-up. Thus, it is not possible to start a Data log using the SFT2841 software and stop it with a remote control order (TC)
■ Circular: the file content is managed in a FIFO memory: when the file is full, the write operation continues and starts again at the start of the file. Stopping the write operation only results from an external event. In the absence of the stop command, recording is continuous.

These 2 modes are exclusive: it is not possible to have a Data log configured in Limited mode simultaneously with a Data log configured in Circular mode.



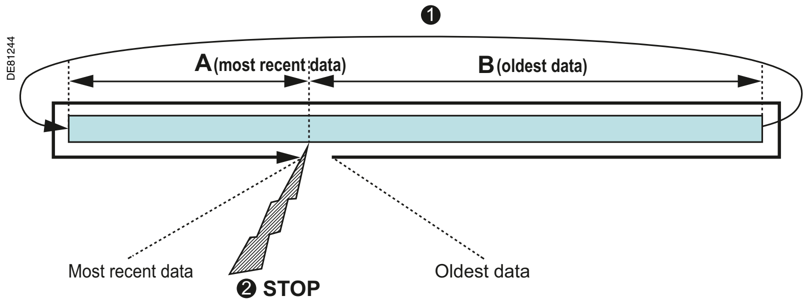
Data log in Limited mode.

Data log (DLG)



Data log in Circular mode.

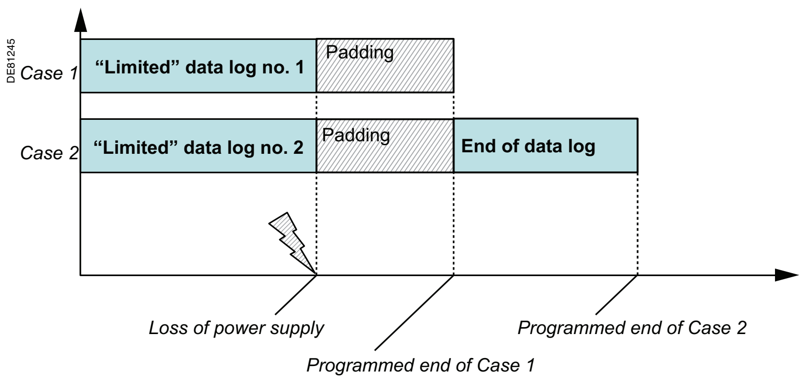
The figure below illustrates the principle of padding on a short-lived interruption and a prolonged interruption for a Data log configured in Circular mode.



Circular mode: stopping recording

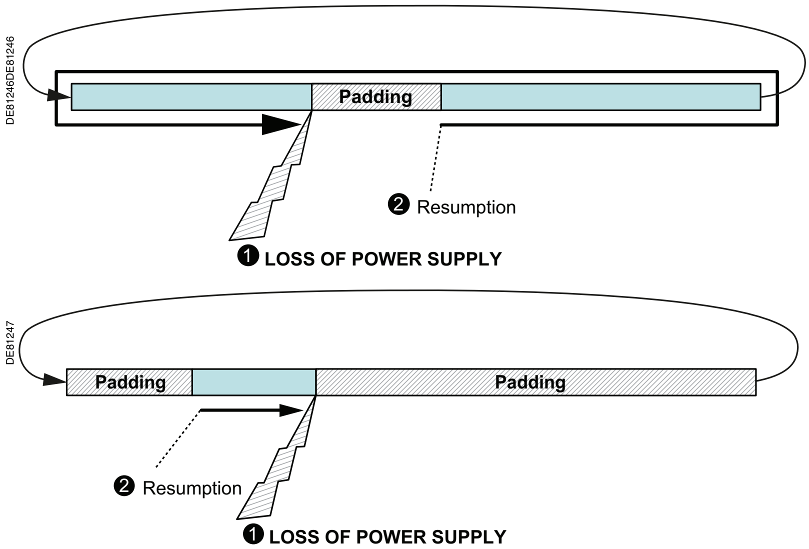
Downgraded operation

In the event of loss of the power supply during execution of the Data log function, storage is interrupted then automatically restarted when the power supply returns.
In both Limited and Circular configuration modes, on restarting the value 0x8000 is recorded in the file as a padding value for the period of non-operation.
The figure below illustrates the principle of padding on a short-lived interruption and a prolonged interruption for a Data log configured in Limited mode.
The principle of padding does not apply to a Data log configured in Limited mode and deliberately stopped by the user prior to completion.



Limited mode: padding after interruption of the recording.

Data log (DLG)



Circular mode: padding after interruption of the recording.

Characteristics

Configuration parameters	
Content of a COMTRADE file	Configuration file (*.CFG): date, variable characteristics, transformation ratio of the selected variable values Samples file (*.DAT): recorded variables
Total file duration	1 s to 30 days
Sampling period	1 s to 24 hours
Variables available for recording	See the table of available data below.
Number of files	1 to 20
Number of variables per file	1 to 15
Source of starting and stopping	■ SFT 2841 software ■ Logic equation or Logipam ■ Remote communication ■ Logic or GOOSE input
File format	COMTRADE - IEC60255-24 Ed 1 - 2001

Note: *These parameters are configured with the SFT2841 software.*

The following measurements, when available in the Sepam relay, can be selected using the SFT2841 software.

Available measurements	Designation	Units
Current		
Phase current (main inputs)	I1 I2 I3	A
Phase current (additional inputs)	I’1 I’2 I’3	A
Measured residual current	I0m, I’0m	A
Calculated residual current	I0c, I’0c	A
Demand current	I1ave, I2ave, I3ave	A
Peak demand current	I1max, I2max, I3max	A

Data log (DLG)

Available data	Designation	Units
Voltage		
Phase-to-neutral voltages (main inputs)	V1 V2 V3	V
Phase-to-neutral voltages (additional inputs)	V'1 V'2 V'3	V
Phase-to-phase voltages (main inputs)	U21 U32 U13	V
Phase-to-phase voltages (additional inputs)	U'21 U'32 U'13	V
Residual voltage	V0 V'0	V
Neutral-point voltage	Vnt	V
Positive-sequence voltage	Vd V'd	V
Negative-sequence voltage	Vi V'i	V
Frequency	F F'	Hz
Energy		
Active power	P	MW
Active peak demand power	Pmax	MW
Active power per phase	P1 P2 P3	MW
Reactive power	Q	Mvar
Reactive peak demand power	Qmax	Mvar
Reactive power per phase	Q1 Q2 Q3	Mvar
Apparent power	S	MVA
Apparent power per phase	S1 S2 S3	MVA
Power factor (cos φ)	cosPhi	
Active energy meter (+ and -)	Eam+ Eam-	MW.h
Calculated active energy meter (+ and -)	Eac+ Eac-	MW.h
Reactive energy meter (+ and -)	Erm+ Erm-	Mvar.h
Calculated reactive energy meter (+ and -)	Erc+ Erc-	Mvar.h
Other		
Rotor speed of rotation	meas.speed	rpm
Temperature	T1 to T16	° C /° F
Network diagnosis		
Unbalance ratio	Ii / Ib	% Ib or % I'b
Current THD	Ithd	%
Voltage THD	Uthd	%
Phase displacement φ0, φ'0, φ0Σ	φ0, φ'0, φ0Σ	°
Phase displacement φ1, φ2, φ3	φ1, φ2, φ3	°

Data log (DLG)

Available data	Designation	Units
Assistance with maintenance		
Thermal capacity used	Ech	%
Running hours counter	Ch	hours
Phase differential current	Idiff1, Idiff2, Idiff3	A
Phase through current	It1 It2 It3	A
Positive-sequence and phase-to-earth apparent impedances	Zd Z21 Z32 Z13	Ω
Neutral-point third harmonic voltage	Vt_H3 V3nt V3r	% Vntp
Residual third harmonic voltage	Vo_H3	% Vnp
Breaking current monitoring	S(kA)2	$(kA)^2$
Auxiliary power supply monitoring	Vaux	V
Capacitive current unbalance	Ir'1 Ir'2 Ir'3 Ir'0	A

Input

Designation	Syntax	Equations	Logipam
Triggering DLG	V_DLG_START	■	■

Output

Designation	Syntax	Equations	Logipam	Matrix
Recording in progress	V_DLG_ACTIVED	■	■	

Synchro-check: voltage comparison and out-of-sync context

Operation

Voltage comparison

For the synchro-check function (ANSI 25), the MCS025 module continuously measures the amplitude, frequency and phase differences between the 2 voltages to be checked, Usynch1 and Usynch2.
The measurement of the differences between the 2 voltages is useful to implement the function and identify the value that is impeding synchronization. The differences are calculated in the following order: amplitude, frequency and phase. As soon as a difference is greater than the threshold set in the synchro-check function, the following differences are not calculated.

Out-of-sync context

Out-of-sync context gives a precise indication of the cause of the failure of a synchronization request.
It is only provided when the switchgear control function with the "closing with synchro-check" option is activated.

When a synchronization request fails, the amplitude, frequency and phase differences of the Usynch1 and Usynch2 voltages measured by the MCS025 module are recorded, with the date and time, at the end of the switchgear control function "closing request time" delay.

Readout

The amplitude, frequency and phase differences and out-of-sync context may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Amplitude difference	
Measurement range	0 to 120 % of Usynch1 (or Vsynch1)
Unit	% of Usynch1 (or Vsynch1)
Resolution	0.1 %
Accuracy	±2 %
Refresh interval	1 second (typical)
Frequency difference	
Measurement range	0 to 10 Hz
Unit	Hz
Resolution	0.01 Hz
Accuracy	0.05 Hz
Refresh interval	1 second (typical)
Phase difference	
Measurement range	0 to 359°
Unit	°
Resolution	1°
Accuracy	±2°
Refresh interval	1 second (typical)

Thermal capacity used
Cooling time constant

Thermal capacity used

Operation
The thermal capacity used is calculated by the thermal overload protection function for cables, capacitors or machines.
The thermal capacity used is related to the load. The thermal capacity used measurement is given as a percentage of the rated thermal capacity.

Saving of thermal capacity used
The thermal capacity used is saved in the event of a Sepam power outage. The saved value is used again after the outage.

Readout
The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link
- an analog converter with the MSA141 option.

Resetting to zero
The thermal capacity used may be reset to zero, after entry of a password, on:
- the Sepam display via the clear key
- the display of a PC with the SFT2841 software.

Characteristics

Measurement range	0 to 800 %
Units	%
Display format	3 significant digits
Resolution	1 %
Refresh interval	1 second (typical)

Cooling time constant

Operation
The machine thermal overload protection function (49 RMS machine) uses a cooling time constant (T2) that may be entered by the user, according to the data given by the machine manufacturer or automatically learnt by Sepam.
T2 is estimated:
- after a heating/cooling sequence:
  - heating period detected by ES > 70 %
  - followed by a shutdown detected by I < 10 % of Ib
- when the machine temperature is measured by RTDs connected to MET148-2 module no. 1:
  - RTD 1, 2 or 3 assigned to motor/generator stator temperature measurement
  - RTD 1, 3 or 5 assigned to transformer temperature measurement.

After each new heating/cooling sequence is detected, a new T2 value is estimated and displayed in the related SFT2841 screen. Measurement accuracy may be improved by using RTD 8 to measure the ambient temperature.
The machine thermal overload function has 2 groups of thermal settings for cases such as natural or forced ventilation or 2-speed motors. A time constant is estimated for each group of thermal settings.

Readout
The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	5 to 600 min
Units	min
Resolution	1 min
Accuracy	±5 %
Display format	3 significant digits

Operating time before tripping
Waiting time after tripping

Remaining operating time before overload tripping

Operation
The thermal capacity used is calculated by the thermal overload protection function for cables, capacitors or machines. The time depends on the thermal capacity used.

Readout
The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0 to 999 min
Units	min
Display format	3 significant digits
Resolution	1 min
Refresh interval	1 second (typical)

Waiting time before authorization of overload closing

Operation
This period corresponds to the time it takes the motor to have cooled down enough to allow restarting without tripping again.

Readout
The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0 to 999 min
Units	min
Display format	3 significant digits
Resolution	1 min
Refresh interval	1 second (typical)

Running hours and operating time counter Starting current and starting time

Running hours and operating time counter

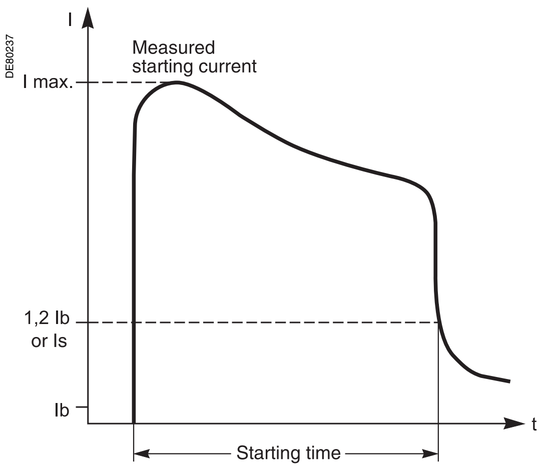
The counter gives the running total time during which the protected device (motor, generator or transformer) has been operating, i.e. whenever a phase current is 10% over Ib.
For capacitor applications, up to 4 counters are available for the running time of steps 1 to 4. These counters total the time that a capacitor step has been connected to the network (capacitor step switch closed).
The initial counter value may be modified using the SFT2841 software.
The counters are saved in the event of an auxiliary power failure.

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Range	0 to 65535
Units	hours



Starting current and starting time

Operation

The starting time is defined as follows:
- If the locked rotor/excessive starting time protection (ANSI code 48/51LR) is active, the starting time is the time separating the moment when one of the 3 phase currents exceeds Is and the moment when the 3 currents drop back below Is, Is being the value of the current set point for protection function 48/51LR.
- If the locked rotor/excessive starting time protection (ANSI code 48/51LR) is not active, the starting time is the time separating the moment when one of the 3 phase currents exceeds 1.2 Ib and the moment when the 3 currents drop back below 1.2 Ib.

The maximum phase current obtained during this time corresponds to the starting current.
Both values are saved in the event of an auxiliary power failure.

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Starting time		
Measurement range		0 to 300 s
Units		s or ms
Display format		3 significant digits
Resolution		10 ms or 1 digit
Refresh interval		1 second (typical)
Starting current		
Measurement range	48/51LR active	Is to 24 In (1)
	48/51LR inactive	1.2 Ib to 24 In (1)
Units		A or kA
Display format		3 significant digits
Resolution		0.1 A or 1 digit
Refresh interval		1 second (typical)

(1) Or 65.5 kA.

Number of starts before inhibition Start inhibit time

Number of starts before inhibition

Operation
The number of starts allowed before inhibition is calculated by the number of starts protection function (ANSI code 66).
The number of starts depends on the thermal state of the motor.

Readout
The measurement may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Resetting to zero
The number of starts counters may be reset to zero, after entry of a password, on:
- the Sepam display via the clear key
- the display of a PC with the SFT2841 software.

Characteristics

Measurement range	0 to 60
Units	None
Display format	3 significant digits
Resolution	1
Refresh interval	1 second (typical)

Start inhibit time

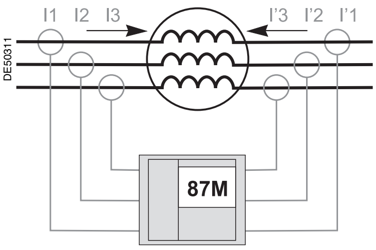
Operation
The start inhibit time only applies to motor applications (M81, M87 and M88). It depends on both the starts per hour protection (ANSI code 66) and the machine thermal overload protection (ANSI code 49RMS) if they have been activated. This time expresses the waiting time until another start is allowed.

If at least one of these functions picks up, a "START INHIBIT" message informs the user that starting is not allowed.

Readout
The number of starts and waiting time may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0 to 360 min
Units	min
Display format	3 significant digits
Resolution	1 min
Refresh interval	1 second (typical)



Differential current

Operation

The differential current Id is calculated to facilitate the implementation of the ANSI 87T and ANSI 87M differential protection functions:

- for a rotating machine (ANSI 87M), it is calculated for each phase by:

$$|\vec{Id}| = |\vec{I} + \vec{I'}|$$

- when a transformer is used (ANSI 87T), the Id calculation takes into account the vector shift and transformation ratio:

$$|\vec{Id}| = |\overrightarrow{Irec} + \overrightarrow{I'\ rec}|$$

The Id value is expressed with respect to In1, the rated current of the main channels.

Readout

The measurements may be accessed via:

- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0.015 to 40 In
Units	A or kA
Resolution	0.1 A
Accuracy (1)	±5 %
Display format	3 significant digits
Refresh interval	1 second (typical)

(1) At In, under reference conditions (IEC 60255-6).

Through current

Operation

The through current It is calculated to facilitate the implementation of the ANSI 87T and ANSI 87M differential protection functions:

- for a rotating machine (ANSI 87M), it is calculated for each phase by:

$$|\vec{It}| = \left|\frac{\vec{I} - \vec{I'}}{2}\right|$$

- when a transformer is used (ANSI 87T), the It calculation takes into account the vector shift and transformation ratio:

$$|\vec{It}| = \max(|\overrightarrow{Irec}|, |\overrightarrow{I'\ rec}|)$$

The It value is expressed with respect to In1, the rated current of the main channels.

Readout

The measurements may be accessed via:

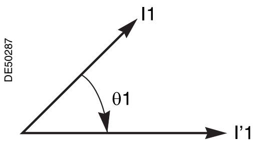
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0.015 to 40 In
Units	A or kA
Resolution	0.1 A
Accuracy (1)	±5 %
Display format	3 significant digits
Refresh interval	1 second (typical)

(1) At In, under reference conditions (IEC 60255-6).

Current phase displacement



Operation

Current phase displacement between the main phase currents (I) and additional phase currents (I') (θ1, θ2, θ3) is calculated for each phase.
The measurements are corrected by taking account of the connection and the direction of rotation of the phases to create an image of the vector shift, which must be set in order to use the ANSI 87T differential protection: θi/30 = vector shift.

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0 to 359°
Units	°
Resolution	1°
Accuracy (1)	±2°
Display format	3 significant digits
Refresh interval	1 second (typical)

***(1)** At In, under reference conditions (IEC 60255-6).*

Apparent positive sequence impedance
Apparent phase-to-phase impedances

Apparent positive sequence impedance

Operation

Apparent positive sequence impedance is used to facilitate the implementation of the underimpedance field loss protection function (ANSI 40).

$$Zd = \frac{|Vd|}{|Id|}$$

Readout

The measurement may be accessed via:
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0 to 200 kΩ
Units	Ω
Resolution	0.001 Ω
Accuracy (1)	±5 %
Refresh interval	1 second (typical)

***(1)** At In, Un, under reference conditions (IEC 60255-6).*

Apparent phase-to-phase impedances

Operation

Apparent phase-to-phase impedances are used to facilitate the implementation of the backup underimpedance protection function (ANSI 21B). They are expressed as the ratio of phase-to-phase voltage to phase-to-phase current.

$$Z21 = \frac{|\vec{U21}|}{|\vec{I}\,21|} \text{ with } \overrightarrow{I21} = \vec{I1} - \vec{I2}$$

$$Z32 = \frac{|\vec{U32}|}{|\vec{I}\,32|} \text{ with } \overrightarrow{I32} = \vec{I2} - \vec{I3}$$

$$Z13 = \frac{|\vec{U13}|}{|\vec{I}\,13|} \text{ with } \overrightarrow{I13} = \vec{I3} - \vec{I1}$$

Readout

The measurement may be accessed via:
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0 to 200 kΩ
Units	Ω
Resolution	0.001 Ω
Accuracy (1)	±5 %
Refresh interval	1 second (typical)

***(1)** At In, Un, under reference conditions (IEC 60255-6).*

Third harmonic neutral point voltage
Third harmonic residual voltage

Third harmonic neutral point voltage

Operation

Measurement of the 3rd harmonic component of the zero sequence voltage measured at the neutral point of a generator or motor (V3nt).
The value is used for the implementation of the third harmonic undervoltage protection function (ANSI 27TN/64G2).

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0.2 to 30 % of Vntp
Units	% of Vntp
Resolution	0.1 %
Accuracy (1)	±1 %
Refresh interval	1 second (typical)

***(1)** Under reference conditions (IEC 60255-6).*

Third harmonic residual voltage

Operation

Measurement of the 3rd harmonic component of the residual voltage, the residual voltage being calculated by the vector sum of the phase-to-neutral voltages.

The value is used for the implementation of the third harmonic undervoltage protection function (ANSI 27TN/64G2).

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0.2 to 90 % of Vnp
Units	% fo Vnp
Resolution	0.1 %
Accuracy (1)	±1 %
Refresh interval	1 second (typical)

***(1)** Under reference conditions (IEC 60255-6).*

Capacitance

Operation

This operation gives the total capacitance for each phase of the connected capacitor bank steps to allow the condition of the capacitors to be monitored.
It covers star and delta connections (parameter set in the "Particular characteristics" screen of the SFT2841 setting and operating software). For this measurement, the installation is considered a perfect capacitance, without any consideration of the resistances added by the connection of the capacitor bank steps.

- Capacitances measured for star-connected capacitor bank steps:
  - C1: total capacitance phase 1
  - C2: total capacitance phase 2
  - C3: total capacitance phase 3
- Capacitances measured for delta-connected capacitor bank steps:
  - C21: total capacitance between phases 1 and 2
  - C32: total capacitance between phases 2 and 3
  - C13: total capacitance between phases 3 and 1.

Readout

The capacitance measurements may be accessed via:

- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0 to 30 F
Unit	µF, mF or F
Resolution	0.1 µF
Accuracy	±5 %
Refresh interval	1 second (typical)

Accuracy

The measurement accuracy is valid if the resistance and inductance per phase of the capacitor bank connecting cable (cable between the Sepam CT and the capacitor bank) respect the following conditions:

- for a star-connected bank:

$$L\omega < 0.05 \times \left|\frac{1}{C\omega}\right|$$

$$R < 0.027 \times \left|\frac{1}{C\omega}\right|$$

where R is the resistance per phase in Ω
L is the inductance per phase in H
ω is the angular frequency in radians/s
C is the total capacitance per phase in F

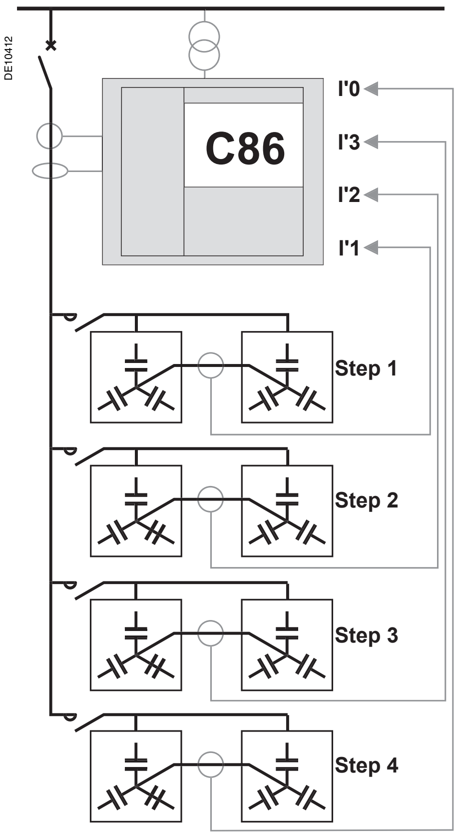
- for a delta-connected bank:

$$L\omega < 0.017 \times \left|\frac{1}{C\omega}\right|$$

$$R < 0.009 \times \left|\frac{1}{C\omega}\right|$$

where R is the resistance per phase in Ω
L is the inductance per phase in H
ω is the angular frequency in radians/s
C is the total capacitance between phases in F

Capacitor unbalance current



Operation

This function measures the unbalance current of double star-connected capacitor bank steps. This type of current is characteristic of capacitor module damage.

The measurement is carried out via the additional phase and zero sequence current channels:

- I'1: capacitor step 1 unbalance current measurement
- I'2: capacitor step 2 unbalance current measurement
- I'3: capacitor step 3 unbalance current measurement
- I'0: capacitor step 4 unbalance current measurement.

Readout

The measurements may be accessed via:

- the Sepam display via the key
- the screen of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0.02 to 20 I'n
Unit	A
Resolution	0.1 A
Accuracy	±5 %
Refresh interval	1 second (typical)

Back up any existing files before changing the MSR function parameter settings as this will result in loss of the existing files.

Operation

This Data log function, available only in motor applications, is used to view in the form of curves how some measurements change during motor starting.
The number of measurements and recording duration can be configured using the SFT2841 software.
The files are saved in a FIFO memory (First In First Out): when the maximum number of files is reached, a new file replaces the oldest.
Using the Motor start report function does not affect the quality of service of Sepam's active protection functions.

A Motor start report in progress cannot be interrupted by another motor start.
In the event of loss of the power supply or changes to parameters apart from the duration, the sampling frequency and/or the selected variables, the file currently being recorded is still saved (it is however ignored when calculating the MST), but the completed files are backed up using the battery.

Transfer

The files are transferred locally or remotely:
- Locally: using a PC connected to the programming port and running the SFT2841 software
- Remotely: using a ACE850 and ACE969 communication module (TP and FO) and a dedicated supervision system program.

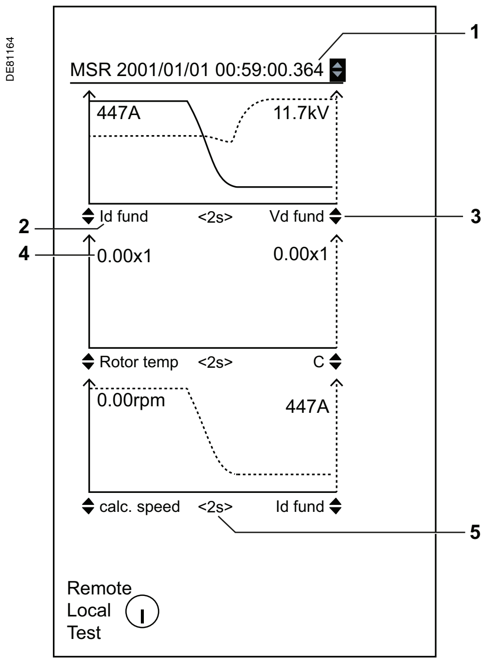
Only completed files can be transferred.

Read

The files can be viewed:
- after downloading, on a PC screen, using the WaveWin software
- on the Sepam display using the key then the Diagnosis menu.

In the latter case, depending on the type of Sepam display (integrated advanced UMI or integrated mimic-based UMI), up to three graphics can be viewed. Each graphic is used to display 2 curves corresponding to the selected variables using the SFT2841 software.

1 Time tagging of the selected file and file selection zone
2 Name of the 1st variable associated with the Y-axis
3 Selection zone for the variable to be associated with the Y-axis
4 Maximum value observed for the recorded variable
5 Duration of read time



View of 3 graphics relating to 1 MSR on an integrated mimic-based UMI.

Motor start report (MSR)

Configuring the display

1 To select the MSR file to be viewed:
Press the ↵ key as many times as necessary, with the current file selection zone active (item 1).
The file number in the series is briefly displayed before giving way to the time-tagged data.

2 To associate one of the selected variables with each Y-axis:

■ Select the axis to be configured by moving to the ◆ symbol using the ▲ (go to the previous axis) and ▼ (go to the next axis) keys.

■ Once the axis has been selected, use the ↵ key to modify the variable to be used. The screen is automatically refreshed.

Pressing the clear key can briefly hide the values appearing on the graphics. This option is only found on the integrated advanced UMI.

Note: *The curve display on Sepam should be used with caution because it does not achieve the accuracy obtained with COMTRADE file viewing software.*

Characteristics

Configuration parameters	
Content of a COMTRADE file	Configuration file (*.CFG): date, variable characteristics, transformation ratio of the selected variable values Samples file (*.DAT): recorded variables
Total file duration	2 s to 144 s
Sampling frequency	Depends on the configured duration (144 s maximum). Example: For a duration of 144 s the frequency is 1 Hz, for a duration of 2 s the frequency is 72 Hz.
Variables available for recording	See the table of available data below.
Number of files	1 to 5 with standard cartridge 1 to 20 with extended cartridge
Number of variables per file	1 to 5 with standard cartridge 1 to 10 with extended cartridge
File format	COMTRADE - IEC60255-24 Ed 1 - 2001

Note: *These parameters are configured with the SFT 2841 software.*

Available data	Designation	Units
Phase-to-phase voltages U21, U32, U13	u21_fund u32_fund u13_fund	V
I1, I2, I3	i1_fund i2_fund i3_fund	A
Temperature	T1_to_T16	° C / ° F
Rotor speed of rotation (1)	calc.speed	rpm
Rotor speed of rotation (2)	meas.speed	rpm
Rotor resistance (3)	Rr+	Ω
Rotor thermal capacity used (3)	Rotor_temp	pu
Stator resistance (3)	Rs	Ω
Stator thermal capacity used (4)	Stator_temp	pu
Motor thermal capacity used (3)	Motor_temp	pu
Positive-sequence current	Id_fund	A
Negative-sequence current	Ii_fund	A
Positive-sequence voltage	Vd_fund	V
Negative-sequence voltage	Vi_fund	V
Measured residual current	Io_fund	A
Calculated residual current	Sum_Io	A
Residual voltage	Vo_fund	V
Motor torque (3)	C	pu
Slip (1)	g	pu
Frequency (5)	F	Hz

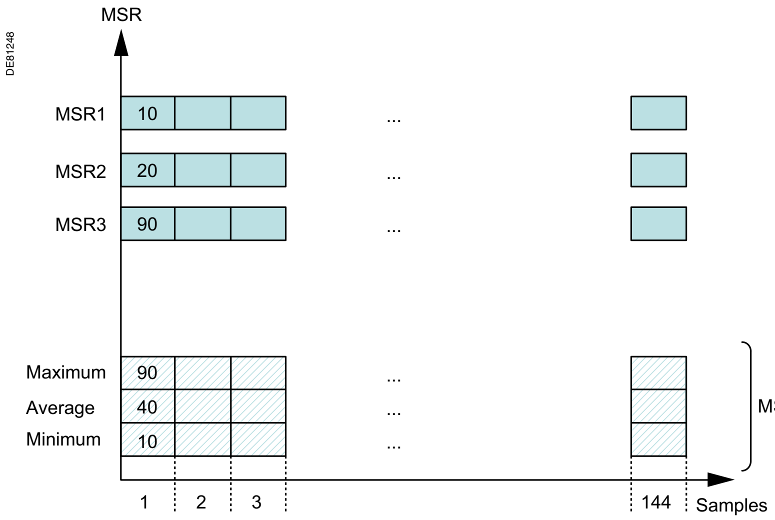
__(1)__ The value used is that provided by the 49RMS motor thermal overload protection if this has been activated.
__(2)__ The value used is that for input I104 if the 49RMS generic thermal overload protection has been activated.
__(3)__ The value used is that provided by the 49RMS motor thermal overload protection if this has been activated. The value is 0 if the 49RMS generic thermal overload protection has been activated.
__(4)__ The value used is that for the active 49RMS protection: motor thermal overload or generic thermal overload.
__(5)__ Only available for the main voltage channels.

Input				
Designation	**Syntax**	**Equations**	**Logipam**	
Triggering MSR	V_MSR_START	■	■	
Output				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
MSR in progress	V_MSR_TRIGGED	■	■	

Motor start trend (MST)

Operation

This function, only available for motor applications, is related to the Motor start trend function. It is used to calculate and display in the form of curves the minimum, demand and maximum values for each value recorded by the Motor start report function (MSR).
These recalculated values which are stored in a file of 144 samples covering a 30-day period, can be viewed on the Sepam screen. When the current 30-day period has ended, it is automatically archived in COMTRADE format and will no longer be able to be viewed on the Sepam display (see the Read section).
The files are saved in a FIFO memory (First In First Out): when the maximum number of files is reached, a new file replaces the oldest. The number of files available varies between 12 and 18 depending on the type of memory cartridge installed on Sepam.
The trends are only recalculated at the end of each Motor start report.



Calculating an MST using the available MSRs.

A Motor start report interrupted prior to completion is not taken into account when calculating the Motor start trend function.
Using the Motor start report function does not affect the quality of service of Sepam's active protection functions.

Comment on managing date changes:
On changing to a date prior to the start date of the current MST, this MST is not closed and any new MSR will be taken into account in its calculation.
On changing to a date after the end date of the current MST, this MST is closed and a new MST is created.

Transfer

The files are transferred locally or remotely:
■ Locally: using a PC connected to the programming port and running the SFT2841 software
■ Remotely: using a ACE850 and ACE969 communication module (TP and FO) and a dedicated supervision system program.
Only completed files can be transferred.

Downloading an MST file for the current period is automatically cancelled in the following cases:
■ Triggering an MSR
■ Triggering calculation of an MST at the end of an MSR.
Downloading an MST file for another period is automatically cancelled when this file is the oldest and needs to be replaced by a new file due to the FIFO memory being full.

Motor start trend (MST)

Read

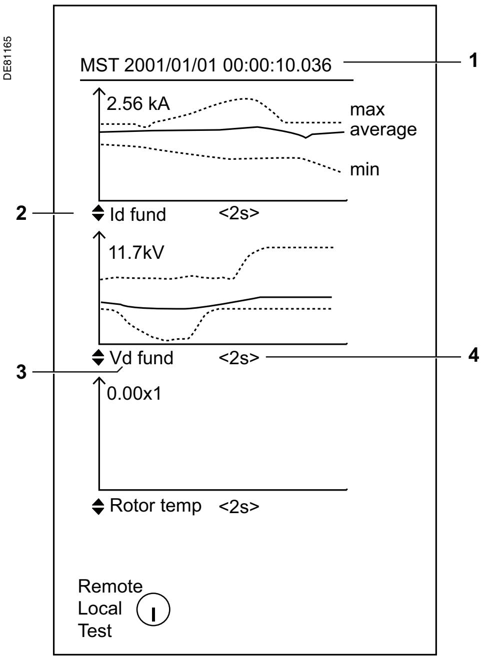
- The current file and all completed files can be downloaded and viewed on a PC screen, using software compatible with the COMTRADE format.
- Only the current file can be viewed on the Sepam display:

1 Press the key
2 Select the Diagnosis menu
3 Press the key

Depending on the type of Sepam display (integrated advanced UMI or integrated mimic-based UMI), 1 to 3 graphics can be viewed simultaneously. Each graphic can be used to restore curves representing the change in the minimum, demand and maximum values for the values recorded by the Motor start report function (MSR).

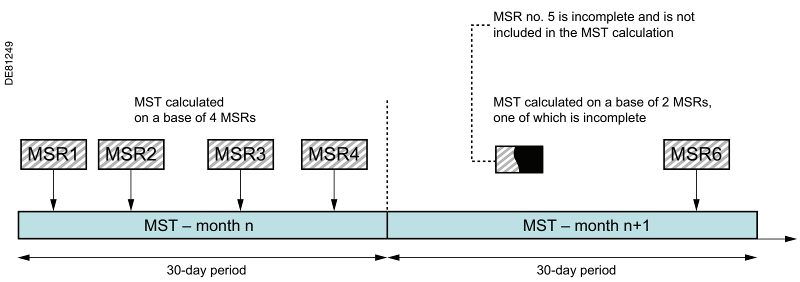
Note: *The curve display on Sepam should be used with caution because it does not achieve the accuracy obtained with COMTRADE file viewing software.*

1 Time tagging of the current file
2 Selection of the variable to be associated with the Y-axis
3 Name of the analyzed variable
4 Duration of read time for each file



View of 3 graphics relating to an MST on an integrated mimic-based UMI.

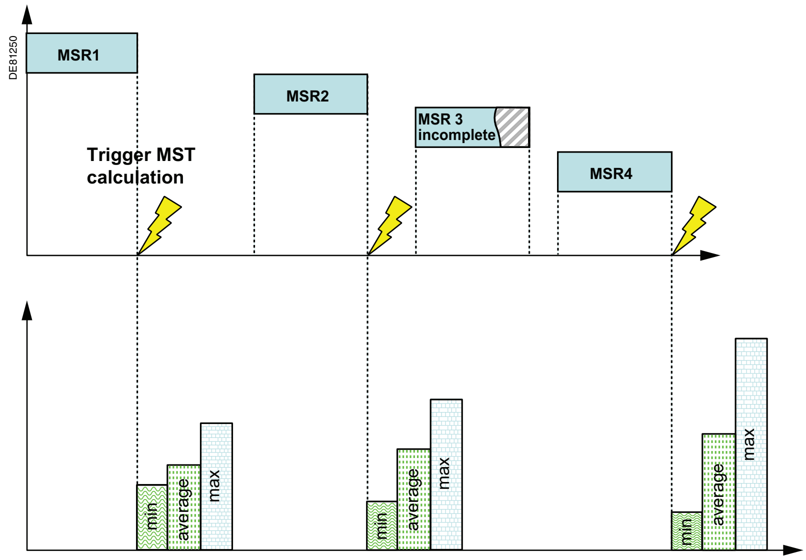
Block diagrams



Taking account of the MSRs when calculating an MST.

The current MST file is only refreshed when recording of the MSR file is complete. The current MST file is archived 30 days after its creation. A new MST file is initiated after the 1st restart in the following period.

Motor start trend (MST)



Evolution of an MST file during the operating time of the observed motor starts.

Characteristics

Content of a COMTRADE file	Configuration file (*.CFG): date, variable characteristics, transformation ratio of the selected variable values Samples file (*.DAT): recorded variables
Total file duration	30 days/144 samples
Sampling period	5 hours
Variables available for recording	See table of available data for the MST function.
Number of files	1 to 12 with standard cartridge 1 to 18 with extended cartridge
File format	COMTRADE - IEC60255-24 Ed 1 - 2001

Note: *These parameters are configured with the SFT 2841 software.*

Operation

The VT (Voltage Transformer) supervision function is used to supervise the complete phase and residual voltage measurement chain:
- voltage transformers
- VT connection to Sepam
- Sepam voltage analog inputs.

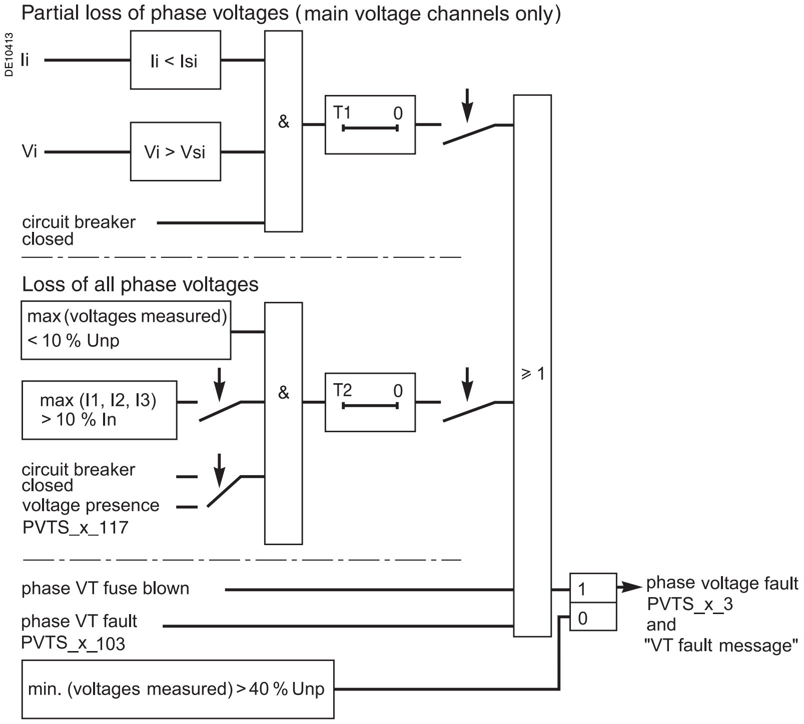
There are two units for the function, one for supervision of the main voltage channel VTs and the other for supervision of the additional voltage channel VTs.

The function processes the following failures:
- partial loss of phase voltages, detected by:
  - presence of negative sequence voltage
  - and absence of negative sequence current
- loss of all phase voltages, detected by:
  - presence of current on one of the three phases
  - and absence of all measured voltages
- tripping of the phase VT (and/or residual VT) protection relay, detected by the acquisition on a logic input of the fuse blown contact or auxiliary contact of the circuit breaker protecting the VTs
- other types of failures may be processed using the logic equation editor.

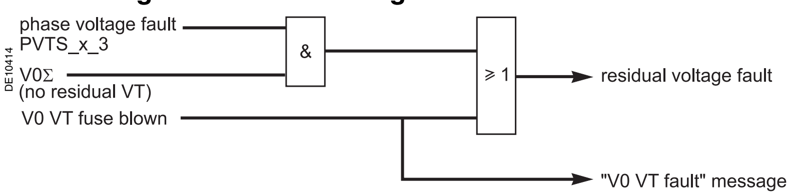
The "Phase voltage fault" and "Residual voltage fault" information disappears automatically when the situation returns to normal, i.e. as soon as:
- the cause of the fault has disappeared
- and all of the measured voltages are present.

Use of circuit breaker closed information
The "circuit breaker closed" information is used to detect the loss of one, two or three voltages, if it is connected to a logic input.
In certain applications, the position of the circuit breaker is not sufficient to determine the presence of voltages. In such cases, the equation editor can be used to precisely define the conditions for voltage presence.

Block diagram: phase voltage fault detection.



Block diagram: residual voltage fault detection.



Consequences of a VT fault on protection functions

A "Phase voltage fault" affects the following protection functions:
- 21B, 27, 27D, 27TN, 32P, 32Q, 37P, 40, 47, 50/27, 51V, 78PS
- 59, only in cases where the protection function is set up for phase-to-neutral overvoltage, when the voltages are measured by two phase VTs + V0VTs
- 67.

A "residual voltage fault" affects the following protection functions:
- 59N
- 67N/67NC.

The behavior of the protection functions in the event of a "Phase voltage fault" or Residual voltage fault" is to be set up and the following choices are proposed:
- for protection functions 21B, 27, 27D, 27TN, 32P, 32Q, 37P, 40, 47, 50/27, 51V, 59N, 59, 78PS: inhibition or no inhibition
- for protection function 67: inhibition or non-directional operation (50/51)
- for protection function 67N/67NC: inhibition or non-directional operation (50N/ 51N).

VT supervision
ANSI code 60FL

Setting advice
The partial loss of voltages is based on the detection of the presence of negative sequence voltage and the absence of negative sequence current.
By default:
- the presence of negative sequence voltage is detected when: Vi > 10 % Vnp (Vsi)
- the absence of negative sequence current is detected when: Ii < 5 % In (Isi)
- time delay T1 is 1 s.

These default settings ensure the stability of the VT supervision function in the event of short-circuits or transient phenomena on the network.
The Isi set point may be raised for highly unbalanced networks.

Time delay T1 is to be set shorter than the voltage and power protection function tripping times.

Time delay T2 for the detection of the loss of all voltages must be longer than the time it takes for a short-circuit to be cleared by the protection function 50/51 or 67, to avoid the detection of a VT loss of voltage fault triggered by a 3-phase short-circuit.

The time delay for the 51V protection function must be longer than the T1 and T2 time delays used for the detection of voltage losses.

Characteristics

Validation of the detection of partial loss of phase voltages	
Setting	Yes / No
Vsi set point	
Setting	10 % to 100 % of Vnp
Accuracy	±5 %
Resolution	1 %
Pick-up / drop-out ratio	95 % ±2.5 %
Isi set point	
Setting	5 % to 100 % of In
Accuracy	±5 %
Resolution	1 %
Pick-up / drop-out ratio	105 % ±2.5 % or > (1 + 0.01 In/Isi) x 100 %
Time delay T1 (partial loss of phase voltages)	
Setting	0.1 s to 300 s
Accuracy	±2 % or ±25 ms
Resolution	10 ms
Validation of the detection of the loss of all phase voltages	
Setting	Yes / No
Detection of the loss of all voltages with verification of the presence of current	
Setting	Yes / No
Voltage presence detected by	
Setting	Breaker closed / Logic equation or Logipam
Time delay T2 (loss of all voltages)	
Setting	0.1 s to 300 s
Accuracy	±2 % or ±25 ms
Resolution	10 ms
Voltage and power protection behavior	
Setting	No action / inhibition
Protection 67 behavior	
Setting	Non-directional / inhibition
Protection 67N/67NC behavior	
Setting	Non-directional / inhibition

Inputs

Designation	Syntax	Equations	Logipam
Phase VT fault	PVTS_x_103	■	■
Inhibition of function	PVTS_x_113	■	■
Voltage presence	PVTS_x_117	■	■

Outputs

Designation	Syntax	Equations	Logipam	Matrix
Function output	PVTS_x_3	■	■	■
Function inhibited	PVTS_x_16	■	■	

***Note**: x = unit number: x = 1: main channels (V).*
x = 2: additional channels (V').

CT supervision
ANSI code 60

Operation
The CT (Current Transformer) supervision function is used to supervise the complete phase current measurement chain:
- phase current sensors (1 A/5 A CTs or LPCTs)
- phase current sensor connection to Sepam
- Sepam phase current analog inputs.

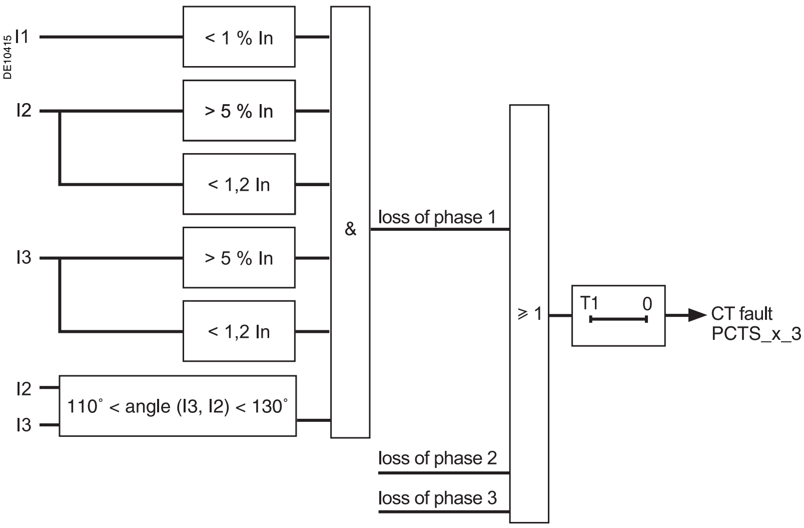
There are two units for the function, one for supervision of the main current channel CTs (I) and the other for supervision of the additional current channel CTs (I').

The function is inactive if only 2 phase current sensors are connected.

The "Main CT fault" or "Additional CT fault" information disappears automatically when the situation returns to normal, i.e. as soon as the three phase currents are measured and have values greater than 10 % of In.

In the event of the loss of a phase current, the following protection functions may be inhibited to avoid nuisance tripping:
- 21B, 46, 40, 32P, 37P, 32Q, 78PS, 64REF
- 51N and 67N, if I0 is calculated by the sum of the phase currents.

Block diagram
DE10415

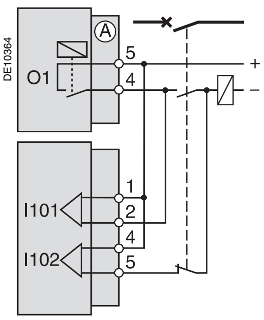


Characteristics

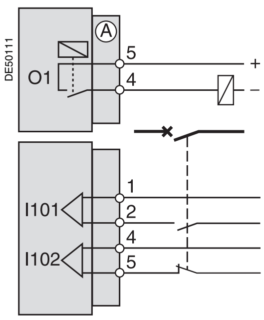
Time delay				
Setting		0.15 s to 300 s		
Accuracy		±2 % or ± 25 ms		
Resolution		10 ms		
Inhibition of protection functions 21B, 32P, 32Q, 37P, 40, 46, 51N, 64REF, 67N, 78PS				
Setting		No action / inhibition		
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Inhibition of function	PCTS_x_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Delayed output	PCTS_x_3	■	■	■
Phase 1 fault	PCTS_x_7	■	■	
Phase 2 fault	PCTS_x_8	■	■	
Phase 3 fault	PCTS_x_9	■	■	
Function inhibited	PCTS_x_16	■	■	

***Note**: x = unit number: x = 1: main channels (I).*
x = 2: additional channels (I').

Trip and closing circuit supervision
ANSI code 74



Connection for shunt trip unit supervision.



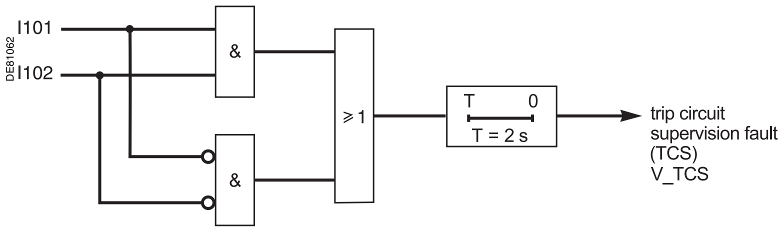
Connection for undervoltage trip unit supervision.

Trip circuit supervision and open / closed matching

Operation

This supervision function is designed for trip circuits:
■ with shunt trip units
The function detects:
□ circuit continuity
□ loss of supply
□ mismatching of position indication contacts.
The function inhibits closing of the breaking device.
■ with undervoltage trip units
The function detects:
□ only mismatching of position indication contacts, trip unit supervision being unnecessary in this case.
The information is accessible in the matrix ("trip circuit" message) and via remote indication TS1.

Block diagram

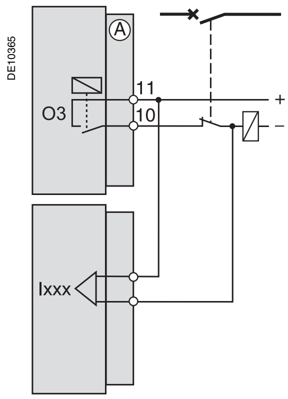


Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Trip circuit supervision fault	V_TCS		■	■

TS/TC equivalence for each protocol

Modbus	DNP3	IEC 60870-5-103	IEC 61850
TS	**Binary Input**	**ASDU, FUN, INF**	**LN.DO.DA**
TS1	BI17	1, 160, 36	XCBR1.EEHealth.stVal

Trip and closing circuit supervision
ANSI code 74



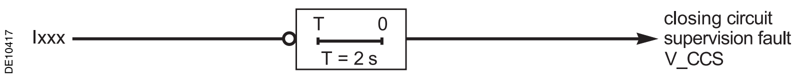
Connection for closing circuit supervision.

Closing circuit supervision

Operation

This function monitors closing coil continuity. It calls for the wiring diagram opposite, connected to a logic input configured with the "Closing coil supervision" function.
The information is accessible in the matrix ("closing circuit" message) and via remote indication TS234.

Block diagram



Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Closing circuit supervision fault	V_CCS		■	■

TS/TC equivalence for each protocol

Modbus	DNP3	IEC 60870-5-103	IEC 61850
TS	**Binary Input**	**ASDU, FUN, INF**	**LN.DO.DA**
TS234	BI121	2, 21, 23	XCBR1.EEHealth.stVal

Open and close order supervision

Operation

Following a circuit breaker open or close order, the system checks whether, after a 200 ms time delay, the circuit breaker has actually changed status.
If the circuit breaker status does not match the last order sent, a "Control fault" message and remote indication TS2 are generated.

Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Control fault (circuit breaker monitoring)	V_CTRLFAUT		■	■

TS/TC equivalence for each protocol

Modbus	DNP3	IEC 60870-5-103	IEC 61850
TS	**Binary Input**	**ASDU, FUN, INF**	**LN.DO.DA**
TS2	BI16	1, 20, 5	Command Termination -

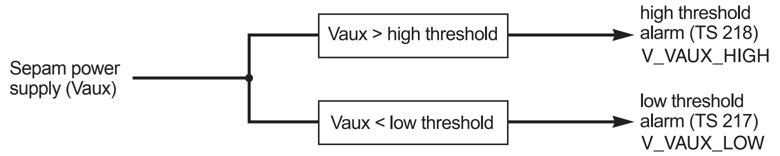
Auxiliary power supply monitoring

Operation

The auxiliary power supply is an important factor in cubicle operation. This function monitors it by measuring the Sepam power supply voltage and comparing the measured value to a low and high threshold. If the value is outside the thresholds, an alarm is generated. The related information is available in the matrix and in Logipam.

Block diagram

DE10418



Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measured auxiliary voltage Vaux, Low threshold alarm, High threshold alarm				
Measurement range		20 to 275 V DC		
Units		V		
Resolution		0.1 V (1 V on display)		
Accuracy		±10 % or ±4 V		
Refresh interval		1 second (typical)		
Rated auxiliary voltage				
Setting		24 to 250 V DC		
Resolution		1 V		
Low threshold				
Setting		60 to 95 % of rated V (minimum 20 V)		
Resolution		1 V		
Accuracy		±10 % or ±4 V		
High threshold				
Setting		105 to 150 % of rated V (maximum 275 V)		
Resolution		1 V		
Accuracy		±10 % or ±4 V		
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Auxiliary power supply monitoring on	V_VAUX_ON		■	
High threshold alarm	V_VAUX_HIGH		■	■
Low threshold alarm	V_VAUX_LOW		■	■

TS/TC equivalence for each protocol

Modbus	DNP3	IEC 60870-5-103	IEC 61850
TS	**Binary Input**	**ASDU, FUN, INF**	**LN.DO.DA**
TS217	BI13	2, 20, 10	LPHD1.PwrSupAlm.stVal
TS218	BI14	2, 20, 11	LPHD1.PwrSupAlm.stVal

Cumulative breaking current Number of operations

Cumulative breaking current monitoring

Operation

This function gives the cumulative breaking current in $(kA)^2$ for five current ranges. It is based on measurement of the fundamental component on main channels (I).
The current ranges displayed are:
- 0 < I < 2 In
- 2 In < I < 5 In
- 5 In < I < 10 In
- 10 In < I < 40 In
- I > 40 In.

This function gives the cumulative breaking current in $(kA)^2$ for five current ranges.This value is monitored by an adjustable set point. When the set point is overrun, an alarm is sent and is available in the matrix and via remote indication TS235.
Each value is saved in the event of an auxiliary power failure.
The initial values may be introduced using the SFT2841 software tool to take into account the real state of a breaking device used.
Refer to switchgear documentation for use of this information.

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Cumulative breaking current measured				
Range			0 to 65535 $(kA)^2$	
Units			primary $(kA)^2$	
Resolution			$1(kA)^2$	
Accuracy (1)			±10 % ±1 digit	
Alarm set point				
Setting			0 to 65535 $(kA)^2$	
Resolution			1(kA)2	
Accuracy (1)			±10 % ±1 digit	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Cumulative breaking current threshold overrun	V_MAXBRKCUR		■	■

(1) At In, under reference conditions (IEC 60255-6).

TS/TC equivalence for each protocol

Modbus	DNP3	IEC 60870-5-103	IEC 61850
TS	**Binary Input**	**ASDU, FUN, INF**	**LN.DO.DA**
TS235	BI135	2, 21, 40	XCBR1.SumSwAAlm.stVal

Number of operations

Operation

The function also gives the total number of breaking device operations.
It is activated by tripping orders (O1 relay).
The number of operations is saved in the event of an auxiliary power failure.
It may be reinitialized using the SFT2841 software.

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Range	0 to 4.10^9
Units	None
Resolution	1
Refresh interval	1 second (typical)

Operating time

Operation

This function gives the value of the opening operating time of a breaking device [1]v defined with the open command (O1 relay) and change of status of the device open position contact connected to the I102 input [2] .
The value is saved in the event of an auxiliary power failure.

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

***(1)** Refer to switchgear documentation for use of this information.*
***(2)** Optional MES120 module.*

Characteristics

Measurement range	20 to 300
Units	ms
Resolution	1 ms
Accuracy	±1 ms typical
Display format	3 significant digits

Charging time

Operation

This function gives the value of the breaking device [1] operating mechanism charging time, determined according to the device closed position status change contact and the end of charging contact connected to the Sepam logic inputs [2].
The value is saved in the event of an auxiliary power failure.

Readout

The measurements may be accessed via:
- the Sepam display via the key
- the display of a PC with the SFT2841 software
- the communication link.

***(1)** Refer to switchgear documentation for use of this information.*
***(2)** Optional MES120 module.*

Characteristics

Measurement range	1 to 20
Units	s
Resolution	1s
Accuracy	±0.5 s
Display format	3 significant digits

Number of racking out operations

Operation

This function keeps a count of circuit breaker or contactor rackouts.
The information may be used for breaking device maintenance.
The breaking device "racked out" or "disconnected" position must be wired to a logic input and set up in the SFT2841 software in order for rackouts to be counted.
The number of rackouts is saved in the event of an auxiliary power failure. It may be reinitialized using the SFT2841 software.

Readout

The measurements may be accessed via:

- the display of a PC with the SFT2841 software
- the communication link.

Characteristics

Measurement range	0 to 65535
Units	None
Resolution	1
Refresh interval	1 second (typical)

Contents

Contents

Setting ranges

Functions	Settings		Time delays
ANSI 12 - Overspeed			
	100 to 160 % of Ωn		1 to 300 s
ANSI 14 - Underspeed			
	10 to 100 % of Ωn		1 to 300 s
ANSI 21B - Underimpedance			
Impedance Zs	0.05 to 2.00 Vn/Ib		
ANSI 24 - Overfluxing (V/Hz)			
Tripping curve	Definite time		
	IDMT type A, B or C		
Gs set point	1.03 to 2 pu	Definite time	0.1 to 20000 s
		IDMT	0.1 to 1250 s
ANSI 25 - Synchro-check			
Measured voltages	Phase-to-phase	Phase-to-neutral	
Rated primary phase-to-phase voltage			
Unp sync1 (Vnp sync1 = Unp sync1/$\sqrt{3}$)	220 V to 250 kV	220 V to 250 kV	
Unp sync2 (Vnp sync2 = Unp sync2/$\sqrt{3}$)	220 V to 250 kV	220 V to 250 kV	
Rated secondary phase-to-phase voltage			
Uns sync1	90 V to 120 V	90 V to 230 V	
Uns sync2	90 V to 120 V	90 V to 230 V	
Synchro-check setpoints			
dUs set point	3 % to 30 % of Unp sync1	3 % to 30 % of Vnp sync1	
dfs set point	0.05 to 0.5 Hz	0.05 to 0.5 Hz	
dPhi set point	5 to 80°	5 to 80°	
Us high set point	70 % to 110 % Unp sync1	70 % to 110 % Vnp sync1	
Us low set point	10 % to 70 % Unp sync1	10 % to 70 % Vnp sync1	
Other settings			
Lead time	0 to 0.5 s	0 to 0.5 s	
Operating modes: no-voltage conditions for which coupling is allowed	Dead1 AND Live2	Dead1 AND Live2	
	Live1 AND Dead2	Live1 AND Dead2	
	Dead1 XOR Dead2	Dead1 XOR Dead2	
	Dead1 OR Dead2	Dead1 OR Dead2	
	Dead1 AND Dead2	Dead1 AND Dead2	

Functions	Settings	Time delays
ANSI 27 - Undervoltage (L-L) or (L-N)		
Tripping curve	Definite time	
	IDMT	
	Definite time with a curve that can be customized	
Set point	5 to 100 % of Unp	0.05 to 300 s
Measurement origin	Main channels (U) or additional channels (U')	
ANSI 27D - Positive sequence undervoltage		
Set point and time delay	15 to 60 % of Unp	0.05 to 300 s
Measurement origin	Main channels (U) or additional channels (U')	
ANSI 27R - Remanent undervoltage		
Set point and time delay	5 to 100 % of Unp	0.05 to 300 s
Measurement origin	Main channels (U) or additional channels (U')	
ANSI 27TN/64G2 - Third harmonic undervoltage		
Vs set point (fixed)	0.2 to 20 % of Vntp	0.5 to 300 s
K set point (adaptive)	0.1 to 0.2	0.5 to 300 s
Positive sequence undervoltage	50 to 100 % of Unp	
Minimum apparent power	1 to 90 % of Sb (Sb = $\sqrt{3}$.Un.Ib)	
ANSI 32P - Directional active overpower		
	1 to 120 % of Sn (2)	0.1 s to 300 s
ANSI 32Q - Directional reactive overpower		
	5 to 120 % of Sn (2)	0.1 s to 300 s
ANSI 37 - Phase undercurrent		
	0.05 to 1 Ib	0.05 s to 300 s
ANSI 37P - Directional active underpower		
	5 to 100 % of Sn (2)	0.1 s to 300 s
ANSI 38/49T - Temperature monitoring		
Alarm set point TS1	0 °C to 180 °C or 32 °F to 356 °F	
Trip set point TS2	0 °C to 180 °C or 32 °F to 356 °F	
ANSI 40 - Field loss (underimpedance)		
Common point: Xa	0.02 Vn/Ib to 0.2 Vn/Ib + 187.5 kΩ	
Circle 1: Xb	0.2 Vn/Ib to 1.4 Vn/Ib + 187.5 kΩ	0.05 to 300 s
Circle 2: Xc	0.6 Vn/Ib to 3 Vn/Ib + 187.5 kΩ	0.1 to 300 s

***(1)** Sn* = $\sqrt{3}$.In.Unp.

3

3

Functions	Settings		Time delays	
ANSI 46 - Negative sequence / unbalance				
Tripping curve	Definite time			
	Schneider Electric			
	IEC: SIT/A, LTI/B, VIT/B, EIT/C			
	IEEE: MI (D), VI (E), EI (F)			
	RI² (setting constant from 1 to 100)			
Is set point	0.1 to 5 Ib	Definite time	0.1 to 300 s	
	0.1 to 0.5 Ib (Schneider Electric)	IDMT	0.1 to 1s	
	0.1 to 1 Ib (IEC, IEEE)			
	0.03 to 0.2 Ib (RI²)			
Measurement origin	Main channels (I) or additional channels (I')			
ANSI 47 - Negative sequence overvoltage				
Set point and time delay	1 to 50 % of Unp		0.05 to 300 s	
Measurement origin	Main channels (U) or additional channels (U')			
ANSI 48/51LR - Locked rotor / excessive starting time				
Is set point	0.5 Ib to 5 Ib	ST starting time	0.5 s to 300 s	
		LT and LTS time delays	0.05 s to 300 s	
ANSI 49RMS - Thermal overload for cables				
Admissible current	1 to 1.73 Ib			
Time constant T1	1 to 600 min			
ANSI 49RMS - Thermal overload for capacitors				
Alarm current		1.05 Ib to 1.70 Ib		
Trip current		1.05 Ib to 1.70 Ib		
Positioning of the hot tripping curve	Current setting	1.02 x trip current to 2 Ib		
	Time setting	1 to 2000 minutes (variable range depending on the trip current and current setting)		
ANSI 49RMS - Generic thermal overload			**Mode 1**	**Mode 2**
Accounting for negative sequence component		0 - 2.25 - 4.5 - 9		
Time constant	Heating		T1: 1 to 600 min	T1: 1 to 600 min
	Cooling		T2: 5 to 600 min	T2: 5 to 600 min
Alarm and tripping set points (Es1 and Es2)		0 to 300 % of rated thermal capacity		
Initial thermal capacity used (Es0)		0 to 100 %		
Switching of thermal settings condition		by logic input		
		by Is set point adjustable from 0.25 to 8 Ib		
Maximum equipment temperature		60 to 200 °C (140 °F to 392 °F)		
Measurement origin	Main channels (I) or additional channels (I')			
ANSI 49RMS - Motor thermal overload				
Measurement origin	I1, I2, I3			
Choice of thermal model	2 time constants/generic (see settings associated with generic thermal overload)			
Current set point - change of thermal settings		1 to 10 pu of Ib (± 0.1 pu of Ib)		
Characteristic times	Operating time accuracy	± 2 % or ±1 s		
Stator thermal settings				
Time constants	Motor thermal capacity used (τ long)	1 to 600 mn ± 1 mn		
	Stator thermal capacity used (τ short)	1 to 60 mn ± 0.1 mn		
	Cooling (τ cool)	5 to 600 mn ± 1 mn		
Tripping current set point (K)	50 to 173 % of Ib (± 1 % of Ib)			
Alarm current set point	50 to 173 % of Ib (± 1 % of Ib)			
Thermal exchange coefficient between the stator and the motor (α)	0 to 1 (± 0.01)			
Current characterizing hot state	0.5 to 1 pu of Ib (± 0.1 pu of Ib)			
Accounting for ambient temperature	yes / no			
Maximum equipment temperature (Tmax)	70 to 250 °C (± 1 °C) or 158 to 482 °F (± 1 °F)			
Rotor thermal settings				
Locked rotor amperes (IL)	1 to 10 pu of Ib (± 0.01 pu of Ib)			
Locked rotor torque (LRT)	0.2 to 2 pu of nominal torque (+/- 0.01 pu of nominal torque)			
Locked rotor cold limit time (Tc)	1 to 300 s (± 0.1 s)			
Locked rotor hot limit time (Th)	1 to 300 s (± 0.1 s)			

Functions	Settings		Time delays
ANSI 49RMS - Transformer thermal overload			
Measurement origin	I1, I2, I3 / I'1, I'2, I'3		
Choice of thermal model	Dry-type transformer Immersed transformer Generic		
Type of dry-type transformer	Natural ventilation (AN) / Forced ventilation (AF)		
Type of oil-filled transformer	Distribution ONAN / Power ONAN / ONAF / OF / OD		
Alarm set point (θ alarm)	Immersed transformer: 98 to 160 °C (± 1 °C) or 208 to 320 °F (± 1 °F)		
	Dry-type transformer: 95 to 245 °C (± 1 °C) or 203 to 473 °F (± 1 °F)		
Tripping set point (θ trip)	Immersed transformer: 98 to 160 °C (± 1 °C) or 208 to 320 °F (± 1 °F)		
	Dry-type transformer: 95 to 245 °C (± 1 °C) or 203 to 473 °F (± 1 °F)		
Time constant for dry-type transfo (τ)	1 to 600 mn ± 1 mn		
Time constant for oil-filled transfo	winding (τ wdg)	1 to 600 mn ± 1 mn	
	oil (τ oil)	5 to 600 mn ± 1 mn	
ANSI 50BF - Breaker failure			
Presence of current	0.2 to 2 In		
Operating time	0.05 s to 3 s		
ANSI 50/27 - Inadvertent energization			
Is set point	0.05 to 4 In		
Vs set point	10 to 100 % Unp		T1: 0 to 10 s
			T2: 0 to 10 s
ANSI 50/51 - Phase overcurrent			
	Tripping time delay	**Timer hold**	
Tripping curve	Definite time	DT	
	SIT, LTI, VIT, EIT, UIT (1)	DT	
	RI	DT	
	IEC: SIT/A, LTI/B, VIT/B, EIT/C	DT or IDMT	
	IEEE: MI (D), VI (E), EI (F)	DT or IDMT	
	IAC: I, VI, EI	DT or IDMT	
	Customized	DT	
Is set point	0.05 to 24 In	Definite time	Inst; 0.05 s to 300 s
	0.05 to 2.4 In	IDMT	0.1 s to 12.5 s at 10 Is
Timer hold	Definite time (DT; timer hold)		Inst; 0.05 s to 300 s
	IDMT (IDMT; reset time)		0.5 s to 20 s
Measurement origin	Main channels (I) or additional channels (I')		
Harmonic 2 restraint	5 to 50 %		
Min short-circuit current Isc	In to 999 kA		
Confirmation	None		
	By negative sequence overvoltage		
	By phase-to-phase undervoltage		

***(1)** Tripping as of 1.2 Is.*

Functions	Settings		Time delays
ANSI 50N/51N or 50G/51G - Earth fault			
	Tripping time delay	**Timer hold**	
Tripping curve	Definite time	DT	
	SIT, LTI, VIT, EIT, UIT (1)	DT	
	RI	DT	
	CEI: SIT/A,LTI/B, VIT/B, EIT/C	DT or IDMT	
	IEEE: MI (D), VI (E), EI (F)	DT or IDMT	
	IAC: I, VI, EI	DT or IDMT	
	EPATR-B, EPATR-C	DT	
	Customized	DT	
Is0 set point	0.01 to 15 In0 (min. 0.1 A)	Definite time	Inst; 0.05 s to 300 s
	0.01 to 1 In0 (min. 0.1 A)	IDMT	0.1 s to 12.5 s at 10 Is0
	0.6 to 5 A	EPATR-B	0.5 to 1 s
	0.6 to 5 A	EPATR-C	0.1 to 3 s
Timer hold	Definite time (DT; timer hold)		Inst; 0.05 s to 300 s
	IDMT (IDMT; reset time)		0.5 s to 20 s
Measurement origin	I0 input, I’0 input, sum of phase currents I0Σ or sum of phase currents I’0Σ		
ANSI 50V/51V - Voltage-restrained overcurrent			
	Tripping time delay	**Timer hold**	
Tripping curve	Definite time	DT	
	SIT, LTI, VIT, EIT, UIT (1)	DT	
	RI	DT	
	IEC: SIT/A, LTI/B, VIT/B, EIT/C	DT or IDMT	
	IEEE: MI (D), VI (E), EI (F)	DT or IDMT	
	IAC: I, VI, EI	DT or IDMT	
	Customized	DT	
Is set point	0.5 to 24 In	Definite time	Inst; 0.05 s to 300 s
	0.5 to 2.4 In	IDMT	0.1 s to 12.5 s at 10 Is
Timer hold	Definite time (DT; timer hold)		Inst; 0.05 s to 20 s
	IDMT (IDMT; reset time)		0.5 s to 300 s
Measurement origin	Main channels (I) or additional channels (I’)		
ANSI 51C - Capacitor bank unbalance			
Is set point	0.05 A to 2 I’n	Definite time	0.1 to 300 s
ANSI 59 - Overvoltage (L-L) or (L-N)			
Set point and time delay	50 to 150 % of Unp or Vnp		0.05 to 300 s
Set point and time delay for additional channels of the B83 application	1.5 to 150 % of Unp or Vnp		0.05 to 300 s
Measurement origin	Main channels (U) or additional channels (U’)		
ANSI 59N - Neutral voltage displacement			
Tripping curve	Definite time		
	IDMT		
Set point	2 to 80 % of Unp	Definite time	0.05 to 300 s
	2 to 10 % of Unp	IDMT	0.1 to 100 s
Measurement origin	Main channels (U), additional channels (U’) or neutral-point voltage Vnt		
ANSI 64REF - Restricted earth fault differential			
Is0 set point	0.05 to 0.8 In (In ⩾ 20 A)		
	0.1 to 0.8 In (In < 20 A)		
Measurement origin	Main channels (I, I0) or additional channels (I’, I’0)		
ANSI 66 - Starts per hour			
Permitted number of consecutive cold starts (Nc)	1 to 5	Delay between consecutive starts	1 to 90 mn
Permitted number of consecutive hot starts (Nh)	1 to (Nc - 1)	Delay between stop/start	0 to 90 mn

***(1)** Tripping as of 1.2 Is.*

Functions		Settings		Time delays
ANSI 67 - Directional phase overcurrent				
Characteristic angle		30°, 45°, 60°		
		Tripping time delay	**Timer hold delay**	
Tripping curve		Definite time	DT	
		SIT, LTI, VIT, EIT, UIT (1)	DT	
		RI	DT	
		IEC: SIT/A, LTI/B, VIT/B, EIT/C	DT or IDMT	
		IEEE: MI (D), VI (E), EI (F)	DT or IDMT	
		IAC: I, VI, EI	DT or IDMT	
		Customized	DT	
Is set point		0.1 to 24 In	Definite time	Inst; 0.05 s to 300 s
		0.1 to 2.4 In	IDMT	0.1 s to 12.5 s at 10 Is
Timer hold		Definite time (DT; timer hold)		Inst; 0.05 s to 300 s
		IDMT (IDMT; reset time)		0.5 s to 20 s
ANSI 67N/67NC type 1 - Directional earth fault, according to I0 projection				
Characteristic angle		-45°, 0°, 15°, 30°, 45°, 60°, 90°		
Is0 set point		0.01 to 15 In0 (mini. 0,1 A)	Definite time	Inst; 0.05 s to 300 s
Vs0 set point		2 to 80 % of Unp		
Memory time		T0mem time	0; 0.05 s to 300 s	
		V0mem validity set point	0; 2 to 80 % of Unp	
Measurement origin		I0 input, I’0 input		
ANSI 67N/67NC type 2 - Directional earth fault, according to I0 vector magnitude directionalized on a tripping half-plane				
Characteristic angle		-45°, 0°, 15°, 30°, 45°, 60°, 90°		
		Tripping time delay	**Timer hold delay**	
Tripping curve		Definite time	DT	
		SIT, LTI, VIT, EIT, UIT (1)	DT	
		RI	DT	
		IEC: SIT/A,LTI/B, VIT/B, EIT/C	DT or IDMT	
		IEEE: MI (D), VI (E), EI (F)	DT or IDMT	
		IAC: I, VI, EI	DT or IDMT	
		Customized	DT	
Is0 set point		0.01 to 15 In0 (min. 0.1 A)	Definite time	Inst; 0.05 s to 300 s
		0.01 to 1 In0 (min. 0.1 A)	IDMT	0.1 s to 12.5 s at 10 Is0
Vs0 set point		2 to 80 % of Unp		
Timer hold		Definite time (DT; timer hold)		Inst; 0.05 s to 300 s
		IDMT (IDMT; reset time)		0.5 s to 20 s
Measurement origin		I0 input, I’0 input or sum of phase currents I0Σ		
ANSI 67N/67NC type 3 - Directional earth fault, according to I0 vector magnitude directionalized on a tripping sector				
Tripping sector start angle		0° to 359°		
Tripping sector end angle		0° to 359°		
Is0 set point	CSH core balance CT (2 A rating)	0.1 A to 30 A	Definite time	Inst; 0.05 to 300 s
	1 A CT	0.005 to 15 In0 (min. 0.1 A)		
	Core balance CT + ACE990 (range 1)	0.01 to 15 In0 (min. 0.1 A)		
Vs0 set point		Calculated V0 (sum of 3 voltages)	2 to 80% of Unp	
		Measured V0 (external VT)	0.6 to 80% of Unp	
Measurement origin		I0 input or I’0 input		

(1) *Tripping from 1.2 Is.*

Functions	Settings		Time delays
ANSI 78PS - Pole slip			
Stabilization delay	1 to 300 s		
Maximum variation of internal angle	100 to 1000 °		
Confirmation delay	0 to 300 ms		
Equal-area criterion			
Confirmation delay	0.1 to 300 s		
Power swings			
Number of turns	1 to 30		
Maximum time between 2 turns	1 to 300 s		
ANSI 81H - Overfrequency			
Set point and time delay	49 to 55 Hz or 59 to 65 Hz		0.1 to 300 s
Measurement origin	Main channels (U) or additional channels (U')		
ANSI 81L - Underfrequency			
Set point and time delay	40 to 51 Hz or 50 to 61 Hz		0.1 to 300 s
Measurement origin	Main channels (U) or additional channels (U')		
ANSI 81R - Rate of change of frequency			
	0.1 to 10 Hz/s		0.15 to 300 s
ANSI 87M - Machine differential			
Ids set point	0.05 to 0.5 In (In ⩾ 20 A)		
	0.1 to 0.5 In (In < 20 A)		
ANSI 87T - Transformer differential			
High set point	3 to 18 In1		
Percentage-based curve			
Ids set point	30 to 100 % In1		
Slope Id/It	15 to 50 %		
Slope Id/It2	Without, 50 to 100 %		
Slope change point	1 to 18 In1		
Restraint on energization			
Isinr set point	1 to 10 %		
Delay	0 to 300 s		
Restraint on CT loss			
Activity	On / Off		
Harmonic restraints	**Conventional**	**Self-adaptive**	
Selection of restraint	Conventional	Self-adaptive	
Harmonic 2 percentage set point	Off, 5 to 40 %		
Harmonic 2 restraint	Phase-specific/Global		
Harmonic 5 percentage set point	Off, 5 to 40 %		
Harmonic 5 restraint	Phase-specific/Global		

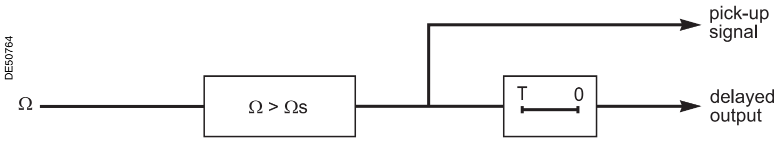
Overspeed
ANSI code 12

Detection of excessive machine speeds to protect generators and processes.

Description

Detection of machine overspeed to detect synchronous generator racing due to loss of synchronism, or for process monitoring, for example.
The rotation speed is calculated by measuring the time between pulses transmitted by a proximity sensor at each passage of one or more cams driven by the rotation of the motor or generator shaft (see a more in-depth description in the "Metering functions" chapter).
The speed acquisition parameters must be set on the "Particular characteristics" screen of the SFT2841 software.
The "Rotor speed measurement" function must be assigned to logic input I104 for the function to work.
The protection picks up if the speed measured exceeds the speed set point.
The protection includes a definite time delay T.

Block diagram



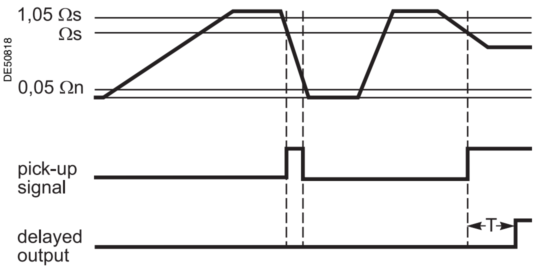
Characteristics

Settings				
Set point Ωs				
Setting range	100 to 160 % of Ωn			
Accuracy (1)	±2 %			
Resolution	1 %			
Drop out/pick up ratio	95 %			
Time delay T				
Setting range	1 s to 300 s			
Accuracy (1)	±25 ms or ±(60000/(Ωs (2) x R (3))) ms			
Resolution	1 s			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P12_x_101	■	■	
Protection inhibition	P12_x_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P12_x_1	■	■	
Delayed output	P12_x_3	■	■	■
Protection inhibited	P12_x_16	■	■	

x: unit number.
***(1)** Under reference conditions (IEC 60255-6).*
***(2)** Ωs in rpm.*
***(3)** R: Number of pulses (cam) per rotation.*

Underspeed
ANSI code 14

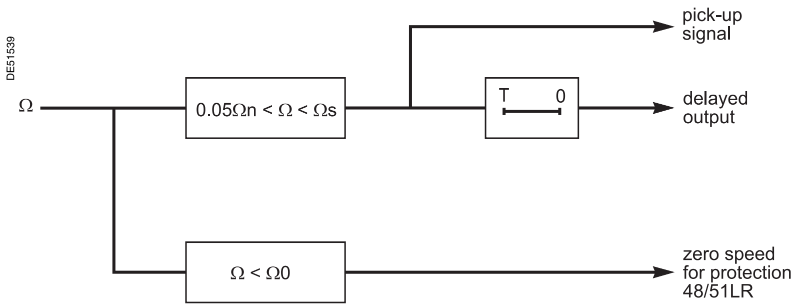
Monitoring of underspeeds and detection of rotor locking.



Description
Monitoring of machine speed:
- detection of machine underspeed after starting, for process monitoring, for example
- zero-speed data for detection of locked rotor.

The rotation speed is calculated by measuring the time between pulses transmitted by a proximity sensor at each passage of one or more cams driven by the rotation of the motor or generator shaft (see a more in-depth description in the "Metering functions" chapter).
The speed-acquisition and zero-speed detection parameters must be set on the "Particular characteristics" screen of the SFT2841 software.
The "Rotor speed measurement" function must be assigned to logic input I104 for the function to work.
The protection function picks up if the speed measured drops below the speed set point after having first exceeded the set point by 5 %. Zero speed is detected by unit 1 and is used by protection function 48/51 LR to detect rotor locking.
The protection includes a definite (DT) time delay T.

Block diagram

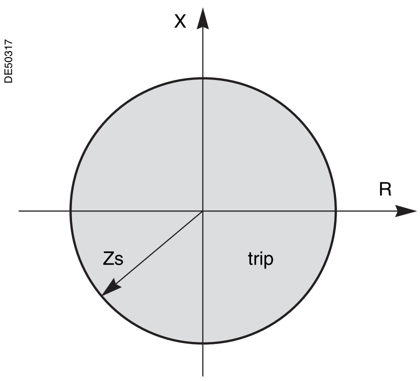


Characteristics

Settings				
Set point Ωs				
Setting range	10 to 100 % of Ωn			
Accuracy (1)	±2 %			
Resolution	1 %			
Drop out/pick up ratio	105 %			
Time delay T				
Setting range	1 s to 300 s			
Accuracy (1)	±25 ms or ±(60000/(Ωs (2) x R (3))) ms			
Resolution	1 s with T>(60/(Ωs (2) x R (3)))			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P14_x_101	■	■	
Protection inhibition	P14_x_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P14_x_1	■	■	
Delayed output	P14_x_3	■	■	■
Protection inhibited	P14_x_16	■	■	
Zero speed	P14_x_38	■	■	

x: unit number.
***(1)** Under reference conditions (IEC 60255-6).*
***(2)** Ωs in rpm.*
***(3)** R: Number of pulses (cam) per rotation.*

Phase-to-phase short-circuit protection for generators.

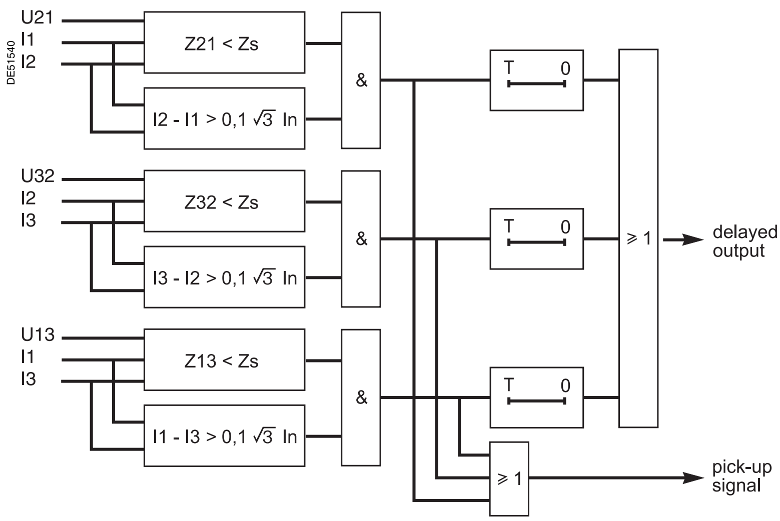


Description

The protection function is made up of a circular tripping characteristic on the impedance plane (R, X), with a definite time delay (constant, DT).
It picks up when one of the apparent, phase-to-phase impedances enters the circular tripping characteristic.
Apparent impedances:

$$\vec{Z}_{21} = \frac{\vec{U}_{21}}{\vec{I1} - \vec{I2}},\ \vec{Z}_{32} = \frac{\vec{U}_{32}}{\vec{I2} - \vec{I3}},\ \vec{Z}_{13} = \frac{\vec{U}_{13}}{\vec{I3} - \vec{I1}}.$$

Block diagram



Characteristics

Settings				
Set point Ωs				
Setting range	0.05Vn/Ib ⩽ Zs ⩽ 2 Vn/Ib or 0.001 Ω			
Accuracy (1)	±2 %			
Resolution	0.001 Ω or 1 digit			
Drop out/pick up ratio	105 %			
Time delay T				
Setting range	200 ms ⩽ T ⩽ 300 s			
Accuracy (1)	±2 % or from -10 ms to +25 ms			
Resolution	10 ms or 1 digit			
Characteristic times (1)				
Operation time	pick-up < 35 ms from infinite to Zs/2 (typically 25 ms)			
Overshoot time	< 40 ms			
Reset time	< 50 ms			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P21B_1_101	■	■	
Protection inhibition	P21B_1_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P21B_1_1	■	■	
Delayed output	P21B_1_3	■	■	■
Protection inhibited	P21B_1_16	■	■	

(1) Under reference conditions (IEC 60255-6).

Example: synchronous generator

Synchronous generator data:
- S = 3.15 MVA
- Un1 = 6.3 kV
- Xd = 233 %
- X'd = 21 %

Protection setting

To set the protection function, it is necessary to calculate the rated generator impedance:
- $Ib = S/(\sqrt{3}\,Un1) = 289$ A
- $Zn = Un1/(\sqrt{3}\,Ib) = 12.59\ \Omega$

The tripping parameter is typically set to 30 % of the rated generator impedance:
$Zs = 0.30 \times Zn = 3.77\ \Omega$.
This protection function is used to back up other protection functions. Its setting must therefore ensure discrimination with the other protection functions.
T = 0.9 s, for example, for a network where faults are cleared in 0.6 s.

Overfluxing (V/Hz)
ANSI code 24

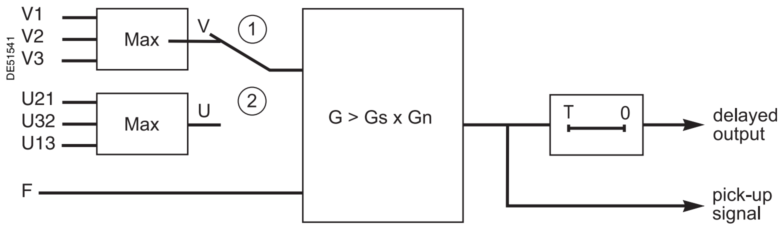
Protection of magnetic circuits in transformers and generators.

Description
Protection which detects overfluxing of transformer or generator magnetic circuits by calculating the ratio between the greatest phase-to-neutral or phase-to-phase voltage divided by the frequency.

Overfluxing of magnetic circuits is caused by machine operation with excessive voltage or insufficient frequency. It provokes saturation of the magnetic materials and results in temperature rise. In severe cases, a major leakage flux may occur and seriously damage the materials around the magnetic circuit.

The protection function picks up when the U/f or V/f ratio, depending on machine coupling, exceeds the set point. The function is delayed (definite time (DT) or IDMT) according to three curves (see tripping curve equation on page 226).

The typical tripping set point is 1.05 pu.

Block diagram


where G = U/f or V/f depending on machine coupling
Gn = Un/fn or Vn/fn depending on the voltage
Gs = the set point

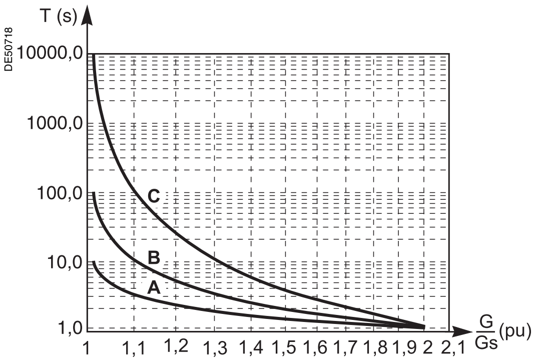
(1) *phase-to-neutral voltage, see the table below.*

(2) *phase-to-phase voltage, see the table below.*

Machine coupling
This setting adapts the function voltage measurement to the coupling of the magnetic circuit, depending on the measurements made possible by Sepam wiring.

Voltage used by the protection function							
VT wiring	**3V**	**2U + V 0**	**2U**	**1U + V 0**	**1U**	**1V + V 0**	**1V**
Delta coupling	(2)	(2)	(2)	(2)	(2)	(1)	(1)
Star coupling	(1)	(1)	(2)	(2)	(2)	(1)	(1)

Overfluxing (V / Hz)
ANSI code 24



Voltage/frequency ratio IDMT tripping curves

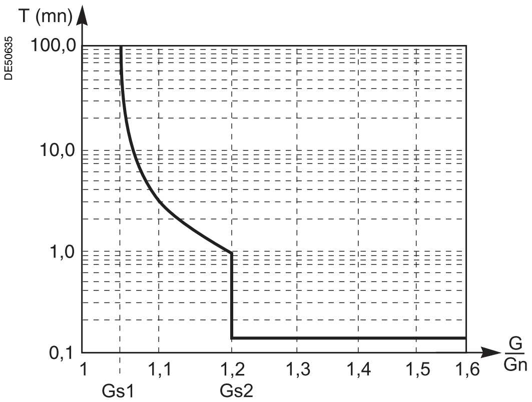
Characteristics

Settings				
Machine coupling				
Setting range		Delta / star		
Tripping curve				
Setting range		Definite time IDMT: type A, type B, type C		
Gs set point				
Setting range		1.03 to 2.0 pu (2)		
Accuracy (1)		±2 %		
Resolution		0.01 pu (2)		
Drop out/pick up ratio		98 % ±1 %		
Time delay T (operation time at 2 pu)				
Definite time	Setting range	0.1 to 20000 s		
	Accuracy (1)	±2 % or from -10 ms to +25 ms		
IDMT	Setting range	0.1 to 1250 s		
	Accuracy (1)	±5 % or from -10 ms to +25 ms		
Resolution		10 ms or 1 digit		
Characteristic times (1)				
Operation time		pick-up < 40 ms from 0.9 Gs to 1,1 Gs at fn		
Overshoot time		< 40 ms from 0.9 Gs to 1.1 Gs at fn		
Reset time		< 50 ms from 1.1 Gs to 0.9 Gs at fn		

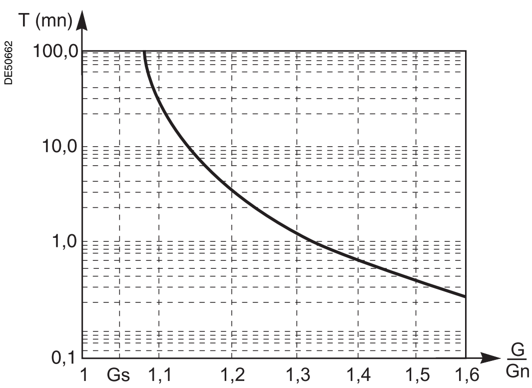
Inputs			
Designation	**Syntax**	**Equations**	**Logipam**
Protection reset	P24_x_101	■	■
Protection inhibition	P24_x_113	■	■

Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P24_x_1	■	■	
Delayed output	P24_x_3	■	■	■
Protection inhibited	P24_x_16	■	■	

x: unit number.
(1) *Under reference conditions (IEC 60255-6).*
(2) *1 pu represents 1 x Gn.*



Example 1. synchronous generator
A generator is often protected with two tripping set points:
■ an IDMT set point, set to 1.05 Gn with a long delay.
Example: type B curve, Gs1 = 1.05 and T1 = 8 s
■ a definite time (DT) set point, set to approximately 1.2 Gn with a tripping time of approximately ten seconds.
For example: DT, Gs2 = 1.2 and T2 = 5 s.



Example 2. transformer
A transformer is generally protected by an IDMT set point, set to 1.05 Gn with a long delay.
For example: type C curve, Gs = 1.05 and T = 4 s.

3

Protection function which checks the synchronization of the electrical networks upstream and downstream of a circuit breaker and allows closing when the differences in voltage, frequency and phase are within authorized limits.

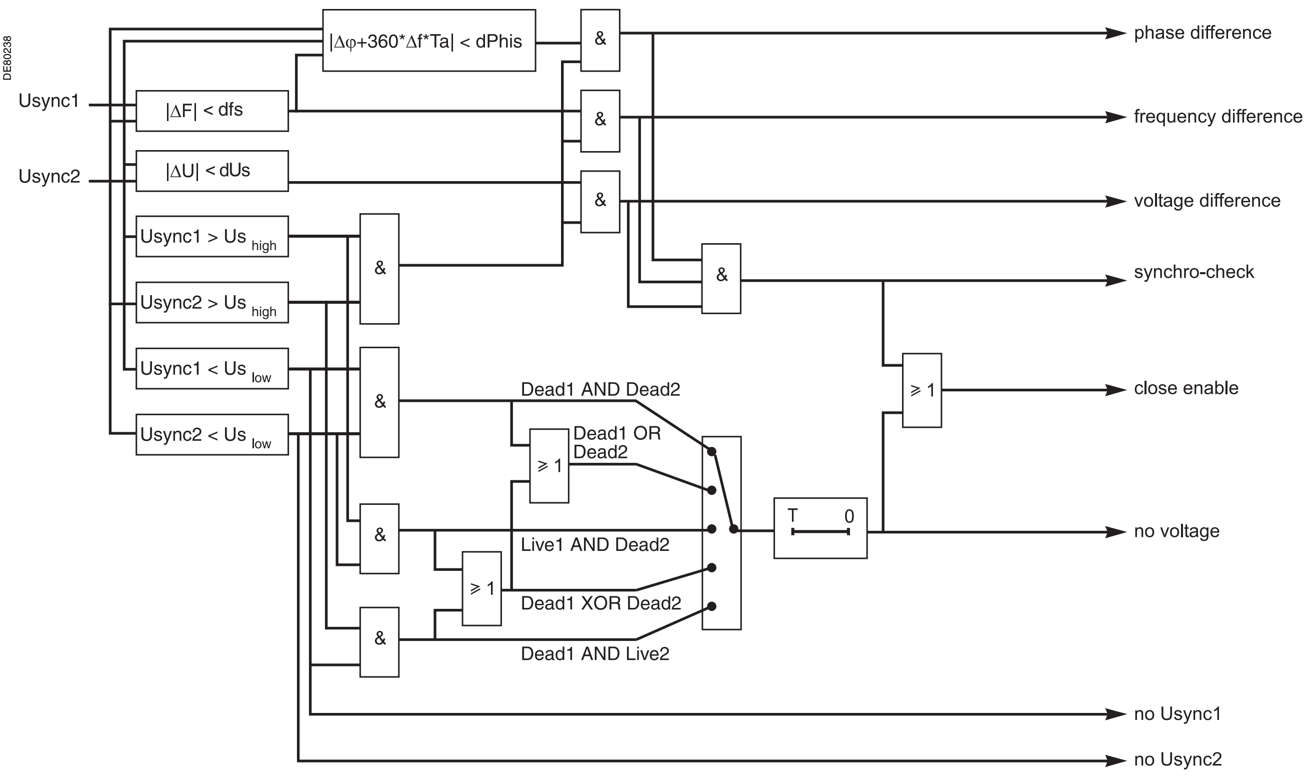
Operation

The synchro-check function is designed to allow circuit breaker closing without any risk of dangerous coupling between two voltages Usync1 and Usync2. The voltages compared may be two phase-to-phase voltages or two phase-to-neutral voltages.

The function is activated when there is a phase, frequency or amplitude difference, within set limits, between the voltages that are compared.

The function is available in the optional MCS025 module. The "Close enable" logic data must be cabled to a logic input on the Sepam. All other data and measurements are transmitted to the Sepam base unit via the CCA785 connection cord.

Block diagram



Anticipation

It is possible to anticipate the function by a time Ta, taking into account the frequency difference and the circuit breaker closing time, in order for the voltages to be synchronized at the time of coupling.

Voltage checking

When one of the two voltages is absent, coupling may be authorized according to one of five voltage checking modes.

- Usync1 absent and Usync2 present (Dead1 AND Live2)
- Usync1 present and Usync2 absent (Live1 AND Dead2)
- One voltage is present and the other is absent (Dead1 XOR Dead2)
- One or both of the two voltages are absent (Dead1 OR Dead2)
- Both voltages are absent (Dead1 AND Dead2).

The presence of each of the voltages is detected by comparing the voltage to the high set point (Us high). The absence of either of the voltages is detected by comparing the voltage to the low set point (Us low).

Synchro-check
ANSI code 25

User information

The following measurements are available:
- voltage difference
- frequency difference
- phase difference.

Characteristics

Settings				
dUs set point				
Setting range	3 % Unsync1 to 30 % Unsync1			
Accuracy (1)	±2.5 % or 0,003 Unsync1			
Resolution	1 %			
Drop out/pick up ratio	106 %			
dfs set point				
Setting range	0.05 Hz to 0.5 Hz			
Accuracy (1)	±10 mHz			
Resolution	0.01 Hz			
Drop out/pick up	< 15 mHz			
dPhis set point				
Setting range	5° to 50°			
Accuracy (1)	±2°			
Resolution	1°			
Drop out/pick up ratio	120 %			
Us high set point				
Setting range	70 % Unsync1 to 110 % Unsync1			
Accuracy (1)	±1 %			
Resolution	1 %			
Drop out/pick up ratio	93 %			
Us low set point				
Setting range	10 % Unsync1 to 70 % Unsync1			
Accuracy (1)	±1 %			
Resolution	1 %			
Drop out/pick up ratio	106 %			
Anticipation of circuit breaker closing time				
Setting range	0 to 500 ms			
Accuracy (1)	±2 % or ±25 ms			
Resolution	10 ms or 1 digit			
Voltage checking				
Setting range	In service / Out of service			
Operating mode with no voltage				
Setting range	Dead1 AND Live2 Live1 AND Dead2 Dead1 XOR Dead2 Dead1 OR Dead2 Dead1 AND Dead2			
Characteristic times (1)				
Operation time	< 190 ms			
dU operation time	< 120 ms			
df operation time	< 190 ms			
dPhi operation time	< 190 ms			
Reset time	< 50 ms			
Outputs (1)				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Close enable				
Synchro-check	P25_1_46	■	■	
No voltage	P25_1_47	■	■	
Phase difference	P25_1_49	■	■	
Frequency difference	P25_1_50	■	■	
Voltage difference	P25_1_51	■	■	
No Usync1	P25_1_52	■	■	
No Usync2	P25_1_53	■	■	

(1) Under reference conditions (IEC 60255-6).

Undervoltage (L-L or L-N)
Code ANSI 27

Protection against phase-to-neutral or phase-to-phase voltage dips.

Operation

Protection against voltage dips or detection of abnormally low voltage in order to:

- Trigger automatic load shedding
- Trigger a source transfer
- Disconnect a generator, in conformity with a "Grid code".

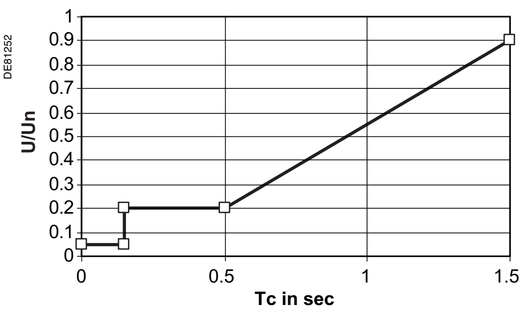
It includes a time delay T with:

- definite time (DT)
- inverse definite minimum time (see the tripping curve equation on page 226)
- definite time with a curve T(U/Un) that can be customized point by point.

Whether operation is phase-to-neutral or phase-to-phase voltage depends on the connection chosen for the voltage inputs.

Custom "Grid code" curve

Production installations must stay connected to the grid whenever the voltage is higher than that defined by the "Grid code" curve. The custom curve is defined point by point, with the disconnection time Tc in seconds on the X-axis and the voltage U/Un in pu on the Y-axis.

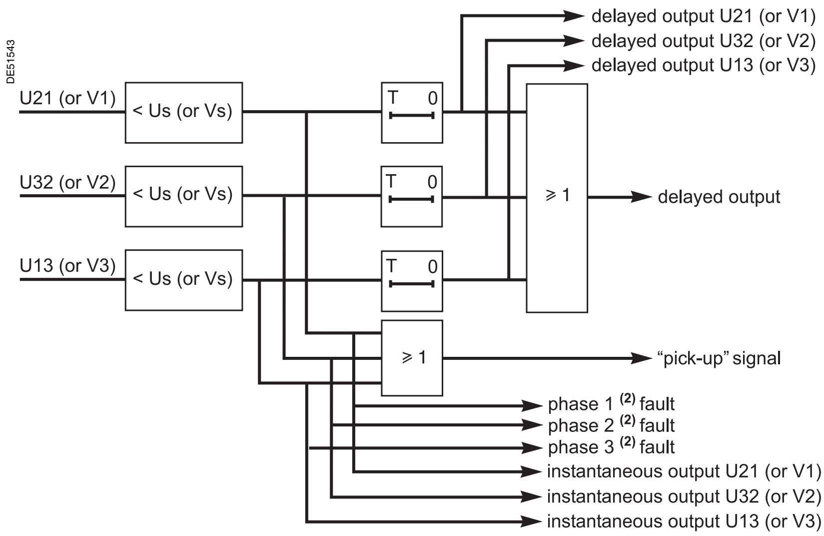


"Grid code" curve.

Connection conditions			
Connection type	V1, V2, V3 (1)	U21, U32 + V0	U21, U32
Operation in phase-to-neutral voltage	YES	YES	NO
Operation in phase-to-phase voltage	YES	YES	YES
Connection type	U21 (1)	V1 (1)	
Operation in phase-to-neutral voltage	NO	On V1	only
Operation in phase-to-phase voltage	On U21 only	NO	

(1) With or without V0.

Block diagram



Characteristics

Settings	
Measurement origin	
Setting range	Main channels (U) / Additional channels (U')
Voltage acquisition mode	
Setting range	Phase-to-phase voltage / Phase-to-neutral voltage
Tripping curve	
Setting range	Definite time / IDMT / Customizable
Us (or Vs) set point	
Setting range	5 % of Unp (or Vnp) to 100 % of Unp (or Vnp)
Accuracy (1)	±2 % or ±0,005 Unp
Resolution	1 %
Drop-out/pick-up ratio	103 % ±2 %
Time delay T (tripping time for zero voltage)	
Setting range	50 ms to 300 s
Accuracy (1)	±2 % or ±25 ms
Resolution	10 ms or 1 digit
Characteristic times	
Operating time	Pick-up < 40 ms from 1.1 Us (Vs) to 0.9 Us (Vs) (25 ms typical)
Overshoot time	< 40 ms from 1.1 Us (Vs) to 0.9 Us (Vs)
Reset time	< 50 ms from 0.9 Us (Vs) to 1.1 Us (Vs)

Inputs			
Designation	**Syntax**	**Equations**	**Logipam**
Reset protection	P27_x_101	■	■
Inhibit protection	P27_x_113	■	■

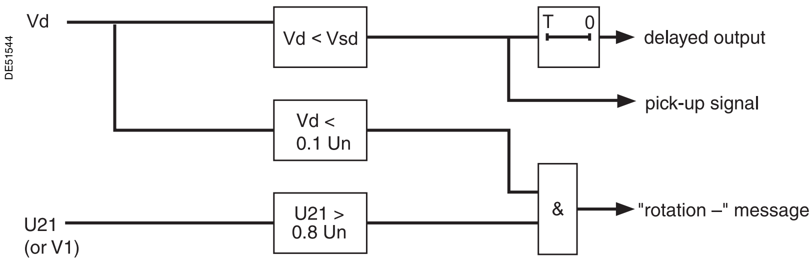
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P27_x_1	■	■	
Time-delayed output	P27_x_3	■	■	■
Phase 1 fault (2)	P27_x_7	■	■	
Phase 2 fault (2)	P27_x_8	■	■	
Phase 3 fault (2)	P27_x_9	■	■	
Protection inhibited	P27_x_16	■	■	
Instantaneous output V1 or U21	P27_x_23	■	■	
Instantaneous output V2 or U32	P27_x_24	■	■	
Instantaneous output V3 or U13	P27_x_25	■	■	
Delayed output V1 or U21	P27_x_26	■	■	
Delayed output V2 or U32	P27_x_27	■	■	
Delayed output V3 or U13	P27_x_28	■	■	

x: Unit number.
***(1)** Under reference conditions (IEC 60255-6).*
***(2)** When the protection in used is phase-to-neutral voltage.*

Positive sequence undervoltage and phase rotation direction check
ANSI code 27D

Motor protection against incorrect voltages.

Description
Protection of motors against faulty operation due to insufficient or unbalanced network voltage. It is based on measurement of the positive sequence voltage Vd.
It includes a definite time delay T.
It does not operate when only a single phase-to-neutral or phase-to-phase voltage is connected.
This protection also detects the phase rotation direction. The protection function considers that the phase rotation direction is reversed when the positive sequence voltage is less than 10 % of Unp and when the phase-to-phase voltage is greater than 80 % of Unp. When this is the case, the alarm message "ROTATION –" is generated.

Block diagram


Characteristics

Settings				
Measurement origin				
Setting range	Main channels (U) / Additional channels (U')			
Vsd set point				
Setting range	15 % Unp to 60 % Unp			
Accuracy (1)	±2 % or ±0.005 Unp			
Resolution	1 %			
Drop out/pick up ratio	103 % ±2 %			
Time delay T				
Setting range	50 ms to 300 s			
Accuracy (1)	±2 % or ±25 ms			
Resolution	10 ms or 1 digit			
Characteristic times				
Operation time	Pick-up < 40 ms from 1.1 Vsd to 0.9 Vsd			
Overshoot time	< 40 ms from 1.1 Vsd to 0.9 Vsd			
Reset time	< 50 ms from 0.9 Vsd to 1.1 Vsd			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P27D_x_101	■	■	
Protection inhibition	P27D_x_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P27D_x_1	■	■	
Delayed output	P27D_x_3	■	■	■
Protection inhibited	P27D_x_16	■	■	

x: unit number.
***(1)** Under reference conditions (IEC 60255-6).*

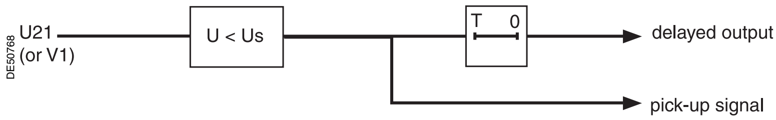
Remanent undervoltage
ANSI code 27R

Detection of the remanent voltage sustained by rotating machines.

Description

Protection used to check that remanent voltage sustained by rotating machines has been cleared before allowing the busbars supplying the machines to be re-energized, to avoid electrical and mechanical transients.
This protection is single-phase. It picks up when the U21 or V1 voltage is less than the Us set point. The protection includes a definite time delay (constant).

Block diagram



Characteristics

Settings				
Measurement origin				
Setting range	Main channels (U) / Additional channels (U’)			
Us set point				
Setting range	5 % Unp to 100 % Unp			
Accuracy (1)	±5 % or 0.005 Unp			
Resolution	1 %			
Drop out/pick up ratio	103 % ±2 %			
Time delay T				
Setting range	50 ms to 300 s			
Accuracy (1)	±2 % or ±25 ms			
Resolution	10 ms or 1 digit			
Characteristic times				
Operation time	Pick-up < 45 ms from 1.1 Us to 0.9 Us			
Overshoot time	< 35 ms from 1.1 Us to 0.9 Us			
Reset time	< 35 ms from 0.9 Us to 1.1 Us			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P27R_x_101	■	■	
Protection inhibition	P27R_x_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P27R_x_1	■	■	
Delayed output	P27R_x_3	■	■	■
Protection inhibited	P27R_x_16	■	■	

x: unit number.
***(1)** Under reference conditions (IEC 60255-6).*

3

Third harmonic undervoltage
ANSI code 27TN/64G2

Generator protection against insulation faults. This function should be combined with 59N or 51N to ensure 100 % stator earth fault protection (64G).

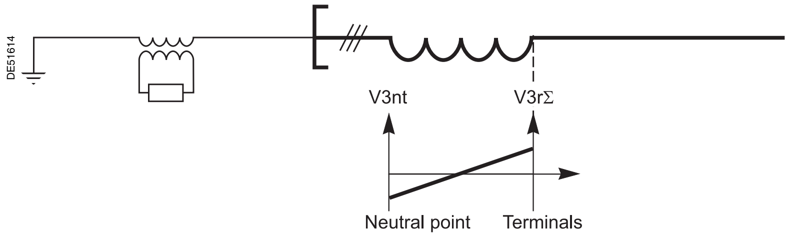
Description

Protection of generators against phase-to-earth insulation faults, by the detection of a reduction of the third harmonic residual voltage.This function protects 10 to 20 % of the stator winding on the neutral point end. Complete protection of the stator winding is ensured by combining this function with function 59N or 51N, which protects 85 to 95 % of the winding on the terminal end.

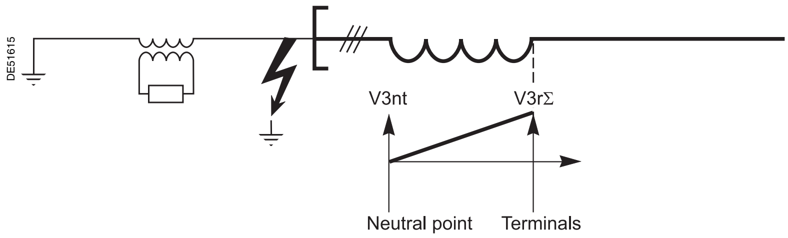
Due to their geometric characteristics, generators produce third-order harmonic voltages (H3) in addition to the fundamental electromotive force. The amplitude of the H3 voltage may vary from 0 to 10 % of Vn, as a function of:
- ■ network and generator characteristics
- ■ the load on the generator. It is generally higher under full-load conditions than under no-load conditions.

In the absence of a fault, the H3 voltage must be at least 0.2 % of Vn for protection function 27TN.

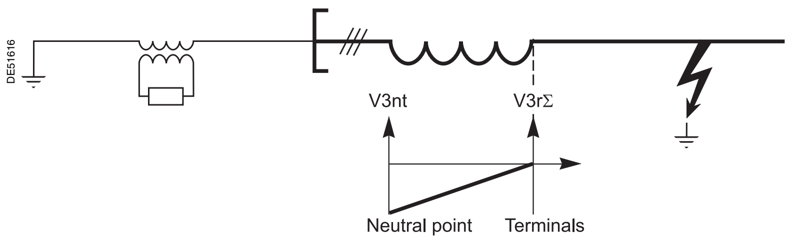
H3 voltage with no fault
During normal operation, the H3 voltage is measured at each end of the windings.



H3 voltage with a fault on the neutral point end
When a single-phase fault occurs in the stator winding near the machine neutral point, the neutral point impedance is short-circuited which leads to a drop in the H3 voltage on the neutral point end.



H3 voltage with a fault on the terminal end
When a single-phase fault occurs in the stator winding near the machine terminals, the H3 voltage increases on the neutral point end.



The third harmonic undervoltage protection function detects the drop in the H3 voltage caused by a single-phase fault on the neutral-point end.
Two types of tripping set points are available according to the sensors connected:
- ■ fixed set point: tripping for H3 neutral point undervoltage. The setting requires preliminary measurements.
- ■ adaptive set point: tripping for H3 neutral point undervoltage depending on a set point whose value depends on the H3 residual voltage. The setting does not require preliminary measurements.

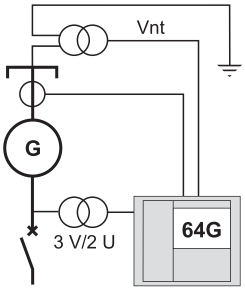
Availability of set points depending on the sensors used

Voltage measurements		Available types	
VT neutral point	**VT terminals**	**27TN fixed set point**	**27TN adaptive set point**
-	All wiring	-	-
■	V1 or U21	-	-
■	U21, U32	■	-
■	V1, V2, V3	■	■

3

Third harmonic undervoltage
ANSI code 27TN/64G2
Fixed set point

DE50326



Operation (fixed set point)

The DT delayed trip order is issued if the neutral point H3 voltage set point V3nt is less than the Vs set point.
The protection function operates only if the neutral point H3 voltage before the fault is greater than 0.2 % of the network phase-to-neutral voltage.
The protection function is inhibited if the power produced by the generator is low or if the positive sequence voltage is insufficient.

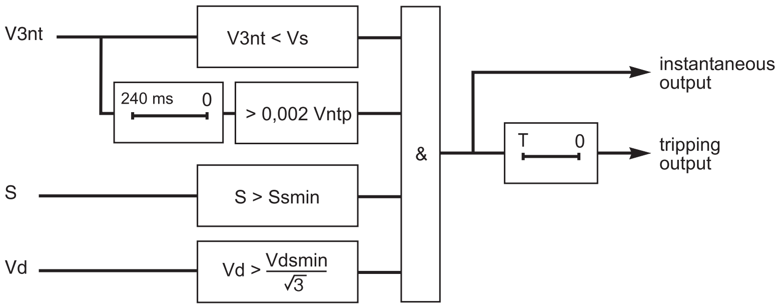
Adjustment
This function is adjusted according to a series of measurements on the neutral point H3 voltage of the generator. These measurements are used to determine the lowest H3 voltage value under normal operating conditions.
The measurements should be carried out:

- under no-load conditions, not connected to the network
- at a number of load levels because the H3 voltage level depends on the load.

The parameter is set below the lowest H3 voltage value measured. The Sepam unit provides the neutral point H3 voltage measurement to facilitate adjustment of the protection function.

Block diagram

DE51545

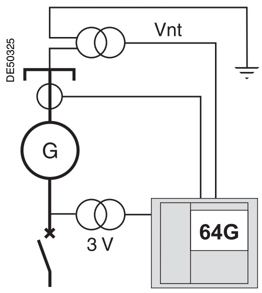


Characteristics

Settings				
Type of set point				
Setting range	Fixed			
Third harmonic voltage set point Vs				
Setting range	0.2 to 20 % of Vntp			
Accuracy (1)	±5 % or ±0.05 V of neutral point Vnts			
Resolution	0.1 %			
Drop out/pick up ratio	105 %			
Time delay				
Setting range	0.5 to 300 s			
Accuracy (1)	±2 % or from -10 ms to +25 ms			
Resolution	10 ms or 1 digit			
Advanced settings				
Ssmin set point				
Setting range	1 % to 90 % of $\sqrt{3}$.Unp.Ib			
Accuracy (1)	±5 %			
Resolution	1 %			
Drop out/pick up ratio	105 %			
Vdsmin positive sequence undervoltage set point				
Setting range	50 % to 100 % of Unp			
Accuracy (1)	±5 %			
Resolution	1 %			
Drop out/pick up ratio	105 %			
Characteristic times (1)				
Operation time	typically 140 ms from 2 Vs to 0			
Overshoot time	< 65 ms			
Reset time	< 65 ms			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P27TN/64G2_x_101	■	■	
Protection inhibition	P27TN/64G2_x_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Tripping output	P27TN/64G2_x_3	■	■	■
Protection inhibited	P27TN/64G2_x_16	■	■	
Instantaneous output	P27TN/64G2_x_23	■	■	

x: unit number.
***(1)** Under reference conditions (IEC 60255-6).*

Third harmonic undervoltage
ANSI code 27TN/64G2
Adaptive set point



Operation (adaptive set point)

The H3 voltage (terminal end) V3rΣ is compared to the H3 voltage V3nt measured on the neutral point end. The protection function calculates the H3 residual voltage using the three phase-to-neutral voltages. Use of the H3 residual voltage is the means to adapt the tripping set point according to the normal H3 voltage level.
Time-delayed definite time (DT) tripping occurs when:

$$|V3nt| \leq \frac{K}{3(1-K)} \times |V3r\Sigma| \quad .$$

The protection function operates only if the neutral point H3 voltage before the fault is greater than 0.2 % of the network phase-to-neutral voltage and if the positive sequence voltage is greater than 30 % of the phase-to-neutral voltage.

Adjustment

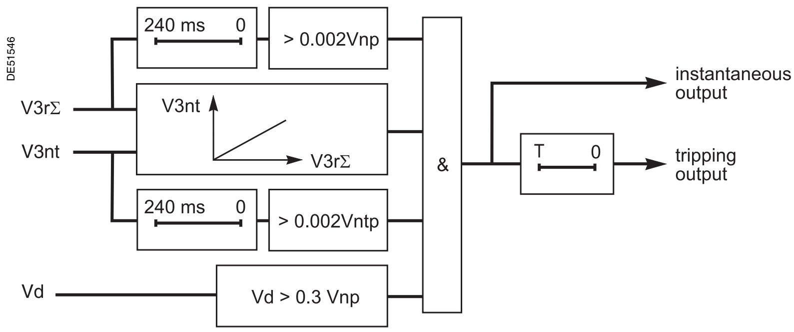
This function does not require any particular measurements but, in certain cases, it may be necessary to adjust the K setting.
The Sepam unit measures the neutral point H3 voltage V3nt and the H3 residual voltage V3rΣ to facilitate adjustment of the protection function.

- V3nt is expressed in % of the primary voltage of the neutral point sensor Vntp
- V3rΣ is expressed in % of the primary voltage of the terminal-side sensors Vnp.

If the primary voltages of the sensors are different, V3nt must be adapted to the terminal-side primary voltage Vnp using the equation:

$$\textbf{V3nt (\%Vnp) = V3nt (\%Vntp) x } \frac{\textbf{Vntp}}{\textbf{Vnp}}$$

Block diagram



Characteristics

Settings				
Type of set point				
Setting range	Adaptive			
Time delay				
Setting range	0.5 to 300 s			
Accuracy (1)	±2 % or from -10 ms to +25 ms			
Resolution	10 ms or 1 digit			
Advanced settings				
K set point				
Setting range	0.1 to 0.2			
Accuracy (1)	±1 %			
Resolution	0.01			
Drop out/pick up ratio	105 %			
Characteristic times (1)				
Operation time	typically 140 ms (2)			
Overshoot time	< 65 ms			
Reset time	< 65 ms			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P27TN/64G2_x_101	■	■	
Protection inhibition	P27TN/64G2_x_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Tripping output	P27TN/64G2_x_3	■	■	■
Protection inhibited	P27TN/64G2_x_16	■	■	
Instantaneous output	P27TN/64G2_x_23	■	■	

x: unit number.
***(1)** Under reference conditions (IEC 60255-6).*
***(2)** Measured for a variation of 2V3nt to 0 with V3rΣ = 30 %.*

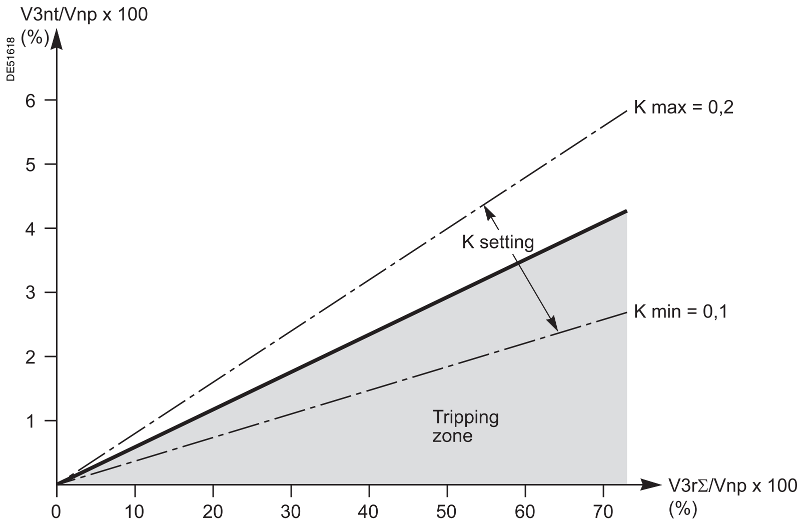
3

Third harmonic undervoltage
ANSI code 27TN/64G2
Adaptive set point

Curves $\frac{K}{3(1-K)} \times |V3r\Sigma|$

Table with maximum values of V3nt (%Vnp)

V3rΣ (%Vnp) \ K	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.20
1	0.04	0.04	0.05	0.05	0.05	0.06	0.06	0.07	0.07	0.08	0.08
2	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.17
3	0.11	0.12	0.14	0.15	0.16	0.18	0.19	0.20	0.22	0.23	0.25
4	0.15	0.16	0.18	0.20	0.22	0.24	0.25	0.27	0.29	0.31	0.33
5	0.19	0.21	0.23	0.25	0.27	0.29	0.32	0.34	0.37	0.39	0.42
6	0.22	0.25	0.27	0.30	0.33	0.35	0.38	0.41	0.44	0.47	0.50
7	0.26	0.29	0.32	0.35	0.38	0.41	0.44	0.48	0.51	0.55	0.58
8	0.30	0.33	0.36	0.40	0.43	0.47	0.51	0.55	0.59	0.53	0.67
9	0.33	0.37	0.41	0.45	0.49	0.53	0.57	0.61	0.66	0.70	0.75
10	0.37	0.41	0.45	0.50	0.54	0.59	0.63	0.68	0.73	0.78	0.83
15	0.56	0.62	0.68	0.75	0.81	0.88	0.95	1.02	1.10	1.17	1.25
20	0.74	0.82	0.91	1.00	1.09	1.18	1.27	1.37	1.46	1.56	1.67
25	0.93	1.03	1.14	1.25	1.36	1.47	1.59	1.71	1.83	1.95	2.08
30	1.11	1.24	1.36	1.49	1.63	1.76	1.90	2.05	2.20	2.35	2.50
40	1.48	1.65	1.82	1.99	2.17	2.35	2.54	2.73	2.93	3.13	3.33
50	1.85	2.06	2.27	2.49	2.71	2.94	3.17	3.41	3.66	3.91	4.17
60	2.22	2.47	2.73	2.99	3.26	3.53	3.81	4.10	4.39	4.69	4.10
70	2.59	2.88	3.18	3.49	3.80	4.12	4.44	4.78	5.12	5.47	5.83
80	2.96	3.30	3.64	3.98	4.34	4.71	5.08	5.46	5.85	6.26	6.67
90	3.33	3.71	4.09	4.48	4.88	5.29	5.71	6.14	6.59	7.04	7.50



Directional active overpower
ANSI code 32P

Protection against reverse power and overloads.

Description

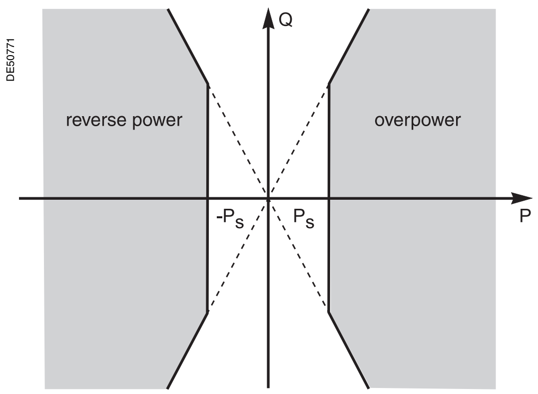
Two-way protection based on calculated active power, for the following applications:

■ active overpower protection to detect overloads and allow load shedding

■ reverse active power protection:

□ against generators running like motors when the generators draw active power

□ against motors running like generators when the motors supply active power.



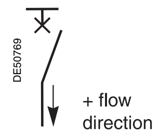
Operating zone.

The protection function picks up if the active power flowing in one direction or the other (supplied or drawn) is greater than the Ps set point.
It includes a definite time delay T.
It is based on the two or three-wattmeter method, depending on the connection conditions:

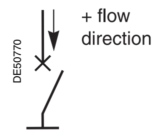
■ V1, V2, V3 and I1, I2, I3: 3 wattmeters
■ V1, V2, V3 and I1, I3: 2 wattmeters
■ U21, U32 + V0 and I1, I2, I3: 3 wattmeters
■ U21, U32 + V0 and I1, I3: 2 wattmeters
■ U21, U32 without V0: 2 wattmeters
■ other cases: protection function unavailable.

The function is enabled only if the following condition is met:
$P \geqslant 3.1\ \%\ Q$ which provides a high level of sensitivity and high stability in the event of short-circuits.
The power sign is determined according to the general feeder or incomer parameter, according to the convention:

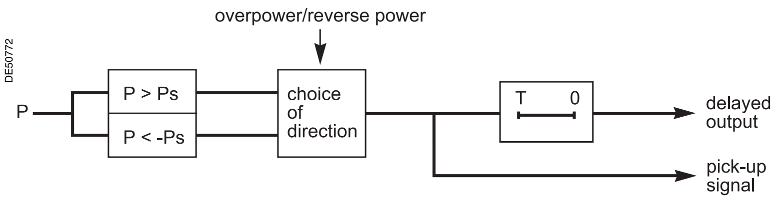
■ for the feeder circuit:
□ power supplied by the busbars is positive
□ power supplied to the busbar is negative



■ for the incomer circuit:
□ power supplied to the busbar is positive
□ power supplied by the busbars is negative.



Block diagram



Characteristics

Settings				
Tripping direction				
Setting range	Overpower/reverse power			
Ps set point				
Setting range	1 % of Sn (2) to 120 % of Sn (2)			
Accuracy (1)	±0.3 % Sn for Ps between 1 % Sn and 5 % Sn ±5 % for Ps between 5 % Sn and 40 % Sn ±3 % for Ps between 40 % Sn and 120 % Sn			
Resolution	0.1 kW			
Drop out/pick up ratio	93.5 % ±5 % or > (1 - 0.004 Sn/Ps) x 100 %			
Time delay T				
Setting range	100 ms to 300 s			
Accuracy (1)	±2 % or -10 ms to +25 ms			
Resolution	10 ms or 1 digit			
Characteristic times				
Operation time	< 90 ms at 2 Ps			
Overshoot time	< 40 ms at 2 Ps			
Reset time	< 105 ms at 2 Ps			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P32P_x_101	■	■	
Protection inhibition	P32P_x_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P32P_x_1	■	■	
Delayed output	P32P_x_3	■	■	■
Protection inhibited	P32P_x_16	■	■	
Positive active power	P32P_x_19	■	■	
Negative active power	P32P_x_20	■	■	

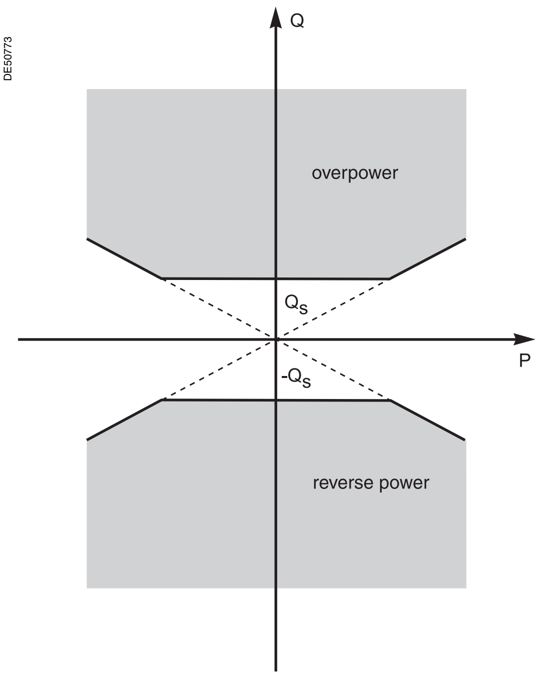
x: unit number.
***(1)** Under reference conditions (IEC 60255-6).*
***(2)** Sn = $\sqrt{3}$ Un In.*

Directional reactive overpower
ANSI code 32Q

Protection against field loss on synchronous machines.

Description

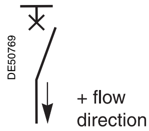
Two-way protection based on calculated reactive power to detect field loss on synchronous machines:
- reactive overpower protection for motors which consume more reactive power following field loss
- reactive power feedback protection for protecting generators which consume more reactive power following field loss.



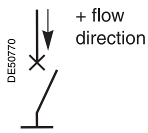
Operating zone.

The protection function picks up if the reactive power flowing in one direction or the other (supplied or drawn) is greater than the Qs set point.
It includes a definite time delay T.
It is based on the two or three-wattmeter method, depending on the connection conditions:
- V1, V2, V3 and I1, I2, I3: 3 wattmeters
- V1, V2, V3 and I1, I3: 2 wattmeters
- U21, U32 + V0 and I1, I2, I3: 3 wattmeters
- U21, U32 + V0 and I1, I3: 2 wattmeters
- U21, U32 without V0: 2 wattmeters
- other cases: protection function unavailable.

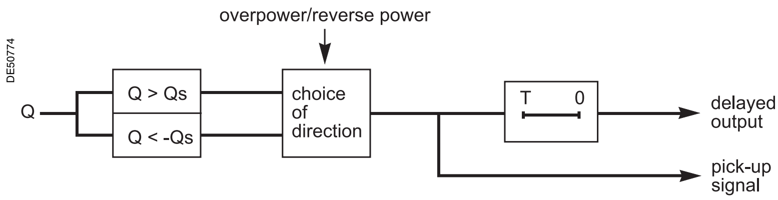
The function is enabled only if the following condition is met:
Q ⩾ 3.1 % P which provides a high level of sensitivity and high stability in the event of short-circuits.
Assuming the wiring is the same, the power sign is determined according to the general feeder or incomer parameter, according to the convention:
- for the feeder circuit:
  - □ power supplied by the busbars is positive
  - □ power supplied to the busbar is negative



- for the incomer circuit:
  - □ power supplied to the busbar is positive
  - □ power supplied by the busbars is negative.



Block diagram



Characteristics

Settings				
Tripping direction				
Setting range	Overpower/reverse power			
Qs set point				
Setting range	5 % of Sn (2) to 120 % of Sn (2)			
Accuracy (1)	±5 % for Qs between 5 % Sn and 40 % Sn ±3 % for Qs between 40 % Sn and 120 % Sn			
Resolution	0.1 kW			
Drop out/pick up ratio	93.5 % ±5 % or > (1- 0.004 Sn/Qs) x 100 %			
Time delay T				
Setting range	100 ms to 300 s			
Accuracy (1)	±2 % or -10 ms to +25 ms			
Resolution	10 ms or 1 digit			
Characteristic times				
Operation time	< 90 ms at 2 Qs			
Overshoot time	< 95 ms at 2 Qs			
Reset time	< 95 ms at 2 Qs			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P32Q_1_101	■	■	
Protection inhibition	P32Q_1_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P32Q_1_1	■	■	
Delayed output	P32Q_1_3	■	■	■
Protection inhibited	P32Q_1_16	■	■	
Positive reactive power	P32Q_1_54	■	■	
Negative reactive power	P32Q_1_55	■	■	

***(1)** Under reference conditions (IEC 60255-6).*
***(2)** Sn = $\sqrt{3}$.Un.In.*

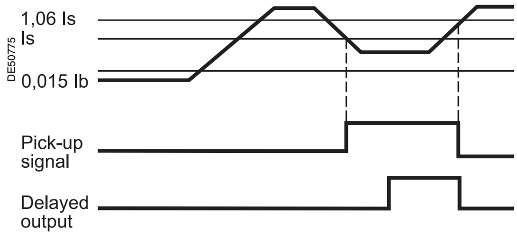
Phase undercurrent
ANSI code 37

Protection for pumps.

Description
Protection of pumps against the consequences of a loss of priming by detection of motor no-load operation.

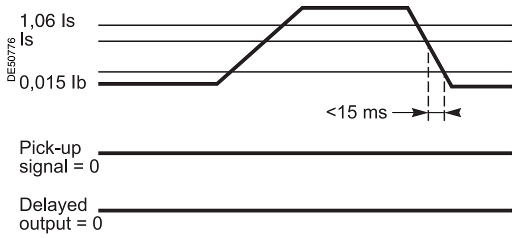
This protection is single-phase.

- it picks up when phase 1 current (I1) drops below the Is set point.



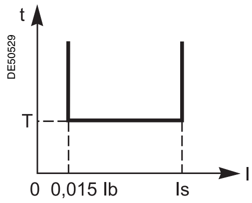
Current sag.

- it is inactive when the current is less than 1.5 % of In.
- it is insensitive to current drops due to circuit breaker tripping.



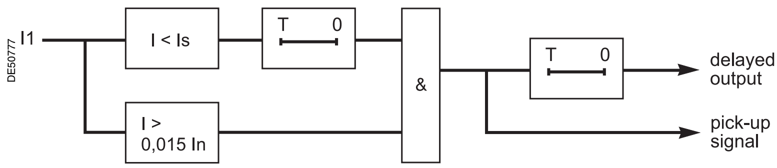
Circuit breaker tripping.

- the protection function includes a definite time delay.



This protection function may be inhibited by a logic input.
It can be remotely reset by a remote control order (TC32).

Block diagram



Phase undercurrent
ANSI code 37

Characteristics

Settings				
Is set point				
Setting range	5 % Ib to 100 % Ib			
Accuracy (1)	±5 %			
Resolution	1 %			
Drop out/pick up ratio	106 % ±3 %			
Time delay T				
Setting range	50 ms to 300 s			
Accuracy (1)	±2 % or ±25 ms			
Resolution	10 ms or 1 digit			
Characteristic times				
Operation time	pick-up < 55 ms from 2 Is to 0.02 In			
Overshoot time	< 40 ms from 2 Is to 0.02 In			
Reset time	< 45 ms from 0.02 In to 2 Is			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P37_1_101	■	■	
Protection inhibition	P37_1_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P37_1_1	■	■	
Delayed output	P37_1_3	■	■	■
Protection inhibited	P37_1_16	■	■	

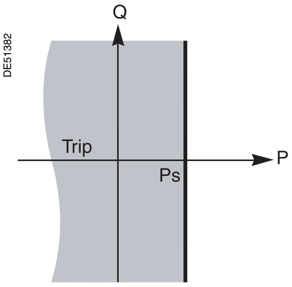
***(1)** Under reference conditions (IEC 60255-6).*

TS/TC equivalence for each protocol

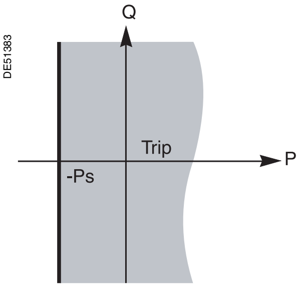
Modbus	DNP3	IEC 60870-5-103	IEC 61850
TC	**Binary Output**	**ASDU, FUN, INF**	**LN.DO.DA**
TC32	BO13	20, 105, 101	A37_PTUC.ProRs.ctlVal

Directional active underpower
ANSI code 37P

Check on active power flow.



Tripping zone (normal direction).

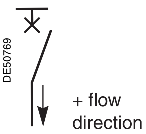


Tripping zone (reverse direction).

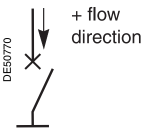
Description
Two-way protection based on active power. The function monitors the calculated active power flows:
- to adapt the number of parallel sources to fit the network load power demand
- to create an isolated system in an installation with its own generating unit.

The protection function picks up if the active power flowing in one direction or the other (supplied or drawn) is less than the Ps set point.
It includes a definite (DT) time delay T.
It is based on the two or three-wattmeter method, depending on the connection conditions:
- V1, V2, V3 and I1, I2, I3: 3 wattmeters
- V1, V2, V3 and I1, I3: 2 wattmeters
- U21, U32 + V0 and I1, I2, I3: 3 wattmeters
- U21, U32 + V0 and I1, I3: 2 wattmeters
- U21, U32 without V0: 2 wattmeters
- other cases: protection function unavailable.

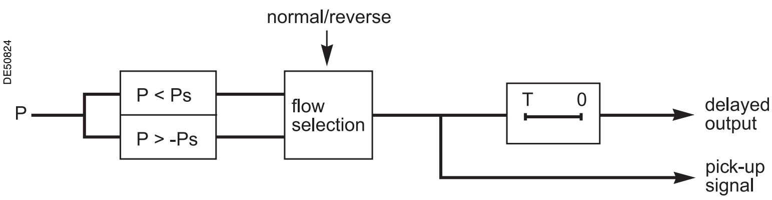
The power sign is determined according to the general feeder or incomer parameter, according to the convention:
- for the feeder circuit:
  - power supplied by the busbars is positive (normal direction)
  - power supplied to the busbars is negative



- for the incomer circuit:
  - power supplied to the busbar is positive (normal direction)
  - power supplied by the busbars is negative.



Block diagram



Characteristics

Settings				
Tripping direction				
Setting range	Normal / reverse			
Ps set point				
Setting range	5 % of Sn (2) to 100 % of Sn (2)			
Accuracy (1)	±5 % for Ps between 5 % Sn and 40 % Sn ±3 % for Ps between 40 % Sn and 120 % Sn			
Resolution	0.1 kW			
Drop out/pick up ratio	106 %			
Time delay T				
Setting range	100 ms to 300 s			
Accuracy (1)	±2 % or -10 ms to +25 ms			
Resolution	10 ms or 1 digit			
Characteristic times				
Operation time	< 120 ms			
Overshoot time	< 65 ms			
Reset time	< 60 ms			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P37P_x_101	■	■	
Protection inhibition	P37P_x_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P37P_x_1	■	■	
Delayed output	P37P_x_3	■	■	■
Protection inhibited	P37P_x_16	■	■	

x: unit number.
***(1)** Under reference conditions (IEC 60255-6).*
***(2)** Sn = $\sqrt{3}$.Un.In.*

Protection against heat rise in equipment by measuring the temperature with a sensor.

Description

Protection that detects abnormal heat rise by measuring the temperature inside equipment fitted with sensors:

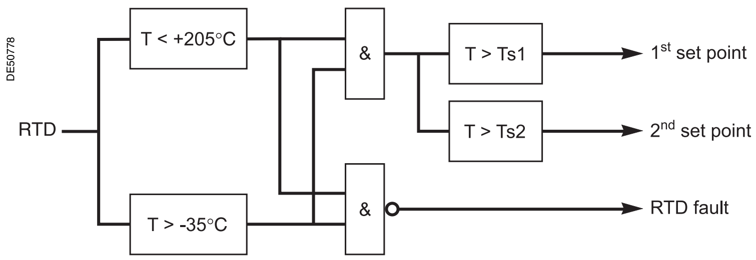
- transformer: protection of primary and secondary windings
- motor and generator: protection of stator windings and bearings.

This protection function is associated with an RTD of the Pt100 platinum (100 Ω at 0 °C or 32 °F) or nickel (Ni100 or Ni120) type, in accordance with the IEC 60751 and DIN 43760 standards.

- it picks up when the monitored temperature is greater than the Ts set point
- it has two independent set points:
  - alarm set point
  - tripping set point
- when the protection function is activated, it detects whether the RTD is shorted or disconnected:
  - RTD shorting is detected if the measured temperature is less than -35 °C or -31 °F (measurement displayed "****")
  - RTD disconnection is detected if the measured temperature is greater than +205 °C or +401 °F (measurement displayed "-****").

If an RTD fault is detected, the protection function is inhibited and its output relays are set to zero.
The "RTD fault" item is also made available in the control matrix and an alarm message is generated specifying the number of the MET148-2 module for the faulty RTD.

Block diagram



Characteristics

Settings				
Alarm and trip set points TS1, TS2				
Setting range	0°C to 180°C		32°F to 356°F	
Accuracy (1)	±1.5°C		±2.7°F	
Resolution	1°C		1°F	
Pick up / drop out difference	3°C		5.4°F	
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P38/49T_x_101	■	■	
Protection inhibition	P38/49T_x_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Protection output	P38/49T_x_3	■	■	■
Alarm	P38/49T_x_10	■	■	■
RTD fault	P38/49T_x_12	■	■	
Protection inhibited	P38/49T_x_16	■	■	

x: unit number.
***(1)** Under reference conditions (IEC 60255-6).*

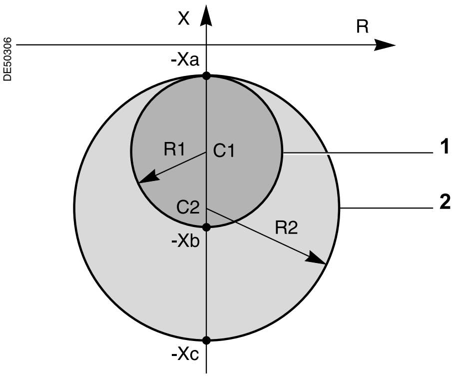
Field loss
ANSI code 40

Protection against field loss on synchronous machines or generators.

Description
The protection function is made up of two circular tripping characteristics on the impedance plane (R, X). It picks up when the positive sequence impedance Zd enters one of the circular tripping characteristics.

$$\vec{Zd} = \frac{\vec{Vd}}{\vec{Id}}$$

DE50306



Circular tripping characteristics

■ Case of a generator incomer or motor feeder

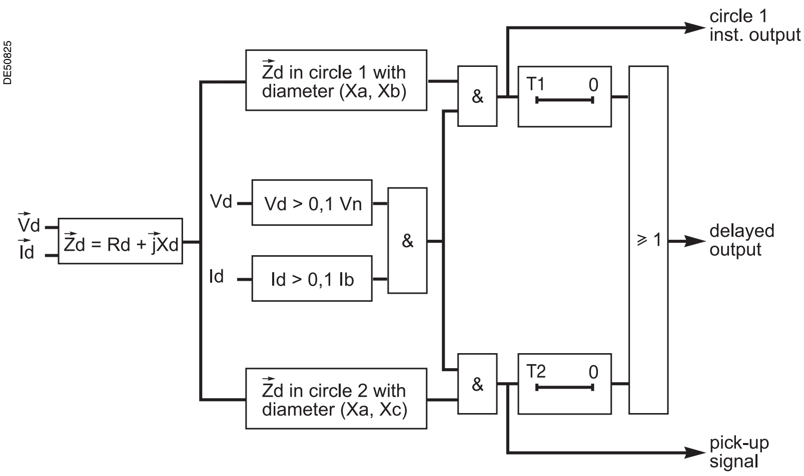
	Circle 1	Circle 2
Centre	C1 = -(Xa + Xb)/2	C2 = -(Xa + Xc)/2
Radius	R1 = (Xb - Xa)/2	R2 = (Xc - Xa)/2

■ Case of a generator feeder or motor incomer:
the tripping characteristics are symmetrical with respect to the R axis

	Circle 1	Circle 2
Centre	C1 = (Xa + Xb)/2	C2 = (Xa + Xc)/2
Radius	R1 = (Xb - Xa)/2	R2 = (Xc - Xa)/2

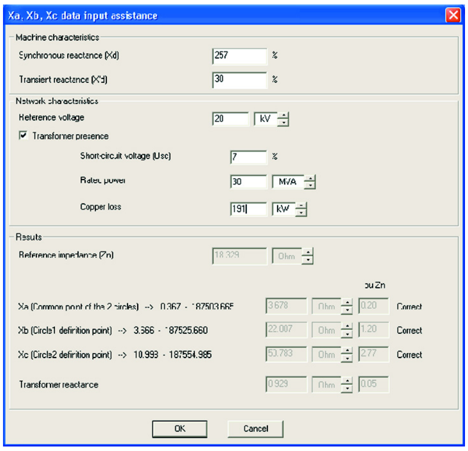
Block diagram

DE50825



Field loss
ANSI code 40

PE50148



SFT2841 setting help

The SFT2841 software includes a setting assistance function to calculate the values of Xa, Xb and Xc according to the electrical characteristics of the machine (and transformer, when applicable).

Data used:

■ synchronous machine:

□ synchronous reactance Xd in %

□ transient synchronous reactance X'd in %

■ transformer:

□ winding 1 voltage Un1 in V/kV

□ short-circuit voltage Usc in %

□ rated power in kVA/MVA

□ copper losses in kΩ/MΩ

The proposed settings are circle 1 with a diameter Zn if Xd ≥ 200 % or a diameter Xd/2 in all other cases, and circle 2 with a diameter Xd.

The two circles are offset from zero by -X'd/2.

Zn = the rated machine impedance:

$$Zn = \frac{Un1}{\sqrt{3}Ib}.$$

Characteristics

Settings	
Common point: Xa	
Setting range	0.02Vn/Ib ≤ Xa ≤ 0.20Vn/Ib + 187.5 kΩ or 0.001 Ω
Accuracy (1)	±5 %
Resolution	1 %
Circle 1: Xb	
Setting range	0.20Vn/Ib ≤ Xb ≤ 1.40Vn/Ib + 187.5 kΩ
Accuracy (1)	±5 %
Resolution	0.001 Ω or 1 digit
Drop out/pick up ratio	105 % ±3 % of circle 1 diameter
Circle 2: Xc	
Setting range	0.60Vn/Ib ≤ Xc ≤ 3Vn/Ib + 187.5 kΩ
Accuracy (1)	±5 %
Resolution	0.001 Ω or 1 digit
Drop out/pick up ratio	105 % ±3 % of circle 2 diameter
T1 time: tripping time delay circle 1	
Setting range	50 ms ≤ T ≤ 300 s
Accuracy (1)	±2 % or from -10 ms to +25 ms
Resolution	10 ms or 1 digit
T2 time: tripping time delay circle 2	
Setting range	100 ms ≤ T ≤ 300 s
Accuracy (1)	±2 % or from -10 ms to +25 ms
Resolution	10 ms or 1 digit
Characteristic times (1)	
Operation time	Pick-up < 40 ms from 0 to C1 (typically 25 ms) Pick-up < 40 ms from 0 to C2 (typically 25 ms)
Overshoot time	< 50 ms
Reset time	< 50 ms (for T1 = 0)

Inputs			
Designation	**Syntax**	**Equations**	**Logipam**
Protection reset	P40_1_101	■	■
Protection inhibition	P40_1_113	■	■

Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P40_1_1	■	■	
Delayed output	P40_1_3	■	■	■
Protection inhibited	P40_1_16	■	■	
Instantaneous protection 1 (circle 1)	P40_1_23	■	■	

(1) Under reference conditions (IEC 60255-6).

Example 1. Synchronous generator

Synchronous generator data

- S = 3.15 MVA
- Un1 = 6.3 kV
- Xd = 233 %
- X'd = 21 %

Protection setting

To set the protection function, it is necessary to calculate the rated generator impedance Zn:

- **Ib = S/($\sqrt{3}$.Un1) = 289 A**
- **Zn = Un1/ ($\sqrt{3}$.Ib) = 12.586 Ω**

Generally speaking, circle 1 is set with a diameter Zn, offset by -X'd/2, and circle 2 is set with a diameter Xd, offset by -X'd/2:

- **Xa = (X'd(%)/200)Zn = 1.321 Ω**
- **Xb = (X'd(%)/200 + min(1,Xd/200))×Zn = 15.984 Ω**
- **Xc = (X'd(%)/200 + Xd/100)Zn = 30.646 Ω**

The faults detected in circle 1 are violent field-loss faults that must be cleared rapidly. Circle 2 may concern faults other than field-loss faults and its tripping time is longer:

- T1 = 70 ms
- T2 = 500 ms.

Example 2. Generator-transformer unit applications

Synchronous generator data

- Sg = 19 MVA
- Un2 = 5.5 kV
- Xd = 257 %
- X'd = 30 %

Transformer data

- St = 30 MVA
- Un1 = 20 kV / Un2 = 5.5 kV
- Usc = 7 %
- Pcu = 191 kW

Protection setting

To set the protection function, it is necessary to calculate the rated generator impedance at voltage Un1:

- **Ib = Sg/($\sqrt{3}$ Un1) = 548 A**
- **Zn = Un1/ ($\sqrt{3}$.Ib) = 21.071 Ω**

The transformer impedance at voltage Un1 is:
Zt = Usc/100.$(Un1)^2$/St = 0.933 Ω
The transformer resistance at voltage Un1 is:
Rt = Pcu.$(Un1/St)^2$ = 0.085 Ω
The transformer reactance at voltage Un1 is:

$$\mathbf{Xt = \sqrt{Zt^2 - Rt^2} = 0{,}929\ \Omega}$$

Circle 1 is set with a diameter Zn, offset by -X'd/2 and the transformer reactance.
Circle 2 is set with a diameter Xd, offset by -X'd/2 and the transformer reactance.

- **Xa = (X'd(%)/200)Zn + Xt = 4.09 Ω**
- **Xb = (X'd(%)/200 + 1)Zn + Xt = 25.161 Ω**
- **Xc = (X'd(%)/200 + Xd(%)/100)Zn + Xt = 58.243 Ω**

The faults detected in circle 1 are violent field-loss faults that must be cleared rapidly. Circle 2 may concern faults other than field-loss faults and its tripping time is longer:

- T1 = 70 ms
- T2 = 500 ms.

Negative sequence / unbalance
ANSI code 46

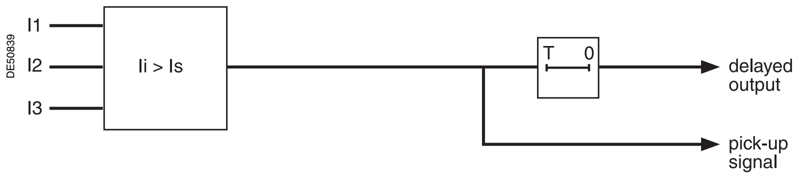
Phase unbalance protection for lines and equipment.

3

Description
Protection against phase unbalance, detected by the measurement of negative sequence current:
- sensitive protection to detect 2-phase faults at the ends of long lines
- protection of equipment against temperature rise, caused by an unbalanced power supply, phase inversion or loss of phase, and against phase current unbalance.

This function picks up if the negative sequence component of phase currents is greater than the operation set point.
It is time-delayed. The time delay may be definite time or IDMT according to a standardized curve, a specially adapted Schneider curve or an RI^2 curve for generator protection.

Tripping curve
Schneider IDMT
IEC inverse time SIT / A
IEC very inverse time VIT or LTI / B
IEC extremely inverse time EIT / C
IEEE moderately inverse (IEC / D)
IEEE very inverse (IEC / E)
IEEE extremely inverse (IEC / F)
RI^2 curve

Block diagram


Characteristics

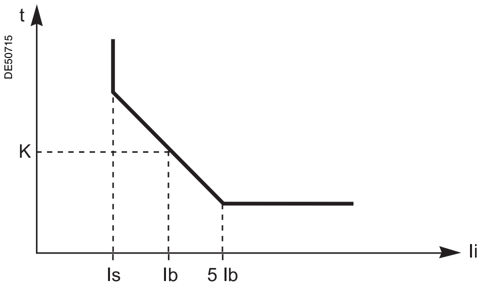
Settings		
Measurement origin		
Setting range		Main channels (I) Additional channels (I')
Tripping curve		
Setting range		See list above
Is set point		
Setting range	definite time	10 % to 500 % of Ib or I'b
	Schneider IDMT	10 % to 50 % of Ib or I'b
	IEC or IEEE IDMT	10 % to 100 % of Ib or I'b
	RI^2 curve	3 % to 20 % of Ib or I'b
Accuracy (1)		±5 % or ±0.004 In
Resolution		1 %
Drop out/pick up ratio		93.5 % ±5 % or > (1 - 0.005 In/Is) x 100 %
Time delay T		
Setting range	definite time	100 ms ⩽ T ⩽ 300 s
	IDMT	100 ms ⩽ T ⩽ 1 s or TMS (2)
Accuracy (1)	definite time	±2 % or ±25 ms
	IDMT	±5 % or ±35 ms
Resolution		10 ms or 1 digit
K (RI^2 curve only)		
Setting range		1 to 100
Resolution		1
Characteristic times		
Operation time		Pick-up < 55 ms at 2 Is
Overshoot time		< 50 ms at 2 Is
Reset time		< 55 ms at 2 Is

Inputs			
Designation	**Syntax**	**Equations**	**Logipam**
Protection reset	P46_x_101	■	■
Protection inhibition	P46_x_113	■	■

Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P46_x_1	■	■	
Delayed output	P46_x_3	■	■	■
Protection inhibited	P46_x_16	■	■	

x: unit number.
(1) Under reference conditions (IEC 60255-6).
(2) Setting ranges in TMS (Time Multiplier Setting) mode:
Inverse (SIT) and IEC SIT/A: 0.034 to 0.336
Very inverse (VIT) and IEC VIT/B: 0.067 to 0.666
Very inverse (LTI) and IEC LTI/B: 0.008 to 0.075
Ext. inverse (EIT) and IEC EIT/C: 0.124 to 1.237
IEEE moderately inverse: 0.415 to 4.142
IEEE very inverse: 0.726 to 7.255
IEEE extremely inverse: 1.231 to 12.30.

Negative sequence / unbalance
ANSI code 46



RI^2 curve.

Setting example for RI^2 curves
A generator can handle a certain level of negative sequence current on a continuous basis. The Is continuous level, indicated by the manufacturer, is generally between 5 and 10 % of the base current Ib.
Typical values are:

Type of generator		Ii permissible (% Ib)
Salient poles	with amortisseur windings	10
	without amortisseur windings	5
Cylindrical rotors	Indirectly cooled	10
	Sn ⩽ 960 MVA	8
	960 MVA < Sn ⩽ 1200 MVA	6
	1200 MVA < Sn	5

Reference IEEE C37.102-1987.

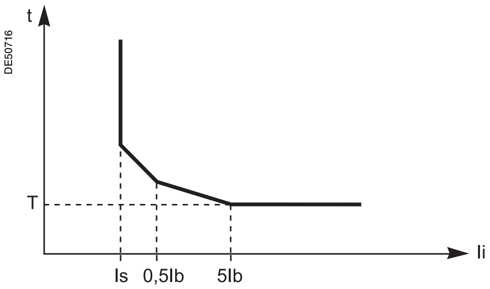
When this current level is exceeded, the generator can handle a negative sequence current Ii for a time td, corresponding to the following equation:

$$td = \frac{K}{\left(\frac{Ii}{Ib}\right)^2}$$

The K value is an adjustable constant that depends on the type of generator, generally between 1 and 40. Typical values of K are:

Type of generator		K
Salient poles		40
Synchronous condenser		30
Cylindrical rotors	Indirectly cooled	20
	Sn ⩽ 800 MVA	10
	800 MVA < Sn ⩽ 1600 MVA	10 - 0.00625.(MVA - 800)

Reference IEEE C37.102-1987.



Schneider curve.

Schneider IDMT curve
For Ii > Is, the time delay depends on the value of Ii/Ib (Ib: base current of the protected equipment defined when the general parameters are set).
T corresponds to the time delay for Ii/Ib = 5.
The tripping curve is defined according to the following equations:

■ for Is/Ib ⩽ Ii/Ib ⩽ 0.5

$$t = \frac{3.19}{(Ii/Ib)^{1.5}} \times T$$

■ for 0.5 ⩽ Ii/Ib ⩽ 5

$$t = \frac{4.64}{(Ii/Ib)^{0.96}} \times T$$

■ for Ii/Ib > 0.5
t = T.

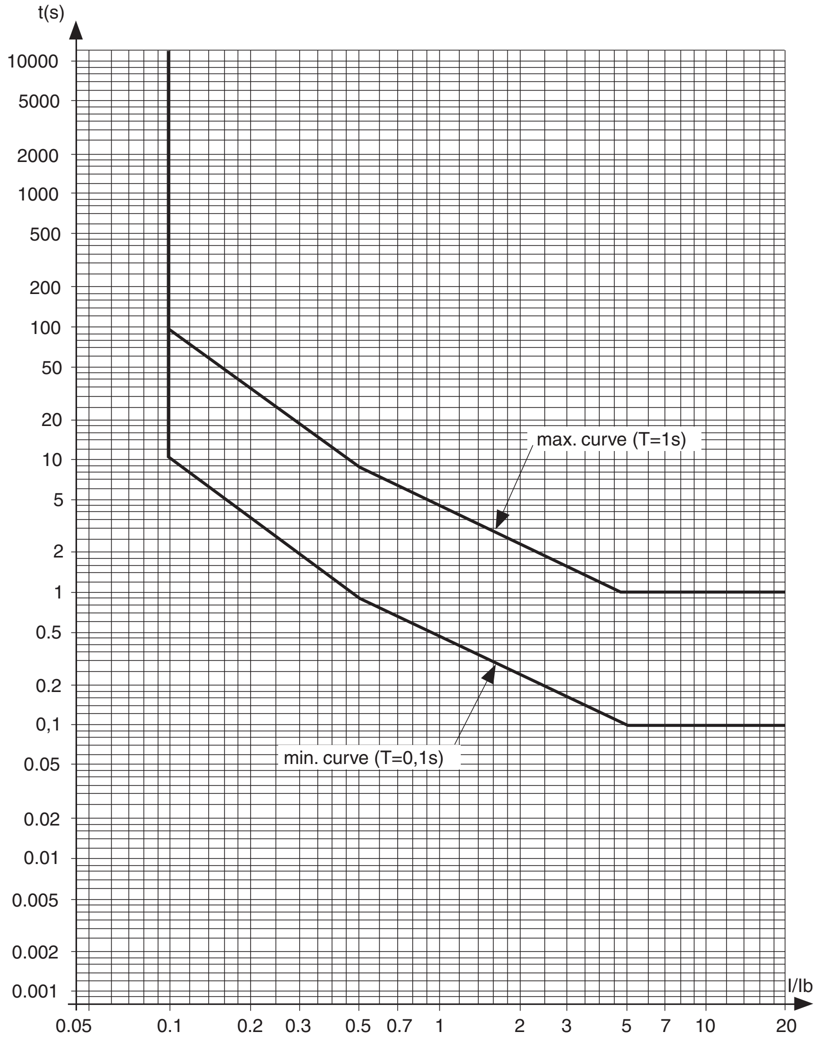
Determination of tripping time for different negative sequence current values for a given Schneider curve

Use the table to find the value of X that corresponds to the required negative sequence current. The tripping time is equal to XT.

Example

given a tripping curve with the setting T = 0.5 s.
What is the tripping time at 0.6 Ib?
Use the table to find the value of X that corresponds to 60 % of Ib.
The table indicates X = 7.55. The tripping time is equal to: 0.5 x 7.55 = 3.755 s.

Schneider IDMT tripping curve



Ii (% Ib)	10	15	20	25	30	33.33	35	40	45	50	55	57.7	60	65	70	75
X	99.95	54.50	35.44	25.38	19.32	16.51	15.34	12.56	10.53	9.00	8.21	7.84	7.55	7.00	6.52	6.11

Ii (% Ib) cont.	80	85	90	95	100	110	120	130	140	150	160	170	180	190	200	210
X cont.	5.74	5.42	5.13	4.87	4.64	4.24	3.90	3.61	3.37	3.15	2.96	2.80	2.65	2.52	2.40	2.29

Ii (% Ib) cont.	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370
X cont.	2.14	2.10	2.01	1.94	1.86	1.80	1.74	1.68	1.627	1.577	1.53	1.485	1.444	1.404	1.367	1.332

Ii (% Ib) cont.	380	390	400	410	420	430	440	450	460	470	480	490	⩾ 500
X cont.	1.298	1.267	1.236	1.18	1.167	1.154	1.13	1.105	1.082	1.06	1.04	1.02	1

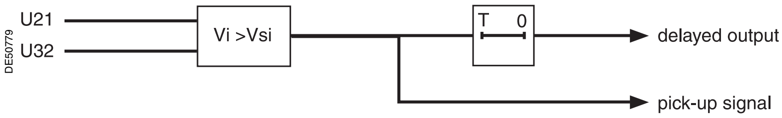
Negative sequence overvoltage
ANSI code 47

Phase unbalance protection.

Description

Protection against phase unbalance resulting from phase inversion, unbalanced supply or distant fault, detected by the measurement of negative sequence voltage Vi.
It includes a definite time delay T.
It does not operate when only one voltage is connected to Sepam.

Block diagram



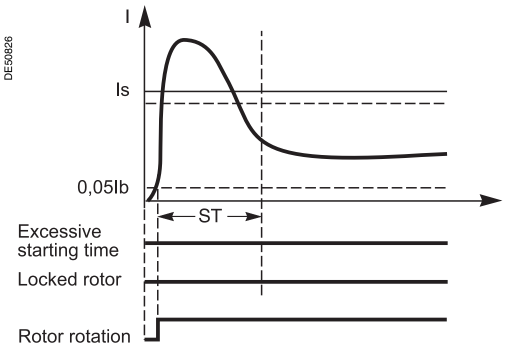
Characteristics

Settings				
Measurement origin				
Setting range	Main channels (U) / Additional channels (U')			
Vsi set point				
Setting range	1 % Unp to 50 % Unp			
Accuracy (1)	±2 % or 0.005 Unp			
Resolution	1 %			
Drop out/pick up ratio	97 % ±1 % or > (1 - 0.006 Unp/Vsi) x 100 %			
Time delay T				
Setting range	50 ms to 300 s			
Accuracy (1)	±2 % or ±25 ms			
Resolution	10 ms or 1 digit			
Characteristic times				
Operation time	Pick-up < 40 ms at 2 Vsi			
Overshoot time	< 50 ms at 2 Vsi			
Reset time	< 50 ms at 2 Vsi			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P47_x_101	■	■	
Protection inhibition	P47_x_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P47_x_1	■	■	
Delayed output	P47_x_3	■	■	■
Protection inhibited	P47_x_16	■	■	

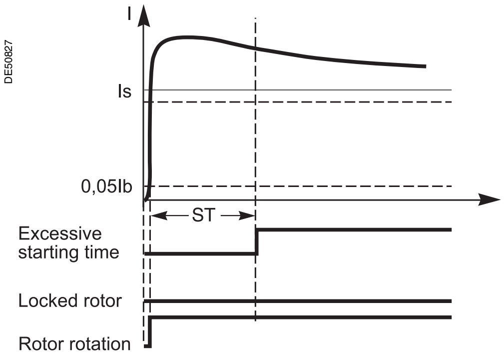
x: unit number.
***(1)** Under reference conditions (IEC 60255-6).*

Excessive starting time, locked rotor
ANSI code 48/51LR

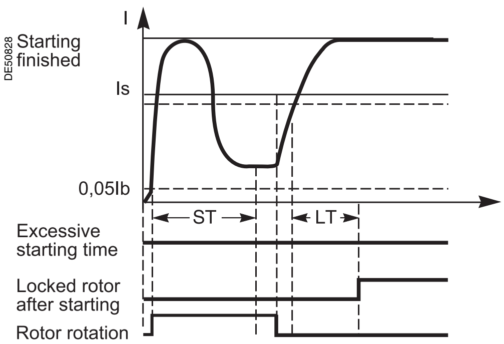
Detection of excessive starting time and locked rotors for motor protection.



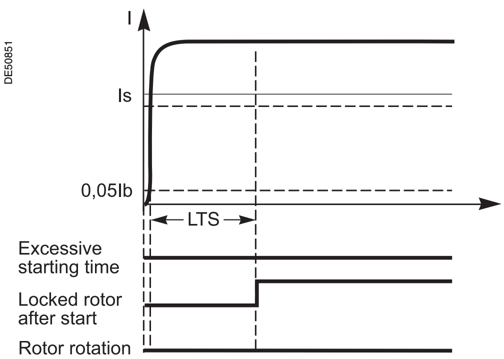
Case of normal starting.



Case of excessive starting time.



Case of locked rotor.



Case of locked rotor at start.

Description

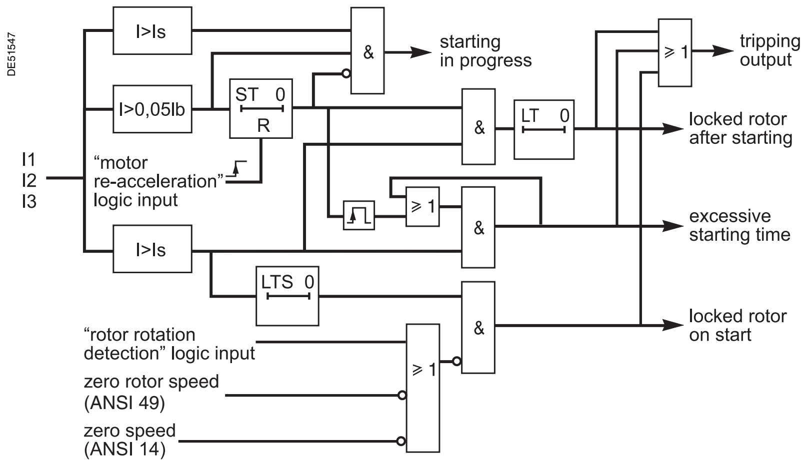
Protection against motor overheating caused by:
- ■ excessive motor starting time due to overloads (e.g. conveyor) or insufficient supply voltage
- ■ locked rotor due to motor load (e.g. crusher):
  - □ during normal operation, after a normal start
  - □ directly at motor start, before detection of an excessive starting time.

This function is three-phase.
Starting is detected when the current drawn is greater than 5 % of current Ib.
This function comprises two parts:
- ■ excessive starting time: during starting, the protection picks up when one of the 3 phase currents is greater than the set point Is for a longer period of time than the ST time delay (normal starting time)
- ■ locked rotor:
  - □ during normal operation (after starting), the protection picks up when one of the 3 phase currents is greater than the set point Is for a longer period of time than the LT time delay (DT).
  - □ locked on start: large motors may have very long starting times, due to their inertia or a reduction in the voltage. This starting time may be longer than the permissible rotor locking time. To protect such a motor against rotor locking, an LTS time may be set to initiate tripping if a start is detected (I > Is) and if the motor speed is zero.

Zero motor speed is detected by one of the three following options:
- ■ Rotor rotation detection logic input from a zero speed sensor
- ■ minimum speed function (ANSI 14)
- ■ motor thermal overload function (ANSI 49)

Motor re-acceleration
During re-acceleration, the motor draws a level of current similar to the start-up current (> Is), but in this case the current did not first drop to a level under 5 % of Ib.
The ST time delay, which corresponds to the normal starting time, can be reinitialised by a logic input or information from a logic equation or the Logipam program ("motor re-acceleration" input) and enables the user to:
- ■ reinitialize the **excessive starting time** protection
- ■ set the **locked rotor** protection LT time delay to a low value.

Block diagram



Excessive starting time, locked rotor
ANSI code 48/51LR

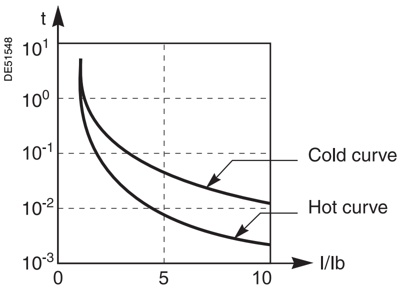
Characteristics

Settings				
Is set point				
Setting range		50 % to 500 % of Ib		
Accuracy (1)		±5 %		
Resolution		1 %		
Drop out/pick up ratio		93.5 % ±5 %		
Time delay T				
Setting range	ST	500 ms to 300 s		
	LT	50 ms to 300 s		
	LTS	50 ms to 300 s		
Accuracy (1)		±2 % or ±25 ms at 2 Is		
Resolution		10 ms		
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P48/51LR_1_101	■	■	
Motor re-acceleration	P48/51LR_1_102	■	■	
Protection inhibition	P48/51LR_1_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Protection output	P48/51LR_1_3	■	■	■
Locked rotor	P48/51LR_1_13	■	■	■
Excessive starting time	P48/51LR_1_14	■	■	■
Locked rotor at start-up	P48/51LR_1_15	■	■	■
Protection inhibited	P48/51LR_1_16	■	■	
Starting in progress	P48/51LR_1_22	■	■	

***(1)** Under reference conditions (IEC 60255-6).*

Thermal overload for cables
ANSI code 49RMS

Protection of cables against thermal damage caused by overloads.



Tripping curves.

Description

This protection function is used to protect cables against overloads, based on measurement of the current drawn.
The current measured by the thermal protection is an RMS 3-phase current which takes into account harmonics up to number 13.
The highest current of the three phases I1, I2 and I3, subsequently called phase current Iph, is used to calculate the heat rise:
$\mathbf{Iph = max(I1, I2, I3)}$.

The calculated heat rise, proportional to the square of the current drawn, depends on the current drawn and the previous temperature status. Under steady-state conditions, it is equal to:

$$\mathbf{E = \left(\frac{Iph}{Ib}\right)^2 \times 100} \text{ in \%}$$

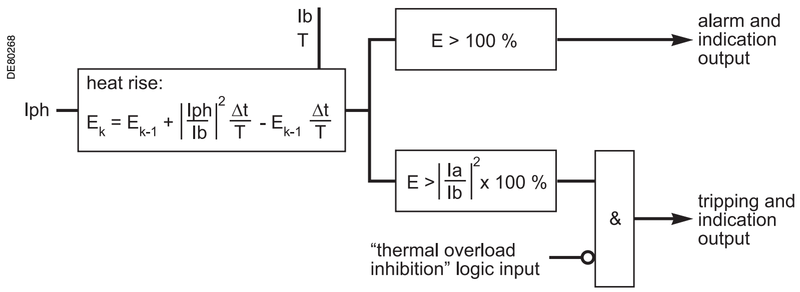
The protection function issues the trip order when the phase current is greater than the permissible current for the cable. The value of the base current Ib must absolutely be less than the permissible current Ia. By default, we use Ib ≈ Ia/1.4.
The protection tripping time is set by the time constant T.

Cold curve: $$\mathbf{\frac{t}{T} = ln\left(\frac{\left(\frac{I}{Ib}\right)^2}{\left(\frac{I}{Ib}\right)^2 - \left(\frac{Ia}{Ib}\right)^2}\right)}$$ where ln: natural logarithm.

Hot curve: $$\mathbf{\frac{t}{T} = ln\left(\frac{\left(\frac{I}{Ib}\right)^2 - 1}{\left(\frac{I}{Ib}\right)^2 - \left(\frac{Ia}{Ib}\right)^2}\right)}$$ where ln: natural logarithm.

The present heat rise is saved in the event of an auxiliary power failure.

Block diagram



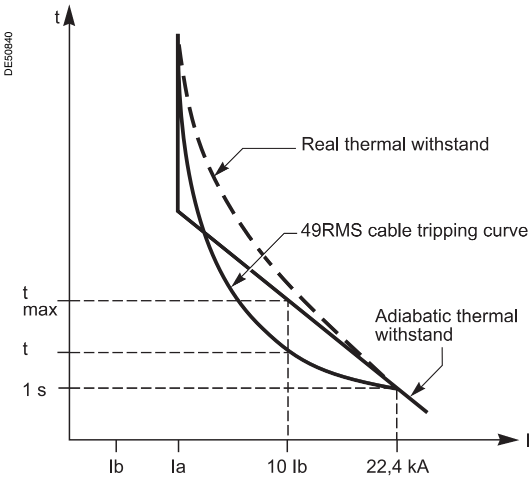
User information

The following information is available for the user:
- heat rise
- time before tripping (with constant current).

Characteristics

Settings				
Permissible current Ia				
Setting range	< 1 to 1.73 Ib			
Accuracy (1)	±2 %			
Resolution	1 A			
Time constant T				
Setting range	1 min. to 600 min.			
Resolution	1 min.			
Characteristic times (1)				
Operation time accuracy	±2 % or ±1 s			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P49RMS_1_101	■	■	
Protection inhibition	P49RMS_1_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Delayed output	P49RMS_1_3	■	■	■
Alarm	P49RMS_1_10	■	■	■
Inhibit closing	P49RMS_1_11	■	■	■
Protection inhibited	P49RMS_1_16	■	■	
Hot state	P49RMS_1_18	■	■	
Inhibit thermal overload	P49RMS_1_32	■	■	

***(1)** Under reference conditions (IEC 60255-6).*



Example

Consider a copper cable, 185 mm², with a permissible current Ia = 485 A and a 1- second thermal withstand Ith_1 s = 22.4 kA.
The thermal time constant of a cable depends in its installation method. Typical time-constant values are between 10 and 60 minutes. For buried cables, the time constant is between 20 and 60 minutes, for non-buried cables, it is between 10 and 40 minutes.
For the cable in question, the selected values are T = 30 minutes and Ib = 350 A.

Check on compatibility between the 49RMS curve and the adiabatic thermal withstand.
Conditions are correct at 10 Ib.
In the range of currents close to the permissible current, the 1-second thermal withstand is used to estimate maximum thermal withstand for the cable, assuming there are no heat exchanges. The maximum tripping time is calculated as:
I^2 x tmax = constant = (Ith_1 s)^2 x 1.

For the cable in question and at 10 Ib:
tmax = (Ith_1 s/ I0Ib)^2 = (22400 / 3500)^2 = 41 s.

For I = 10 Ib = 3500 A and Ia/Ib = 1.38, the value of k in the cold tripping curve table is k ≈ 0.0184.
The tripping time at 10 Ib is therefore:
t = k x T x 60 = 0.0184 x 30 x 60 = 35.6s < tmax.

For a 10 Ib fault occuring after a rated operation phase, with 100 % heat rise, the value of k is: k ≈ 0.0097.
The tripping time is:
t = k x T x 60 = 0.0097 x 30 x 60 = 17.5 s

Check on discrimination
Discrimination between 49RMS for the cable and the downstream protection curves, including 49RMS protection functions, must be checked to avoid any risk of nuisance tripping.

Curves for initial heat rise = 0 %

Iph/Ib Ia/Ib	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.25	1.30
0.50	1.7513	1.1856	0.8958	0.7138	0.5878	0.4953	0.4247	0.3691	0.3244	0.2877	0.2572	0.2314	0.2095	0.1907	0.1744	0.1601
0.55		1.8343	1.2587	0.9606	0.7717	0.6399	0.5425	0.4675	0.4082	0.3603	0.3207	0.2877	0.2597	0.2358	0.2152	0.1972
0.60			1.9110	1.3269	1.0217	0.8267	0.6897	0.5878	0.5090	0.4463	0.3953	0.3531	0.3178	0.2877	0.2619	0.2396
0.65				1.9823	1.3907	1.0793	0.8789	0.7373	0.6314	0.5491	0.4832	0.4295	0.3849	0.3473	0.3153	0.2877
0.70					2.0488	1.4508	1.1338	0.9287	0.7829	0.6733	0.5878	0.5191	0.4629	0.4159	0.3763	0.3424
0.75						2.1112	1.5075	1.1856	0.9762	0.8267	0.7138	0.6253	0.5540	0.4953	0.4463	0.4047
0.80							2.1699	1.5612	1.2349	1.0217	0.8687	0.7527	0.6615	0.5878	0.5270	0.4759
0.85								2.2254	1.6122	1.2819	1.0652	0.9091	0.7904	0.6966	0.6206	0.5578
0.90									2.2780	1.6607	1.3269	1.1069	0.9480	0.8267	0.7306	0.6526
0.95										2.3279	1.7070	1.3699	1.1470	0.9855	0.8618	0.7636
1.00											2.3755	1.7513	1.4112	1.1856	1.0217	0.8958
1.05												2.4209	1.7937	1.4508	1.2228	1.0566
1.10													2.4643	1.8343	1.4890	1.2587
1.15														2.5060	1.8734	1.5258
1.20															2.5459	1.9110
1.25																2.5844

Iph/Ib Ia/Ib	1.35	1.40	1.45	1.50	1.55	1.60	1.65	1.70	1.75	1.80	1.85	1.90	1.95	2.00	2.20	2.40
0.50	0.1475	0.1365	0.1266	0.1178	0.1099	0.1028	0.0963	0.0905	0.0852	0.0803	0.0759	0.0718	0.0680	0.0645	0.0530	0.0444
0.55	0.1815	0.1676	0.1553	0.1444	0.1346	0.1258	0.1178	0.1106	0.1040	0.0980	0.0925	0.0875	0.0829	0.0786	0.0645	0.0539
0.60	0.2201	0.2029	0.1878	0.1744	0.1623	0.1516	0.1418	0.1330	0.1251	0.1178	0.1111	0.1051	0.0995	0.0943	0.0773	0.0645
0.65	0.2637	0.2428	0.2243	0.2080	0.1934	0.1804	0.1686	0.1581	0.1485	0.1397	0.1318	0.1245	0.1178	0.1116	0.0913	0.0762
0.70	0.3132	0.2877	0.2653	0.2456	0.2281	0.2125	0.1984	0.1858	0.1744	0.1640	0.1545	0.1459	0.1380	0.1307	0.1067	0.0889
0.75	0.3691	0.3383	0.3113	0.2877	0.2667	0.2481	0.2314	0.2165	0.2029	0.1907	0.1796	0.1694	0.1601	0.1516	0.1236	0.1028
0.80	0.4326	0.3953	0.3630	0.3347	0.3098	0.2877	0.2680	0.2503	0.2344	0.2201	0.2070	0.1952	0.1843	0.1744	0.1418	0.1178
0.85	0.5049	0.4599	0.4210	0.3873	0.3577	0.3316	0.3084	0.2877	0.2691	0.2523	0.2371	0.2233	0.2107	0.1992	0.1617	0.1340
0.90	0.5878	0.5332	0.4866	0.4463	0.4112	0.3804	0.3531	0.3289	0.3072	0.2877	0.2701	0.2541	0.2396	0.2263	0.1832	0.1516
0.95	0.6836	0.6170	0.5608	0.5127	0.4710	0.4347	0.4027	0.3744	0.3491	0.3265	0.3061	0.2877	0.2710	0.2557	0.2064	0.1704
1.00	0.7956	0.7138	0.6456	0.5878	0.5383	0.4953	0.4578	0.4247	0.3953	0.3691	0.3456	0.3244	0.3052	0.2877	0.2314	0.1907
1.05	0.9287	0.8267	0.7431	0.6733	0.6142	0.5633	0.5191	0.4804	0.4463	0.4159	0.3888	0.3644	0.3424	0.3225	0.2585	0.2125
1.10	1.0904	0.9606	0.8569	0.7717	0.7005	0.6399	0.5878	0.5425	0.5027	0.4675	0.4363	0.4082	0.3830	0.3603	0.2877	0.2358
1.15	1.2934	1.1231	0.9916	0.8862	0.7996	0.7269	0.6651	0.6118	0.5654	0.5246	0.4884	0.4563	0.4274	0.4014	0.3192	0.2609
1.20	1.5612	1.3269	1.1549	1.0217	0.9147	0.8267	0.7527	0.6897	0.6353	0.5878	0.5460	0.5090	0.4759	0.4463	0.3531	0.2877
1.25	1.9473	1.5955	1.3593	1.1856	1.0509	0.9425	0.8531	0.7780	0.7138	0.6583	0.6098	0.5671	0.5292	0.4953	0.3898	0.3165
1.30	2.6214	1.9823	1.6286	1.3907	1.2155	1.0793	0.9696	0.8789	0.8026	0.7373	0.6808	0.6314	0.5878	0.5491	0.4295	0.3473
1.35		2.6571	2.0161	1.6607	1.4212	1.2445	1.1069	0.9959	0.9041	0.8267	0.7604	0.7029	0.6526	0.6081	0.4725	0.3804
1.40			2.6915	2.0488	1.6918	1.4508	1.2727	1.1338	1.0217	0.9287	0.8502	0.7829	0.7245	0.6733	0.5191	0.4159
1.45				2.7249	2.0805	1.7220	1.4796	1.3001	1.1601	1.0467	0.9527	0.8733	0.8050	0.7458	0.5699	0.4542
1.50					2.7571	2.1112	1.7513	1.5075	1.3269	1.1856	1.0712	0.9762	0.8958	0.8267	0.6253	0.4953
1.55						2.7883	2.1410	1.7797	1.5347	1.3529	1.2106	1.0952	0.9992	0.9179	0.6859	0.5397
1.60							2.8186	2.1699	1.8074	1.5612	1.3783	1.2349	1.1185	1.0217	0.7527	0.5878
1.65								2.8480	2.1980	1.8343	1.5870	1.4031	1.2587	1.1414	0.8267	0.6399
1.70									2.8766	2.2254	1.8605	1.6122	1.4272	1.2819	0.9091	0.6966

Curves for initial heat rise = 0 %

Iph/Ib Ia/Ib	2.60	2.80	3.00	3.20	3.40	3.60	3.80	4.00	4.20	4.40	4.60	4.80	5.00	5.50	6.00	6.50
0,50	0.0377	0.0324	0.0282	0.0247	0.0219	0.0195	0.0175	0.0157	0.0143	0.0130	0.0119	0.0109	0.0101	0.0083	0.0070	0.0059
0.55	0.0458	0.0393	0.0342	0.0300	0.0265	0.0236	0.0212	0.0191	0.0173	0.0157	0.0144	0.0132	0.0122	0.0101	0.0084	0.0072
0.60	0.0547	0.0470	0.0408	0.0358	0.0316	0.0282	0.0252	0.0228	0.0206	0.0188	0.0172	0.0157	0.0145	0.0120	0.0101	0.0086
0.65	0.0645	0.0554	0.0481	0.0421	0.0372	0.0331	0.0297	0.0268	0.0242	0.0221	0.0202	0.0185	0.0170	0.0141	0.0118	0.0101
0.70	0.0752	0.0645	0.0560	0.0490	0.0433	0.0385	0.0345	0.0311	0.0282	0.0256	0.0234	0.0215	0.0198	0.0163	0.0137	0.0117
0.75	0.0869	0.0745	0.0645	0.0565	0.0499	0.0444	0.0397	0.0358	0.0324	0.0295	0.0269	0.0247	0.0228	0.0188	0.0157	0.0134
0.80	0.0995	0.0852	0.0738	0.0645	0.0570	0.0506	0.0453	0.0408	0.0370	0.0336	0.0307	0.0282	0.0259	0.0214	0.0179	0.0153
0.85	0.1130	0.0967	0.0837	0.0732	0.0645	0.0574	0.0513	0.0462	0.0418	0.0380	0.0347	0.0319	0.0293	0.0242	0.0203	0.0172
0.90	0.1276	0.1091	0.0943	0.0824	0.0726	0.0645	0.0577	0.0520	0.0470	0.0427	0.0390	0.0358	0.0329	0.0271	0.0228	0.0194
0.95	0.1433	0.1223	0.1057	0.0923	0.0813	0.0722	0.0645	0.0581	0.0525	0.0477	0.0436	0.0400	0.0368	0.0303	0.0254	0.0216
1.00	0.1601	0.1365	0.1178	0.1028	0.0905	0.0803	0.0718	0.0645	0.0584	0.0530	0.0484	0.0444	0.0408	0.0336	0.0282	0.0240
1.05	0.1780	0.1516	0.1307	0.1139	0.1002	0.0889	0.0794	0.0714	0.0645	0.0586	0.0535	0.0490	0.0451	0.0371	0.0311	0.0264
1.10	0.1972	0.1676	0.1444	0.1258	0.1106	0.0980	0.0875	0.0786	0.0711	0.0645	0.0589	0.0539	0.0496	0.0408	0.0342	0.0291
1.15	0.2177	0.1848	0.1589	0.1383	0.1215	0.1076	0.0961	0.0863	0.0779	0.0708	0.0645	0.0591	0.0544	0.0447	0.0374	0.0318
1.20	0.2396	0.2029	0.1744	0.1516	0.1330	0.1178	0.1051	0.0943	0.0852	0.0773	0.0705	0.0645	0.0593	0.0488	0.0408	0.0347
1.25	0.2629	0.2223	0.1907	0.1656	0.1452	0.1285	0.1145	0.1028	0.0927	0.0842	0.0767	0.0702	0.0645	0.0530	0.0444	0.0377
1.30	0.2877	0.2428	0.2080	0.1804	0.1581	0.1397	0.1245	0.1116	0.1007	0.0913	0.0832	0.0762	0.0700	0.0575	0.0481	0.0408
1.35	0.3142	0.2646	0.2263	0.1960	0.1716	0.1516	0.1349	0.1209	0.1091	0.0989	0.0901	0.0824	0.0757	0.0621	0.0520	0.0441
1.40	0.3424	0.2877	0.2456	0.2125	0.1858	0.1640	0.1459	0.1307	0.1178	0.1067	0.0972	0.0889	0.0816	0.0670	0.0560	0.0475
1.45	0.3725	0.3122	0.2661	0.2298	0.2007	0.1770	0.1574	0.1409	0.1269	0.1150	0.1047	0.0957	0.0878	0.0720	0.0602	0.0510
1.50	0.4047	0.3383	0.2877	0.2481	0.2165	0.1907	0.1694	0.1516	0.1365	0.1236	0.1124	0.1028	0.0943	0.0773	0.0645	0.0547
1.55	0.4391	0.3659	0.3105	0.2674	0.2330	0.2050	0.1820	0.1627	0.1464	0.1325	0.1205	0.1101	0.1010	0.0828	0.0691	0.0585
1.60	0.4759	0.3953	0.3347	0.2877	0.2503	0.2201	0.1952	0.1744	0.1568	0.1418	0.1290	0.1178	0.1080	0.0884	0.0738	0.0625
1.65	0.5154	0.4266	0.3603	0.3091	0.2686	0.2358	0.2089	0.1865	0.1676	0.1516	0.1377	0.1258	0.1153	0.0943	0.0786	0.0666
1.70	0.5578	0.4599	0.3873	0.3316	0.2877	0.2523	0.2233	0.1992	0.1789	0.1617	0.1469	0.1340	0.1229	0.1004	0.0837	0.0709

Iph/Ib Ia/Ib	7.00	7.50	8.00	8.50	9.00	9.50	10.00	12.50	15.00	17.50	20.00
0.50	0.0051	0.0045	0.0039	0.0035	0.0031	0.0028	0.0025	0.0016	0.0011	0.0008	0.0006
0.55	0.0062	0.0054	0.0047	0.0042	0.0037	0.0034	0.0030	0.0019	0.0013	0.0010	0.0008
0.60	0.0074	0.0064	0.0056	0.0050	0.0045	0.0040	0.0036	0.0023	0.0016	0.0012	0.0009
0.65	0.0087	0.0075	0.0066	0.0059	0.0052	0.0047	0.0042	0.0027	0.0019	0.0014	0.0011
0.70	0.0101	0.0087	0.0077	0.0068	0.0061	0.0054	0.0049	0.0031	0.0022	0.0016	0.0012
0.75	0.0115	0.0101	0.0088	0.0078	0.0070	0.0063	0.0056	0.0036	0.0025	0.0018	0.0014
0.80	0.0131	0.0114	0.0101	0.0089	0.0079	0.0071	0.0064	0.0041	0.0028	0.0021	0.0016
0.85	0.0149	0.0129	0.0114	0.0101	0.0090	0.0080	0.0073	0.0046	0.0032	0.0024	0.0018
0.90	0.0167	0.0145	0.0127	0.0113	0.0101	0.0090	0.0081	0.0052	0.0036	0.0026	0.0020
0.95	0.0186	0.0162	0.0142	0.0126	0.0112	0.0101	0.0091	0.0058	0.0040	0.0030	0.0023
1.00	0.0206	0.0179	0.0157	0.0139	0.0124	0.0111	0.0101	0.0064	0.0045	0.0033	0.0025
1.05	0.0228	0.0198	0.0174	0.0154	0.0137	0.0123	0.0111	0.0071	0.0049	0.0036	0.0028
1.10	0.0250	0.0217	0.0191	0.0169	0.0151	0.0135	0.0122	0.0078	0.0054	0.0040	0.0030
1.15	0.0274	0.0238	0.0209	0.0185	0.0165	0.0148	0.0133	0.0085	0.0059	0.0043	0.0033
1.20	0.0298	0.0259	0.0228	0.0201	0.0179	0.0161	0.0145	0.0093	0.0064	0.0047	0.0036
1.25	0.0324	0.0282	0.0247	0.0219	0.0195	0.0175	0.0157	0.0101	0.0070	0.0051	0.0039
1.30	0.0351	0.0305	0.0268	0.0237	0.0211	0.0189	0.0170	0.0109	0.0075	0.0055	0.0042
1.35	0.0379	0.0329	0.0289	0.0255	0.0228	0.0204	0.0184	0.0117	0.0081	0.0060	0.0046
1.40	0.0408	0.0355	0.0311	0.0275	0.0245	0.0220	0.0198	0.0126	0.0087	0.0064	0.0049
1.45	0.0439	0.0381	0.0334	0.0295	0.0263	0.0236	0.0212	0.0135	0.0094	0.0069	0.0053
1.50	0.0470	0.0408	0.0358	0.0316	0.0282	0.0252	0.0228	0.0145	0.0101	0.0074	0.0056
1.55	0.0503	0.0437	0.0383	0.0338	0.0301	0.0270	0.0243	0.0155	0.0107	0.0079	0.0060
1.60	0.0537	0.0466	0.0408	0.0361	0.0321	0.0288	0.0259	0.0165	0.0114	0.0084	0.0064
1.65	0.0572	0.0496	0.0435	0.0384	0.0342	0.0306	0.0276	0.0176	0.0122	0.0089	0.0068
1.70	0.0608	0.0527	0.0462	0.0408	0.0363	0.0325	0.0293	0.0187	0.0129	0.0095	0.0073

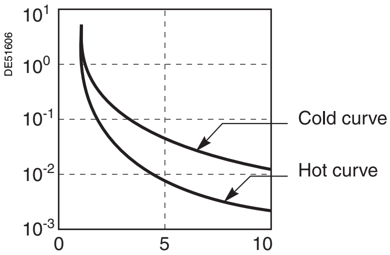
Curves for initial heat rise = 100 %

Iph/Ib **Ia/Ib**	**1.15**	**1.20**	**1.25**	**1.30**	**1.35**	**1.40**	**1.45**	**1.50**	**1.55**	**1.60**	**1.65**	**1.70**	**1.75**	**1.80**	**1.85**	**1.90**
1.10	1.0531	0.6487	0.4673	0.3629	0.2948	0.2469	0.2113	0.1839	0.1622	0.1446	0.1300	0.1178	0.1074	0.0984	0.0907	0.0839
1.15		1.3203	0.8518	0.6300	0.4977	0.4094	0.3460	0.2984	0.2613	0.2316	0.2073	0.1871	0.1700	0.1555	0.1429	0.1319
1.20			1.5243	1.0152	0.7656	0.6131	0.5093	0.4339	0.3765	0.3314	0.2950	0.2650	0.2400	0.2187	0.2004	0.1846
1.25				1.6886	1.1517	0.8817	0.7138	0.5978	0.5126	0.4472	0.3954	0.3533	0.3185	0.2892	0.2642	0.2427
1.30					1.8258	1.2685	0.9831	0.8030	0.6772	0.5840	0.5118	0.4543	0.4073	0.3682	0.3352	0.3070
1.35						1.9433	1.3705	1.0729	0.8830	0.7492	0.6491	0.5713	0.5088	0.4576	0.4148	0.3785
1.40							2.0460	1.4610	1.1536	0.9555	0.8149	0.7092	0.6263	0.5596	0.5047	0.4586
1.45								2.1371	1.5422	1.2267	1.0218	0.8755	0.7647	0.6776	0.6072	0.5489
1.50									2.2188	1.6159	1.2935	1.0829	0.9316	0.8165	0.7257	0.6519
1.55										2.2930	1.6832	1.3550	1.1394	0.9838	0.8650	0.7708
1.60											2.3609	1.7452	1.4121	1.1921	1.0327	0.9106
1.65												2.4233	1.8027	1.4652	1.2415	1.0787
1.70													2.4813	1.8563	1.5150	1.2879

Iph/Ib **Ia/Ib**	**1.95**	**2.00**	**2.20**	**2.40**	**2.60**	**2.80**	**3.00**	**3.20**	**3.40**	**3.60**	**3.80**	**4.00**	**4.20**	**4.40**	**4.60**	**4.80**
1.10	0.0779	0.0726	0.0562	0.0451	0.0371	0.0312	0.0266	0.0230	0.0201	0.0177	0.0157	0.0141	0.0127	0.0115	0.0105	0.0096
1.15	0.1223	0.1137	0.0877	0.0702	0.0576	0.0483	0.0411	0.0355	0.0310	0.0273	0.0243	0.0217	0.0196	0.0177	0.0161	0.0147
1.20	0.1708	0.1586	0.1217	0.0970	0.0795	0.0665	0.0566	0.0488	0.0426	0.0375	0.0333	0.0298	0.0268	0.0243	0.0221	0.0202
1.25	0.2240	0.2076	0.1584	0.1258	0.1028	0.0858	0.0729	0.0628	0.0547	0.0482	0.0428	0.0382	0.0344	0.0311	0.0283	0.0259
1.30	0.2826	0.2614	0.1981	0.1566	0.1276	0.1063	0.0902	0.0776	0.0676	0.0594	0.0527	0.0471	0.0424	0.0383	0.0348	0.0318
1.35	0.3474	0.3204	0.2410	0.1897	0.1541	0.1281	0.1085	0.0932	0.0811	0.0713	0.0632	0.0564	0.0507	0.0458	0.0417	0.0380
1.40	0.4194	0.3857	0.2877	0.2253	0.1823	0.1512	0.1278	0.1097	0.0953	0.0837	0.0741	0.0661	0.0594	0.0537	0.0488	0.0445
1.45	0.4999	0.4581	0.3384	0.2635	0.2125	0.1758	0.1483	0.1271	0.1103	0.0967	0.0856	0.0763	0.0686	0.0619	0.0562	0.0513
1.50	0.5907	0.5390	0.3938	0.3046	0.2446	0.2018	0.1699	0.1454	0.1260	0.1104	0.0976	0.0870	0.0781	0.0705	0.0640	0.0584
1.55	0.6940	0.6302	0.4545	0.3491	0.2790	0.2295	0.1928	0.1646	0.1425	0.1247	0.1102	0.0982	0.0881	0.0795	0.0721	0.0657
1.60	0.8134	0.7340	0.5213	0.3971	0.3159	0.2589	0.2169	0.1849	0.1599	0.1398	0.1234	0.1098	0.0984	0.0888	0.0805	0.0734
1.65	0.9536	0.8537	0.5952	0.4492	0.3553	0.2901	0.2425	0.2063	0.1781	0.1555	0.1372	0.1220	0.1093	0.0985	0.0893	0.0814
1.70	1.1221	0.9943	0.6776	0.5059	0.3977	0.3234	0.2695	0.2288	0.1972	0.1720	0.1516	0.1347	0.1206	0.1086	0.0984	0.0897

Iph/Ib **Ia/Ib**	**5.00**	**5.50**	**6.00**	**6.50**	**7.00**	**7.50**	**8.00**	**8.50**	**9.00**	**9.50**	**10.00**	**12.50**	**15.00**	**17.50**	**20.00**
1.10	0.0088	0.0072	0.0060	0.0051	0.0044	0.0038	0.0033	0.0030	0.0026	0.0024	0.0021	0.0014	0.0009	0.0007	0.0005
1.15	0.0135	0.0111	0.0093	0.0078	0.0067	0.0059	0.0051	0.0045	0.0040	0.0036	0.0033	0.0021	0.0014	0.0011	0.0008
1.20	0.0185	0.0152	0.0127	0.0107	0.0092	0.0080	0.0070	0.0062	0.0055	0.0049	0.0045	0.0028	0.0020	0.0014	0.0011
1.25	0.0237	0.0194	0.0162	0.0137	0.0118	0.0102	0.0090	0.0079	0.0071	0.0063	0.0057	0.0036	0.0025	0.0018	0.0014
1.30	0.0292	0.0239	0.0199	0.0169	0.0145	0.0126	0.0110	0.0097	0.0087	0.0078	0.0070	0.0045	0.0031	0.0023	0.0017
1.35	0.0349	0.0285	0.0238	0.0201	0.0173	0.0150	0.0131	0.0116	0.0103	0.0093	0.0083	0.0053	0.0037	0.0027	0.0021
1.40	0.0408	0.0334	0.0278	0.0235	0.0202	0.0175	0.0154	0.0136	0.0121	0.0108	0.0097	0.0062	0.0043	0.0031	0.0024
1.45	0.0470	0.0384	0.0320	0.0271	0.0232	0.0202	0.0177	0.0156	0.0139	0.0124	0.0112	0.0071	0.0049	0.0036	0.0028
1.50	0.0535	0.0437	0.0364	0.0308	0.0264	0.0229	0.0200	0.0177	0.0157	0.0141	0.0127	0.0081	0.0056	0.0041	0.0031
1.55	0.0602	0.0491	0.0409	0.0346	0.0297	0.0257	0.0225	0.0199	0.0177	0.0158	0.0143	0.0091	0.0063	0.0046	0.0035
1.60	0.0672	0.0548	0.0456	0.0386	0.0330	0.0286	0.0251	0.0221	0.0197	0.0176	0.0159	0.0101	0.0070	0.0051	0.0039
1.65	0.0745	0.0607	0.0505	0.0427	0.0365	0.0317	0.0277	0.0245	0.0218	0.0195	0.0176	0.0112	0.0077	0.0057	0.0043
1.70	0.0820	0.0668	0.0555	0.0469	0.0402	0.0348	0.0305	0.0269	0.0239	0.0214	0.0193	0.0122	0.0085	0.0062	0.0047

Protection of equipment against thermal damage due to overloads.



Tripping curves.

Description

This function is used to protect capacitor banks with or without anti-harmonic inductors against overloads, based on the measurement of the current drawn.

The current measured by the thermal protection is an RMS 3-phase current which takes into account harmonics up to number 13.
The highest current of the three phases I1, I2 and I3, subsequently called phase current Iph, is used to calculate the heat rise:

$$Iph = max(I1, I2, I3)$$

Taking capacitor step ratio into account

When the number of steps (>1) and capacitor step ratio are set in the particular characteristics, the thermal overload protection function takes into account the participation of each step in the calculation of heat rise.

The rated current of step x (Ibgx) is equal to the fraction of current that the step represents in relation to the rated current of the capacitor bank (Ib).

$$Ibgx = \frac{Kgx}{\sum_{x=1}^{n} Kgx} Ib$$

where Ib is the rated current of the capacitor bank
x is the step number
n is the total number of steps, between 2 and 4
Kgx is the capacitor step ratio value of step x

The rated current of the sequence of steps (Ibseq) is calculated. It is the sum of the rated currents (Ibgx) of the steps closed during the sequence.

$$Ibseq = \sum_{x=1}^{n} p(x) Ibgx$$

where x is the step number
n is the total number of steps, between 2 and 4
p(x) is the position of the step x:
- p(x) = 1 when the step switch x is closed
- p(x) = 0 when the step switch x is open.

The heat rise is proportional to the square of the drawn current in relation to the rated current of the sequence. Under steady state conditions, it is equal to:

$$E = \left(\frac{Iph}{Ibseq}\right)^2 \times 100 \quad \text{as a \%}$$

If the closed positions of the steps are not acquired or if the number of steps set in the particular characteristics is 1, the rated current of the sequences is equal to the rated current of the capacitor bank. In such cases, the heat rise is proportional to the drawn current in relation to the rated current of the capacitor bank. Under steady state conditions, it is equal to:

$$E = \left(\frac{Iph}{Ib}\right)^2 \times 100 \quad \text{as a \%}$$

3

Thermal overload for capacitors
ANSI code 49RMS

Operation curve
The protection function gives a tripping order when the current drawn is greater than the overload current, with respect to the rated current of the sequence.
The tripping time is set by assigning a hot tripping time to a setting current. This setting is used to calculate a time factor:

$$C = \frac{1}{\ln\left(\frac{\left(\frac{Is}{Ib}\right)^2 - 1}{\left(\frac{Is}{Ib}\right)^2 - \left(\frac{Itrip}{Ib}\right)^2}\right)}$$ where In: natural logarithm.

The tripping time with an initial heat rise of 0 % is then given by:

$$t = C \times \ln\left(\frac{\left(\frac{Iph}{Ibseq}\right)^2}{\left(\frac{Iph}{Ibseq}\right)^2 - \left(\frac{Itrip}{Ibseq}\right)^2}\right) \times Ts$$ where In: natural logarithm.

= k x Ts

The tripping time with an intial heat rise of 100 % is then given by:

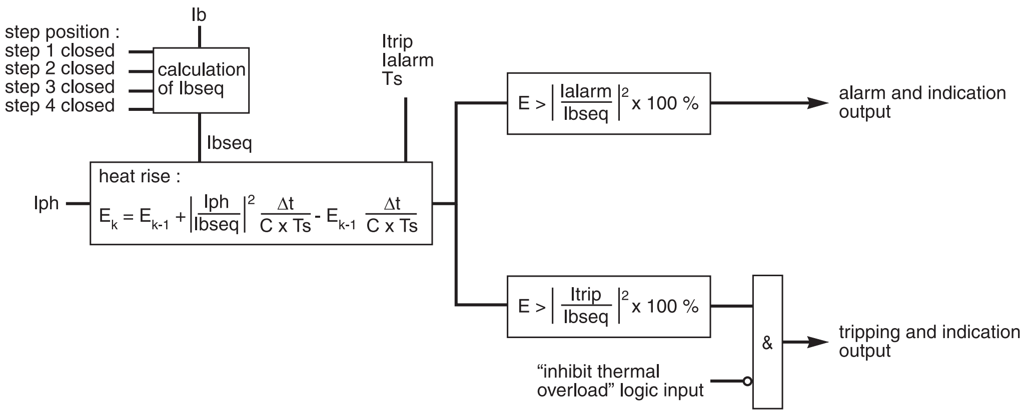
$$t = C \times \ln\left(\frac{\left(\frac{Iph}{Ibseq}\right)^2 - 1}{\left(\frac{Iph}{Ibseq}\right)^2 - \left(\frac{Itrip}{Ibseq}\right)^2}\right) \times Ts$$ where In: natural logarithm.

= k x Ts

The tripping curve tables give the values of k for an inital heat rise from 0 % to 100 %.
The current heat rise is saved in the event of an auxiliary power failure.

Block diagram

DE80269



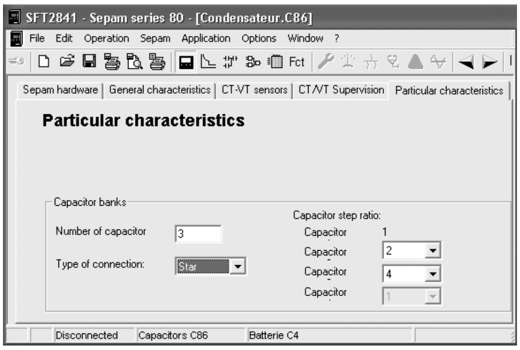
Thermal overload for capacitors
ANSI code 49RMS

User information
The following information is available for the user:
- heat rise
- time before tripping (with constant current).

Characteristics

Settings				
Alarm current Ialarm				
Setting range	1.05 to 1.70 Ib			
Accuracy [(1)]	±2 %			
Resolution	1 A			
Tripping current Itrip				
Setting range	1.05 to 1.70 Ib			
Accuracy [(1)]	±2 %			
Resolution	1 A			
Setting current Is				
Setting range	1.02 Itrip to 2 Ib			
Accuracy [(1)]	±2 %			
Resolution	1 A			
Setting time Ts				
Setting range	1 to 2000 minutes (range varies depending on the tripping and setting currents)			
Resolution	1 min			
Characteristic times				
Operation time accuracy	±2 % or ±2 s			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P49RMS_1_101	■	■	
Protection inhibition	P49RMS_1_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Delayed output	P49RMS _1_3	■	■	■
Alarm	P49RMS _1_10	■	■	■
Inhibit closing	P49RMS _1_11	■	■	■
Protection inhibited	P49RMS _1_16	■	■	
Hot state	P49RMS _1_18	■	■	

(1) Under reference conditions (IEC 60255-6).



Parameter setting of capacitor bank step ratio.

Example

Given a 350 kvar capacitor bank with 3 steps, and no anti-harmonic inductors, for a voltage of 2 kV. The capacitor step ratio is 1.2.2.

The rated current of the capacitor bank is:
Ib = Q /(√3 Un)= 350000 (√3 x 2000) = 101 A

According to the manufacturer data, this capacitor bank can operate continuously with an overload current of 120 % Ib and for 20 minutes with an overload of 140 % Ib.

The protection settings are:
Itrip = 120 % Ib = 121 A
Is = 140 % Ib = 141 A
Ts = 20 min.

Steps 1 and 2 closed
Steps 1 and 2 are closed in the sequence in progress. The sequence current is:

$$\mathbf{Ibseq} = \frac{1+2+0}{1+2+2} \times \mathbf{Ib = 61\ A}$$

For a current of 125 % Ibseq = 76 A, and an initial heat rise of 100 %, the value of k in the tripping curve tables is: k = 2.486.

The tripping time is:
t = k x Ts = 2.486 x 20 ≈ 50 min

All the steps closed
When all the steps are closed, the sequence current is the rated current of the capacitor bank:

$$\mathbf{Ibseq} = \frac{1+2+2}{1+2+2} \times \mathbf{Ib = 101\ A}$$

For a current of 140 % Ibseq = 141 A, and an initial heat rise of 0 %, the value of k in the tripping curve tables is: k = 2.164.

The tripping time is:
t = k x Ts = 2.164 x 20 ≈ 43 min

The table below summarizes the rated sequence current, the tripping current and examples of tripping times for overload currents of 125 % Ib and 140 % Ib, for initial heat rises of 0 % and 100 %.

Closed step numbers			Ibseq (A)	Itrip (A)	125 % Ibseq			140 % Ibseq		
					Iph (A)	Tripping time (mn)		Iph (A)	Tripping time (mn)	
1	2	3				0 %	100 %		0 %	100 %
■	-	-	$\frac{1+0+0}{1+2+2} \times Ib = 20$	24	25	83	50	28	43	20
■	■	-	$\frac{1+2+0}{1+2+2} \times Ib = 61$	73	76	83	50	85	43	20
-	■	■	$\frac{0+2+2}{1+2+2} \times Ib = 81$	97	101	83	50	113	43	20
■	■	■	$\frac{1+2+2}{1+2+2} \times Ib = 101$	121	126	83	50	141	43	20

Curves for initial heat rise = 0 %

Is = 1.2 Ib

Iph/Ibseq Itrip/Ibseq	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50	1.55	1.60	1.65	1.70	1.75	1.80
1.05	9.1282	6.7632	5.4705	4.6108	3.9841	3.5018	3.1171	2.8020	2.5389	2.3157	2.1239	1.9574	1.8115	1.6828	1.5683
1.10		3.7989	2.8277	2.2954	1.9404	1.6809	1.4809	1.3209	1.1896	1.0798	0.9865	0.9061	0.8362	0.7749	0.7207
1.15			1.8980	1.4189	1.1556	0.9796	0.8507	0.7510	0.6712	0.6056	0.5506	0.5037	0.4634	0.4282	0.3973

Is = 1.2 Ib

Iph/Ibseq Itrip/Ibseq	1.85	1.90	1.95	2.00	2.20	2.40	2.60	2.80	3.00	3.20	3.40	3.60	3.80	4.00
1.05	1.4660	1.3741	1.2911	1.2158	0.9747	0.8011	0.6713	0.5714	0.4927	0.4295	0.3779	0.3352	0.2995	0.2692
1.10	0.6725	0.6293	0.5905	0.5554	0.4435	0.3635	0.3040	0.2584	0.2226	0.1939	0.1704	0.1511	0.1349	0.1212
1.15	0.3699	0.3456	0.3237	0.3040	0.2417	0.1976	0.1649	0.1399	0.1204	0.1047	0.0920	0.0815	0.0728	0.0653

Is = 1.3 Ib

Iph/Ibseq Itrip/Ibseq	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50	1.55	1.60	1.65	1.70	1.75	1.80
1.05	15.0540	11.1530	9.0217	7.6039	6.5703	5.7750	5.1405	4.6210	4.1871	3.8189	3.5027	3.2281	2.9875	2.7752	2.5864
1.10		6.7905	5.0545	4.1030	3.4684	3.0047	2.6470	2.3611	2.1265	1.9301	1.7633	1.6197	1.4948	1.3852	1.2883
1.15			3.9779	2.9738	2.4220	2.0530	1.7829	1.5740	1.4067	1.2692	1.1539	1.0557	0.9711	0.8974	0.8327
1.20				2.5077	1.8824	1.5378	1.3070	1.1375	1.0063	0.9010	0.8143	0.7415	0.6794	0.6257	0.5790
1.25					1.5305	1.1532	0.9449	0.8050	0.7021	0.6223	0.5582	0.5052	0.4607	0.4227	0.3898

Is = 1.3 Ib

Iph/Ibseq Itrip/Ibseq	1.85	1.90	1.95	2.00	2.20	2.40	2.60	2.80	3.00	3.20	3.40	3.60	3.80	4.00
1.05	2.4177	2.2661	2.1292	2.0051	1.6074	1.3211	1.1071	0.9424	0.8126	0.7084	0.6233	0.5529	0.4939	0.4440
1.10	1.2021	1.1249	1.0555	0.9927	0.7927	0.6498	0.5435	0.4619	0.3979	0.3465	0.3047	0.2701	0.2412	0.2167
1.15	0.7753	0.7242	0.6785	0.6372	0.5066	0.4141	0.3456	0.2933	0.2523	0.2195	0.1929	0.1709	0.1525	0.1370
1.20	0.5378	0.5013	0.4688	0.4396	0.3478	0.2834	0.2360	0.1999	0.1717	0.1493	0.1310	0.1160	0.1035	0.0929
1.25	0.3611	0.3358	0.3134	0.2933	0.2309	0.1874	0.1557	0.1316	0.1129	0.0981	0.0860	0.0761	0.0678	0.0609

Is = 1.4 Ib

Iph/Ibseq Itrip/Ibseq	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50	1.55	1.60	1.65	1.70	1.75	1.80
1.05	21.4400	15.8850	12.8490	10.8300	9.3578	8.2251	7.3214	6.5815	5.9634	5.4391	4.9887	4.5976	4.2550	3.9525	3.6837
1.10		9.9827	7.4306	6.0317	5.0988	4.4171	3.8914	3.4710	3.1261	2.8375	2.5922	2.3811	2.1975	2.0364	1.8939
1.15			6.1214	4.5762	3.7270	3.1593	2.7435	2.4222	2.1647	1.9531	1.7757	1.6246	1.4944	1.3810	1.2813
1.20				4.1525	3.1170	2.5464	2.1642	1.8836	1.6664	1.4920	1.3483	1.2278	1.1249	1.0361	0.9587
1.25					2.9310	2.2085	1.8095	1.5416	1.3446	1.1918	1.0689	0.9676	0.8823	0.8095	0.7466
1.30						2.0665	1.5627	1.2839	1.0964	0.9582	0.8508	0.7643	0.6929	0.6327	0.5813
1.35							1.3673	1.0375	0.8546	0.7314	0.6404	0.5696	0.5125	0.4653	0.4254

Is = 1.4 Ib

Iph/Ibseq Itrip/Ibseq	1.85	1.90	1.95	2.00	2.20	2.40	2.60	2.80	3.00	3.20	3.40	3.60	3.80	4.00
1.05	3.4434	3.2275	3.0325	2.8557	2.2894	1.8816	1.5768	1.3422	1.1573	1.0089	0.8877	0.7874	0.7034	0.6323
1.10	1.7672	1.6537	1.5516	1.4593	1.1654	0.9552	0.7989	0.6791	0.5849	0.5094	0.4479	0.3970	0.3545	0.3186
1.15	1.1931	1.1145	1.0440	0.9805	0.7796	0.6372	0.5318	0.4513	0.3882	0.3378	0.2968	0.2629	0.2346	0.2107
1.20	0.8906	0.8302	0.7763	0.7279	0.5760	0.4692	0.3907	0.3310	0.2844	0.2472	0.2170	0.1921	0.1714	0.1538
1.25	0.6916	0.6432	0.6002	0.5618	0.4421	0.3589	0.2981	0.2521	0.2163	0.1878	0.1647	0.1457	0.1299	0.1165
1.30	0.5367	0.4977	0.4634	0.4328	0.3386	0.2738	0.2268	0.1914	0.1640	0.1422	0.1246	0.1102	0.0981	0.0880
1.35	0.3913	0.3617	0.3358	0.3129	0.2431	0.1957	0.1617	0.1361	0.1164	0.1009	0.0883	0.0780	0.0694	0.0622

3

Curves for initial heat rise = 0 %

Is = 2 Ib

Iph/Ibseq **Itrip/Ibseq**	**1.10**	**1.15**	**1.20**	**1.25**	**1.30**	**1.35**	**1.40**	**1.45**	**1.50**	**1.55**	**1.60**	**1.65**	**1.70**	**1.75**	**1.80**
1.05	69.6380	51.5950	41.7340	35.1750	30.3940	26.7150	23.7800	21.3760	19.3690	17.6660	16.2030	14.9330	13.8200	12.8380	11.9650
1.10		33.9580	25.2760	20.5180	17.3440	15.0260	13.2370	11.8070	10.6340	9.6521	8.8176	8.0995	7.4750	6.9270	6.4425
1.15			22.0350	16.4730	13.4160	11.3720	9.8756	8.7189	7.7922	7.0303	6.3916	5.8479	5.3792	4.9710	4.6123
1.20				16.0520	12.0490	9.8435	8.3659	7.2814	6.4415	5.7674	5.2122	4.7460	4.3485	4.0053	3.7060
1.25					12.4460	9.3782	7.6840	6.5465	5.7100	5.0610	4.5392	4.1087	3.7467	3.4375	3.1703
1.30						10.0300	7.5843	6.2313	5.3211	4.6505	4.1294	3.7096	3.3629	3.0708	2.8210
1.35							8.2921	6.2917	5.1827	4.4353	3.8838	3.4544	3.1081	2.8215	2.5799
1.40								6.9790	5.3124	4.3868	3.7619	3.3000	2.9399	2.6491	2.4081
1.50										5.1152	3.9169	3.2491	2.7969	2.4617	2.1997
1.60												3.8403	2.9564	2.4625	2.1271
1.70														2.8932	2.2383

Is = 2 Ib

Iph/Ibseq **Itrip/Ibseq**	**1.85**	**1.90**	**1.95**	**2.00**	**2.20**	**2.40**	**2.60**	**2.80**	**3.00**	**3.20**	**3.40**	**3.60**	**3.80**	**4.00**
1.05	11.1840	10.4830	9.8495	9.2753	7.4358	6.1115	5.1214	4.3594	3.7590	3.2768	2.8832	2.5574	2.2846	2.0537
1.10	6.0114	5.6254	5.2781	4.9642	3.9642	3.2494	2.7177	2.3099	1.9896	1.7328	1.5235	1.3506	1.2059	1.0836
1.15	4.2947	4.0117	3.7581	3.5295	2.8064	2.2936	1.9142	1.6245	1.3975	1.2159	1.0683	0.9464	0.8446	0.7586
1.20	3.4426	3.2091	3.0008	2.8138	2.2265	1.8138	1.5104	1.2795	1.0993	0.9555	0.8388	0.7426	0.6624	0.5946
1.25	2.9368	2.7311	2.5486	2.3855	1.8775	1.5240	1.2659	1.0704	0.9184	0.7974	0.6994	0.6187	0.5515	0.4949
1.30	2.6048	2.4157	2.2489	2.1007	1.6433	1.3288	1.1007	0.9289	0.7958	0.6901	0.6047	0.5346	0.4762	0.4271
1.35	2.3729	2.1935	2.0365	1.8978	1.4745	1.1871	0.9804	0.8257	0.7061	0.6116	0.5354	0.4730	0.4210	0.3774
1.40	2.2046	2.0301	1.8787	1.7459	1.3461	1.0785	0.8878	0.7459	0.6369	0.5509	0.4817	0.4252	0.3782	0.3388
1.50	1.9875	1.8112	1.6620	1.5337	1.1600	0.9190	0.7509	0.6276	0.5337	0.4603	0.4016	0.3538	0.3143	0.2812
1.60	1.8779	1.6825	1.5240	1.3920	1.0256	0.8008	0.6484	0.5386	0.4560	0.3920	0.3411	0.2998	0.2659	0.2376
1.70	1.8713	1.6215	1.4355	1.2893	0.9143	0.7007	0.5610	0.4625	0.3895	0.3335	0.2894	0.2538	0.2246	0.2004

Curves for initial heat rise = 100 %

Is = 1.2 Ib

Iph/Ibseq	**1.10**	**1.15**	**1.20**	**1.25**	**1.30**	**1.35**	**1.40**	**1.45**	**1.50**	**1.55**	**1.60**	**1.65**	**1.70**	**1.75**	**1.80**
Itrip/Ibseq															
1.05	2.5249	1.4422	1.0000	0.7585	0.6064	0.5019	0.4258	0.3679	0.3226	0.2862	0.2563	0.2313	0.2102	0.1922	0.1766
1.10		1.624	1.000	0.720	0.559	0.454	0.381	0.3257	0.2835	0.2501	0.2229	0.2004	0.1816	0.1655	0.1518
1.15			1.000	0.645	0.477	0.377	0.310	0.2621	0.2260	0.1979	0.1754	0.1570	0.1417	0.1288	0.1177

Is = 1.2 Ib

Iph/Ibseq	**1.85**	**1.90**	**1.95**	**2.00**	**2.20**	**2.40**	**2.60**	**2.80**	**3.00**	**3.20**	**3.40**	**3.60**	**3.80**	**4.00**
Itrip/Ibseq														
1.05	0.1630	0.1511	0.1405	0.1311	0.1020	0.0821	0.0677	0.0569	0.0486	0.0421	0.0368	0.0325	0.0289	0.0259
1.10	0.1398	0.1293	0.1201	0.1119	0.0867	0.0696	0.0573	0.0481	0.0410	0.0354	0.0310	0.0273	0.0243	0.0217
1.15	0.1082	0.0999	0.0926	0.0861	0.0664	0.0531	0.0436	0.0366	0.0312	0.0269	0.0235	0.0207	0.0184	0.0165

Is = 1.3 Ib

Iph/Ibseq	**1.10**	**1.15**	**1.20**	**1.25**	**1.30**	**1.35**	**1.40**	**1.45**	**1.50**	**1.55**	**1.60**	**1.65**	**1.70**	**1.75**	**1.80**
Itrip/Ibseq															
1.05	4.1639	2.3784	1.6492	1.2509	1.0000	0.8276	0.7021	0.6068	0.5320	0.4719	0.4226	0.3815	0.3467	0.3170	0.2913
1.10		2.9020	1.7875	1.2878	1.0000	0.8123	0.6802	0.5823	0.5068	0.4470	0.3984	0.3583	0.3246	0.2959	0.2713
1.15			2.0959	1.3521	1.0000	0.7901	0.6498	0.5493	0.4737	0.4148	0.3676	0.3291	0.2970	0.2699	0.2468
1.20				1.5014	1.0000	0.7541	0.6039	0.5017	0.4274	0.3708	0.3264	0.2905	0.2610	0.2364	0.2154
1.25					1.0000	0.6820	0.5222	0.4227	0.3541	0.3036	0.2648	0.2341	0.2092	0.1886	0.1713

Is = 1.3 Ib

Iph/Ibseq	**1.85**	**1.90**	**1.95**	**2.00**	**2.20**	**2.40**	**2.60**	**2.80**	**3.00**	**3.20**	**3.40**	**3.60**	**3.80**	**4.00**
Itrip/Ibseq														
1.05	0.2688	0.2491	0.2317	0.2162	0.1682	0.1354	0.1117	0.0939	0.0802	0.0694	0.0607	0.0535	0.0476	0.0426
1.10	0.2499	0.2311	0.2146	0.2000	0.1550	0.1243	0.1023	0.0859	0.0733	0.0633	0.0554	0.0488	0.0434	0.0389
1.15	0.2268	0.2094	0.1941	0.1805	0.1393	0.1114	0.0915	0.0767	0.0653	0.0564	0.0492	0.0434	0.0386	0.0345
1.20	0.1974	0.1819	0.1682	0.1562	0.1199	0.0955	0.0783	0.0655	0.0557	0.0481	0.0419	0.0369	0.0328	0.0293
1.25	0.1565	0.1438	0.1327	0.1230	0.0938	0.0745	0.0609	0.0508	0.0432	0.0372	0.0324	0.0285	0.0253	0.0226

Is = 1.4 Ib

Iph/Ibseq	**1.10**	**1.15**	**1.20**	**1.25**	**1.30**	**1.35**	**1.40**	**1.45**	**1.50**	**1.55**	**1.60**	**1.65**	**1.70**	**1.75**	**1.80**
Itrip/Ibseq															
1.05	5.9304	3.3874	2.3488	1.7816	1.4243	1.1788	1.0000	0.8642	0.7577	0.6721	0.6019	0.5434	0.4938	0.4515	0.4148
1.10		4.2662	2.6278	1.8931	1.4701	1.1942	1.0000	0.8560	0.7451	0.6571	0.5857	0.5267	0.4771	0.4350	0.3988
1.15			3.2252	2.0806	1.5388	1.2158	1.0000	0.8453	0.7289	0.6383	0.5657	0.5064	0.4570	0.4154	0.3797
1.20				2.4862	1.6559	1.2488	1.0000	0.8307	0.7077	0.6141	0.5405	0.4811	0.4323	0.3914	0.3567
1.25					1.9151	1.3061	1.0000	0.8095	0.6780	0.5814	0.5072	0.4484	0.4007	0.3612	0.3280
1.30						1.4393	1.0000	0.7750	0.6330	0.5339	0.4603	0.4035	0.3581	0.3211	0.2903
1.35							1.0000	0.7053	0.5521	0.4544	0.3855	0.3340	0.2940	0.2618	0.2355

Is = 1.4 Ib

Iph/Ibseq	**1.85**	**1.90**	**1.95**	**2.00**	**2.20**	**2.40**	**2.60**	**2.80**	**3.00**	**3.20**	**3.40**	**3.60**	**3.80**	**4.00**
Itrip/Ibseq														
1.05	0.3829	0.3548	0.3300	0.3079	0.2396	0.1928	0.1590	0.1337	0.1142	0.0988	0.0864	0.0762	0.0678	0.0607
1.10	0.3673	0.3398	0.3155	0.2940	0.2278	0.1828	0.1505	0.1263	0.1078	0.0931	0.0814	0.0718	0.0638	0.0571
1.15	0.3490	0.3222	0.2986	0.2778	0.2143	0.1714	0.1408	0.1180	0.1005	0.0868	0.0758	0.0668	0.0593	0.0531
1.20	0.3269	0.3011	0.2786	0.2587	0.1985	0.1582	0.1296	0.1085	0.0923	0.0796	0.0694	0.0611	0.0543	0.0486
1.25	0.2997	0.2753	0.2541	0.2355	0.1796	0.1426	0.1165	0.0973	0.0827	0.0712	0.0621	0.0546	0.0485	0.0433
1.30	0.2643	0.2420	0.2228	0.2060	0.1561	0.1235	0.1006	0.0838	0.0711	0.0612	0.0533	0.0468	0.0415	0.0371
1.35	0.2135	0.1948	0.1788	0.1649	0.1240	0.0976	0.0793	0.0659	0.0558	0.0480	0.0417	0.0367	0.0325	0.0290

Curves for initial heat rise = 100 %

Is = 2 Ib

Iph/Ibseq Itrip/Ibseq	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50	1.55	1.60	1.65	1.70	1.75	1.80
1.05	19.2620	11.0020	7.6288	5.7866	4.6259	3.8286	3.2480	2.8069	2.4611	2.1831	1.9550	1.7648	1.6039	1.4663	1.3473
1.10		14.5120	8.9388	6.4398	5.0007	4.0622	3.4016	2.9118	2.5344	2.2351	1.9923	1.7915	1.6230	1.4797	1.3565
1.15			11.6100	7.4893	5.5392	4.3766	3.5996	3.0427	2.6238	2.2975	2.0364	1.8228	1.6451	1.4951	1.3669
1.20				9.6105	6.4010	4.8272	3.8656	3.2112	2.7355	2.3737	2.0892	1.8597	1.6709	1.5129	1.3788
1.25					8.1323	5.5465	4.2465	3.4375	2.8792	2.4688	2.1537	1.9041	1.7014	1.5337	1.3927
1.30						6.9855	4.8534	3.7614	3.0722	2.5911	2.2342	1.9582	1.7380	1.5583	1.4088
1.35							6.0646	4.2771	3.3484	2.7556	2.3380	2.0258	1.7828	1.5879	1.4280
1.40								5.3051	3.7883	2.9911	2.4776	2.1131	1.8388	1.6241	1.4511
1.50										4.1166	2.9979	2.3998	2.0090	1.7283	1.5149
1.60												3.2166	2.3778	1.9239	1.6242
1.70														2.4956	1.8670

Is = 2 Ib

Iph/Ibseq Itrip/Ibseq	1.85	1.90	1.95	2.00	2.20	2.40	2.60	2.80	3.00	3.20	3.40	3.60	3.80	4.00
1.05	1.2436	1.1525	1.0718	1.0000	0.7783	0.6262	0.5165	0.4343	0.3709	0.3209	0.2806	0.2476	0.2202	0.1972
1.10	1.2495	1.1559	1.0733	1.0000	0.7750	0.6217	0.5118	0.4297	0.3666	0.3168	0.2768	0.2441	0.2170	0.1943
1.15	1.2562	1.1597	1.0750	1.0000	0.7713	0.6169	0.5066	0.4247	0.3618	0.3124	0.2727	0.2404	0.2136	0.1911
1.20	1.2638	1.1640	1.0768	1.0000	0.7673	0.6115	0.5010	0.4192	0.3567	0.3076	0.2683	0.2363	0.2099	0.1877
1.25	1.2725	1.1690	1.0790	1.0000	0.7628	0.6057	0.4949	0.4133	0.3511	0.3025	0.2636	0.2320	0.2059	0.1841
1.30	1.2826	1.1747	1.0814	1.0000	0.7578	0.5992	0.4882	0.4069	0.3451	0.2969	0.2585	0.2274	0.2017	0.1802
1.35	1.2945	1.1813	1.0842	1.0000	0.7522	0.5920	0.4808	0.3998	0.3386	0.2910	0.2531	0.2224	0.1971	0.1760
1.40	1.3085	1.1891	1.0874	1.0000	0.7459	0.5841	0.4728	0.3921	0.3315	0.2844	0.2471	0.2170	0.1922	0.1715
1.50	1.3463	1.2094	1.0958	1.0000	0.7306	0.5652	0.4539	0.3744	0.3152	0.2697	0.2337	0.2048	0.1811	0.1614
1.60	1.4070	1.2406	1.1082	1.0000	0.7102	0.5410	0.4303	0.3527	0.2955	0.2520	0.2178	0.1904	0.1681	0.1496
1.70	1.5237	1.2953	1.1286	1.0000	0.6816	0.5089	0.4000	0.3253	0.2711	0.2302	0.1983	0.1730	0.1524	0.1355

Operation

This function is used to protect a transformer against overloads, based on the measurement of the current taken.
IEC standard 60076-2 proposes 2 thermal models for evaluating the winding thermal capacity used during an overload, depending on whether the transformer is dry-type or immersed.

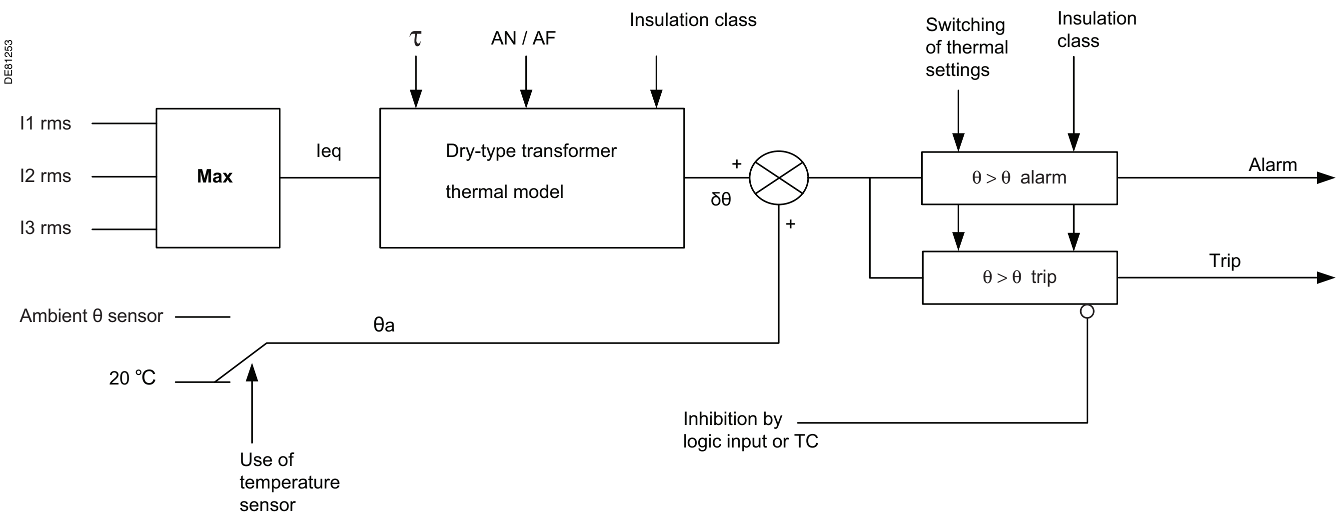
Taking account of harmonics
The equivalent current Ieq measured by the transformer thermal overload protection is the highest of the phase rms currents (the rms current takes account of harmonic numbers up to 13).

Taking account of 2 operating conditions
The choice between thermal sets 1 and 2 is made by the "switching of thermal settings" logic input. This means you can have thermal set 1 for normal transformer operation and thermal set 2 for unusual transformer operation.

Dry-type transformer

For dry-type transformers, the thermal model used in the Sepam relay conforms to standard IEC 60076-12 (with 1 time constant).

Block diagram



Dry-type transformer thermal model
The thermal limit for dry-type transformers is determined by the thermal limit for insulating components in order to avoid damaging them. The table below defines the maximum permissible temperature and the winding temperature gradient according to the insulation class:

Insulation class (°C)	Gradient $\Delta\theta n$	Maximum permissible winding temperature θ_{max}
105 (A)	75 °C (67 °F)	130 °C (266 °F)
120 (E)	90 °C (194 °F)	145 °C (293 °F)
130 (B)	100 °C (212 °F)	155 °C (311 °F)
155 (F)	125 °C (257 °F)	180 °C (356 °F)
180 (H)	150 °C (302 °F)	205 °C (401 °F)
200	170 °C (338 °F)	225 °C (437 °F)
220	190 °C (374 °F)	245 °C (473 °F)

The winding maximum permissible thermal capacity used equals:

$\theta_{max} - \theta_a$

Where:

θ_a : ambient temperature (rated value equals 20 °C or 68 °F)

$\Delta\theta n$: temperature gradient at rated current Ib

θ_{max} : insulating component maximum permissible temperature according to the insulation class

The temperature build-up $\delta\theta$ in the dry-type transformer winding is calculated as follows:

$$\mathbf{Ieq} \geq \mathbf{5}\ \%\ \mathrm{Ib}: \delta\theta_{\mathbf{n}} = \delta\theta_{\mathbf{n-1}} + \left[\Delta\theta\mathbf{n} \cdot \left(\frac{\mathbf{I_{eq}}}{\mathbf{Ib}}\right)^{\mathbf{q}} - \delta\theta_{\mathbf{n-1}}\right] \cdot \frac{\mathbf{dt}}{\tau}$$

$$\mathbf{Ieq} < \mathbf{5}\ \%\ \mathrm{Ib}: \delta\theta_{\mathbf{n}} = \delta\theta_{\mathbf{n-1}} \cdot \left(\mathbf{1} - \frac{\mathbf{dt}}{\tau}\right)$$

Where:
τ : dry-type transformer time constant
q : equals 1.6 for transformers with natural cooling (AN)
equals 2 for transformers with forced cooling (AF)

The protection trips when the temperature build-up $\delta\theta$ in the winding reaches $\theta_{\mathbf{max}} - \theta_{\mathbf{a}}$.

Evaluating the time constant
The thermal protection function protects the MV winding as well as the LV winding. Therefore the time constant τ corresponds to the lowest value of the MV winding and LV winding time constants.

The time constant is evaluated, for each winding, according to standard IEC 60076-12 as follows:

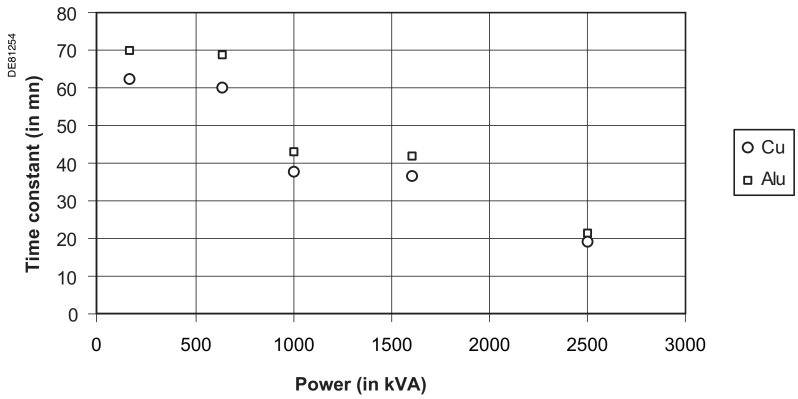
$$\tau = \frac{\mathbf{C} \cdot (\Delta\theta_{\mathbf{n}} - \theta_{\mathbf{e}})}{\mathbf{Pr}}$$

Where:
Pr : total winding loss in Watts
C : winding thermal capacity in Watts min, given by the winding material:
■ Aluminum: 15 times weight of Al conductor (kg) + 24.5 times weight of epoxy and other insulating component (kg)
■ Copper: 6.42 times weight of Cu conductor (kg) + 24.5 times weight of epoxy and other insulating component (kg)
$\theta_{\mathbf{e}}$: contribution of the core to the thermal capacity used:

■ 5 °C (41 °F) for MV winding
■ 25 °C (77 °F) for LV winding

Example of a class B dry-type transformer:
Regardless of the winding material, the LV winding has the lowest time constant.

The following graph gives the values of the time constant τ for different 20 kV / 410 V dry-type transformer power ratings:



20 kV / 410 V dry-type transformer time constant.

Saving the thermal capacity used
On loss of the auxiliary power supply, the winding thermal capacity used is saved.

Operating information
The following information is available to the operator:

- the winding relative thermal capacity used E as a %: $E_k = 100 \cdot \dfrac{\theta_k - \theta a}{\Delta\theta_n}$
- the time before tripping in minutes (at constant current)

Accounting for ambient temperature
The characteristics of dry-type transformers are defined for an ambient temperature of 20 °C (68 °F). When the Sepam is equipped with the temperature sensor module option, the ambient temperature is measured by sensor no. 8 and added to the winding temperature.

3

Thermal overload for transformers
ANSI code 49RMS

Characteristics

Settings				
Measurement origin				
Setting range	I1, I2, I3 / I'1, I'2, I'3			
Choice of transformer or thermal model				
Setting range	Dry-type transformer			
	Natural ventilation (AN)			
	Forced ventilation (AF)			
	Generic model[(1)]			
Insulation class				
Setting range	105 (A)			
	120 (E)			
	130 (B)			
	155 (F)			
	180 (H)			
	200			
	220			
Alarm set point (θ alarm)				
Setting range	class 105: 95 °C to 130 °C (203 °F to 266 °F)			
	class 120: 110 °C to 145 °C (230 °F to 293 °F)			
	class 130: 120 °C to 155 °C (248 °F to 311 °F)			
	class 155: 145 °C to 180 °C (293 °F to 356 °F)			
	class 180: 170 °C to 205 °C (338 °F to 401 °F)			
	class 200: 190 °C to 225 °C (374 °F to 437 °F)			
	class 220: 210 °C to 245 °C (410 °F to 473 °F)			
Resolution	1 °C (1 °F)			
Tripping set point (θ trip)				
Setting range	class 105: 95 °C to 130 °C (203 °F to 266 °F)			
	class 120: 110 °C to 145 °C (230 °F to 293 °F)			
	class 130: 120 °C to 155 °C (248 °F to 311 °F)			
	class 155: 145 °C to 180 °C (293 °F to 356 °F)			
	class 180: 170 °C to 205 °C (338 °F to 401 °F)			
	class 200: 190 °C to 225 °C (374 °F to 437 °F)			
	class 220: 210 °C to 245 °C (410 °F to 473 °F)			
Resolution	1 °C (1 °F)			
Transformer time constant (τ)				
Setting range	1 min to 600 min			
Resolution	1 min			
Accounting for ambient temperature				
Setting range	yes / no			
Characteristic times				
Operating time accuracy	±2 % or ±1 s			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Reset protection	P49RMS_1_101	■	■	
Inhibit protection	P49RMS_1_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Time-delayed output	P49RMS _1_3	■	■	■
Alarm	P49RMS _1_10	■	■	■
Inhibit closing	P49RMS _1_11	■	■	■
Protection inhibited	P49RMS _1_16	■	■	
Hot state	P49RMS _1_18	■	■	
Thermal overload inhibited	P49RMS_1_32	■	■	
Zero speed	P49RMS_1_38	■	■	

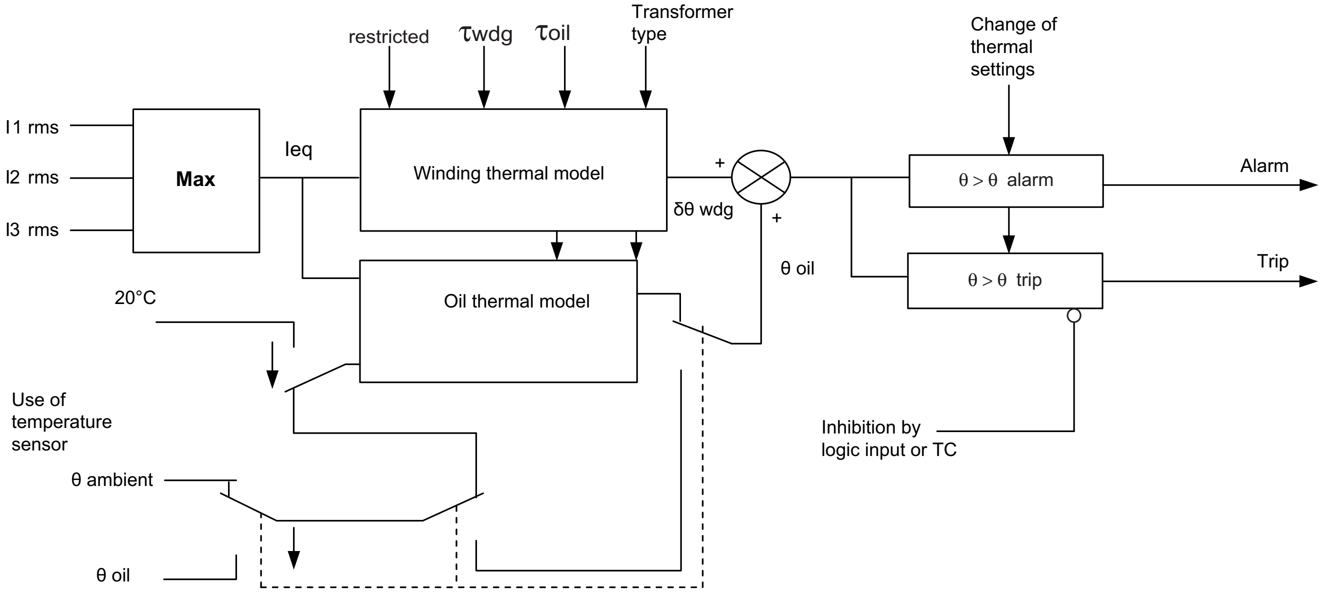
(1) See settings associated with generic thermal overload.

Immersed transformer

For immersed transformers, the thermal model used in the Sepam relay conforms to standard IEC 60076-7 (with 2 time constants).
The thermal limit for immersed transformers is determined by the thermal limit for the oil, to avoid the formation of bubbles that could damage the dielectric strength of the oil.

Block diagram

DE81255



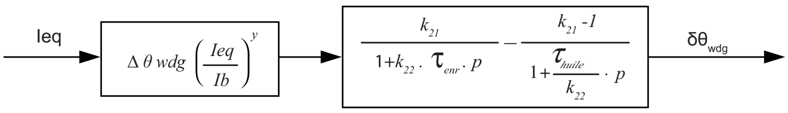
Immersed transformer thermal model

The immersed transformer thermal model takes account of thermal exchanges between the winding and the oil. To this end IEC standard 60076-2 proposes a model for each of the transformer components:

- a thermal model with 2 time constants for the winding
- a thermal model with 1 time constant for the oil.

The winding thermal model transfer function is as follows:

DE81256



Where $\Delta\theta enr$: winding temperature gradient at current Ib
y : winding thermal capacity used exponent
κ_{21} : thermal exchange coefficient between the winding and the oil
κ_{22} : multiplying factor applied to the time constants
τ_{enr} : winding time constant
τ_{huile} : oil time constant

Thermal overload for transformers
ANSI code 49RMS

IEC standard 60076-7 proposes, depending on the nature of the immersed transformer, the following values κ_{22}

Transformer	κ_{21}		$\Delta\theta enr$	y	τ_{enr}	τ_{huile}
ONAN (distribution)	1	2	23 °C	1,6	4 min	180 min
ONAN (power)	2	2	26 °C	1,3	10 min	210 min
ONAF	2	2	26 °C	1,3	7 min	150 min
OF	1.3	1	22 °C	1,3	7 min	90 min
OD	1	1	29 °C	2	7 min	90 min

Note: *For distribution ONAN and OD transformers, the winding thermal model only reacts with the winding time constant.*

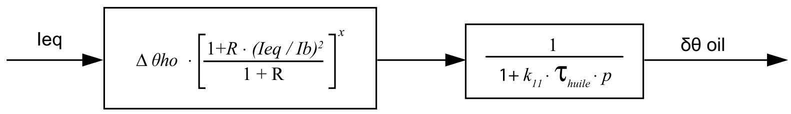
When the winding and oil time constants are given by the immersed transformer manufacturer, the user can enter them in place of the default values proposed by the standard.
For transformers in which the oil flow can be restricted, exchanges between the winding and the oil are worse, so the winding thermal capacity used values are exceeded. In this case coefficient κ_{21} takes the following values:

Transformer	Restricted flow	
	OFF	ON
ONAN (power)	2	3
ONAF	2	3
OF	1,3	1,45

Accounting for ambient temperature
The characteristics of immersed transformers are defined for an ambient temperature of 20 °C (68 °F). When the Sepam is equipped with the temperature sensor module option, the ambient temperature is measured by sensor no. 8 and added to the oil temperature rise.

The oil thermal model transfer function is as follows:

DE81257



Where $\Delta\theta ho$: oil temperature gradient at current Ib
R : ratio between the on-load losses and the no-load losses
x : oil thermal capacity used exponent
κ_{11} : multiplying factor applied to the oil time constant

IEC standard 60076-7 proposes, depending on the nature of the immersed transformer, the following values:

Transformer	κ_{11}	$\Delta\theta ho$	x	R
ONAN (distribution)	1	55 °C	0,8	5
ONAN (power)	0,5	52 °C	0,8	6
ONAF	0,5	52 °C	0,8	6
OF	1	56 °C	1	6
OD	1	49 °C	1	6

Taking account of the oil temperature
When the Sepam is equipped with the temperature sensor module option, sensor no. 8 can be assigned to the oil temperature measurement. In this case the oil temperature measurement is substituted for the oil thermal model. The measured oil temperature θ_{oil} is added to the winding temperature rise.

Saving the thermal capacity used
On loss of the auxiliary power supply, both the winding and oil thermal capacity used are saved.

Operating information
The following information is available to the operator:
- the time before tripping in minutes (at constant current)
- the relative thermal capacity used E_k of the transformer expressed as a %:
  - when the oil temperature is estimated by a calculation:

$$E_k = 100 \cdot \frac{\theta_k - \theta_{ambiant}}{\Delta\theta enr + \Delta\theta ho}$$

  - when the oil temperature is measured:

$$E_k = 100 \cdot \frac{\theta_k - \theta_{huile}}{\Delta\theta enr}$$

Thermal overload for transformers
ANSI code 49RMS

Characteristics

Settings				
Measurement origin				
Setting range	I1, I2, I3 / I'1, I'2, I'3			
Choice of transformer or thermal model				
Setting range	Immersed transformer			
	ONAN (distribution)			
	ONAN (power)			
	ONAF			
	OD			
	OF			
	Generic model[(1)]			
Alarm set point (θ alarm)				
Setting range	Immersed transfo:	98 °C to 160 °C (208 °F to 320 °F)		
	Dry-type transfo:	95 °C to 245 °C (203 °F to 473 °F)		
Resolution	1 °C (1 °F)			
Tripping set point (θ trip)				
Setting range	Immersed transfo:	98 °C to 160 °C (208 °F to 320 °F)		
	Dry-type transfo:	95 °C to 245 °C (203 °F to 473 °F)		
Resolution	1 °C (1 °F)			
Winding time constant (τ_{enr})				
Setting range	1 mn to 600 mn			
Resolution	1 min			
Oil time constant (τ_{huile})				
Setting range	5 mn to 600 mn			
Resolution	1 min			
Accounting for ambient temperature				
Setting range	yes / no			
Accounting for oil temperature				
Setting range	yes / no			
Restricted oil flow				
Setting range	on / off			
Characteristic times				
Operating time accuracy	±2 % or ±1 s			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Reset protection	P49RMS_1_101	■	■	
Inhibit protection	P49RMS_1_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Time-delayed output	P49RMS _1_3	■	■	■
Alarm	P49RMS _1_10	■	■	■
Inhibit closing	P49RMS _1_11	■	■	■
Protection inhibited	P49RMS _1_16	■	■	
Hot state	P49RMS _1_18	■	■	
Thermal overload inhibited	P49RMS_1_32	■	■	
Zero speed	P49RMS_1_38	■	■	

***(1)** See settings associated with generic thermal overload.*

Glossary of transformer type abbreviations:
- AN: air-cooled transformer with natural ventilation
- AF: air-cooled transformer with forced ventilation
- ONAN: transformer immersed in mineral oil, cooled by natural air convection
- ONAF: transformer immersed in oil with forced circulation
- OD: transformer immersed in oil with forced circulation, directed into the windings
- OF: transformer immersed in oil with forced circulation

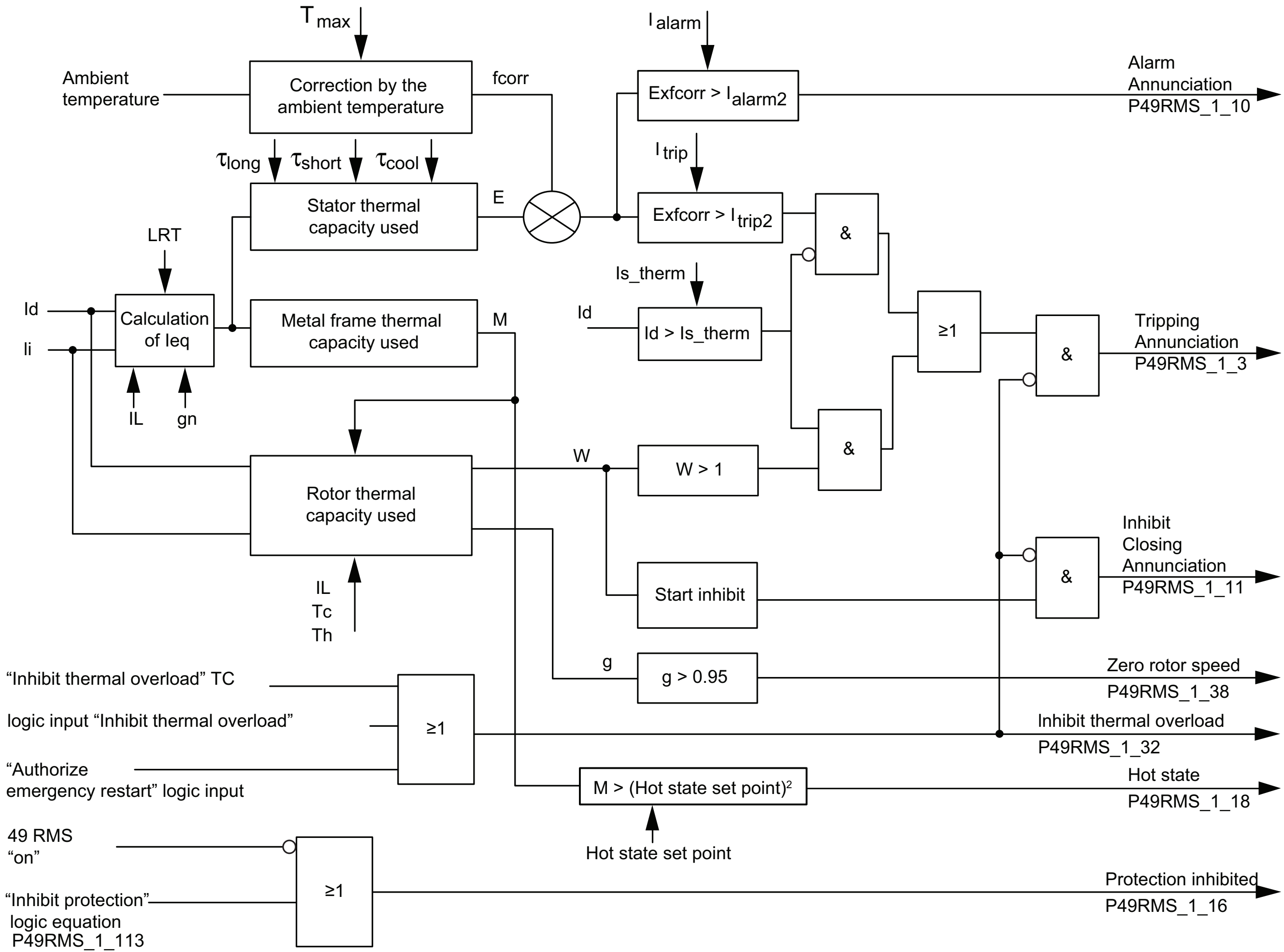
Thermal overload for motors
ANSI code 49RMS

Operation
This function is used to protect the stator and the rotor of an asynchronous motor.

Block diagram
The stator thermal overload protection is provided by a thermal model with 2 time constants (τlong and τshort).

The rotor excessive starting time thermal protection is provided by an adiabatic thermal model.

DE81258



Blocking of tripping and closing inhibition
The protection tripping and inhibit closing outputs can be inhibited by:
- an "Inhibit thermal overload" latched logic input
- an "Authorize emergency restart" latched logic input
- an "Inhibit thermal overload" remote control order (TC).

Start inhibit
When the protection trips, circuit breaker closing is inhibited until the rotor thermal capacity used allows another motor start.
This inhibit is grouped together with the "Starts per hour" protection function, and signaled by the message "INHIBIT START".
The inhibit time before starting is authorized can be accessed from:
- the "Machine diagnosis" tab in the SFT2841 software
- the Sepam front panel.

"Hot state" set point
The thermal overload function provides a "hot state" data item used by the starts per hour function (ANSI code 66). It is used to distinguish between cold starts and hot starts. The number of consecutive starts per hour is stated by the motor manufacturer.
Depending on the manufacturer, the previous load current defining hot state varies between 0.6 Ib and Ib. Hence the "hot state" set point can be adjusted to suit the motor characteristics.

Saving the thermal capacity used
On loss of the auxiliary power supply, the thermal capacity used of the rotor W, the stator E and the metal frame M are saved and reused in their current state until the relay is re-energized.

Operating information
The following information can be accessed from the "Machine diagnosis" tab in the SFT2841 software and the Sepam front panel:
- the stator thermal capacity used
- the time before the stator protection trips (at constant current)
- the time before restarting is authorized.

Thermal overload for motors
ANSI code 49RMS

Characteristics

Settings		
Measurement origin		
Setting range	I1, I2, I3	
Choice of thermal model		
Setting range	2 Constant	
	Generic(1)	
Thermal model switching threshold		Is_therm
Setting range	1 to 10 pu of Ib	
Resolution	0.1 pu of Ib	
Stator thermal settings		
Motor thermal capacity used time constant		τ_{long}
Setting range	1 mn to 600 mn	
Resolution	1 mn	
Stator thermal capacity used time constant		τ_{short}
Setting range	1 mn to 60 mn	
Resolution	0,1 mn	
Cooling time constant		τ_{cool}
Setting range	5 mn to 600 mn	
Resolution	1 mn	
Tripping current set point		Itrip
Setting range	50 % to 173 % of Ib	
Resolution	1 % of Ib	
Alarm current set point		Ialarm
Setting range	50 % to 173 % of Ib	
Resolution	1 % of Ib	
Thermal exchange coefficient between the stator and the motor		α
Setting range	0 to 1	
Resolution	0.01	
Hot state set point		
Setting range	0.5 to 1 pu of Ib	
Resolution	0.01 pu of Ib	
Accounting for ambient temperature		
Setting range	Yes / No	
Maximum equipment temperature (insulation class)		Tmax
Setting range	70 °C to 250 °C or 158 °F to 482 °F	
Resolution	1 °C or 1 °F	
Rotor thermal settings		
Locked rotor amperes		I_L
Setting range	1 to 10 pu of Ib	
Resolution	0.01 pu of Ib	
Locked rotor torque		LRT
Setting range	0.2 to 2 pu of Ib	
Resolution	0.01 pu of Ib	
Locked cold rotor limit time		Tc
Setting range	1 s to 300 s	
Resolution	0.1 s	
Locked hot rotor limit time		Th
Setting range	1 s to 300 s	
Resolution	0.1 s	
Characteristic times		
Operating time accuracy	±2 % or ±1 s	

(1) See settings associated with generic thermal overload.

Inputs			
Designation	**Syntax**	**Equations**	**Logipam**
Reset protection	P49RMS_1_101	■	■
Inhibit protection	P49RMS_1_113	■	■

Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Time-delayed output	P49RMS_1_3	■	■	■
Alarm	P49RMS_1_10	■	■	■
Inhibit closing	P49RMS_1_11	■	■	■
Protection inhibited	P49RMS_1_16	■	■	
Hot state	P49RMS_1_18	■	■	
Thermal overload inhibited	P49RMS_1_32	■	■	
Zero speed	P49RMS_1_38	■	■	

Thermal overload for motors
ANSI code 49RMS

1 Selection of the motor / generic thermal overload protection function
2 Switching threshold between the stator and rotor thermal models (Is_therm)
3 Rotor thermal model parameters
4 Stator thermal model parameters
5 Calculated stator thermal model parameters

Help with parameter setting

The function parameters are set using the motor manufacturer data and the SFT2841 software (49RMS tab in the protection functions).

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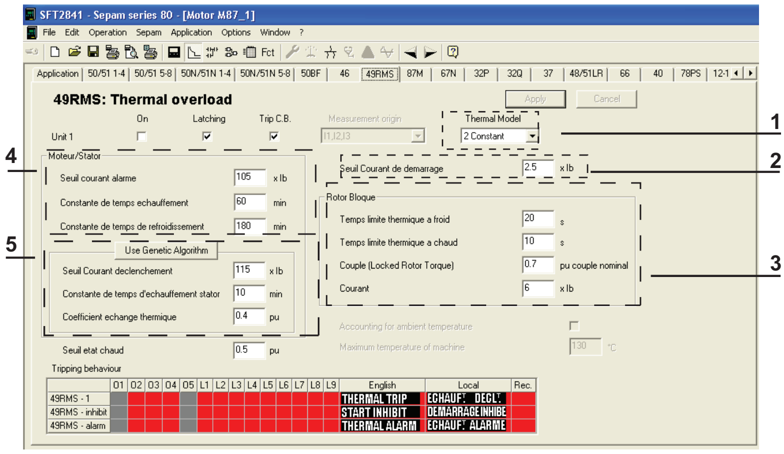

SFT2841 software: 49RMS protection parameter-setting screen for a motor application.

Parameter-setting procedure

1. Select the thermal overload protection function by choosing the "2 Time constants" value from the "Thermal Model" drop-down list.

Note: *The "Generic" value selects the generic thermal overload protection function (see page 153 to set the parameters for this protection function).*

2. Enter the rotor and stator parameters using the motor manufacturer data.

■ Rotor parameters:
□ Locked cold rotor limit time (Tc)
□ Locked hot rotor limit time (Th)
□ Locked rotor torque (LRT)
□ Starting current (IL)
■ Stator parameters:
□ Heating time constant: τlong
□ Cooling time constant: τcool

3. Determine in graphic form the switching threshold between the stator and rotor thermal models (Is_therm).
Depending on the manufacturer curves, there are 2 possible scenarios:
■ If there is any discontinuity between the manufacturer curves (see example on next page), choose Is_therm at the stator breaking point.
■ If there is no discontinuity:
□ Plot the locked cold rotor thermal model curve, between IL and Ib, using the equation below in order to determine Is_therm:
$W(I) = Tc \times (IL / I)^2$
□ Determine the value of Is_therm for which the rotor thermal model (adiabatic) no longer corresponds to the manufacturer's locked cold rotor curve.

Thermal overload for motors
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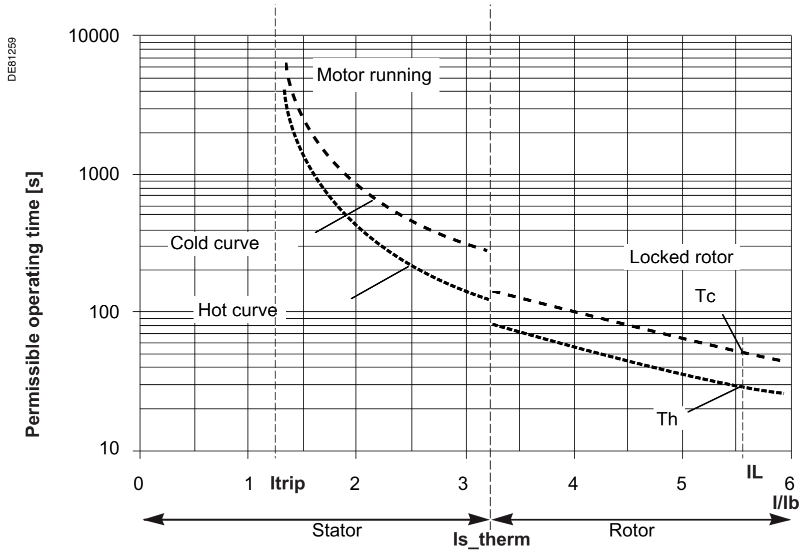


Determination of Is_therm in the case of discontinuous manufacturer curves.

Itrip: permissible continuous current and tripping set point in pu of Ib
IL: starting current in pu of Ib
Tc: Locked cold rotor limit time
Th: Locked hot rotor limit time

4. Determine the following stator parameters:
- Tripping current set point Itrip
- Stator thermal capacity used time constant τshort
- Thermal exchange coefficient α

If these parameters are not available, proceed as follows to calculate them using the SFT2841 software:
4.1. Press the "Use Genetic Algorithm" button which can be accessed from the 49RMS tab in the protection functions.

4.2. Enter 4 typical points found on the manufacturer's cold stator curve.

4.3. Press the "Use Genetic Algorithm" button: the SFT2841 software calculates all 3 parameters.

Example of parameter setting no. 1: 3100 kW / 6.3 kV motor

We have the following manufacturer data:

Parameter	Name	Value	Rotor / stator
insulation class		F	-
rated current	Ib	320 A	-
starting current	IL	5.6 Ib	rotor
rated torque	Tn	19,884 Nm	rotor
starting torque	LRT	0.7 Tn	rotor
motor time constant	τ long	90 minutes	stator
cooling constant	τ cool	300 minutes	stator
locked cold / hot rotor limit time	Tc / Th	29 s / 16.5 s	rotor
starting time		2.3 s	-
number of consecutive cold (hot) starts		3 (2)	-

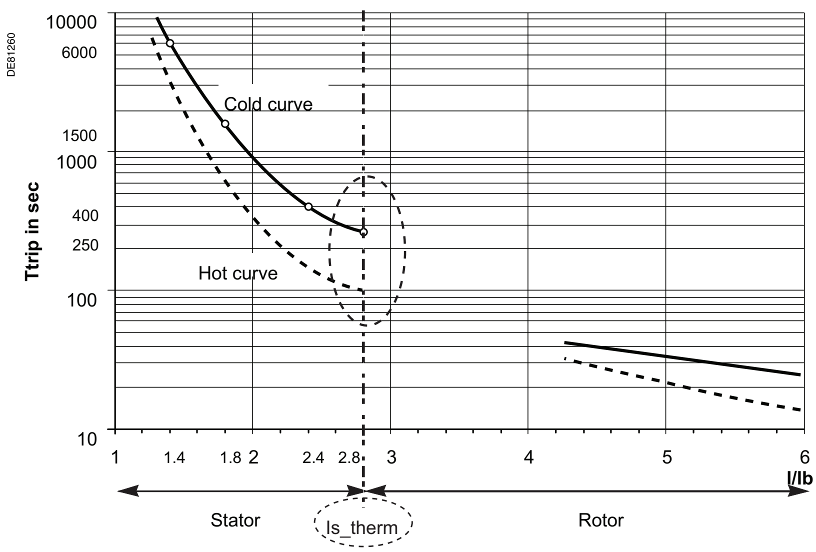
Setting the function parameters

1. Selection of "2 Time constants" from the "Thermal Model" drop-down list to select the motor thermal overload protection function.

2. Set the rotor and stator model parameters using the manufacturer data:

Rotor parameter	Name	Value
Locked cold rotor limit time	Tc	29 s
Locked hot rotor limit time	Th	16.5 s
Locked rotor torque	LRT	0.7 pu rated torque
Starting current	IL	5.6 Ib
Stator parameter	**Name**	**Value**
Alarm current set point	Ialarm	< Itrip
Heating time constant	τ long	90 minutes
Cooling time constant	τ cool	300 minutes

3. Determination of Is_therm switching threshold between the 2 models:
In this example there is a clear distinction between the rotor and stator manufacturer curves.
Therefore the Is_therm switching threshold at the rotor curve breaking point is selected.
Hence Is_therm = 2.8 Ib



4. Determination of the stator parameters:
For example on the cold stator curve (previous graphic) the following 4 points are selected, spread between Ib and Is_therm:

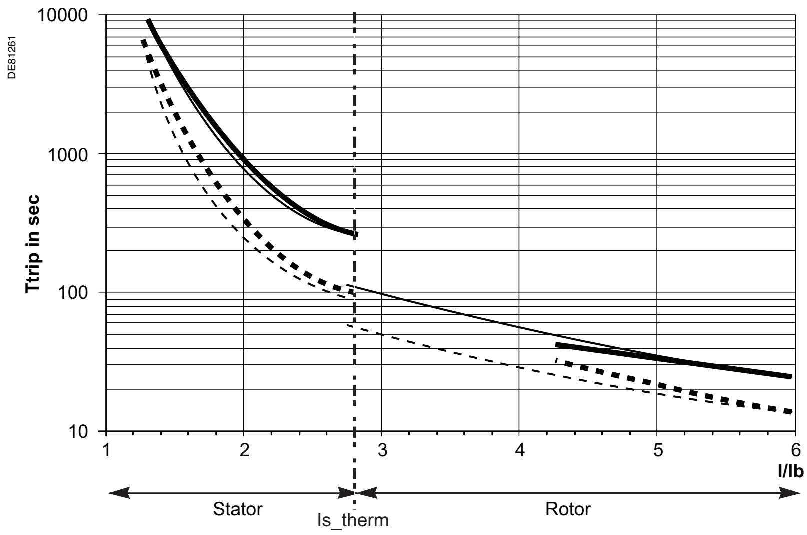
I/Ib	Ttrip
1.4	6000 s
1.8	1500 s
2.4	400 s
2.8	250 s

The SFT2841 software calculates the missing stator parameters on the basis of these 4 points:

Calculated stator parameter	Name	Value
Tripping current set point	Itrip	1.2 Ib
Stator heating time constant	τshort	5.5 mn
Thermal exchange coefficient between stator and motor	α	0.7

The function parameter setting is complete:

On the graphic below the manufacturer curves are bold lines, whereas the curves generated from the configured model are fine lines.
The function protects the motor beyond its stated characteristics.



Comparison of the manufacturer curves and the configured model.

Example of parameter setting no. 2: 600 kW / 6 kV motor

We have the following manufacturer data:

Parameter	Name	Value	Rotor / stator
insulation class		F	-
rated current	Ib	69.9 A	-
starting current	IL	6 Ib	rotor
rated torque	Tn	392.2 kgm	rotor
starting torque	LRT	0.9 Tn	rotor
motor time constant	τlong	60 minutes	stator
cooling constant	τcool	180 minutes	stator
locked cold / hot rotor limit time	Tc / Th	33.5 s / 25 s	rotor
starting time		1.2 s	-
number of consecutive cold (hot) starts		2 (1)	-

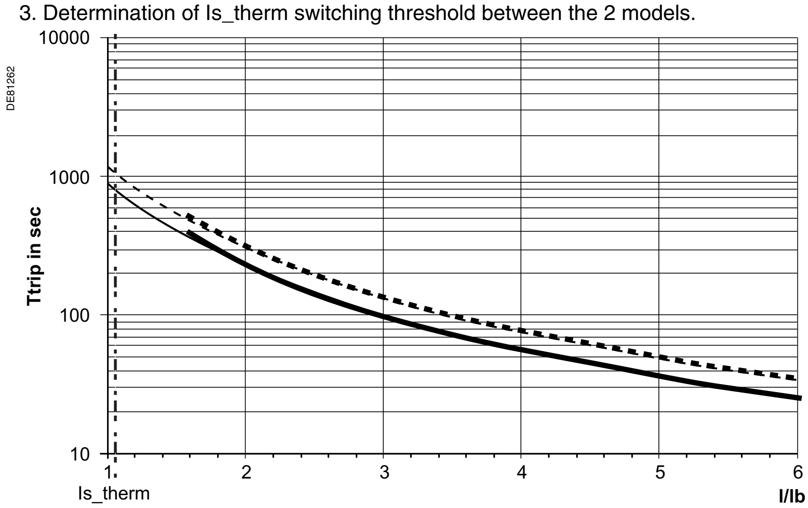
Setting the function parameters

1. Selection of the "2 Time constants" value from the "Thermal Model" drop-down list to select the motor thermal overload protection function.

2. Set the rotor and stator parameters using the manufacturer data:

Rotor parameter	Name	Value
Locked cold rotor limit time	Tc	33.5 s
Locked hot rotor limit time	Th	25 s
Locked rotor torque	LRT	0.9 pu rated torque
Starting current	IL	6 Ib
Stator parameter	**Name**	**Value**
Alarm current set point	Ialarm	< Itrip
Heating time constant	τlong	60 minutes
Cooling time constant	τcool	180 minutes

3. Determination of Is_therm switching threshold between the 2 models.



In this example the rotor and stator manufacturer curves (in bold lines) merge into one another.
We therefore plot the rotor model curves (in fine lines) defined by:

- cold curve

$$W(I) = 33,5 \cdot (6 / I)^2$$

- hot curve

$$W(I) = 25 \cdot (6 / I)^2$$

We can see that the rotor model curve coincides with the manufacturer curve over the whole current range I/Ib.
We therefore select the Is_therm switching threshold = 1.01 Ib.
The rotor model thus protects the motor over its whole operating range.

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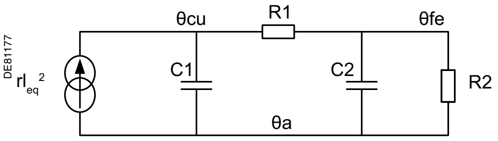
4. Determination of the stator parameters:
The SFT2841 software calculates the following stator parameters:

Calculated stator parameter	Name	Value
Tripping current set point	Itrip	1.01 Ib
Stator heating time constant	τshort	60 Minutes
Thermal exchange coefficient between stator and motor	α	1

In this example, the stator thermal overload protection is only used to define the thermal state of the motor, in order to be able to:
- change the locked cold rotor limit time value to its corresponding hot value
- define the hot / cold thermal state of the motor.

The function parameter setting is complete.



Stator thermal model.

rI_{eq}^2 : heat generated by the copper losses at equivalent current Ieq
C1 : stator thermal capacity
R1 : thermal resistance between the stator and the motor metal frame
C2 : motor thermal capacity
R2 : motor thermal resistance
θa : ambient temperature
θcu : stator winding temperature
θfe : motor metal frame temperature
τshort = R1C1: stator winding time constant
τlong = R2C2 : motor metal frame time constant

Stator thermal model

The stator thermal model takes account of thermal exchanges between the stator winding and the motor metal frames using 2 time constants.

Having used α to designate the ratio R2/(R1+R2), the stator winding relative thermal capacity used E transfer function is expressed as follows:

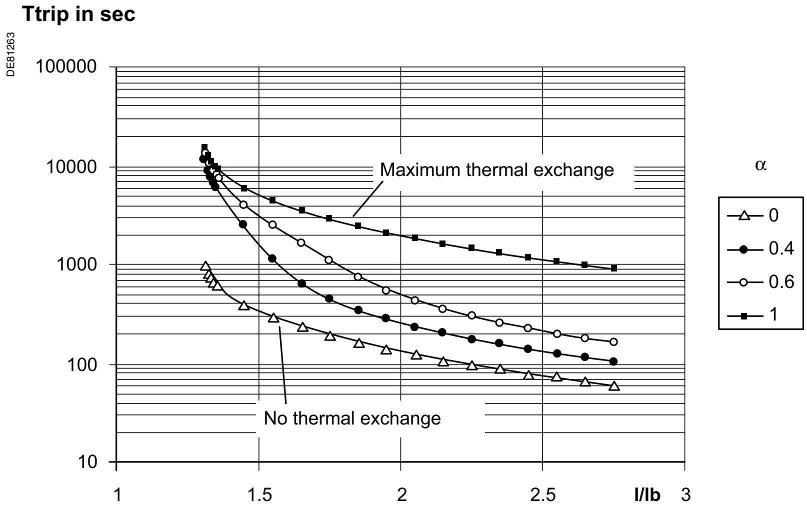
$$E(p) = \left[\frac{(1-\alpha)}{(1+p\tau_{short})} + \frac{\alpha}{(1+p\tau_{long})}\right]$$

where 0 < α < 1.
The thermal model time response with two time constants is proportional to the square of the current.

$$(I_{eq},t) = \left[(1-\alpha)\cdot\left(1-e^{-\frac{t}{\tau_{short}}}\right)+\alpha\cdot\left(1-e^{-\frac{t}{\tau_{long}}}\right)\right]\cdot I_{eq}^2$$

The stator thermal overload protection trips when $E(I_{eq},t) = K^2$, K being the permissible continuous current in pu of Ib.
For α = 0, there is no thermal exchange between the stator and the metal frame since the motor thermal resistance R2 is zero. Thus the stator heats up with the lowest time constant τshort.
Conversely for α = 1, the thermal exchange between the stator and the metal frame is perfect, therefore the stator and the metal frame only make one, resulting in the stator heating up with a time constant close to that of the metal frame τlong.
For 0 < α < 1, thermal management with 2 time constants makes it possible:
- to protect the stator winding correctly against strong overloads, since the resulting time constant is close to the stator time constant
- for the motor to run at low overload as close as possible to the limits defined by the manufacturer data, since the resulting time constant is close to that of the metal frame.

Illustration of the influence of the α coefficient on a motor whose time constants are as follows:
- stator winding: τshort = 4 mn
- metal frame: τlong = 60 mn.



Influence of the α coefficient on a motor.

Stator thermal model (continued)

Equivalent current I_{eq}

The presence of a negative sequence component accelerates the motor temperature build-up. The current negative sequence component is taken into account in the protection function by the equation

$$I_{eq} = \sqrt{\left(\frac{Id}{Ib}\right)^2 + Ki \cdot \left(\frac{Ii}{Ib}\right)^2}$$

where Id is the current positive sequence component
Ii is the current negative sequence component
Ib is the motor rated current
Ki is the negative sequence component coefficient.

For an asynchronous motor, Ki is calculated using the following parameters:
- LRT: locked rotor torque in pu of the rated torque
- I_L: starting current in pu of the rated current Ib
- N: rated speed in rpm.

The number of pairs of poles np is defined by the expression:

$$np = int\left(\frac{60 \cdot fn}{N}\right)$$

The rated slip g_n is defined by the expression:

$$g_n = 1 - \frac{N \cdot np}{60 \cdot fn}$$

where fn is the network frequency in Hz.

The coefficient Ki is defined by the expression:

$$Ki = 2\frac{LRT}{g_n \cdot I_L^2} - 1$$

Accounting for ambient temperature

Asynchronous motors are designed to run at a maximum ambient temperature of 40 °C (104 °F). Where Sepam is equipped with the temperature sensor module option (with sensor no. 8 assigned to measuring the ambient temperature), the stator thermal capacity used is multiplied by the correction factor fcorr, from the time when the ambient temperature is higher than 40 °C.

$$fcorr = \frac{T_{max} - 40}{T_{max} - T_{ambiant}}$$

where Tmax is the maximum temperature in the thermal class for the motor insulating components defined in accordance with standard 60085.

Class	70	Y	A	E	B	F	H	200	220	250
Tmax in °C	70	90	105	120	130	155	180	200	220	250
Tmax in °F	158	194	221	248	266	311	356	392	428	482

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Additional information about the models

Stator thermal model (continued)

Metal frame thermal capacity used

Having used β to designate the ratio $\frac{\tau_{long}}{\tau_{long} - \tau_{short}}$

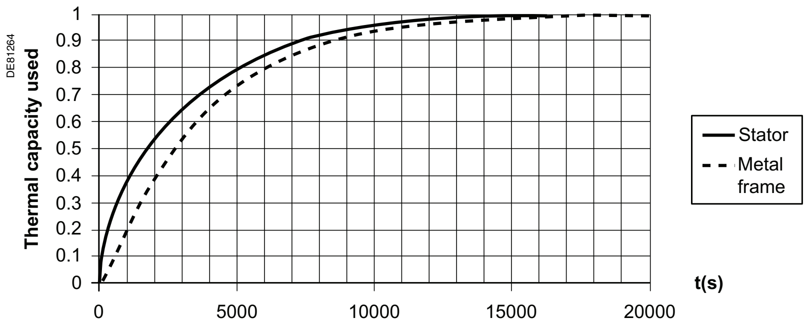
the motor metal frame relative thermal capacity used M transfer function is expressed as follows:

$$M(p) = \left[\frac{(1-\beta)}{(1+p\tau_{short})} + \frac{\beta}{(1+p\tau_{long})}\right]$$

where $\beta > 1$.

Example: Starting with a zero initial thermal capacity used and applying a current the same as the rated current Ib, the stator and metal frame relative thermal capacity used reach 100 %.

Initially, the metal frame thermal capacity used has a zero slope, until the heat transfer is established between the stator and the metal frame.



Stator and metal frame thermal capacity used for a load current Ib.

The metal frame relative thermal capacity used is used to:
- adapt the rotor protection rotor limit time
- define the hot state of the motor.

Cooling time constant

When the current Ieq is less than 5 % of Ib, the motor is deemed to have stopped. In this case it is the cooling time constant τcool of the metal frame that is taken into account to estimate stator cooling.

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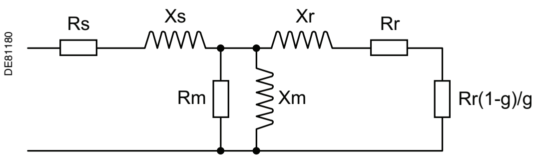
Additional information about the models



Steinmetz diagram.

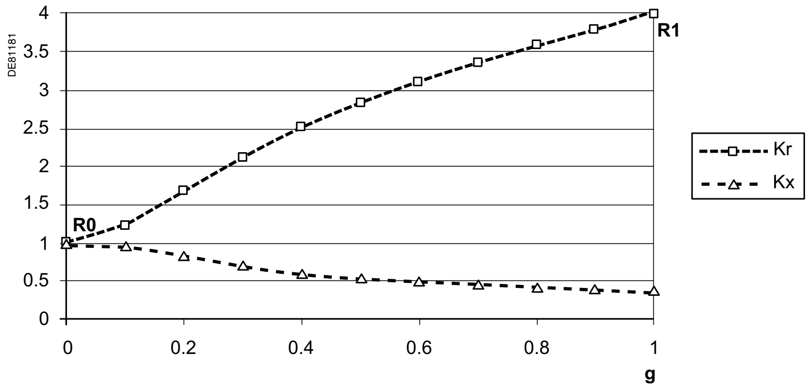
Rs: stator resistance
Xs: stator reactance
Rr: rotor resistance
Xr: rotor reactance
Rm: magnetic loss
Xm: magnetizing reactance
g: slip

Rotor thermal model

For the rotor, guide IEEE C37.96-2000 on protection of asynchronous motors defines an adiabatic thermal model, dependent on the slip, which is based on the equivalent Steinmetz diagram.

During the asynchronous motor starting phase, rotoric currents travel across the rotor conductors to a depth that depends on the slip.
Therefore the rotor inductance Xr and the rotor resistance Rr vary as a function of the slip g as follows:
Rr = Kr g + Ro
Xr = Kx g + Xo

Kr: coefficient taking account of the increase in the rotor resistance
Kx: coefficient taking account of the decrease in the rotor reactance



Coefficients Kr and Kx as a function of the slip.

Assuming that the positive sequence rotor resistance Rr+ varies almost linearly between Ro and R1:

$$R_{r+} = (R_1 - R_0) \cdot g + R_0$$

The proportion of negative sequence current can be high during the motor starting phase. As a result the negative sequence rotor resistance Rr- is high in order to evaluate the rotor thermal capacity used.
It is obtained by replacing the slip g with the negative slip sequence (2 - g).
Thus:

$$R_{r-} = (R_1 - R_0) \cdot (2 - g) + R_0$$

The thermal model used in the Sepam relay measures the active part of the positive sequence impedance during the motor starting phase to evaluate the slip g.

Depending on the motor status, the positive and negative sequence rotor resistances are as follows:

Motor status	R_{r+}	R_{r-}
Stop (g=1)	R_1	R_1
Rated speed (g ≈ 0)	R_0	$2 R_1 - R_0$

3

Rotor thermal model (continued)

The mechanical power developed by the motor equals the electrical power drawn in the resistance Rr (1 - g) / g.
The torque Q equals:

$$Q = \frac{P}{w} = \frac{P}{1-g} = \frac{\frac{R_r(g) \cdot (1-g)}{g} \cdot I_L^2}{1-g} = I_L^2 \cdot \frac{R_r(g)}{g}$$

Thus:

$$R_r(g) = \frac{Q}{I_L^2} \cdot g$$

When the motor has stopped, g = 1. We can therefore deduce that:

$$R_1 = \frac{LRT}{I_L^2} \quad \text{(in pu of Zn)}$$

Where LRT: locked rotor torque in pu of the rated torque
I_L: locked rotor current in pu of Ib

When the motor is at rated speed, the torque Q equals the rated torque Qn and the current equals the rated current In, thus $R_0 = g_n$ (in pu of Zn).
Where:

$$Zn = \frac{Un}{\sqrt{3}Ib}$$

g_n: rated slip

When the motor is at its rated speed of rotation, the ratio between the positive and negative sequence resistances is:

$$2\frac{R_1}{R_0} - 1 = 2\frac{LRT}{g_n \cdot I_L^2} - 1$$

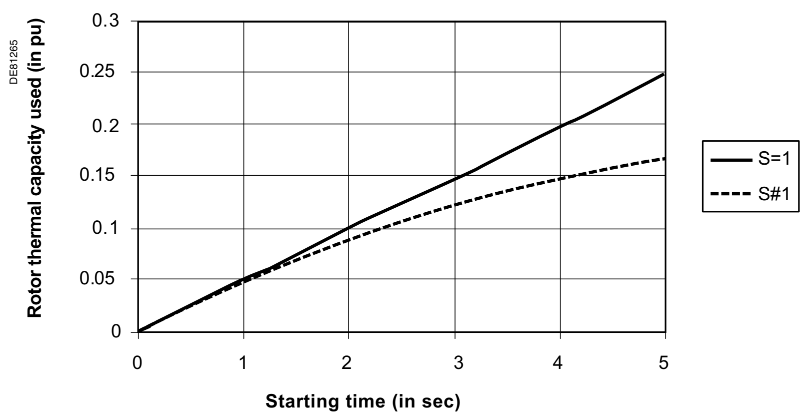
During the starting phase the rotor thermal capacity used W is defined by the following expression:

$$W_n = W_{n-1} + \left[\frac{R_{r+}}{R_1}\left(\frac{Id}{I_L}\right)^2 + \frac{R_{r-}}{R_1}\left(\frac{Ii}{I_L}\right)^2\right] \cdot \frac{dt}{T(M)}$$

Where T(M): locked rotor limit time depends on the thermal state of the motor M:
T(M) = Tc - (Tc - Th) x M, where 0 ≤M ≤1.
Tc: locked cold rotor limit time at the starting current I_L
Th: locked hot rotor limit time at the starting current I_L.

Example for a motor whose starting time is 5 s and the locked cold rotor limit time is 20 s.

- When the rotor is locked, the slip g = 1, as a result Rr+ = R1. Thus the thermal capacity used is 5/20 = 25 %.
- When the slip g changes from 1 to 0 in 5 s, the rotor thermal capacity used is 17 %.



Comparison of the rotor thermal capacity used during normal starting with locked rotor.

Thermal overload for machines
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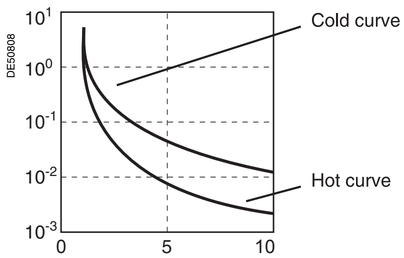
Protection of equipment against thermal damage caused by overloads.

Description

This function is used to protect equipment (motors, transformers, generators) against overloads, based on measurement of the current drawn.

Operation curve

The protection issues a trip order when the heat rise E, calculated according to the measurement of an equivalent current Ieq, is greater than the set point Es.
The greatest permissible continuous current is
$I = Ib\sqrt{Es}$
The protection tripping time is set by the time constant T.
- the calculated heat rise depends on the current drawn and the previous heat rise
- the cold curve defines the protection tripping time based on zero heat rise
- the hot curve defines the protection tripping time based on 100 % rated heat rise.



$$\frac{t}{T} = \ln\frac{\left(\frac{Ieq}{Ib}\right)^2}{\left(\frac{Ieq}{Ib}\right)^2 - Es}$$

$$\frac{t}{T} = \ln\frac{\left(\frac{Ieq}{Ib}\right)^2 - 1}{\left(\frac{Ieq}{Ib}\right)^2 - Es}$$

In: natural logarithm.

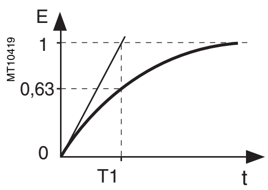
Alarm set point, tripping set point

Two set points are available for heat rise:
- Es1: alarm
- Es2: tripping.

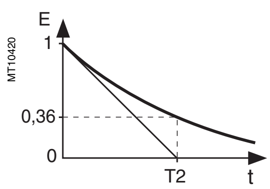
"Hot state" set point

When the function is used to protect a motor, this fixed set point is designed for detection of the hot state used by the number of starts function. The value of the fixed set point is 50 %.

Heat rise and cooling time constants



Heat rise time constant.



Cooling time constant.

For self-ventilated rotating machines, cooling is more effective when the machine is running than when it is stopped. Running and stopping of the equipment are calculated based on the value of the current:
- running if I > 0.1 Ib
- stopped if I < 0.1 Ib.

Two time constants may be set:
- T1: heat rise time constant: concerns equipment that is running
- T2: cooling time constant: concerns equipment that is stopped.

Taking into account harmonics

The current measured by the thermal protection is an RMS 3-phase current which takes into account harmonics up to number 13.

Thermal overload for machines
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Taking into account ambient temperature

Most machines are designed to operate at a maximum ambient temperature of 40°C (104°F). The thermal overload function takes into account the ambient temperature (Sepam equipped with the temperature sensor option (1)) to increase the calculated heat rise value when the temperature measured exceeds 40°C (104°F).

Increase factor: $fa = \frac{Tmax - 40° C}{Tmax - Tambiant}$

where T max is the equipment maximum temperature (according to insulation class)
T ambient is the measured temperature.

Table of insulation classes

Class	Y	A	E	B	F	H	200	220	250
Tmax	90 °C	105 °C	120 °C	130 °C	155 °C	180 °C	200 °C	220 °C	250 °C
Tmax	194 °F	221 °F	248 °F	266 °F	311 °F	356 °F	392 °F	428 °F	482 °F

Reference IEC 60085 (1984).

Adaptation of the protection to motor thermal withstand

Motor thermal protection is often set based on the hot and cold curves supplied by the machine manufacturer.

To fully comply with these experimental curves, additional parameters must be set:

■ initial heat rise, Es0, is used to reduce the cold tripping time.

modified cold curve: $\frac{t}{T} = \ln \frac{\left(\frac{Ieq}{Ib}\right)^2 - Es0}{\left(\frac{Ieq}{Ib}\right)^2 - Es}$ where ln: natural logarithm

■ a second group of parameters (time constants and set points) is used to take into account thermal withstand with locked rotors. This second set of parameters is taken into account when the current is greater than an adjustable set point Is.

Taking into account the negative sequence component

In the case of motors with coiled rotors, the presence of a negative sequence component increases the heat rise in the motor. The negative sequence component of the current is taken into account in the protection function by the equation.

$Ieq = \sqrt{Iph^2 + K \times Ii^2}$ where Iph is the largest phase current
Ii is the negative sequence component of the current
K is a adjustable coefficient

K may have the following values: 0 - 2.25 - 4.5 - 9

For an asynchronous motor, K is determined as follows:

$K = 2 \times \frac{Cd}{Cn} \times \frac{1}{g \times \left(\frac{Id}{Ib}\right)^2} - 1$ where Cn, Cd: rated torque and starting torque
Ib, Id: base current and starting current
g: rated slip

Learning of the cooling time constant T2

The time constant T2 may be learnt according to the temperatures measured in the equipment by temperature sensors connected to the MET148-2 module number 1.

T2 is estimated:

■ after a heating/cooling sequence:
□ heating period detected by ES > 70 %
□ followed by a shutdown detected by Ieq < 10 % of Ib
■ when the machine temperature is measured by RTDs connected to MET148-2 module number 1:
□ RTD 1, 2 or 3 assigned to motor/generator stator temperature measurement
□ RTD 1, 3 or 5 assigned to transformer temperature measurement.

After each new heating/cooling sequence is detected, a new T2 value is estimated.

Following estimation, T2 can be used in two manners:

■ automatically, in which case each new calculated value updates the T2 constant used
■ or manually by entering the value for the T2 parameter.

Measurement accuracy may be improved by using RTD 8 to measure the ambient temperature.

Because the function has two operating modes, a time constant is estimated for each mode.

For generator-transformer unit or motor-transformer unit applications, it is advised to connect the rotating machine RTDs to MET148-2 module number 1 to take advantage of T2 learning on the rotating machine rather than on the transformer.

Start inhibit
The thermal overload protection can inhibit the closing of the motor control device until the heat rise drops back down below a value that allows restarting.
This value takes into account the heat rise produced by the motor when starting.
The inhibition function is grouped together with the **starts per hour** protection function and the indication START INHIBIT informs the user.

Saving the heat rise information
The current heat rise is saved in the event of an auxiliary power failure.

Inhibition of tripping
Tripping of the thermal overload protection may be inhibited by the logic input "Inhibit thermal overload" when required by the process.

Use of two operating modes
The thermal overload protection function may be used to protect equipment with two operating modes, for example:
- transformers with two ventilation modes, with or without forced ventilation (ONAN / ONAF)
- two-speed motors.

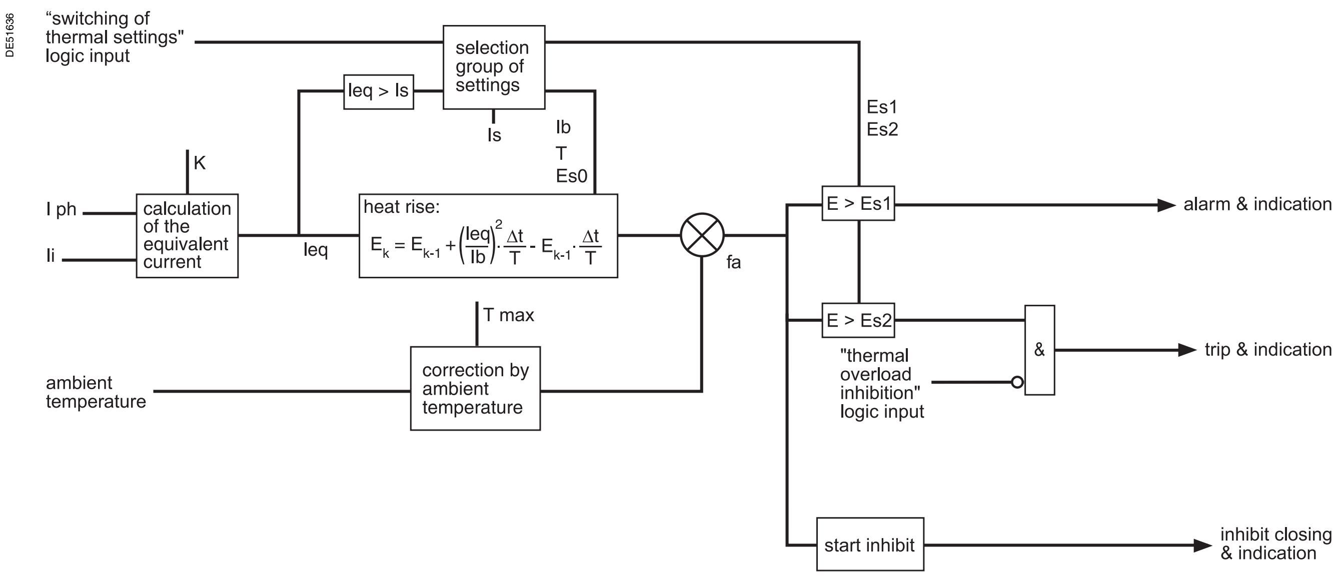
The protection function comprises two groups of settings, and each group is suitable for equipment protection in one of the two operating modes.
Switching from one group of thermal settings to the other is done without losing the heat rise information. It is controlled:
- either via a logic input, assigned to the "switching of thermal settings" function
- or when the phase current reaches an adjustable Is set point (to be used for switching of thermal settings of a motor with locked rotor).

The base current of the equipment, used to calculate heat rise, also depends on the operating mode:
- for logic input switching in mode 2, the base current Ib-mode 2, a specific thermal overload protection setting, is used to calculate the heat rise in the equipment
- in all other cases, the base current Ib, defined as a general Sepam parameter, is used to calculate the heat rise in the equipment.

User information
The following information is available for the user:
- heat rise
- learnt cooling time constant T2
- time before restart enabled (in case of inhibition of starting)
- time before tripping (with constant current).

See the section on measurement and machine operation assistance functions.

Block diagram



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Characteristics

Settings	
Measurement origin	
Setting range	I1, I2, I3 / I'1, I'2, I'3
Taking into account the negative sequence component K	
Setting range	0 - 2.25 - 4.59 - 9
Taking into account ambient temperature	
Setting range	Yes / no
Using the learnt cooling time constant T2	
Setting range	Yes / no
Maximum equipment temperature Tmax (according to insulation class)	
Setting range	60 °C to 200 °C or 140 °F to 392 °F
Resolution	1°C or 1°F
Thermal mode 1	
Alarm set point Es1	
Setting range	0 % to 300 %
Accuracy (1)	±2 %
Resolution	1 %
Tripping set point Es2	
Setting range	0 % to 300 %
Accuracy (1)	±2 %
Resolution	1 %
Initial heat rise set point Es0	
Setting range	0 % to 100 %
Accuracy (1)	±2 %
Resolution	1 %
Heat rise time constant T1	
Setting range	1 min. to 600 min.
Resolution	1 min.
Cooling time constant T2	
Setting range	5 min. to 600 min.
Resolution	1 min.
Thermal mode 2	
Using thermal mode 2	
Setting range	Yes / no
Alarm set point Es1	
Setting range	0 % to 300 %
Accuracy (1)	±2 %
Resolution	1 %
Tripping set point Es2	
Setting range	0 % to 300 %
Accuracy (1)	±2 %
Resolution	1 %
Initial heat rise set point Es0	
Setting range	0 % to 100 %
Accuracy (1)	±2 %
Resolution	1 %
Heat rise time constant T1	
Setting range	1 min. to 600 min.
Resolution	1 min.
Cooling time constant T2	
Setting range	5 min. to 600 min.
Resolution	1 min.
Switching set point for thermal mode 2	
Setting range	25 % to 800 % of Ib
Accuracy (1)	±5 %
Resolution	1 %
Base current Ib - mode 2	
Setting range	0.2 to 2.6 In or I'n
Accuracy (1)	±5 %
Resolution	1 A
Characteristic times (1)	
Operation time accuracy	±2 % or ±1 s

***(1)** Under reference conditions (IEC 60255-8).*

Inputs			
Designation	**Syntax**	**Equations**	**Logipam**
Protection reset	P49RMS_1_101	■	■
Protection inhibition	P49RMS_1_113	■	■

Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Delayed output	P49RMS_1_3	■	■	■
Alarm	P49RMS_1_10	■	■	■
Inhibit closing	P49RMS_1_11	■	■	■
Protection inhibited	P49RMS_1_16	■	■	
Hot state	P49RMS_1_18	■	■	
Inhibit thermal overload	P49RMS_1_32	■	■	

Example 1: motor

The following data are available:

- time constants for on operation T1 and off operation T2:
  - T1 = 25 min.
  - T2 = 70 min.
- maximum steady state current: Imax/Ib = 1.05.

Setting of tripping set point Es2

$Es2 = (Imax/Ib)^2 = 110$ %

Note. If the motor draws a current of 1.05 Ib continuously, the heat rise calculated by the thermal overload protection will reach 110 %.

Setting of alarm set point Es1

Es1 = 90 % (I/Ib = 0.95).

Knegative: 4.5 (usual value)

The other thermal overload parameters do not need to be set. They are not taken into account by default.

Example 2: motor

The following data are available:

- motor thermal withstand in the form of hot and cold curves (see solid line curves in Figure 1)
- cooling time constant T2
- maximum steady state current: Imax/Ib = 1.05.

Setting of tripping set point Es2

$Es2 = (Imax/Ib)^2 = 110$ %

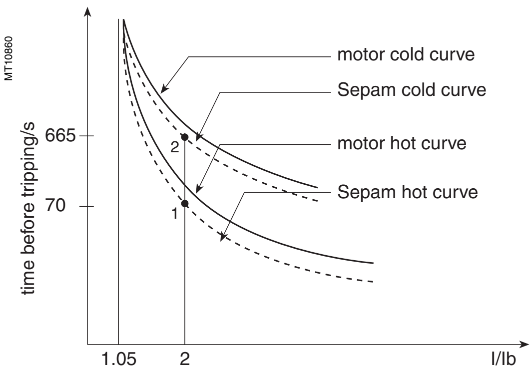
Setting of alarm set point Es1:

Es1 = 90 % (I/Ib = 0.95).

The manufacturer's hot/cold curves (1) may be used to determine the heating time constant T1.

The method consists of placing the Sepam hot/cold curves below those of the motor.

Figure 1. Motor thermal withstand and thermal overload tripping curves.



For an overload of 2Ib, the value t/T1 = 0.0339 (2).

In order for Sepam to trip at point 1 (t = 70 s), T1 is equal to 2065 sec ≈ 34 min.

With a setting of T1 = 34 min., the tripping time is obtained based on a cold state (point 2). In this case, it is equal to t/T1 = 0.3216 ⇒t = 665 sec, i.e. ≈ 11 min., which is compatible with the motor thermal withstand when it is cold.

The negative sequence factor K is calculated using the equation defined on page 154.

The parameters of the 2nd thermal overload relay do not need to be set.

They are not taken into account by default.

Example 3: motor

The following data are available:

- motor thermal withstand in the form of hot and cold curves (see solid line curves in Figure 2)
- cooling time constant T2
- maximum steady state current: Imax/Ib = 1.1.

The thermal overload parameters are determined in the same way as in the previous example.

Setting of tripping set point Es2

$Es2 = (Imax/Ib)^2 = 120$ %

Setting of alarm set point Es1

Es1 = 90 % (I/Ib = 0.95).

The time constant T1 is calculated so that the thermal overload protection trips after 100 seconds (point 1).

With t/T1 = 0.069 (I/Ib = 2 and Es2 = 120 %):

⇒T1 = 100 sec / 0.069 = 1449 sec ≈ 24 min.

The tripping time starting from the cold state is equal to:

t/T1 = 0.3567 ⇒t = 24 min. x 0.3567 = 513 sec (point 2').

This tripping time is too long since the limit for this overload current is 400 sec (point 2).

If the time constant T1 is lowered, the thermal overload protection will trip earlier, below point 2.

The risk that motor starting when hot will not be possible also exists in this case (see Figure 2 in which a lower Sepam hot curve would intersect the starting curve with U = 0.9 Un).

The **Es0 parameter** is a setting that is used to solve these differences by lowering the Sepam cold curve without moving the hot curve.

In this example, the thermal overload protection should trip after 400 sec starting from the cold state.

The following equation is used to obtain the Es0 value:

$$Es0 = \left[\frac{I_{processed}}{I_b}\right]^2 - e^{\frac{t_{necessary}}{T_1}} \times \left[\left[\frac{I_{processed}}{I_b}\right]^2 - Es2\right]$$

where:

$t_{necessary}$: tripping time necessary starting from a cold state.

$I_{processed}$: equipment current.

(1) When the machine manufacturer provides both a time constant T1 and the machine hot/cold curves, the use of the curves is recommended since they are more accurate.

(2) It is possible to use the charts containing the numerical values of the Sepam hot curve or the equation of the curve which is given on page 153.

In numerical values, the following is obtained:

$$\mathbf{Es0} = \mathbf{4} - \mathbf{e}^{\frac{400\ s}{24 \times 60\ s}} \times \left[\mathbf{4} - (\mathbf{1.2})\right] = \mathbf{0.3035} \approx (\mathbf{31\ \%})$$

By setting Es0 = 31 %, point 2' is moved downward to obtain a shorter tripping time that is compatible with the motor thermal withstand when cold (see Figure 3).
Note. A setting Es0 = 100 % therefore means that the hot and cold curves are the same.

Figure 2. Hot/cold curves not compatible with the motor thermal withstand.

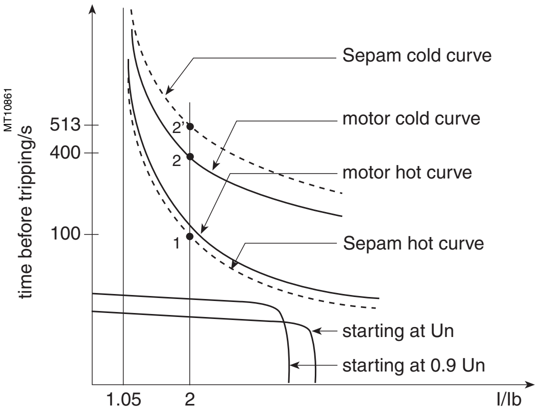
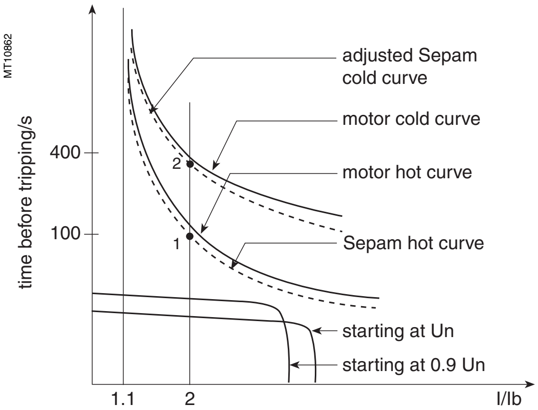
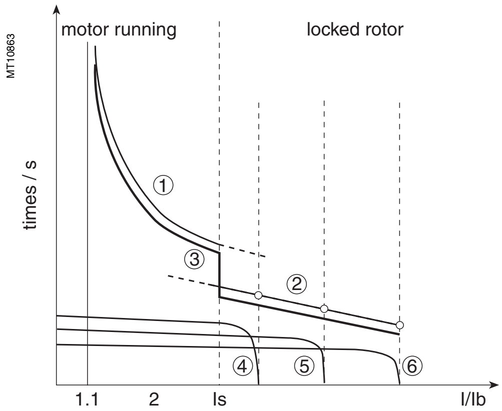


Figure 3. Hot/cold curves compatible with the motor thermal withstand via the setting of an initial heat rise Es0.



Use of the additional setting group
When a motor rotor is locked or is turning very slowly, its thermal behavior is different from that with the rated load.
In such conditions, the motor is damaged by overheating of the rotor or stator. For high power motors, rotor overheating is most often a limiting factor.
The thermal overload parameters chosen for operation with a low overload are no longer valid.
In order to protect the motor in this case, "excessive starting time" protection may be used.
Nevertheless, motor manufacturers provide the thermal withstand curves when the rotor is locked, for different voltages at the time of starting.

Figure 4. Locked rotor thermal withstand.



1. thermal withstand, motor running
2. thermal withstand, motor stopped
3. Sepam tripping curve
4. starting at 65 % Un
5. starting at 80 % Un
6. starting at 100 % Un

In order to take these curves into account, the 2nd thermal overload relay may be used.
The time constant in this case is, in theory, shorter, however, it should be determined in the same way as that of the 1st relay.
The thermal overload protection switches between the first and second relay if the equivalent current Ieq exceeds the Is value (set point current).

Example 4. transformer with 2 ventilation modes

The following data are available:
The rated current of a transformer with 2 ventilation modes is:
- Ib = 200 A without forced ventilation (ONAN mode), the main operating mode of the transformer
- Ib = 240 A with forced ventilation (ONAF mode), a temporary operating mode, to have 20 % more power available

Setting of the base current for ventilation operating mode 1: Ib = 200 A
(to be set in the Sepam general parameters).
Setting of the base current for ventilation operating mode 2: Ib2 = 240 A
(to be set among the specific thermal overload protection settings).
Switching of thermal settings via logic input, to be assigned to the "switching of thermal settings" function and to be connected to the transformer ventilation control unit.
The settings related to each ventilation operating mode (Es set points, time constants, etc.) are to be determined according to the transformer characteristics provided by the manufacturer.

Thermal overload for machines
ANSI code 49RMS
Tripping curves

Cold curves for Es0 = 0 %

I/Ib Es (%)	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50	1.55	1.60	1.65	1.70	1.75	1.80
50	0.6931	0.6042	0.5331	0.4749	0.4265	0.3857	0.3508	0.3207	0.2945	0.2716	0.2513	0.2333	0.2173	0.2029	0.1900	0.1782	0.1676
55	0.7985	0.6909	0.6061	0.5376	0.4812	0.4339	0.3937	0.3592	0.3294	0.3033	0.2803	0.2600	0.2419	0.2257	0.2111	0.1980	0.1860
60	0.9163	0.7857	0.6849	0.6046	0.5390	0.4845	0.4386	0.3993	0.3655	0.3360	0.3102	0.2873	0.2671	0.2490	0.2327	0.2181	0.2048
65	1.0498	0.8905	0.7704	0.6763	0.6004	0.5379	0.4855	0.4411	0.4029	0.3698	0.3409	0.3155	0.2929	0.2728	0.2548	0.2386	0.2239
70	1.2040	1.0076	0.8640	0.7535	0.6657	0.5942	0.5348	0.4847	0.4418	0.4049	0.3727	0.3444	0.3194	0.2972	0.2774	0.2595	0.2434
75	1.3863	1.1403	0.9671	0.8373	0.7357	0.6539	0.5866	0.5302	0.4823	0.4412	0.4055	0.3742	0.3467	0.3222	0.3005	0.2809	0.2633
80	1.6094	1.2933	1.0822	0.9287	0.8109	0.7174	0.6413	0.5780	0.5245	0.4788	0.4394	0.4049	0.3747	0.3479	0.3241	0.3028	0.2836
85	1.8971	1.4739	1.2123	1.0292	0.8923	0.7853	0.6991	0.6281	0.5686	0.5180	0.4745	0.4366	0.4035	0.3743	0.3483	0.3251	0.3043
90	2.3026	1.6946	1.3618	1.1411	0.9808	0.8580	0.7605	0.6809	0.6147	0.5587	0.5108	0.4694	0.4332	0.4013	0.3731	0.3480	0.3254
95		1.9782	1.5377	1.2670	1.0780	0.9365	0.8258	0.7366	0.6630	0.6012	0.5486	0.5032	0.4638	0.4292	0.3986	0.3714	0.3470
100		2.3755	1.7513	1.4112	1.1856	1.0217	0.8958	0.7956	0.7138	0.6455	0.5878	0.5383	0.4953	0.4578	0.4247	0.3953	0.3691
105		3.0445	2.0232	1.5796	1.3063	1.1147	0.9710	0.8583	0.7673	0.6920	0.6286	0.5746	0.5279	0.4872	0.4515	0.4199	0.3917
110			2.3979	1.7824	1.4435	1.2174	1.0524	0.9252	0.8238	0.7406	0.6712	0.6122	0.5616	0.5176	0.4790	0.4450	0.4148
115			3.0040	2.0369	1.6025	1.3318	1.1409	0.9970	0.8837	0.7918	0.7156	0.6514	0.5964	0.5489	0.5074	0.4708	0.4384
120				2.3792	1.7918	1.4610	1.2381	1.0742	0.9474	0.8457	0.7621	0.6921	0.6325	0.5812	0.5365	0.4973	0.4626
125				2.9037	2.0254	1.6094	1.3457	1.1580	1.0154	0.9027	0.8109	0.7346	0.6700	0.6146	0.5666	0.5245	0.4874
130					2.3308	1.7838	1.4663	1.2493	1.0885	0.9632	0.8622	0.7789	0.7089	0.6491	0.5975	0.5525	0.5129
135					2.7726	1.9951	1.6035	1.3499	1.1672	1.0275	0.9163	0.8253	0.7494	0.6849	0.6295	0.5813	0.5390
140						2.2634	1.7626	1.4618	1.2528	1.0962	0.9734	0.8740	0.7916	0.7220	0.6625	0.6109	0.5658
145						2.6311	1.9518	1.5877	1.3463	1.1701	1.0341	0.9252	0.8356	0.7606	0.6966	0.6414	0.5934
150						3.2189	2.1855	1.7319	1.4495	1.2498	1.0986	0.9791	0.8817	0.8007	0.7320	0.6729	0.6217
155							2.4908	1.9003	1.5645	1.3364	1.1676	1.0361	0.9301	0.8424	0.7686	0.7055	0.6508
160							2.9327	2.1030	1.6946	1.4313	1.2417	1.0965	0.9808	0.8860	0.8066	0.7391	0.6809
165								2.3576	1.8441	1.5361	1.3218	1.1609	1.0343	0.9316	0.8461	0.7739	0.7118
170								2.6999	2.0200	1.6532	1.4088	1.2296	1.0908	0.9793	0.8873	0.8099	0.7438
175								3.2244	2.2336	1.7858	1.5041	1.3035	1.1507	1.0294	0.9302	0.8473	0.7768
180									2.5055	1.9388	1.6094	1.3832	1.2144	1.0822	0.9751	0.8861	0.8109
185									2.8802	2.1195	1.7272	1.4698	1.2825	1.1379	1.0220	0.9265	0.8463
190									3.4864	2.3401	1.8608	1.5647	1.3555	1.1970	1.0713	0.9687	0.8829
195										2.6237	2.0149	1.6695	1.4343	1.2597	1.1231	1.0126	0.9209
200										3.0210	2.1972	1.7866	1.5198	1.3266	1.1778	1.0586	0.9605

Cold curves for Es0 = 0 %

I/Ib Es (%)	1.85	1.90	1.95	2.00	2.20	2.40	2.60	2.80	3.00	3.20	3.40	3.60	3.80	4.00	4.20	4.40	4.60
50	0.1579	0.1491	0.1410	0.1335	0.1090	0.0908	0.0768	0.0659	0.0572	0.0501	0.0442	0.0393	0.0352	0.0317	0.0288	0.0262	0.0239
55	0.1752	0.1653	0.1562	0.1479	0.1206	0.1004	0.0849	0.0727	0.0631	0.0552	0.0487	0.0434	0.0388	0.0350	0.0317	0.0288	0.0263
60	0.1927	0.1818	0.1717	0.1625	0.1324	0.1100	0.0929	0.0796	0.069	0.0604	0.0533	0.0474	0.0424	0.0382	0.0346	0.0315	0.0288
65	0.2106	0.1985	0.1875	0.1773	0.1442	0.1197	0.1011	0.0865	0.075	0.0656	0.0579	0.0515	0.0461	0.0415	0.0375	0.0342	0.0312
70	0.2288	0.2156	0.2035	0.1924	0.1562	0.1296	0.1093	0.0935	0.081	0.0708	0.0625	0.0555	0.0497	0.0447	0.0405	0.0368	0.0336
75	0.2474	0.2329	0.2197	0.2076	0.1684	0.1395	0.1176	0.1006	0.087	0.0761	0.0671	0.0596	0.0533	0.0480	0.0434	0.0395	0.0361
80	0.2662	0.2505	0.2362	0.2231	0.1807	0.1495	0.1260	0.1076	0.0931	0.0813	0.0717	0.0637	0.0570	0.0513	0.0464	0.0422	0.0385
85	0.2855	0.2685	0.2530	0.2389	0.1931	0.1597	0.1344	0.1148	0.0992	0.0867	0.0764	0.0678	0.0607	0.0546	0.0494	0.0449	0.0410
90	0.3051	0.2868	0.2701	0.2549	0.2057	0.1699	0.1429	0.1219	0.1054	0.092	0.0811	0.0720	0.0644	0.0579	0.0524	0.0476	0.0435
95	0.3251	0.3054	0.2875	0.2712	0.2185	0.1802	0.1514	0.1292	0.1116	0.0974	0.0858	0.0761	0.0681	0.0612	0.0554	0.0503	0.0459
100	0.3456	0.3244	0.3051	0.2877	0.2314	0.1907	0.1601	0.1365	0.1178	0.1028	0.0905	0.0803	0.0718	0.0645	0.0584	0.0530	0.0484
105	0.3664	0.3437	0.3231	0.3045	0.2445	0.2012	0.1688	0.1438	0.1241	0.1082	0.0952	0.0845	0.0755	0.0679	0.0614	0.0558	0.0509
110	0.3877	0.3634	0.3415	0.3216	0.2578	0.2119	0.1776	0.1512	0.1304	0.1136	0.1000	0.0887	0.0792	0.0712	0.0644	0.0585	0.0534
115	0.4095	0.3835	0.3602	0.3390	0.2713	0.2227	0.1865	0.1586	0.1367	0.1191	0.1048	0.0929	0.0830	0.0746	0.0674	0.0612	0.0559
120	0.4317	0.4041	0.3792	0.3567	0.2849	0.2336	0.1954	0.1661	0.1431	0.1246	0.1096	0.0972	0.0868	0.0780	0.0705	0.0640	0.0584
125	0.4545	0.4250	0.3986	0.3747	0.2988	0.2446	0.2045	0.1737	0.1495	0.1302	0.1144	0.1014	0.0905	0.0813	0.0735	0.0667	0.0609
130	0.4778	0.4465	0.4184	0.3930	0.3128	0.2558	0.2136	0.1813	0.156	0.1358	0.1193	0.1057	0.0943	0.0847	0.0766	0.0695	0.0634
135	0.5016	0.4683	0.4386	0.4117	0.3270	0.2671	0.2228	0.1890	0.1625	0.1414	0.1242	0.1100	0.0982	0.0881	0.0796	0.0723	0.0659
140	0.5260	0.4907	0.4591	0.4308	0.3414	0.2785	0.2321	0.1967	0.1691	0.147	0.1291	0.1143	0.1020	0.0916	0.0827	0.0751	0.0685
145	0.5511	0.5136	0.4802	0.4502	0.3561	0.2900	0.2414	0.2045	0.1757	0.1527	0.1340	0.1187	0.1058	0.0950	0.0858	0.0778	0.0710
150	0.5767	0.5370	0.5017	0.4700	0.3709	0.3017	0.2509	0.2124	0.1823	0.1584	0.1390	0.1230	0.1097	0.0984	0.0889	0.0806	0.0735
155	0.6031	0.5610	0.5236	0.4902	0.3860	0.3135	0.2604	0.2203	0.189	0.1641	0.1440	0.1274	0.1136	0.1019	0.0920	0.0834	0.0761
160	0.6302	0.5856	0.5461	0.5108	0.4013	0.3254	0.2701	0.2283	0.1957	0.1699	0.1490	0.1318	0.1174	0.1054	0.0951	0.0863	0.0786
165	0.6580	0.6108	0.5690	0.5319	0.4169	0.3375	0.2798	0.2363	0.2025	0.1757	0.1540	0.1362	0.1213	0.1088	0.0982	0.0891	0.0812
170	0.6866	0.6366	0.5925	0.5534	0.4327	0.3498	0.2897	0.2444	0.2094	0.1815	0.1591	0.1406	0.1253	0.1123	0.1013	0.0919	0.0838
175	0.7161	0.6631	0.6166	0.5754	0.4487	0.3621	0.2996	0.2526	0.2162	0.1874	0.1641	0.1451	0.1292	0.1158	0.1045	0.0947	0.0863
180	0.7464	0.6904	0.6413	0.5978	0.4651	0.3747	0.3096	0.2608	0.2231	0.1933	0.1693	0.1495	0.1331	0.1193	0.1076	0.0976	0.0889
185	0.7777	0.7184	0.6665	0.6208	0.4816	0.3874	0.3197	0.2691	0.2301	0.1993	0.1744	0.1540	0.1371	0.1229	0.1108	0.1004	0.0915
190	0.8100	0.7472	0.6925	0.6444	0.4985	0.4003	0.3300	0.2775	0.2371	0.2052	0.1796	0.1585	0.1411	0.1264	0.1140	0.1033	0.0941
195	0.8434	0.7769	0.7191	0.6685	0.5157	0.4133	0.3403	0.2860	0.2442	0.2113	0.1847	0.1631	0.1451	0.1300	0.1171	0.1062	0.0967
200	0.8780	0.8075	0.7465	0.6931	0.5331	0.4265	0.3508	0.2945	0.2513	0.2173	0.1900	0.1676	0.1491	0.1335	0.1203	0.1090	0.0993

Thermal overload for machines
ANSI code 49RMS
Tripping curves

Cold curves for Es0 = 0 %

I/Ib	4.80	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	12.50	15.00	17.50	20.00
Es (%)																
50	0.0219	0.0202	0.0167	0.0140	0.0119	0.0103	0.0089	0.0078	0.0069	0.0062	0.0056	0.0050	0.0032	0.0022	0.0016	0.0013
55	0.0242	0.0222	0.0183	0.0154	0.0131	0.0113	0.0098	0.0086	0.0076	0.0068	0.0061	0.0055	0.0035	0.0024	0.0018	0.0014
60	0.0264	0.0243	0.0200	0.0168	0.0143	0.0123	0.0107	0.0094	0.0083	0.0074	0.0067	0.0060	0.0038	0.0027	0.0020	0.0015
65	0.0286	0.0263	0.0217	0.0182	0.0155	0.0134	0.0116	0.0102	0.0090	0.0081	0.0072	0.0065	0.0042	0.0029	0.0021	0.0016
70	0.0309	0.0284	0.0234	0.0196	0.0167	0.0144	0.0125	0.0110	0.0097	0.0087	0.0078	0.0070	0.0045	0.0031	0.0023	0.0018
75	0.0331	0.0305	0.0251	0.0211	0.0179	0.0154	0.0134	0.0118	0.0104	0.0093	0.0083	0.0075	0.0048	0.0033	0.0025	0.0019
80	0.0353	0.0325	0.0268	0.0225	0.0191	0.0165	0.0143	0.0126	0.0111	0.0099	0.0089	0.0080	0.0051	0.0036	0.0026	0.0020
85	0.0376	0.0346	0.0285	0.0239	0.0203	0.0175	0.0152	0.0134	0.0118	0.0105	0.0095	0.0085	0.0055	0.0038	0.0028	0.0021
90	0.0398	0.0367	0.0302	0.0253	0.0215	0.0185	0.0161	0.0142	0.0125	0.0112	0.0100	0.0090	0.0058	0.0040	0.0029	0.0023
95	0.0421	0.0387	0.0319	0.0267	0.0227	0.0196	0.0170	0.0150	0.0132	0.0118	0.0106	0.0095	0.0061	0.0042	0.0031	0.0024
100	0.0444	0.0408	0.0336	0.0282	0.0240	0.0206	0.0179	0.0157	0.0139	0.0124	0.0111	0.0101	0.0064	0.0045	0.0033	0.0025
105	0.0466	0.0429	0.0353	0.0296	0.0252	0.0217	0.0188	0.0165	0.0146	0.0130	0.0117	0.0106	0.0067	0.0047	0.0034	0.0026
110	0.0489	0.0450	0.0370	0.0310	0.0264	0.0227	0.0197	0.0173	0.0153	0.0137	0.0123	0.0111	0.0071	0.0049	0.0036	0.0028
115	0.0512	0.0471	0.0388	0.0325	0.0276	0.0237	0.0207	0.0181	0.0160	0.0143	0.0128	0.0116	0.0074	0.0051	0.0038	0.0029
120	0.0535	0.0492	0.0405	0.0339	0.0288	0.0248	0.0216	0.0189	0.0167	0.0149	0.0134	0.0121	0.0077	0.0053	0.0039	0.0030
125	0.0558	0.0513	0.0422	0.0353	0.0300	0.0258	0.0225	0.0197	0.0175	0.0156	0.0139	0.0126	0.0080	0.0056	0.0041	0.0031
130	0.0581	0.0534	0.0439	0.0368	0.0313	0.0269	0.0234	0.0205	0.0182	0.0162	0.0145	0.0131	0.0084	0.0058	0.0043	0.0033
135	0.0604	0.0555	0.0457	0.0382	0.0325	0.0279	0.0243	0.0213	0.0189	0.0168	0.0151	0.0136	0.0087	0.0060	0.0044	0.0034
140	0.0627	0.0576	0.0474	0.0397	0.0337	0.0290	0.0252	0.0221	0.0196	0.0174	0.0156	0.0141	0.0090	0.0062	0.0046	0.0035
145	0.0650	0.0598	0.0491	0.0411	0.0349	0.0300	0.0261	0.0229	0.0203	0.0181	0.0162	0.0146	0.0093	0.0065	0.0047	0.0036
150	0.0673	0.0619	0.0509	0.0426	0.0361	0.0311	0.0270	0.0237	0.0210	0.0187	0.0168	0.0151	0.0096	0.0067	0.0049	0.0038
155	0.0696	0.0640	0.0526	0.0440	0.0374	0.0321	0.0279	0.0245	0.0217	0.0193	0.0173	0.0156	0.0100	0.0069	0.0051	0.0039
160	0.0720	0.0661	0.0543	0.0455	0.0386	0.0332	0.0289	0.0253	0.0224	0.0200	0.0179	0.0161	0.0103	0.0071	0.0052	0.0040
165	0.0743	0.0683	0.0561	0.0469	0.0398	0.0343	0.0298	0.0261	0.0231	0.0206	0.0185	0.0166	0.0106	0.0074	0.0054	0.0041
170	0.0766	0.0704	0.0578	0.0484	0.0411	0.0353	0.0307	0.0269	0.0238	0.0212	0.0190	0.0171	0.0109	0.0076	0.0056	0.0043
175	0.0790	0.0726	0.0596	0.0498	0.0423	0.0364	0.0316	0.0277	0.0245	0.0218	0.0196	0.0177	0.0113	0.0078	0.0057	0.0044
180	0.0813	0.0747	0.0613	0.0513	0.0435	0.0374	0.0325	0.0285	0.0252	0.0225	0.0201	0.0182	0.0116	0.0080	0.0059	0.0045
185	0.0837	0.0769	0.0631	0.0528	0.0448	0.0385	0.0334	0.0293	0.0259	0.0231	0.0207	0.0187	0.0119	0.0083	0.0061	0.0046
190	0.0861	0.0790	0.0649	0.0542	0.0460	0.0395	0.0344	0.0301	0.0266	0.0237	0.0213	0.0192	0.0122	0.0085	0.0062	0.0048
195	0.0884	0.0812	0.0666	0.0557	0.0473	0.0406	0.0353	0.0309	0.0274	0.0244	0.0218	0.0197	0.0126	0.0087	0.0064	0.0049
200	0.0908	0.0834	0.0684	0.0572	0.0485	0.0417	0.0362	0.0317	0.0281	0.0250	0.0224	0.0202	0.0129	0.0089	0.0066	0.0050

Hot curves

I/lb Es (%)	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50	1.55	1.60	1.65	1.70	1.75	1.80
105		0.6690	0.2719	0.1685	0.1206	0.0931	0.0752	0.0627	0.0535	0.0464	0.0408	0.0363	0.0326	0.0295	0.0268	0.0245	0.0226
110		3.7136	0.6466	0.3712	0.2578	0.1957	0.1566	0.1296	0.1100	0.0951	0.0834	0.0740	0.0662	0.0598	0.0544	0.0497	0.0457
115			1.2528	0.6257	0.4169	0.3102	0.2451	0.2013	0.1699	0.1462	0.1278	0.1131	0.1011	0.0911	0.0827	0.0755	0.0693
120			3.0445	0.9680	0.6061	0.4394	0.3423	0.2786	0.2336	0.2002	0.1744	0.1539	0.1372	0.1234	0.1118	0.1020	0.0935
125				1.4925	0.8398	0.5878	0.4499	0.3623	0.3017	0.2572	0.2231	0.1963	0.1747	0.1568	0.1419	0.1292	0.1183
130				2.6626	1.1451	0.7621	0.5705	0.4537	0.3747	0.3176	0.2744	0.2407	0.2136	0.1914	0.1728	0.1572	0.1438
135					1.5870	0.9734	0.7077	0.5543	0.4535	0.3819	0.3285	0.2871	0.2541	0.2271	0.2048	0.1860	0.1699
140					2.3979	1.2417	0.8668	0.6662	0.5390	0.4507	0.3857	0.3358	0.2963	0.2643	0.2378	0.2156	0.1967
145						1.6094	1.0561	0.7921	0.6325	0.5245	0.4463	0.3869	0.3403	0.3028	0.2719	0.2461	0.2243
150						2.1972	1.2897	0.9362	0.7357	0.6042	0.5108	0.4408	0.3864	0.3429	0.3073	0.2776	0.2526
155						3.8067	1.5950	1.1047	0.8508	0.6909	0.5798	0.4978	0.4347	0.3846	0.3439	0.3102	0.2817
160							2.0369	1.3074	0.9808	0.7857	0.6539	0.5583	0.4855	0.4282	0.3819	0.3438	0.3118
165							2.8478	1.5620	1.1304	0.8905	0.7340	0.6226	0.5390	0.4738	0.4215	0.3786	0.3427
170								1.9042	1.3063	1.0076	0.8210	0.6914	0.5955	0.5215	0.4626	0.4146	0.3747
175								2.4288	1.5198	1.1403	0.9163	0.7652	0.6554	0.5717	0.5055	0.4520	0.4077
180								3.5988	1.7918	1.2933	1.0217	0.8449	0.7191	0.6244	0.5504	0.4908	0.4418
185									2.1665	1.4739	1.1394	0.9316	0.7872	0.6802	0.5974	0.5312	0.4772
190									2.7726	1.6946	1.2730	1.0264	0.8602	0.7392	0.6466	0.5733	0.5138
195									4.5643	1.9782	1.4271	1.1312	0.9390	0.8019	0.6985	0.6173	0.5518
200										2.3755	1.6094	1.2483	1.0245	0.8688	0.7531	0.6633	0.5914

I/lb Es (%)	1.85	1.90	1.95	2.00	2.20	2.40	2.60	2.80	3.00	3.20	3.40	3.60	3.80	4.00	4.20	4.40	4.60
105	0.0209	0.0193	0.0180	0.0168	0.0131	0.0106	0.0087	0.0073	0.0063	0.0054	0.0047	0.0042	0.0037	0.0033	0.0030	0.0027	0.0025
110	0.0422	0.0391	0.0363	0.0339	0.0264	0.0212	0.0175	0.0147	0.0126	0.0109	0.0095	0.0084	0.0075	0.0067	0.0060	0.0055	0.0050
115	0.0639	0.0592	0.0550	0.0513	0.0398	0.0320	0.0264	0.0222	0.0189	0.0164	0.0143	0.0126	0.0112	0.0101	0.0091	0.0082	0.0075
120	0.0862	0.0797	0.0740	0.0690	0.0535	0.0429	0.0353	0.0297	0.0253	0.0219	0.0191	0.0169	0.0150	0.0134	0.0121	0.0110	0.0100
125	0.1089	0.1007	0.0934	0.0870	0.0673	0.0540	0.0444	0.0372	0.0317	0.0274	0.0240	0.0211	0.0188	0.0168	0.0151	0.0137	0.0125
130	0.1322	0.1221	0.1132	0.1054	0.0813	0.0651	0.0535	0.0449	0.0382	0.0330	0.0288	0.0254	0.0226	0.0202	0.0182	0.0165	0.0150
135	0.1560	0.1440	0.1334	0.1241	0.0956	0.0764	0.0627	0.0525	0.0447	0.0386	0.0337	0.0297	0.0264	0.0236	0.0213	0.0192	0.0175
140	0.1805	0.1664	0.1540	0.1431	0.1100	0.0878	0.0720	0.0603	0.0513	0.0443	0.0386	0.0340	0.0302	0.0270	0.0243	0.0220	0.0200
145	0.2055	0.1892	0.1750	0.1625	0.1246	0.0993	0.0813	0.0681	0.0579	0.0499	0.0435	0.0384	0.0341	0.0305	0.0274	0.0248	0.0226
150	0.2312	0.2127	0.1965	0.1823	0.1395	0.1110	0.0908	0.0759	0.0645	0.0556	0.0485	0.0427	0.0379	0.0339	0.0305	0.0276	0.0251
155	0.2575	0.2366	0.2185	0.2025	0.1546	0.1228	0.1004	0.0838	0.0712	0.0614	0.0535	0.0471	0.0418	0.0374	0.0336	0.0304	0.0277
160	0.2846	0.2612	0.2409	0.2231	0.1699	0.1347	0.1100	0.0918	0.0780	0.0671	0.0585	0.0515	0.0457	0.0408	0.0367	0.0332	0.0302
165	0.3124	0.2864	0.2639	0.2442	0.1855	0.1468	0.1197	0.0999	0.0847	0.0729	0.0635	0.0559	0.0496	0.0443	0.0398	0.0360	0.0328
170	0.3410	0.3122	0.2874	0.2657	0.2012	0.1591	0.1296	0.1080	0.0916	0.0788	0.0686	0.0603	0.0535	0.0478	0.0430	0.0389	0.0353
175	0.3705	0.3388	0.3115	0.2877	0.2173	0.1715	0.1395	0.1161	0.0984	0.0847	0.0737	0.0648	0.0574	0.0513	0.0461	0.0417	0.0379
180	0.4008	0.3660	0.3361	0.3102	0.2336	0.1840	0.1495	0.1244	0.1054	0.0906	0.0788	0.0692	0.0614	0.0548	0.0493	0.0446	0.0405
185	0.4321	0.3940	0.3614	0.3331	0.2502	0.1967	0.1597	0.1327	0.1123	0.0965	0.0839	0.0737	0.0653	0.0583	0.0524	0.0474	0.0431
190	0.4644	0.4229	0.3873	0.3567	0.2671	0.2096	0.1699	0.1411	0.1193	0.1025	0.0891	0.0782	0.0693	0.0619	0.0556	0.0503	0.0457
195	0.4978	0.4525	0.4140	0.3808	0.2842	0.2226	0.1802	0.1495	0.1264	0.1085	0.0943	0.0828	0.0733	0.0654	0.0588	0.0531	0.0483
200	0.5324	0.4831	0.4413	0.4055	0.3017	0.2358	0.1907	0.1581	0.1335	0.1145	0.0995	0.0873	0.0773	0.0690	0.0620	0.0560	0.0509

Thermal overload for machines
ANSI code 49RMS
Tripping curves

Hot curves

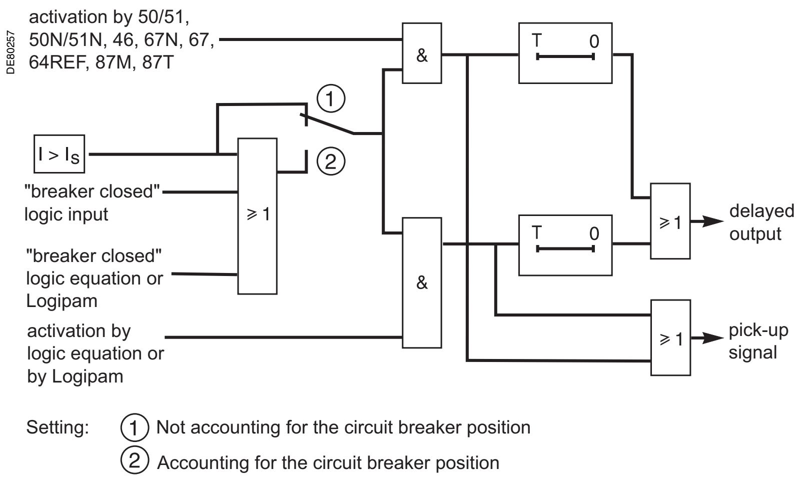
I/Ib Es (%)	4.80	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	12.50	15.00	17.50	20.00
105	0.0023	0.0021	0.0017	0.0014	0.0012	0.0010	0.0009	0.0008	0.0007	0.0006	0.0006	0.0005	0.0003	0.0002	0.0002	0.0001
110	0.0045	0.0042	0.0034	0.0029	0.0024	0.0021	0.0018	0.0016	0.0014	0.0013	0.0011	0.0010	0.0006	0.0004	0.0003	0.0003
115	0.0068	0.0063	0.0051	0.0043	0.0036	0.0031	0.0027	0.0024	0.0021	0.0019	0.0017	0.0015	0.0010	0.0007	0.0005	0.0004
120	0.0091	0.0084	0.0069	0.0057	0.0049	0.0042	0.0036	0.0032	0.0028	0.0025	0.0022	0.0020	0.0013	0.0009	0.0007	0.0005
125	0.0114	0.0105	0.0086	0.0072	0.0061	0.0052	0.0045	0.0040	0.0035	0.0031	0.0028	0.0025	0.0016	0.0011	0.0008	0.0006
130	0.0137	0.0126	0.0103	0.0086	0.0073	0.0063	0.0054	0.0048	0.0042	0.0038	0.0034	0.0030	0.0019	0.0013	0.0010	0.0008
135	0.0160	0.0147	0.0120	0.0101	0.0085	0.0073	0.0064	0.0056	0.0049	0.0044	0.0039	0.0035	0.0023	0.0016	0.0011	0.0009
140	0.0183	0.0168	0.0138	0.0115	0.0097	0.0084	0.0073	0.0064	0.0056	0.0050	0.0045	0.0040	0.0026	0.0018	0.0013	0.0010
145	0.0206	0.0189	0.0155	0.0129	0.0110	0.0094	0.0082	0.0072	0.0063	0.0056	0.0051	0.0046	0.0029	0.0020	0.0015	0.0011
150	0.0229	0.0211	0.0172	0.0144	0.0122	0.0105	0.0091	0.0080	0.0070	0.0063	0.0056	0.0051	0.0032	0.0022	0.0016	0.0013
155	0.0253	0.0232	0.0190	0.0158	0.0134	0.0115	0.0100	0.0088	0.0077	0.0069	0.0062	0.0056	0.0035	0.0025	0.0018	0.0014
160	0.0276	0.0253	0.0207	0.0173	0.0147	0.0126	0.0109	0.0096	0.0085	0.0075	0.0067	0.0061	0.0039	0.0027	0.0020	0.0015
165	0.0299	0.0275	0.0225	0.0187	0.0159	0.0136	0.0118	0.0104	0.0092	0.0082	0.0073	0.0066	0.0042	0.0029	0.0021	0.0016
170	0.0323	0.0296	0.0242	0.0202	0.0171	0.0147	0.0128	0.0112	0.0099	0.0088	0.0079	0.0071	0.0045	0.0031	0.0023	0.0018
175	0.0346	0.0317	0.0260	0.0217	0.0183	0.0157	0.0137	0.0120	0.0106	0.0094	0.0084	0.0076	0.0048	0.0034	0.0025	0.0019
180	0.0370	0.0339	0.0277	0.0231	0.0196	0.0168	0.0146	0.0128	0.0113	0.0101	0.0090	0.0081	0.0052	0.0036	0.0026	0.0020
185	0.0393	0.0361	0.0295	0.0246	0.0208	0.0179	0.0155	0.0136	0.0120	0.0107	0.0096	0.0086	0.0055	0.0038	0.0028	0.0021
190	0.0417	0.0382	0.0313	0.0261	0.0221	0.0189	0.0164	0.0144	0.0127	0.0113	0.0101	0.0091	0.0058	0.0040	0.0030	0.0023
195	0.0441	0.0404	0.0330	0.0275	0.0233	0.0200	0.0173	0.0152	0.0134	0.0119	0.0107	0.0096	0.0061	0.0043	0.0031	0.0024
200	0.0464	0.0426	0.0348	0.0290	0.0245	0.0211	0.0183	0.0160	0.0141	0.0126	0.0113	0.0102	0.0065	0.0045	0.0033	0.0025

Breaker failure
ANSI code 50BF

Backup protection if the circuit breaker does not trip.

Description
If a breaker fails to open following a tripping order (detected by the non-extinction of the fault current), this backup protection sends a tripping order to the upstream or adjacent breakers.
The "breaker failure" protection function is activated by an O1 output tripping order received from the overcurrent protection functions which trip the circuit breaker (50/51, 50N/51N, 46, 67N, 67, 64REF, 87M, 87T). It checks for the disappearance of current during the time interval specified by the time delay T. It may also take into account the position of the circuit breaker, read on the logic inputs to determine the actual opening of the breaker. Wiring a volt-free closed circuit breaker position contact on the "breaker closed" equation editor input or Logipam can ensure that the protection is effective in the following situations:
- When 50BF is activated by protection function 50N/51N (set point Is0 < 0.2 In), detection of the 50BF current set point can possibly not be operational.
- When trip circuit supervision (TCS) is used, the closed circuit breaker contact is short-circuited. Logic input I101 is therefore no longer operational.

Automatic activation of this protection function requires the use of the circuit breaker control function in the control logic. A specific input may also be used to activate the protection by logic equation or by Logipam. That option is useful for adding special cases of activation (e.g. tripping by an external protection unit).
The time-delayed output of the protection function should be assigned to a logic output via the control matrix.
Starting and stopping of the time delay T counter are conditioned by the presence of a current above the set point (I > Is).

Block diagram


Breaker failure
ANSI code 50BF

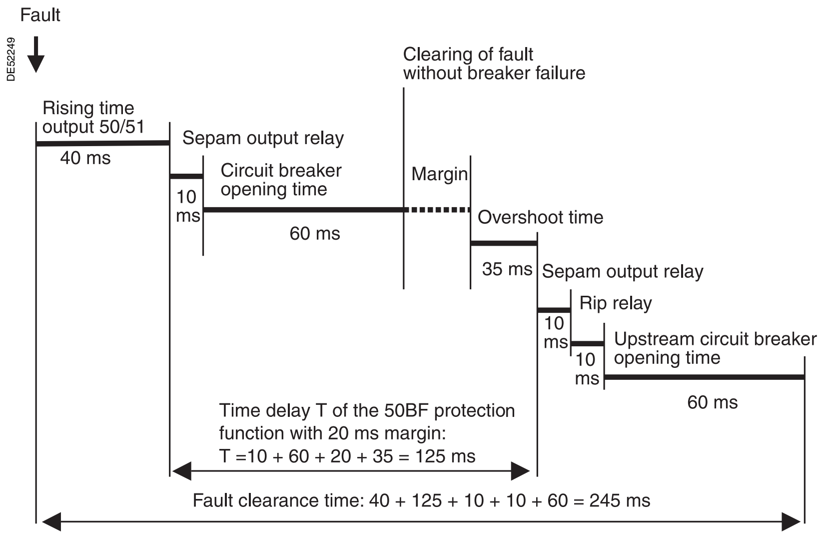
Characteristics

Settings				
Is set point				
Setting range	0.2 In to 2 In			
Accuracy (1)	±5 %			
Resolution	0.1 A			
Drop out/pick up ratio	87.5 % ±2 %			
Time delay T				
Setting range	50 ms to 3 s			
Accuracy (1)	±2 % or -10 ms to +15 ms			
Resolution	10 ms or 1 digit			
Taking into account circuit breaker position				
Setting range	With / without			
Characteristic times				
Overshoot time	< 35 ms at 2 Is			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P50BF_1_101	■	■	
Start 50BF	P50BF_1_107	■	■	
Protection inhibition	P50BF_1_113	■	■	
Breaker closed	P50BF_1_119	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P50BF_1_1	■	■	
Delayed output	P50BF_1_3	■	■	■
Protection inhibited	P50BF_1_16	■	■	

(1) Under reference conditions (IEC 60255-6).

Example of setting

Below is a case that may be used to determine the time-delay setting of the breaker failure function:
- ■ overcurrent protection setting: T = inst
- ■ circuit breaker operating time: 60 ms
- ■ auxiliary relay operating time to open the upstream breaker(s): 10 ms.

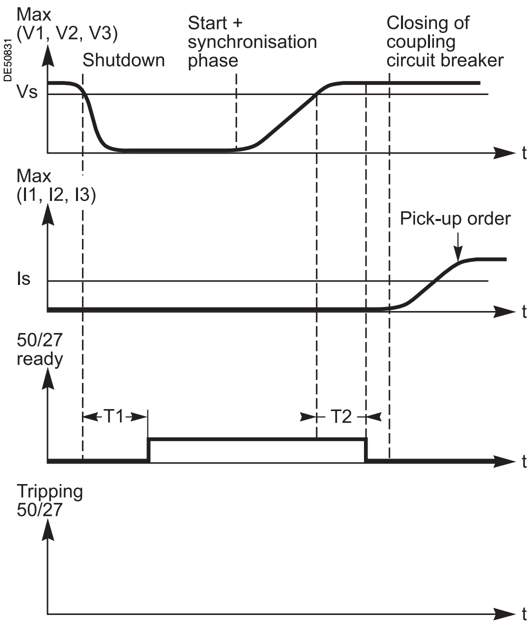


The breaker failure function time delay is the sum of the following times:
- ■ Sepam O1 output relay pick-up time = 10 ms
- ■ circuit breaker opening time = 60 ms
- ■ Breaker failure function overshoot time = 35 ms.

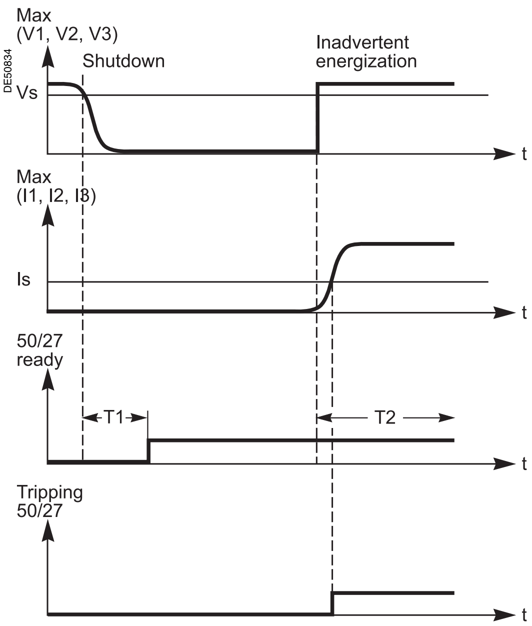
To avoid unwanted tripping of the upstream breakers, add a margin of approximately 20 ms.
The time delay is 125 ms minimum, set at 130 ms.

Inadvertent energization
ANSI code 50/27

Protection against inadvertent energization of generators that are shut down.



Example: Generator shutdown and normal starting.



Example: Generator shutdown and inadvertent starting.

Description

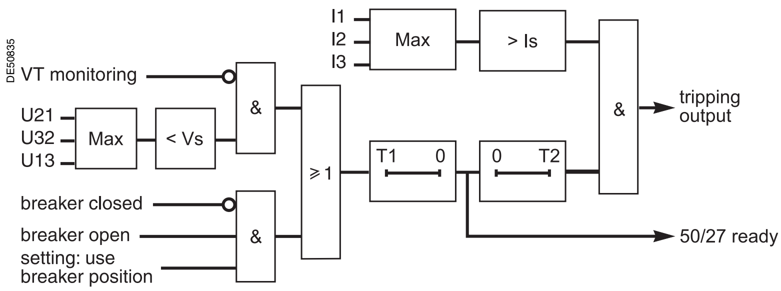
The protection function checks the generator starting sequence to detect inadvertent energization of generators that are shut down.
A generator which is energized when shut down operates like a motor. A starting current occurs and produces significant heat rise that can damage machine windings.

The check on the generator starting sequence is carried out by an instantaneous phase overcurrent protection function, confirmed by an undervoltage protection function. The undervoltage protection function is set up with:
- an on time delay T1 to make the function insensitive to voltage sags
- a timer hold T2 during which the function detects a generator starting current caused by inadvertent energization.

By taking into account the circuit-breaker position, it is possible to check the quality of synchronization. If when the machine couples, the voltage and frequency differences are too high, when the circuit breaker closes, a current immediately appears that the function detects.

When the VT monitoring detects a measurement problem on the voltage channels, the part concerning the voltages is inhibited.

Block diagram



Characteristics

Settings				
Current set point				
Setting range	0.05 to 4 In			
Accuracy (1)	±5 % or 0.02 In			
Resolution	1 A			
Drop out/pick up ratio	95.5 % or 0.015 In			
Voltage set point				
Setting range	10 % to 100 % of Un			
Accuracy (1)	±2 % or 0.005 Unp			
Resolution	1 %			
Drop out/pick up ratio	103 %			
Advanced settings				
Use of breaker position				
Setting range	Used / not used			
T1 time				
Setting range	0 to 10 s			
Accuracy (1)	±2 % or from -10 ms to +25 ms			
Resolution	10 ms or 1 digit			
T2 time				
Setting range	0 to 10 s			
Accuracy (1)	±2 % or from -10 ms to +25 ms			
Resolution	10 ms or 1 digit			
Characteristic times (1)				
Operation time	< 40 ms at 2 Is (typically 30 ms)			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P50/27_1_101	■	■	
Protection inhibition	P50/27_1_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Tripping output	P50/27_1_3	■	■	■
Protection inhibited	P50/27_1_16	■	■	
Protection ready	P50/27_1_35	■	■	

***(1)** Under reference conditions (IEC 60255-6).*

Example of setting

Synchronous generator data

- S = 3.15 MVA
- Un1 = 6.3 kV
- Xd = 233 %
- X'd = 21 %
- X''d = 15 %
- the generator is connected to a network with a Psc = 10 MVA
- the maximum admissible duration of a voltage sag is 2.5 seconds.

To set the protection function, it is necessary to calculate the rated generator impedance:

- $Ib = S/(\sqrt{3}.Un1) = 289$ A
- $Zn = Un1/(\sqrt{3}.Ib) = 12.59\ \Omega$

The network impedance is:
$Zpsc = (Un1)^2/Psc = 3.97\ \Omega$

The Istart starting current is approximately:

$$Istart = \frac{Un1}{\sqrt{3}\left(Zpsc + \frac{X''d}{100} \times Zn\right)} = 621\ A$$

The current set point is set between 20 % and 50 % of the starting current.

$$Is = 0,5 \times Istart \approx 311\ A$$

The voltage set point is often set between 80 % and 85 % of Un. In this example, the selected set point is Us = 85 %.

The T1 time is set longer than the maximum admissible duration of a voltage sag, e.g. T1 = 4 sec.

T2 is set to detect the appearance of a current during starting.
For example, T2 = 250 ms.

Protection against overcurrents and overloads.

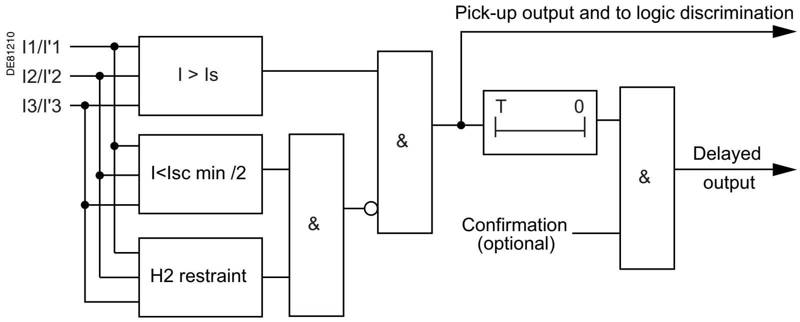
Operation

Protection against overcurrents or overloads:
- It is three-phase and includes a time delay, which is either definite or IDMT.
- Each of the 8 relays has 2 groups of settings. The setting group A or B can be switched by a logic input or a remote control order depending on the parameter setting.
- For better detection of faraway faults, protection can be confirmed by unit 1 of one of the following protections:
  - undervoltage
  - negative sequence overvoltage.
- The custom curve, defined point by point, can be used with this protection.
- An adjustable timer hold delay, either definite or IDMT, allows coordination with electromechanical relays and detection of reboot faults.
- The protection incorporates a harmonic 2 restraint which can be used to set the protection Is set point close to the rated current of the device to be protected, for example to avoid transformer inrush currents.

This harmonic 2 restraint, which can be selected by parameter setting, is active as long as the current is less than half the minimum short-circuit current of the network downstream of the device to be protected.

Tripping curve	Timer hold
Definite time (DT)	Definite time
Standard inverse time (SIT)	Definite time
Very inverse time (VIT or LTI)	Definite time
Extremely inverse time (EIT)	Definite time
Ultra inverse time (UIT)	Definite time
RI curve	Definite time
IEC inverse time SIT / A	Definite time or IDMT
IEC very inverse time VIT or LTI / B	Definite time or IDMT
IEC extremely inverse time EIT / C	Definite time or IDMT
IEEE moderately inverse (IEC / D)	Definite time or IDMT
IEEE very inverse (IEC / E)	Definite time or IDMT
IEEE extremely inverse (IEC / F)	Definite time or IDMT
IAC inverse	Definite time or IDMT
IAC very inverse	Definite time or IDMT
IAC extremely inverse	Definite time or IDMT
Customized	Definite time

Block diagram



Phase overcurrent
ANSI code 50/51

Characteristics

Settings		
Measurement origin		
Setting range	Main channels (I) / Additional channels (I’)	
Tripping curve		
Setting range	See previous page	
Is set point		
Setting range	Definite time	0.05 In ⩽ Is ⩽ 24 In expressed in amperes
	IDMT	0.05 In ⩽ Is ⩽ 2.4 In expressed in amperes
Accuracy (1)	±5 % or ±0.01 In	
Resolution	1 A or 1 digit	
Drop out/pick up ratio	93.5 % ±5 % or > (1 - 0.015 In/Is) x 100 %	
Time delay T (operation time at 10 Is)		
Setting range	Definite time	Inst, 50 ms ⩽ T ⩽ 300 s
	IDMT	100 ms ⩽ T ⩽ 12.5 s or TMS (2)
Accuracy (1)	Definite time	±2 % or from -10 ms to +25 ms
	IDMT	Class 5 or from -10 ms to +25 ms
Resolution	10 ms or 1 digit	
Advanced settings		
Confirmation		
Setting range	By undervoltage (unit 1) By negative sequence overvoltage (unit 1) None, no confirmation	
Timer hold T1		
Setting range	Definite time	0; 0.05 to 300 s
	IDMT (3)	0.5 to 20 s
Resolution	10 ms or 1 digit	
Harmonic 2 restraint		
Setting range	5 to 50 %	
Resolution	1 %	
Minimum short-circuit current Isc		
Setting range	In to 999 kA	
Resolution	de 1 to 9.99 de 10 to 99.9 de 100 to 999 Minimum interval	0.01 0.1 1 0.1A
Characteristic times		
Operation time	pick-up < 40 ms at 2 Is (typically 25 ms) confirmed instantaneous: ■ inst. < 55 ms at 2 Is for Is ⩾ 0.3 In (typically 35 ms) ■ inst. < 70 ms at 2 Is for Is < 0.3 In (typically 50 ms)	
Overshoot time	< 50 ms at 2 Is	
Reset time	< 50 ms at 2 Is (for T1 = 0)	

Inputs			
Designation	**Syntax**	**Equations**	**Logipam**
Protection reset	P50/51_x_101	■	■
Protection inhibition	P50/51_x_113	■	■

Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P50/51_x_1	■	■	
Delayed output	P50/51_x_3	■	■	■
Drop out	P50/51_x_4	■	■	
Phase 1 fault	P50/51_x_7	■	■	
Phase 2 fault	P50/51_x_8	■	■	
Phase 3 fault	P50/51_x_9	■	■	
Protection inhibited	P50/51_x_16	■	■	

x: unit number.
***(1)** Under reference conditions (IEC 60255-6).*
***(2)** Setting ranges in TMS (Time Multiplier Setting) mode*
- *Inverse (SIT) and IEC SIT/A: 0.04 to 4.20*
- *Very inverse (VIT) and IEC VIT/B: 0.07 to 8.33*
- *Very inverse (LTI) and IEC LTI/B: 0.01 to 0.93*
- *Ext. inverse (EIT) and IEC EIT/C: 0.13 to 15.47*
- *IEEE moderately inverse: 0.42 to 51.86*
- *IEEE very inverse: 0.73 to 90.57*
- *IEEE extremely inverse: 1.24 to 154.32*
- *IAC inverse: 0.34 to 42.08*
- *IAC very inverse: 0.61 to 75.75*
- *IAC extremely inverse: 1.08 to 134.4.*

***(3)** Only for standardized tripping curves of the IEC, IEEE and IAC types.*

Earth fault
ANSI code 50N/51N or 50G/51G

Protection against earth faults.

Description

Earth fault protection based on measured neutral, zero sequence or earth fault (tank earth leakage protection) current:

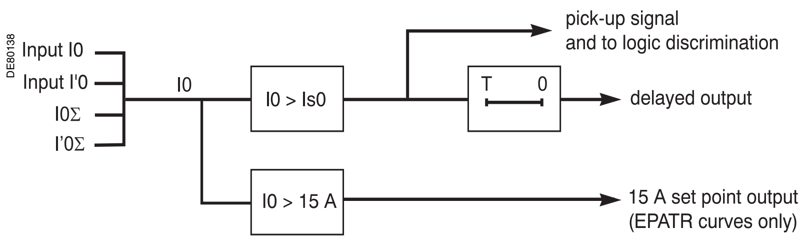
- the protection function has a definite or IDMT time delay.
- each of the eight units has two groups of settings. Switching to setting group A or B can be carried out by a logic input or a remote control order, depending on the settings.
- The protection function includes a harmonic 2 restraint which can be set to provide greater saturation stability of the CT phases when transformers are energized.

The protection function includes a harmonic 2 restraint which prevents an incorrect residual current from being measured on the sum of the 3 CT phases when transformers are energized.

- The restraint value can be set in the configuration. The harmonic 2 restraint is used to trigger the protection on intermittent earth faults.
- the customized curve, defined point by point, can be used with this protection function.
- an adjustable timer hold, definite or IDMT, can be used for coordination with electromagnetic relays and to detect restriking faults.
- each unit can be independently set to one of the two measurement channels I0 or I'0 or to the sum of the phase currents on the main or additional channels. By mixing the possibilities on the different units, it is possible to have:
  - different dynamic set points
  - different applications, e.g. zero sequence and tank earth leakage protection.

Tripping curve	Timer hold curve
Definite time (DT)	Definite time
Standard inverse time (SIT)	Definite time
Very inverse time (VIT or LTI)	Definite time
Extremely inverse time (EIT)	Definite time
Ultra inverse time (UIT)	Definite time
RI curve	Definite time
IEC inverse time SIT / A	Definite time or IDMT
IEC very inverse time VIT or LTI / B	Definite time or IDMT
IEC extremely inverse time EIT / C	Definite time or IDMT
IEEE moderately inverse (IEC / D)	Definite time or IDMT
IEEE very inverse (IEC / E)	Definite time or IDMT
IEEE extremely inverse (IEC / F)	Definite time or IDMT
IAC inverse	Definite time or IDMT
IAC very inverse	Definite time or IDMT
IAC extremely inverse	Definite time or IDMT
EPATR-B	Definite time
EPATR-C	Definite time
Customized	Definite time

Block diagram



Earth fault
ANSI code 50N/51N or 50G/51G

Characteristics

Settings		
Measurement origin		
Setting range	I0 I'0 I0Σ (sum of the main phase channels) I'0Σ (sum of the additional phase channels)	
Tripping curve		
Setting range	See previous page	
Is0 setting		
Definite time setting range	0.01 In0 ⩽ Is0 ⩽ 15 In0 (min. 0.1 A) expressed in amperes	
	Sum of CTs	0.01 In ⩽ Is0 ⩽ 15 In (min. 0.1 A)
	With CSH sensor 2 A rating 20 A rating	 0.1 to 30 A 0.2 to 300 A
	CT	0.01 In0 ⩽ Is0 ⩽ 15 In0 (min. 0.1 A)
	Core balance CT + ACE990	0.01 In0 ⩽ Is0 ⩽ 15 In0 (min. 0.1 A)
IDMT setting range	0.01 In0 ⩽ Is0 ⩽ In0 (min. 0.1 A) expressed in amperes	
	Sum of CTs	0.01 In ⩽ Is0 ⩽ In (min. 0.1 A)
	With CSH sensor 2 A rating 20 A rating	 0.1 to 2 A 0.2 to 20 A
	CT	0.01 In0 ⩽ Is0 ⩽ In0 (min. 0.1 A)
	Core balance CT + ACE990	0.01 In0 ⩽ Is0 ⩽ In0 (min. 0.1 A)
EPATR Setting range	CSH sensor 20 A rating	0.6 to 5 A
	Core balance CT with ACE990 and 15 A ⩽ In0 ⩽ 50 A	0.6 to 5 A
Accuracy (1)	±5 % or ±0.004 In0	
Resolution	1 A or 1 digit	
Drop out/pick up ratio	93.5 % ±5 % or > (1 - 0.005 In0/Is0) x 100 %	
Time delay T (operation time at 10 Is0)		
Setting range	Definite time	Inst, 50 ms ⩽ T ⩽ 300 s
	IDMT	100 ms ⩽ T ⩽ 12.5 s or TMS (2)
	EPATR-B	0.5 to 1 s
	EPATR-C	0.1 to 3 s
Accuracy (1)	Definite time	±2 % or from -10 ms to +25 ms
	IDMT	Class 5 or from -10 ms to +25 ms
Resolution	10 ms or 1 digit	
Advanced settings		
Harmonic 2 restraint		
Fixed threshold	17 % ±3 %	
Timer hold T1		
Setting range	Definite time	0; 0.05 to 300 s
	IDMT (3)	0.5 to 20 s
Resolution	10 ms or 1 digit	
Characteristic times		
Operation time	Pick-up < 40 ms at 2 Is0 (typically 25 ms) Confirmed instantaneous: ■ inst < 55 ms at 2 Is0 for Is ⩾ 0.3 In0 (typically 35 ms) ■ inst < 70 ms at 2 Is0 for Is < 0.3 In0 (typically 50 ms)	
Overshoot time	< 40 ms at 2 Is0	
Reset time	< 50 ms at 2 Is0 (for T1 = 0)	

Inputs

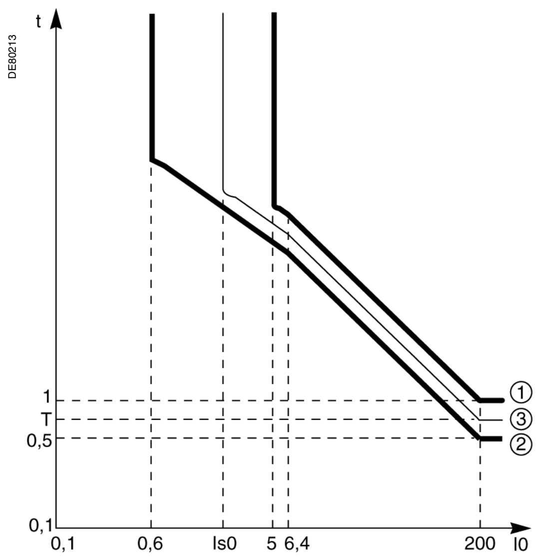
Designation	Syntax	Equations	Logipam
Protection reset	P50N/51N_x_101	■	■
Protection inhibition	P50N/51N_x_113	■	■

Outputs

Designation	Syntax	Equations	Logipam	Matrix
Instantaneous output (pick-up)	P50N/51N_x_1	■	■	
Delayed output	P50N/51N_x_3	■	■	■
Drop out	P50N/51N_x_4	■	■	
Protection inhibited	P50N/51N_x_16	■	■	
15 A set point output	P50N/51N_x_56	■	■	

x: unit number.
(1) *Under reference conditions (IEC 60255-6).*
(2) *Setting ranges in TMS (Time Multiplier Setting) mode*
- *Inverse (SIT) and IEC SIT/A: 0.04 to 4.20*
- *Very inverse (VIT) and IEC VIT/B: 0.07 to 8.33*
- *Very inverse (LTI) and IEC LTI/B: 0.01 to 0.93*
- *Ext. inverse (EIT) and IEC EIT/C: 0.13 to 15.47*
- *IEEE moderately inverse: 0.42 to 51.86*
- *IEEE very inverse: 0.73 to 90.57*
- *IEEE extremely inverse: 1.24 to 154.32*
- *IAC inverse: 0.34 to 42.08*
- *IAC very inverse: 0.61 to 75.75*
- *IAC extremely inverse: 1.08 to 134.4.*

(3) *Only for standardized tripping curves of the IEC, IEEE and IAC types.*



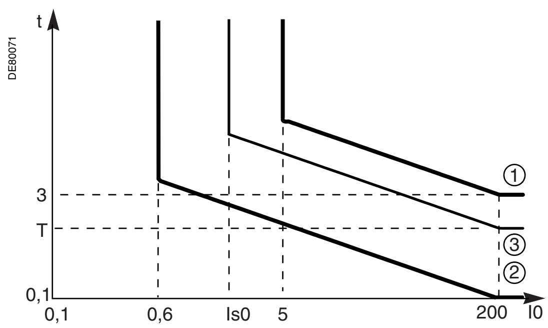
EPATR-B standard curve (log scales)

Curve ① : Is0 = 5 A and T = 1 s
Curve ② : Is0 = 0.6 A and T = 0.5 s
Curve ③ : Is0 and T

EPATR-B curves

EPATR-B tripping curves are defined from the following equations:

- for Is0 ≤ I0 ≤ 6.4 A $\quad \mathbf{t} = \frac{85,386}{I0^{0,(708)}} \times \frac{T}{0,8}$
- for 6.4 A ≤ I0 ≤ 200 A $\quad \mathbf{t} = \frac{140,213}{I0^{0,975}} \times \frac{T}{0,8}$
- for I0 > 200 A $\quad \mathbf{t = T}$



EPATR-C standard curve (log scales)

Curve ①: Is0 = 5 A and T = 3 s
Curve ②: Is0 = 0.6 A and T = 0.1 s
Curve ③: Is0 and T

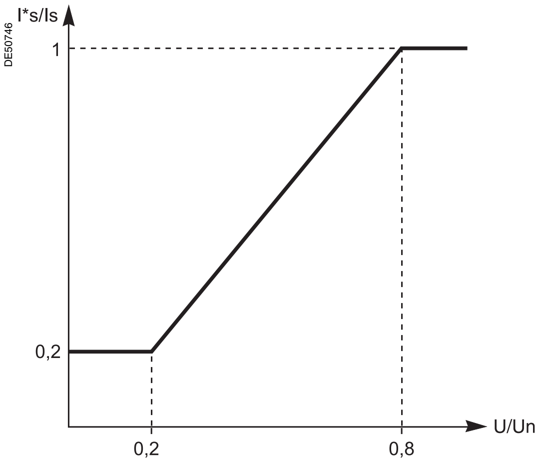
EPATR-C curves

EPATR-C tripping curves are defined from the following equations:

- for Is0 ≤ I0 ≤ 200 A $\quad \mathbf{t} = \frac{72}{I0^{2/3}} \times \frac{T}{2,10}$
- for I0 > 200 A $\quad \mathbf{t = T}$

Voltage-restrained overcurrent
ANSI code 50V/51V

Generator protection against close short-circuits.



Set point adjustment.

Description

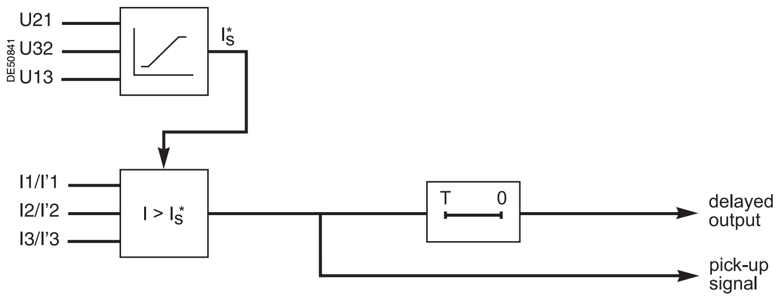
The voltage-restrained overcurrent protection function is used to protect generators. The operation set point is adjusted according to the voltage to take into account cases of faults close to the generator which cause voltage dips and short-circuit current:

■ the protection function is three-phase and has a definite or IDMT time delay
■ the customized curve, defined point by point, may be used with this protection function
■ an adjustable timer hold, definite time or IDMT, can be used for coordination with electromagnetic relays and to detect restriking faults
■ the set point is adjusted according to the lowest of the phase-to-phase voltages measured. The adjusted set point I_s^* is defined by the following equation:

$$I_s^* = \frac{Is}{3} \times \left(4\frac{U}{Un} - 0.2\right)$$

Tripping curve	Timer hold
Definite time (DT)	Definite time
Standard inverse time (SIT)	Definite time
Very inverse time (VIT or LTI)	Definite time
Extremely inverse time (EIT)	Definite time
Ultra inverse time (UIT)	Definite time
RI curve	Definite time
IEC inverse time SIT / A	Definite time or IDMT
IEC very inverse time VIT or LTI / B	Definite time or IDMT
IEC extremely inverse time EIT / C	Definite time or IDMT
IEEE moderately inverse (IEC / D)	Definite time or IDMT
IEEE very inverse (IEC / E)	Definite time or IDMT
IEEE extremely inverse (IEC / F)	Definite time or IDMT
IAC inverse	Definite time or IDMT
IAC very inverse	Definite time or IDMT
IAC extremely inverse	Definite time or IDMT
Customized	Definite time

Block diagram



3

Voltage-restrained overcurrent
ANSI code 50V/51V

Characteristics

Settings		
Measurement origin		
Setting range	Main channels (I) / Additional channels (I')	
Tripping curve		
Setting range	See previous page	
Is set point		
Setting range	Definite time	0.5 In ⩽ Is ⩽ 24 In expressed in amperes
	IDMT	0.5 In ⩽ Is ⩽ 2.4 In expressed in amperes
Accuracy (1)	±5 %	
Resolution	1 A or 1 digit	
Drop out/pick up ratio	93.5 % (with min. reset variance of 0.015 In)	
Time delay T (operation time at 10 Is)		
Setting range	Definite time	Inst, 50 ms ⩽ T ⩽ 300 s
	IDMT	100 ms ⩽ T ⩽ 12.5 s or TMS (2)
Accuracy (1)	Definite time	±2 % or from -10 ms to +25 ms
	IDMT	Class 5 or from -10 ms to +25 ms
Resolution	10 ms or 1 digit	
Advanced settings		
Timer hold T1		
Setting range	Definite time	0; 0.05 to 300 s
	IDMT time (3)	0.5 to 20 s
Resolution	10 ms or 1 digit	
Characteristic times		
Operation time	Pick-up < 35 ms at 2 Is (typically 25 ms) Inst. < 50 ms at 2 Is (confirmed instantaneous) (typically 35 ms)	
Overshoot time	< 50 ms	
Reset time	< 50 ms (for T1 = 0)	

Inputs

Designation	Syntax	Equations	Logipam
Protection reset	P50V/51V_x_101	■	■
Protection inhibition	P50V/51V_x_113	■	■

Outputs

Designation	Syntax	Equations	Logipam	Matrix
Instantaneous output (pick-up)	P50V/51V_x_1	■	■	
Delayed output	P50V/51V_x_3	■	■	■
Drop out	P50V/51V_x_4	■	■	
Phase 1 fault	P50V/51V_x_7	■	■	
Phase 2 fault	P50V/51V_x_8	■	■	
Phase 3 fault	P50V/51V_x_9	■	■	
Protection inhibited	P50V/51V_x_16	■	■	

x: unit number.
***(1)** Under reference conditions (IEC 60255-6).*
***(2)** Setting ranges in TMS (Time Multiplier Setting) mode*
- *Inverse (SIT) and IEC SIT/A: 0.04 to 4.20*
- *Very inverse (VIT) and IEC VIT/B: 0.07 to 8.33*
- *Very inverse (LTI) and IEC LTI/B: 0.01 to 0.93*
- *Ext. inverse (EIT) and IEC EIT/C: 0.13 to 15.47*
- *IEEE moderately inverse: 0.42 to 51.86*
- *IEEE very inverse: 0.73 to 90.57*
- *IEEE extremely inverse: 1.24 to 154.32*
- *IAC inverse: 0.34 to 42.08*
- *IAC very inverse: 0.61 to 75.75*
- *IAC extremely inverse: 1.08 to 134.4.*

***(3)** Only for standardized tripping curves of the IEC, IEEE and IAC types.*

Capacitor bank unbalance
ANSI code 51C

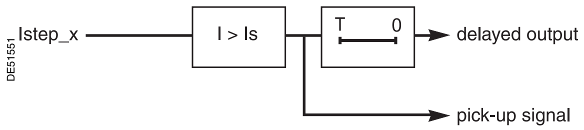
Detection of capacitor bank internal faults by measurement of the unbalance current flowing between the 2 neutral points of a double-star connected capacitor bank.

Description

The capacitor bank unbalance function detects unbalance current flowing between the two neutral points of double-star connected capacitor banks.

The protection function is activated when the unbalance current is higher than the Is current set point during tripping time T.

Block diagram



Characteristics

Settings				
Set point Is				
Setting range	0.02 I'n to 2 I'n with a minimum value of 0.05 A			
Accuracy (1)	±5 %			
Resolution	0.01 A			
Drop out/pick up ratio	93.5 %			
Time delay				
Setting range	0.1 to 300 s			
Accuracy (1)	±2 % or ±25 ms			
Resolution	10 ms or 1 digit			
Characteristic times (1)				
Operation time	Pick-up < 35 ms			
Overshoot time	< 35 ms			
Reset time	< 50 ms			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P51C_x_101	■	■	
Protection inhibition	P51C_x_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output	P51C_x_1	■	■	
Tripping output	P51C_x_3	■	■	■
Protection inhibed	P51C_x_16	■	■	

x: unit number.
***(1)** Under reference conditions (IEC 60255-6).*

Protection against phase-to-neutral or phase-to-phase overvoltages.

Operation

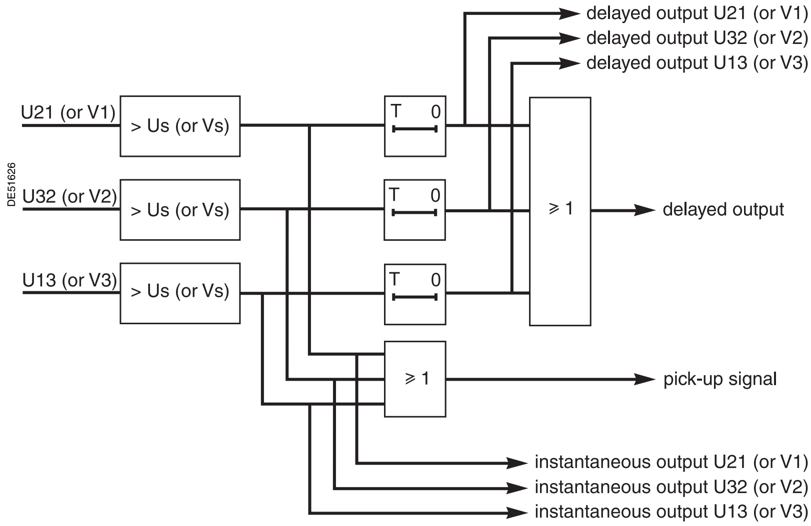
Protection against overvoltages or check that there is sufficient voltage present to authorize a source transfer:

- it is single-phase and operates on phase-to-neutral or phase-to-phase voltage
- it includes a time delay T with definite time
- when operating on phase-to-neutral voltage, it indicates the faulty phase in the alarm associated with the fault.

Whether it operates on phase-to-neutral or phase-to-phase voltage depends on the connection chosen for the voltage inputs.

It can be used for monitoring unbalance in the capacitor banks on each of the phases, when they are fitted with VTs, using the additional channels in the B83 application.

Block diagram



Connection conditions					
Type of connection	V1, V2, V3 (1)	U21, U32 + V0	U21, U32	U21 (1)	V1 (1)
Phase-to-neutral operation	YES	YES	NO	NO	On V1 only
Phase-to-phase operation	YES	YES	YES	On U21 only	NO

(1) With or without V0.

Overvoltage (L-L or L-N)
ANSI code 59

Characteristics

Settings	
Measurement origin	
Setting range	Main channels (U) / Additional channels (U')
Voltage mode	
Setting range	Phase-to-phase voltage / Phase-to-neutral voltage
Us (or Vs) set point	
Setting range	50 % to 150 % of Unp (or Vnp) if Uns < 208 V
	50 % to 135 % of Unp (or Vnp) if Uns ⩾ 208 V
Accuracy (1)	±2 %
Resolution	1 %
Drop out/pick up ratio	97 % ±1 %
U's (or V's) set point for additional channels of the B83 application	
Setting range	1.5 % to 150 % of Unp (or Vnp) if Uns < 208 V
	1.5 % to 135 % of Unp (or Vnp) if Uns ⩾ 208 V
	minimum setting = 1.5 V
Accuracy (1)	2 % or 0.002 Unp)
Resolution	0.2 % between 1.5 % and 9.9 % Unp (Vnp)
	0.5 % if Unp (Vnp) > 10 %
Drop-out/pick-up ratio	
Setting range	97 % to 99 %
Accuracy	1 % or > (1 - 0,002 U'np / V's) x 100 %
Resolution	0,1 %
Time delay T	
Setting range	50 ms to 300 s
Accuracy (1)	±2 % or ±25 ms
Resolution	10 ms or 1 digit
Characteristic times	
Operation time	Pick-up < 40 ms from 0.9 Us (Vs) to 1.1 Us (Vs) (typically 25 ms)
Overshoot time	< 40 ms from 0.9 Us (Vs) to 1.1 Us (Vs)
Reset time	< 50 ms from 1.1 Us (Vs) to 0.9 Us (Vs)

Inputs

Designation	Syntax	Equations	Logipam
Protection reset	P59_x_101	■	■
Protection inhibition	P59_x_113	■	■

Outputs

Designation	Syntax	Equations	Logipam	Matrix
Instantaneous output (pick-up)	P59_x_1	■	■	
Delayed output	P59_x_3	■	■	■
Fault phase 1 (2)	P59_x_7	■	■	
Fault phase 2 (2)	P59_x_8	■	■	
Fault phase 3 (2)	P59_x_9	■	■	
Protection inhibited	P59_x_16	■	■	
Instantaneous output V1 or U21	P59_x_23	■	■	
Instantaneous output V2 or U32	P59_x_24	■	■	
Instantaneous output V3 or U13	P59_x_25	■	■	
Delayed output V1 or U21	P59_x_26	■	■	
Delayed output V2 or U32	P59_x_27	■	■	
Delayed output V3 or U13	P59_x_28	■	■	

x: unit number.
***(1)** Under reference conditions (IEC 60255-6).*
***(2)**When the protection function is used for phase-to-neutral voltage.*

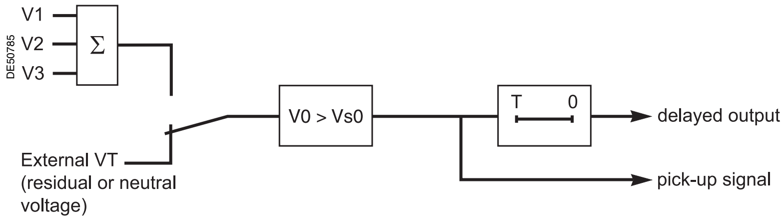
Neutral voltage displacement
ANSI code 59N

Protection against insulation faults

Description

Protection against insulation faults by measuring the residual voltage V0 or the neutral point voltage Vnt for generators and motors.
The residual voltage is obtained by the vector sum of the phase voltages or by measurements using delta connected VTs.
The neutral point voltage is measured by a VT inserted in the neutral point of the generator or the motor.
The protection function includes a time delay T, either definite or IDMT (dependent on the residual voltage V0) (see tripping curve equation on page 226).
It operates only when a residual or neutral point voltage is available, by connecting V1V2V3, V0 or Vnt.

Block diagram



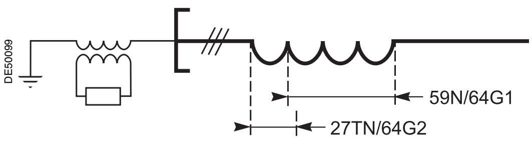
Characteristics

Settings				
Measurement origin				
Setting range	Main channels (V0) Additional channels (V'0) Neutral-point voltage (Vnt)			
Tripping curve				
Setting range	Definite time IDMT (dependent on the residual voltage V0)			
Vs0 set point				
Definite time setting range	2 % Unp to 80 % Unp (for residual voltage V0) 2 % Vntp to 80 % Vntp (for neutral point voltage Vnt)			
IDMT setting range	2 % Unp to 10 % Unp (for residual voltage V0) 2 % Vntp to 10 % Vntp (for neutral point voltage Vnt)			
Accuracy (1)	±2 % or 0.005 Unp			
Resolution	1 %			
Drop out/pick up ratio	97 % ±2 % or > (1 - 0.006 Unp/Vs0) x 100 %			
Time delay T (tripping time at 2 Vs0)				
Definite time setting range	50 ms to 300 s			
IDMT setting range	100 ms to 10 s			
Accuracy (1)	±5 % or ±25 ms			
Resolution	10 ms or 1 digit			
Characteristic times				
Operation time	pick-up < 45 ms (typically 25 ms) at 2 Vs0			
Overshoot time	< 40 ms at 2 Vs0			
Reset time	< 40 ms at 2 Vs0			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P59N_x_101	■	■	
Protection inhibition	P59N_x_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P59N_x_1	■	■	
Delayed output	P59N_x_3	■	■	■
Protection inhibited	P59N_x_16	■	■	

x: unit number.
***(1)** Under reference conditions (IEC 60255-6).*

100 % stator earth fault
ANSI code 64G

Protection against internal faults in generators.



Description

The 64G protection function is made of the two independent functions.

■ protection function 64G1 which commonly corresponds to a neutral voltage displacement function at the fundamental frequency (ANSI code 59N). It may be implemented by an earth fault protection function (ANSI code 51N) when the earth fault current is sufficient.

■ protection function 64G2 which corresponds to a third harmonic undervoltage function (ANSI code 27TN) whose operating principle depends on the type of connection of the generator terminal VTs.

When a single-phase fault occurs, the flow of the zero sequence current increases the potential of the neutral point, detected by protection function 59N. However, given the natural unbalance of the three network phases, the sensitivity set point for 59N cannot be set under 10 % to 15 % of the phase-to-neutral voltage.

If the single-phase fault occurs on a stator winding near the neutral point, the increase in the potential at the neutral point may be insufficient to trip protection function 59N.

The combination of functions 59N and 27TN is the means to protect 100 % of the stator winding. Depending on the settings:

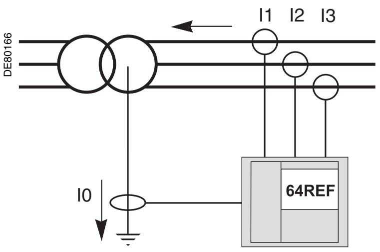
■ protection function 59N protects 85 to 95 % of the stator winding on the terminal side and

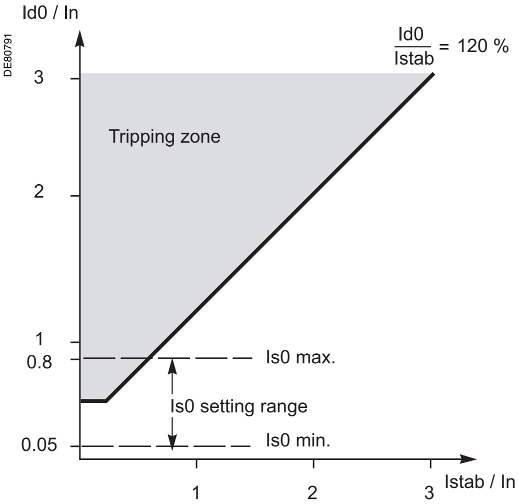
■ protection function 27TN protects 10 to 20 % of the stator winding on the neutral point side.

To create a 100 % stator earth fault protection function, it is necessary to implement the 64G1 (59N or 51N) and the 64G2 (27TN) protection functions (see each of these functions for more information).

Restricted earth fault differential
ANSI code 64REF

Protection of three-phase windings against phase-to-earth faults.

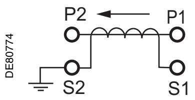




3

Description

The restricted earth fault protection function detects phase-to-earth faults on three-phase windings with earthed neutral. This function protects generators and transformers.
The protected zone is between the 3 phases CTs I1, I2, I3 (or I'1, I'2, I'3) and the neutral point current measurement I0 (or I'0).
The vector associated with the current sensors determines the conventional direction of connection.



Principle

Protection is activated if the following 3 conditions are met:
- $\mathbf{Id0} > \mathbf{Is0}$
- $\mathbf{Id0} > \mathbf{1.2} \times \mathbf{Istab}$
- $\Delta\mathbf{I0} > \mathbf{min}(\mathbf{Is0/4},\ \mathbf{I0min})$

With:
- Id0: differential residual current
- Is0: adjustable trip set point of the protection function
- Istab: stabilization current
- ΔI0: variation of the neutral point current
- I0min: nominal current of the neutral point:
  - □ I0min = 0.05 x In0 si In0 > 20 A
  - □ I0min = 0.10 x In0 si In0 ≤ 20 A

Differential residual current Id0

$$\mathbf{Id0} = \left|\vec{\mathbf{I0}}\Sigma - \vec{\mathbf{I0}}\right|$$

With:
- $\vec{\mathbf{I0}}$: neutral point current
- $\vec{\mathbf{I0}}\Sigma$: residuel current calculated using the sum of the 3 phase currents

Stabilization current Istab

$$\mathbf{Istab}(\mathbf{k}) = \mathbf{max}(\mathbf{It}(\mathbf{k}),\ \alpha \cdot\ \mathbf{Istab}(\mathbf{k}-\mathbf{1}))$$

With:
- k: present moment
- k-1: previous moment in the 64REF protective processing cycle
- α: time constant adaptation coefficient of the time memory to cover dips in the through current It, when the CTs are saturated, on an external multi-phase fault
- It: through current

Through current It

The through current It provides the protection with discrimination and rendered immunity in relation to external multi-phase faults.

$$\mathbf{It} = \mathbf{max}(\mathbf{IR0},\ \beta \cdot\ \mathbf{IR1})$$

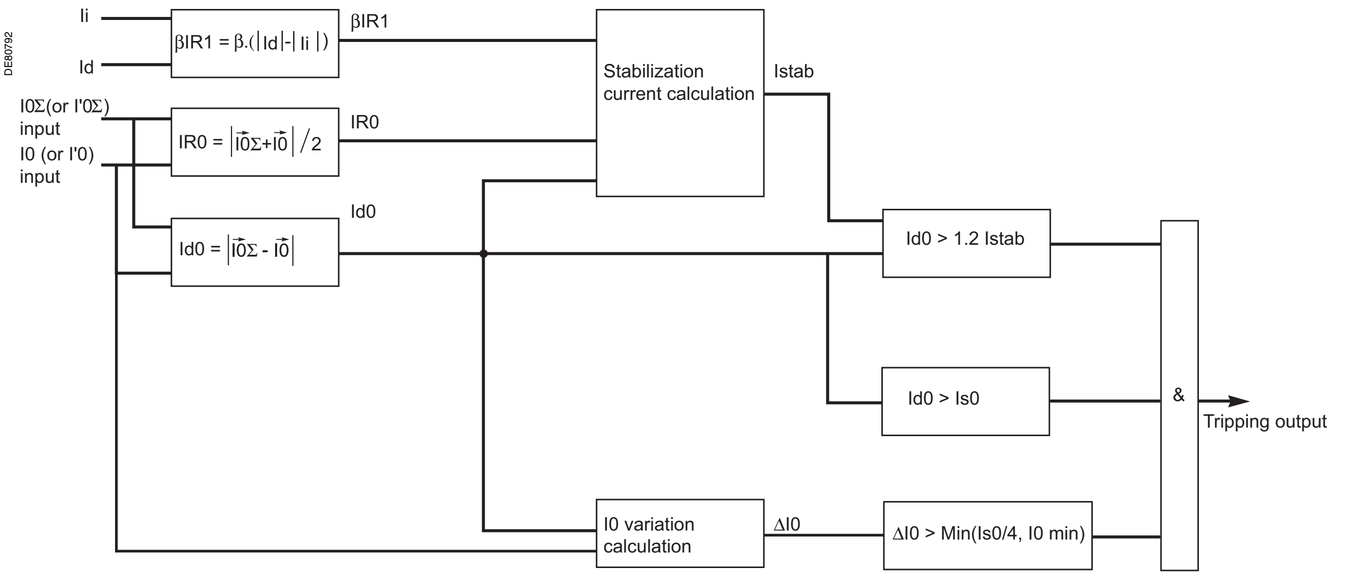
With:
- $\mathbf{IR0} = \left|\vec{\mathbf{I0}}\Sigma + \vec{\mathbf{I0}}\right| / \mathbf{2}$: residual component sensitive to single-phase faults
- $\mathbf{IR1} = |\mathbf{Id}| - |\mathbf{Ii}|$: component sensitive to multi-phase faults
- β : coefficient depending on the nature of the external fault:
  - □ $\beta = \mathbf{max}(\mathbf{2},\ |\mathbf{Id}| / \mathbf{Ib})$ for two-phase/earth or three-phase/earth faults
  - □ β = 0 for single-phase faults

Variation of the neutral point current ΔI0

The neutral point current variation is the difference in the absolute value between the neutral point current before and after the fault has been detected.

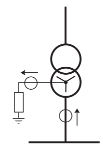
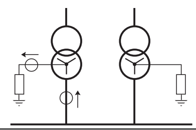
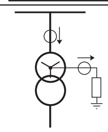
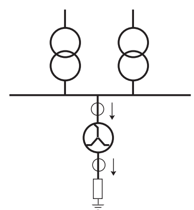
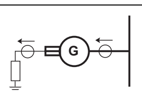
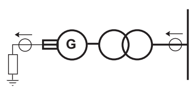
Restricted earth fault differential
ANSI code 64REF

Block diagram



Additional protection on multi-phase faults

When multi-phase/internal earth faults occur, the 64REF protection may experience downgraded operation. The table below defines the usual additional protection for protecting the installation in the event of multi-phase/internal earth faults.

Application	Network diagram	Additional protections
Protection of an incomer on a: ■ Directly earthed, resistive or inductive MV network (1000 V < MV < 50 kV) ■ TN or TT type LV network (< 1000 V)		■ ANSI 87T or ■ ANSI 50/51 at the primary
Protection of parallel incomers on a: ■ HV distribution network (> 50 kV) ■ Directly earthed, resistive or inductive MV network ■ TN or TT type LV network		■ ANSI 87T or ■ ANSI 67
Protection of a feeder on an HV distribution network		■ ANSI 87T or ■ ANSI 50/51N at the neutral point
Protection of zero sequence generator on an MV network		■ ANSI 50/51 or ■ ANSI 50N/51N
Generator protection, in which the neutral is earthed across a low impedance		ANSI 50N/51N at the neutral point
Machine-transformer unit protection, in which the neutral is earthed across a low impedance		■ ANSI 87T or ■ ANSI 50N/51N at the neutral point

Restricted earth fault differential
ANSI code 64REF

Dimensioning current sensors

■ The primary current of the neutral point current transformer must comply with the following rule:
In0 ⩾ 0.1 x I_{1P}, where I_{1P} is the phase-to-earth short-circuit current.

■ Neutral current transformer must be:

□ type 5P20 with an accuracy burden $VA_{CT} \geqslant Rw.in0^2$

□ or defined by a knee-point voltage $Vk \geqslant (R_{CT} + Rw).20.in0$.

■ Phase current transformers must be:

□ type 5P, with an accuracy-limit factor $FLP \geqslant \max\left(20,\ 1.6\frac{I_{3P}}{In},\ 2.4\frac{I_{1P}}{In}\right)$
and an accuracy burden $VA_{CT} \geqslant Rw.in^2$

□ or defined by a knee-point voltage $Vk \geqslant (R_{CT} + Rw)\max\left(20,\ 1.6\frac{I_{3P}}{In},\ 2.4\frac{I_{1P}}{In}\right)in$.

■ Formula legend:
in: phase CT rated secondary current
in0: neutral point CT rated secondary current
R_{CT}: phase CT or neutral CT internal resistance
Rw: resistance of the CT load and wiring
In: phase CT rated primary current
In0: neutral point CT rated primary current
I_{3P}: three-phase short-circuit current
I_{1P}: phase-to-earth short-circuit current

Characteristics

Settings				
Measurement origin				
Setting range	Main channels (I, I0) Additional channels (I', I'0)			
Is0				
Setting range	0.05 In to 0.8 In for In ⩾ 20 A 0.1 In to 0.8 In for In < 20 A			
Accuracy (1)	5 %			
Resolution	1 A or 1 digit			
Drop out/pick up ratio	93 % ±2 %			
Characteristic times				
Operation time	< 55 ms at Id0 = 2.4 Istab			
Overshoot time	< 35 ms at Id0 = 2.4 Istab			
Reset time	< 45 ms at Id0 = 2.4 Istab			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P64REF_x_101	■	■	
Protection inhibition	P64REF_x_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Protection output	P64REF_x_3	■	■	■
Protection inhibited	P64REF_x_16	■	■	

x: unit number.
***(1)** Under reference conditions (IEC 60255-6).*

Starts per hour
ANSI code 66

Protection of motors against mechanical stress caused by starts that are too close together.

Operation
The number of starts is incremented if:
- The current taken exceeds 5 % of the current Ib after circuit breaker closing (and the circuit breaker position is hard-wired on inputs I101 and I102).
- The current taken exceeds 5 % of the current Ib after re-acceleration.

The number of starts over the period Tcons is limited by:
- the permitted number of consecutive cold starts (Nc)
- the permitted number of successive hot starts (Nh).

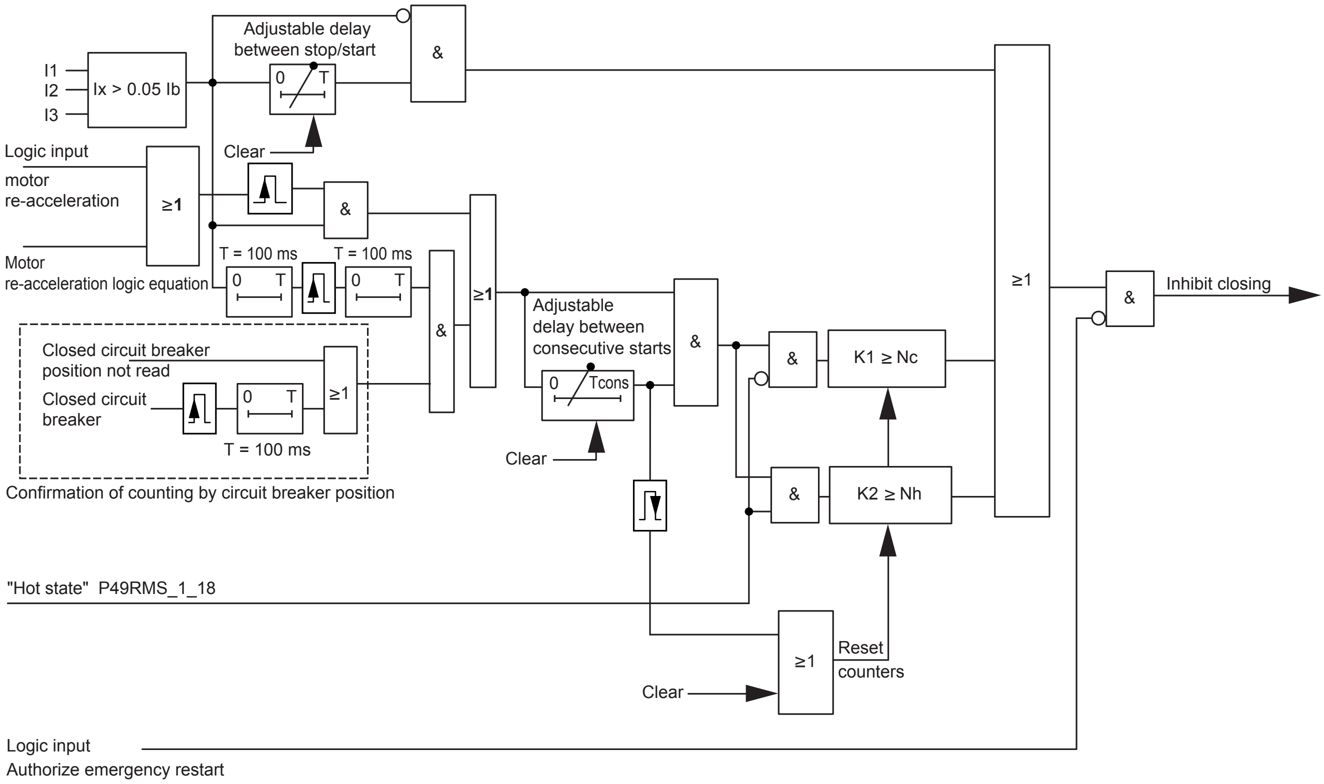
The "stop/start" time delay is used to impose a minimum stopping time between each start.

The motor "hot state" data item is determined by the 49RMS motor thermal overload protection. A "hot state" set point can also be configured using this protection function (see page 140).

Note: *When the 49RMS generic thermal overload protection is used, if ES0 is different from 0%, the ANSI 66 protection function may not work properly.*
As the "hot state" set point is fixed at 50% in the ANSI 66 protection function, according to ES0 setting value, the cold state for the 66 protection function may be reduced or not exist. So the number of starts will be limited by the number of consecutive hot starts, with no impact of number of consecutive cold starts setting.
When the motor curves imply to use ES0 setting to move the "cold curve", it is highly adviced to use the thermal model based on two time constants, that avoid this setting difficulty.

Block diagram

DE81266



Operating information
The following information is available to the operator:
- the number of starts before inhibition
- start inhibit time

(See machine operation help functions on page 58).

Starts per hour
ANSI code 66

Characteristics

Settings				
Delay between consecutive starts (Tcons)				
Setting range	1 mn to 90 mn			
Resolution	1 mn			
Permitted number of consecutive cold starts (Nc)				
Setting range	1 to 5			
Resolution	1			
Permitted number of consecutive hot starts (Nh)				
Setting range	1 to (Nc -1)			
Resolution	1			
Delay between stop/start				
Setting range	0 to 90 mn (0 no time delay)			
Resolution	1 mn			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Reset protection	P66_1_101	■	■	
Motor re-acceleration	P66_1_102	■	■	
Inhibit protection	P66_1_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Protection output	P66_1_3	■	■	■
Protection inhibited	P66_1_16	■	■	
Stop/start inhibit	P66_1_29	■	■	
Startup total reached	P66_1_30	■	■	
Consecutive startups reached	P66_1_31	■	■	

Help with parameter setting

Number of consecutive starts

Motor manufacturers state the permitted number of consecutive cold (Nc) and hot (Nh) starts in the technical data.

Delay between consecutive starts

Consecutive starts are starts that are sufficiently close in relation to the rotor cooling time constant.
The delay between consecutive starts (Tcons) must be set to the value of the rotor cooling time constant:
τ **= (Tc - Th) . LRT / gn**
Where:
Tc: locked cold rotor limit time in seconds
Th: locked hot rotor limit time in seconds
LRT: locked rotor torque in pu
gn: rated slip in pu

Motor hot state set point

The motor thermal capacity used varies from 0 to $Itrip^2$ (Itrip being the motor thermal overload protection tripping current).
In order to be able to perform a hot start without tripping the thermal overload protection, the motor hot state set point must be configured.

There are 2 different scenarios:
■ The motor starting time (tstg) is close to the locked hot rotor limit time (Th).
This scenario corresponds to a motor on which the load's moment of inertia is high, such as a fan. The hot state set point is configured as follows:

$$Shot < Itrip^2 - \frac{tstg}{Th}$$

■ The motor starting time (tstg) is short compared to the locked hot rotor limit time (Th).
The hot state set point is configured as follows:

$$Nc \cdot \left(\frac{tstg}{Tc}\right) < Shot < Itrip^2 - \left(Nh \cdot \frac{tstg}{Th}\right)$$

In this scenario, the ANSI 66 protection function is fully involved in limiting the number of starts, because the thermal protection is well below its tripping current set point (Itrip).

Example 1: 2350 kW / 6 kV motor

Manufacturer data:		
Locked cold rotor limit time	Tc	13 s
Locked hot rotor limit time	Th	9 s
Number of consecutive cold starts	Nc	3
Number of consecutive hot starts	Nh	2
Starting time	tstg	4 s
Rated speed	N	2980 rpm
Locked rotor torque	LRT	0.7 pu
Locked rotor current	Il	6 pu
Continuous permissible current	Itrip	1.2 pu

Calculating the rotor time constant
The rated slip is given by:

$$g_n = 1 - \frac{N \cdot np}{60 \cdot fn}$$

Where:
np: number of poles
fn: network frequency

The number of poles is given by:

$$np = int\left(\frac{60 \cdot fn}{N}\right)$$

hence np = int (60. 50 / 2980) = 1

Therefore:

$$g_n = 1 - \frac{2980}{60 \cdot 50} = 0{,}0067$$

The rotor constant is given by:
τ = (Tc - Th) . LRT / gn
Hence:
τ = (13 - 9) . 0.7 / 0.0067 = 420 s, or **7 mn**

Calculating the hot state set point
The hot state set point is given by:

$$Nc \cdot \left(\frac{tdem}{Tc}\right) < Schaud^2 < Itrip^2 - \left(Nh \cdot \frac{tdem}{Th}\right)$$

Hence:

$$3 \cdot \left(\frac{4}{13}\right) < Schaud^2 < 1,2^2 - \left(2 \cdot \frac{4}{9}\right)$$

Or 0.92 Ib < Shot ^{2} < 0.56 Ib which is impossible.
Therefore a more restrictive hot state set point is selected, allowing 1 hot start and 3 cold starts.
Hence:

$$3 \cdot \left(\frac{4}{13}\right) < Schaud^2 < 1,2^2 - \left(1 \cdot \frac{4}{9}\right)$$

Or 92.30% < Shot² < 99.55 %
Or for the "hot state" set point: 0.96 Ib < Shot < 0.99 Ib

3

Example 2: 506 kW / 10 kV motor

Manufacturer data:		
Locked cold rotor limit time	Tc	60 s
Locked hot rotor limit time	Th	29 s
Number of consecutive cold starts	Nc	2
Number of consecutive hot starts	Nh	1
Starting time	tstg	21 s
Rated speed	N	993 rpm
Locked rotor torque	LRT	0.6 pu
Locked rotor current	Il	5.3 pu
Continuous permissible current	Itrip	1.25 pu

Calculating the rotor time constant
The number of poles equals:
np = int (60. 50 / 993) = 3

We can therefore deduce the rated slip:

$$g_n = 1 - \frac{993 \cdot 3}{60 \cdot 50} = 0,007$$

and the rotor cooling constant:
τ = (60 - 29) . 0.6 / 0.007 = 2657 s, or **44 mn**

Calculating the hot state set point
The hot state set point is given by:

$$2 \cdot \left(\frac{21}{60}\right) < \mathbf{Schaud}^2 < 1,25^2 - \left(1 \cdot \frac{21}{29}\right)$$

Or 70 % < Shot² < 83.83 %
Or for the "hot state" set point: 0.83 Ib < Shot < 0.91 Ib

This setting allows 1 hot start and 3 cold starts.

Phase-to-phase short-circuit protection, with selective tripping according to fault current direction.

Description

This function comprises a phase overcurrent function associated with direction detection and picks up if the phase overcurrent function in the chosen direction (line or busbar) is activated for at least one of the 3 phases (or two of the three phases, depending on the settings).

■ the protection function is three-phase and has a definite or IDMT time delay.

■ each of the two units has two groups of settings. Switching to setting group A or B can be carried out by a logic input or a remote control order, depending on the settings.

■ the customized curve, defined point by point, may be used with this protection function.

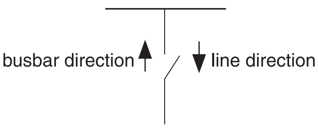
■ an adjustable timer hold, definite time or IDMT, can be used for coordination with electromagnetic relays and to detect restriking faults.

■ the alarm linked to the protection function indicates the faulty phase or phases.

Tripping direction

The direction of the current is determined according to the measurement of the phase in relation to a polarization value. It is qualified as busbar direction or line direction according to the following convention:

DE51557



The tripping zone is set for tripping in busbar zone or tripping in line zone.

The reverse zone is the zone for which the protection function does not trip. The detection of current in the reverse zone is used for indication.

Polarization value

The polarization value is the phase-to-phase value in quadrature with the current for cosθ = 1 (90° connection angle). A phase current vector plane is divided into two half-planes that correspond to the line zone and busbar zone. The characteristic angle θ is the angle of the perpendicular to the boundary line between the 2 zones and the polarization value.

Voltage memory

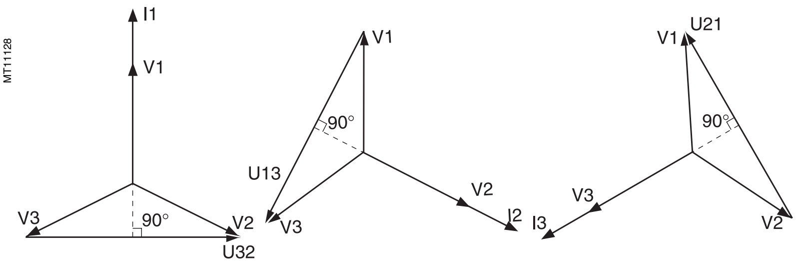
Should all the voltages disappear during a 3-phase fault near the busbars, the voltage level may be insufficient for the fault direction to be detected (< 1.5 % Unp). The protection function therefore uses a voltage memory to reliably determine the direction. The fault direction is saved as long as the voltage level is too low and the current is above the Is set point.

Closing on a pre-existing fault

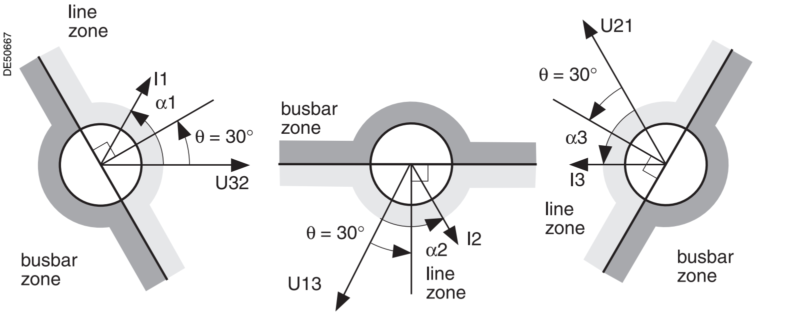
If the circuit breaker is closed when there is a pre-existing 3-phase fault on the busbars, the voltage memory is blank. As a result, the direction cannot be determined and the protection does not trip.

In such cases, a backup 50/51 protection function should be used.

MT11128

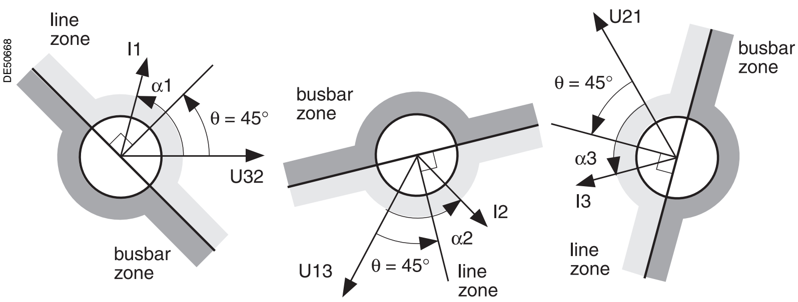


DE50667



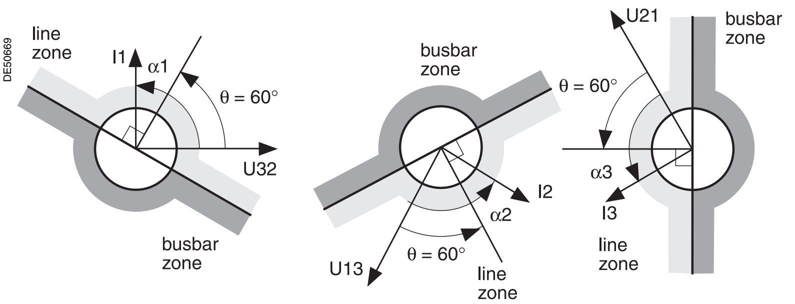
Fault tripping in line zone with θ = 30°.

DE50668



Fault tripping in line zone with θ = 45°.

DE50669



Fault tripping in line zone with θ = 60°.

Tripping logic

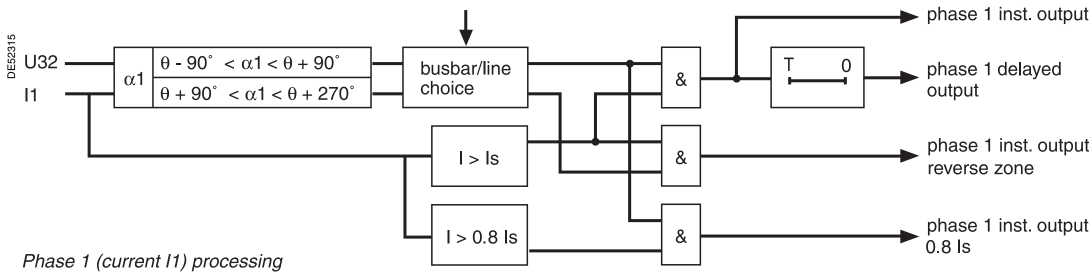
In certain cases, it is wise to select the "two out of three phases" tripping logic. Such cases may occur when two parallel transformers (Dy) must be protected. For a 2-phase fault on a transformer primary winding, there is a 2-1-1 current distribution at the secondary end. The highest current is in the expected zone (operation zone for the faulty incomer, no operation zone for the fault-free incomer).

One of the lowest currents is at the edge of the zone. According to the line parameters, it may even be in the wrong zone.

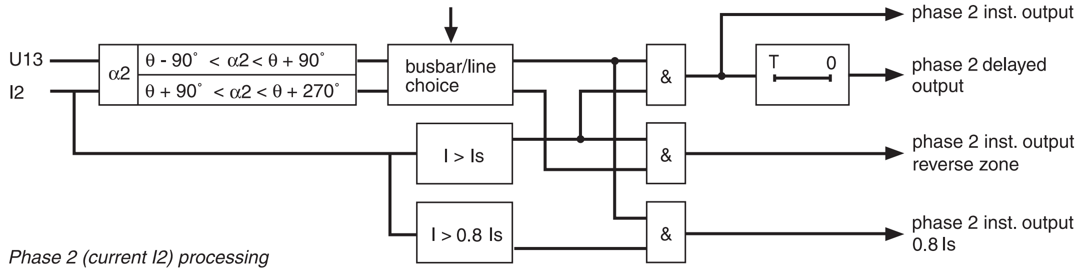
There is therefore a risk of tripping both incomers.

Directional phase overcurrent
ANSI code 67

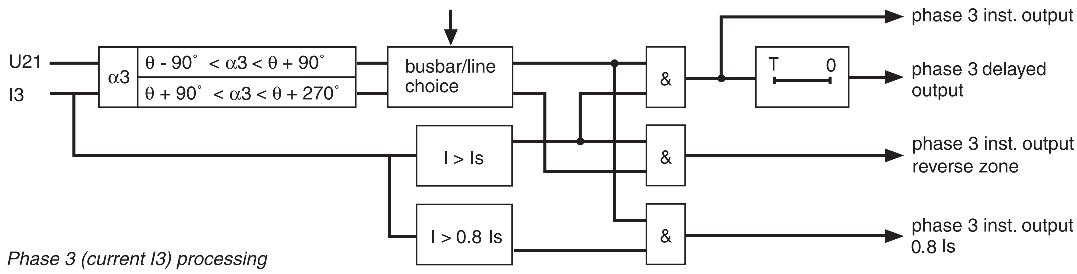
Block diagram



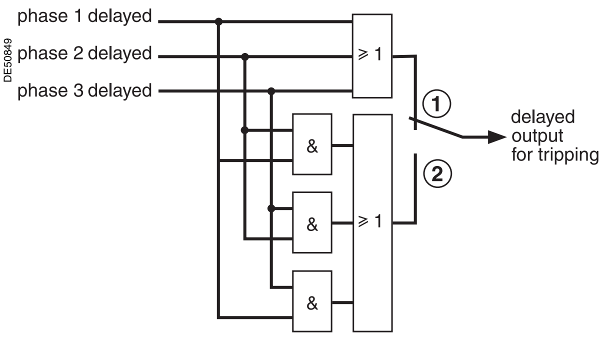
Phase 1 (current I1) processing

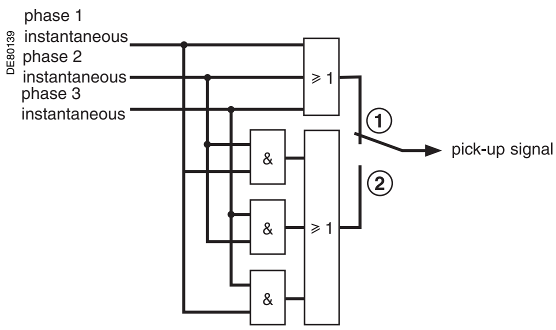


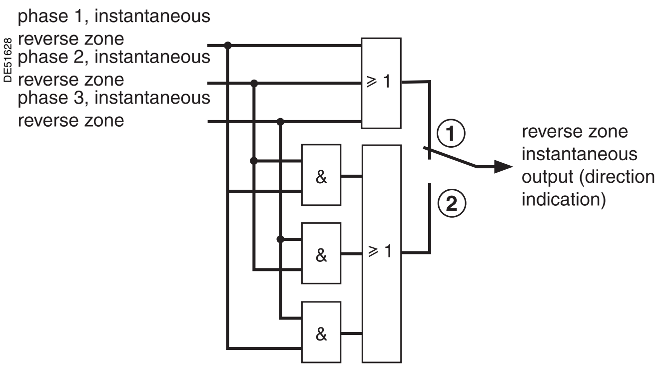
Phase 2 (current I2) processing

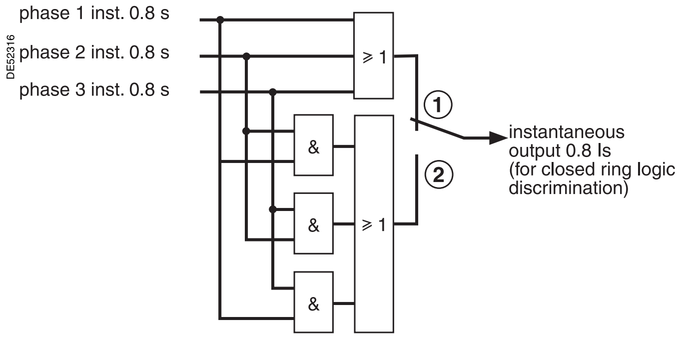


Phase 3 (current I3) processing









Grouping of output data.

Tripping logic parameter setting:

1. *one out of three*
2. *two out of three*

Directional phase overcurrent
ANSI code 67

Tripping curve	Timer hold
Definite time (DT)	Definite time
Standard inverse time (SIT)	Definite time
Very inverse time (VIT or LTI)	Definite time
Extremely inverse time (EIT)	Definite time
Ultra inverse time (UIT)	Definite time
RI curve	Definite time
IEC inverse time SIT / A	Definite time or IDMT
IEC very inverse time VIT or LTI / B	Definite time or IDMT
IEC extremely inverse time EIT / C	Definite time or IDMT
IEEE moderately inverse (IEC / D)	Definite time or IDMT
IEEE very inverse (IEC / E)	Definite time or IDMT
IEEE extremely inverse (IEC / F)	Definite time or IDMT
IAC inverse	Definite time or IDMT
IAC very inverse	Definite time or IDMT
IAC extremely inverse	Definite time or IDMT
Customized	Definite time

Characteristics

Settings		
Characteristic angle θ		
Setting range		30°, 45°, 60°
Accuracy (1)		±2 %
Tripping curve		
Setting range		See list above
Is set point		
Setting range	definite time	0.1 In ⩽ Is ⩽ 24 In in amperes
	IDMT	0.1 In ⩽ Is ⩽ 2.4 In in amperes
Accuracy (1)		±5 % or ±0.01 In
Resolution		1 A or 1 digit
Drop out/pick up ratio		93.5 % ±5 % or > (1 - 0.015 In/Is) x 100 %
Time delay T (operation time at 10 Is)		
Setting range	definite time	Inst, 50 ms ⩽ T ⩽ 300 s
	IDMT	100 ms ⩽ T ⩽ 12.5 s or TMS (2)
Accuracy (1) For T ⩾ 100 ms	definite time (4)	±2 % or from -10 ms to +25 ms
	IDMT	Class 5 or from -10 ms to +25 ms
Resolution		10 ms or 1 digit
Advanced settings		
Tripping direction		
Setting range		Busbar / line
Tripping logic		
Setting range		One out of three / two out of three
Timer hold T1		
Setting range	definite time	0; 0.05 to 300 s
	IDMT (3)	0.5 to 20 s
Resolution		10 ms or 1 digit
Characteristic times		
Operation time		pick-up < 75 ms at 2 Is (typically 65 ms) Inst. < 90 ms at 2 Is (confirmed instantaneous) (typically 75 ms)
Overshoot time		< 45 ms at 2 Is
Reset time		< 55 ms at 2 Is (for T1 = 0)

Inputs

Designation	Syntax	Equations	Logipam
Protection reset	P67_x_101	■	■
Protection inhibition	P67_x_113	■	■

Outputs

Designation	Syntax	Equations	Logipam	Matrix
Instantaneous output (pick-up)	P67_x_1	■	■	
Delayed output	P67_x_3	■	■	■
Drop out	P67_x_4	■	■	
Instantaneous output (reverse zone)	P67_x_6	■	■	
Phase 1 fault	P67_x_7	■	■	
Phase 2 fault	P67_x_8	■	■	
Phase 3 fault	P67_x_9	■	■	
Protection inhibited	P67_x_16	■	■	
Instantaneous output at 0.8 Is	P67_x_21	■	■	
1 out of 3 delayed output	P67_x_36	■	■	
2 out of 3 delayed output	P67_x_37	■	■	

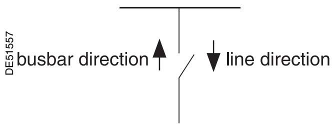
x: unit number.
***(1)** Under reference conditions (IEC 60255-6).*
***(2)** Setting ranges in TMS (Time Multiplier Setting) mode*
Inverse (SIT) and IEC SIT/A: 0.04 to 4.20
Very inverse (VIT) and IEC VIT/B: 0.07 to 8.33
Very inverse (LTI) and IEC LTI/B: 0.01 to 0.93
Ext. inverse (EIT) and IEC EIT/C: 0.13 to 15.47
IEEE moderately inverse: 0.42 to 51.86
IEEE very inverse: 0.73 to 90.57
IEEE extremely inverse: 1.24 to 154.32
IAC inverse: 0.34 to 42.08
IAC very inverse: 0.61 to 75.75
IAC extremely inverse: 1.08 to 134.4.
***(3)** Only for standardized tripping curves of the IEC, IEEE and IAC types.*

Directional earth fault
ANSI code 67N/67NC

Earth fault protection, with selective tripping according to fault current direction.

Description
To adapt to all types of applications and all earthing systems, the protection function operates according to two different types of characteristics, i.e. a choice of:
■ type 1: the protection function uses I0 vector projection.
This projection method is suitable for radial feeders in resistive, isolated or compensated neutral systems.
■ type 2: the protection function uses the I0 vector magnitude and operates like an earth fault protection function with an added direction criterion.
This projection method is suitable for closed ring distribution networks with directly earthed neutral.
■ type 3: the protection function uses the I0 vector magnitude and complies with Italian specification ENEL DK5600. It operates like an earth fault protection function with an added angular direction criterion {*Lim.1*, *Lim.2*}.
This protection method is suitable for distribution networks in which the neutral earthing system varies according to the operational mode.

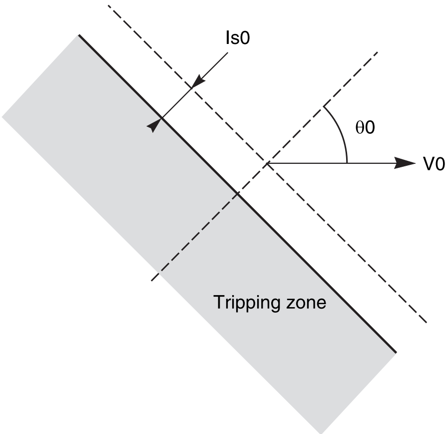
Tripping direction
The direction of the residual current is qualified as busbar direction or line direction according to the following convention:



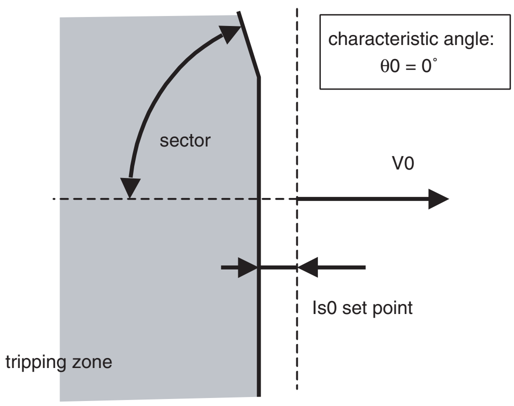
The tripping zone is set for tripping in busbar zone or tripping in line zone.
The reverse zone is the zone for which the protection function does not trip.
The detection of current in the reverse zone is used for indication.

Directional earth fault - Type 1
ANSI code 67N/67NC

Earth fault protection for impedant or compensated neutral systems.



Tripping characteristic of ANSI 67N/67NC type 1 protection (characteristic angle θ0 ≠ 0°).



Tripping characteristic of ANSI 67N/67NC type 1 protection (characteristic angle θ0 = 0°).

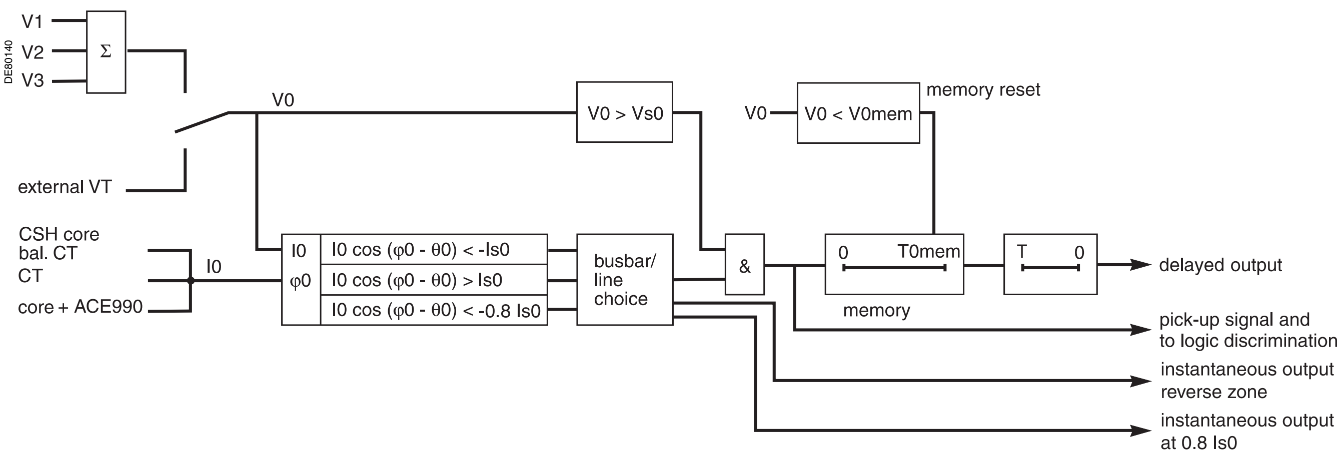
Description

The function determines the projection of the residual current I0 on the characteristic line, the position of which is determined by the setting of characteristic angle θ0 in relation to the residual voltage. The projection value is compared to the Is0 set point.
This protection function is suitable for radial feeders in resistive, isolated or compensated neutral systems.
With compensated neutral systems, it is characterized by its capacity to detect very brief, repetitive faults (recurrent faults). In the case of Petersen coils with no additional resistance, fault detection under steady state conditions is not possible due to the absence of active zero sequence current. The protection function uses the transient current at the beginning of the fault to ensure tripping.
The θ0 = 0° setting is suitable for compensated or impedant neutral systems. When this setting is selected, the parameter setting of the sector is used to reduce the protection tripping zone to ensure its stability on fault-free feeders.
The protection function operates with the residual current measured at one of the relay I0 inputs (operation with sum of three currents impossible). The protection function is inhibited for residual voltages below the Vs0 set point.
It implements a definite time (DT) delay.
The tripping direction may be set at the busbar end or line end.
Each of the two units has two groups of settings. Switching to setting group A or B can be carried out by a logic input or a remote control order, depending on the settings.

Memory

The detection of recurrent faults is controlled by the time delay T0mem which extends the transient pick-up information, thereby enabling the operation of the definite time delay even with faults that are rapidly extinguished (≈ 2 ms) and restrike periodically. Even when a Petersen coil with no additional resistance is used, tripping is ensured due to fault detection during the transient fault appearance. Detection is extended throughout the duration of the fault based on the criterion V0 ⩾ V0mem, within the limit of T0mem. With this type of application, T0mem must be greater than T (definite time delay).

Block diagram



3

Directional earth fault - Type 1
ANSI code 67N/67NC

Characteristics

Settings					
Measurement origin					
Setting range			I0 / I'0		
Characteristic angle θ					
Setting range			-45°, 0°, 15°, 30°, 45°, 60°, 90°		
Accuracy (1)			±2°		
Is0 setting					
Setting range			0.01 In0 ≤ Is0 ≤ 15 In0 (min. 0.1 A) in amperes		
	With CSH sensor	2 A rating	0.1 to 30 A		
		20 A rating	0.2 to 300 A		
	CT		0.01 In0 ≤ Is0 ≤ 15 In0 (min. 0.1 A)		
	Core balance CT with ACE990		0.01 In0 ≤ Is0 ≤ 15 In0 (min. 0.1 A)		
Accuracy (1)			±5 % (at φ0 = 180°)		
Resolution			0.1 A or 1 digit		
Drop out/pick up ratio			93.5 % ±5 %		
Time delay T (definite time (DT) tripping curve)					
Setting range			Inst, 50 ms ≤ T ≤ 300 s		
Accuracy (1)			±2 % or from -10 ms to +25 ms		
Resolution			10 ms or 1 digit		
Advanced settings					
Tripping direction					
Setting range			Busbar / line		
Vs0 set point					
Setting range			2 % Unp to 80 % Unp		
Accuracy (1)			±5 % or ±0.005 Unp		
Resolution			1 %		
Drop out/pick up ratio			93.5 % ±5 % or > (1 - 0.006 Unp/Vs0) x 100 %		
Sector					
Setting range			86°, 83°, 76°		
Accuracy	With CCA634		±2°		
	With CT + CSH30		±3°		
Memory time T0mem					
Setting range			0; 0.05 to 300 s		
Resolution			10 ms or 1 digit		
Memory voltage V0mem					
Setting range			0; 2 to 80 % of Unp		
Resolution			1 %		
Characteristic times					
Operation time			Pick-up < 55 ms at 2 Is0		
Overshoot time			< 45 ms at 2 Is0		
Reset time			< 65 ms (at T0mem = 0)		

Inputs			
Designation	**Syntax**	**Equations**	**Logipam**
Protection reset	P67N_x_101	■	■
Protection inhibition	P67N_x_113	■	■

Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P67N_x_1	■	■	
Delayed output	P67N_x_3	■	■	■
Drop-out	P67N_x_4	■	■	
Instantaneous output (reverse zone)	P67N_x_6	■	■	
Protection inhibited	P67N_x_16	■	■	
Instantaneous output at 0.8 Is0	P67N_x_21	■	■	

x: unit number.
***(1)** Under reference conditions (IEC 60255-6).*

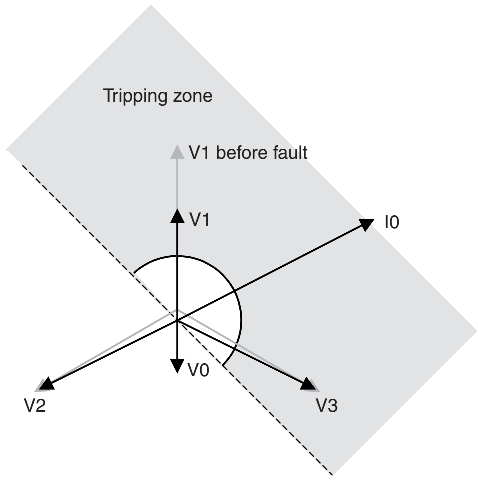
Standard setting

The settings below are given for usual applications in the different earthing systems.
The shaded boxes represent default settings.

	Isolated neutral	**Impedant neutral**	**Compensated neutral**
Is0 set point	Set according to discrimination study	Set according to discrimination study	Set according to discrimination study
Characteristic angle θ0	90°	0°	0°
Time delay T	Set according to discrimination study	Set according to discrimination study	Set according to discrimination study
Direction	Line	Line	Line
Vs0 set point	2 % of Uns	2 % of Uns	2 % of Uns
Sector	N/A	86°	86°
Memory time T0mem	0	0	200 ms
Memory voltage V0mem	0	0	0

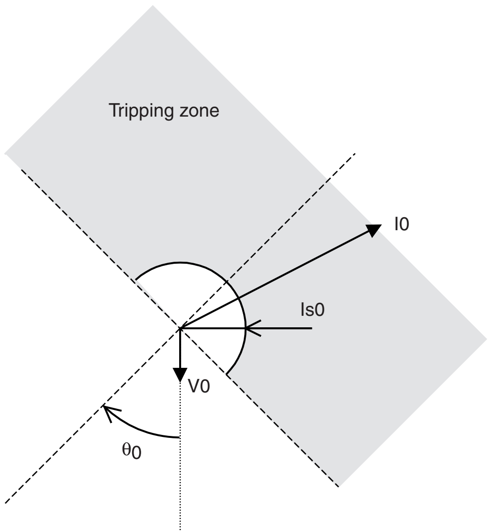
Earth fault protection for impedant or solidly earthed systems.

DE80358



Example of phase 1 to earth fault - Measurement of the 3 phase voltages.

DE80357



Tripping characteristic of ANSI 67N/67NC - type 2 protection function.

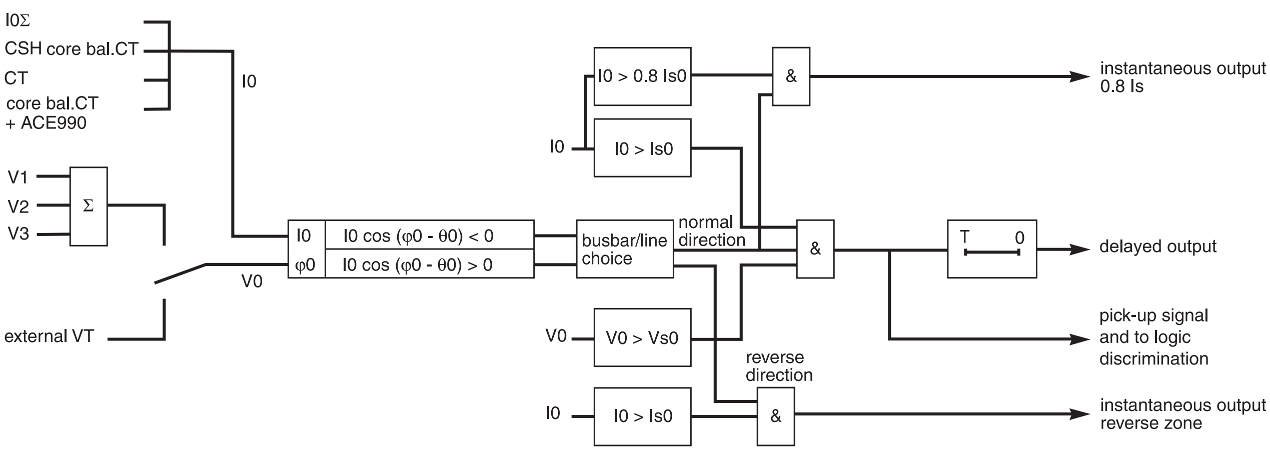
Description

The protection function operates like an earth fault protection function with an added direction criterion.
It is suitable for closed ring distribution networks with directly earthed neutral. It has all the characteristics of an earth fault protection function (50N/51N) and can therefore be easily coordinated with that function.
The residual current is the current measured at one of the Sepam I0 inputs or calculated using the sum of the main phase currents (I), according to the parameter setting.
The tripping direction may be set at the busbar end or line end.
The protection function has a definite or IDMT time delay.
Each of the two units has two groups of settings. Switching to setting group A or B can be carried out by a logic input or a remote control order, depending on the settings.
The customized curve, defined point by point, may be used with this protection function.
An adjustable timer hold, definite time or IDMT, can be used for coordination with electromagnetic relays and to detect restriking faults.

Tripping curve	Timer hold
Definite time (DT)	Definite time
Standard inverse time (SIT)	Definite time
Very inverse time (VIT or LTI)	Definite time
Extremely inverse time (EIT)	Definite time
Ultra inverse time (UIT)	Definite time
RI curve	Definite time
IEC inverse time SIT / A	Definite time or IDMT
IEC very inverse time VIT or LTI / B	Definite time or IDMT
IEC extremely inverse time EIT / C	Definite time or IDMT
IEEE moderately inverse (IEC / D)	Definite time or IDMT
IEEE very inverse (IEC / E)	Definite time or IDMT
IEEE extremely inverse (IEC / F)	Definite time or IDMT
IAC inverse	Definite time or IDMT
IAC very inverse	Definite time or IDMT
IAC extremely inverse	Definite time or IDMT
Customized	Definite time

Block diagram

DE80141



3

Directional earth fault - Type 2
ANSI code 67N/67NC

Characteristics

Settings			
Measurement origin			
Setting range			I0 I'0 I0Σ (sum of the main phase channels)
Characteristic angle θ			
Setting range			-45°, 0°, 15°, 30°, 45°, 60°, 90°
Accuracy (1)			±2°
Tripping curve			
Setting range			See previous page
Is0 set point			
Definite time setting range			0.01 In0 ⩽ Is0 ⩽ 15 In0 (min. 0.1 A) in amperes
	Sum of CTs		0.01 In ⩽ Is0 ⩽ 15 In (min. 0.1 A)
	With CSH sensor	2 A rating	0.1 to 30 A
		20 A rating	0.2 to 300 A
	CT		0.01 In0 ⩽ Is0 ⩽ 15 In0 (min. 0.1 A)
	Core balance CT with ACE990		0.01 In0 ⩽ Is0 ⩽ 15 In0 (min. 0.1 A)
IDMT setting range			0.01 In0 ⩽ Is0 ⩽ In0 (mini 0.1 A) in amperes
	Sum of CTs		0.01 In ⩽ Is0 ⩽ In (min. 0.1 A)
	With CSH sensor	2 A rating	0.1 to 2 A
		20 A rating	0.2 to 20 A
	CT		0.01 In0 ⩽ Is0 ⩽ In0 (min. 0.1 A)
	Core balance CT with ACE990		0.01 In0 ⩽ Is0 ⩽ In0 (min. 0.1 A)
Accuracy (1)			±5 % or ±0.004 In0
Resolution			0.1 A or 1 digit
Drop out/pick up ratio			93.5 % ±5 % or > (1 - 0.005 In0/Is0) x 100 %
Time delay T (operation time at 10 Is0)			
Setting range	definite time		Inst, 50 ms ⩽ T ⩽ 300 s
	IDMT		100 ms ⩽ T ⩽ 12.5 s or TMS (2)
Accuracy (1)	definite time		±2 % or from -10 ms to +25 ms
	IDMT		Class 5 or from -10 ms to +25 ms
Resolution			10 ms or 1 digit
Advanced settings			
Tripping direction			
Setting range			Busbar / line
Vs0 set point			
Setting range			2 % Unp to 80 % Unp
Accuracy (1)			±5 % or ±0.005 Unp
Resolution			1 %
Drop out/pick up ratio			93 % ±5 % or > (1 - 0.006 Unp/Vs0) x 100 %
Timer hold T1			
Setting range	definite time		0; 0.05 to 300 s
	IDMT (3)		0.5 to 20 s
Resolution			10 ms or 1 digit
Characteristic times			
Operation time			Pick-up < 40 ms at 2 Is0 (typically 25 ms) Inst. < 55 ms at 2 Is0 (confirmed instantaneous) (typically 35 ms)
Overshoot time			< 35 ms at 2 Is0
Reset time			< 50 ms at 2 Is0 (for T1 = 0)

Inputs

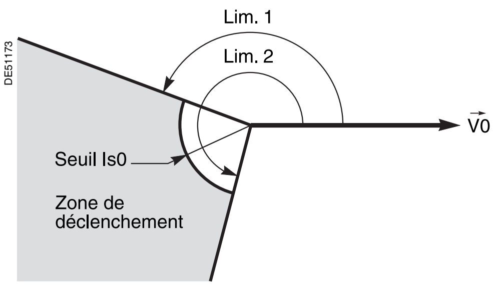
Designation	Syntax	Equations	Logipam
Protection reset	P67N_x_101	■	■
Protection inhibition	P67N_x_113	■	■

Outputs

Designation	Syntax	Equations	Logipam	Matrix
Instantaneous output (pick-up)	P67N_x_1	■	■	
Delayed output	P67N_x_3	■	■	■
Drop out	P67N_x_4	■	■	
Instantaneous output (reverse zone)	P67N_x_6	■	■	
Protection inhibited	P67N_x_16	■	■	
Instantaneous output at 0.8 Is0	P67N_x_21	■	■	

x: unit number.
(1) Under reference conditions (IEC 60255-6).
(2) Setting ranges in TMS (Time Multiplier Setting) mode
Inverse (SIT) and IEC SIT/A: 0.04 to 4.20
Very inverse (VIT) and IEC VIT/B: 0.07 to 8.33
Very inverse (LTI) and IEC LTI/B: 0.01 to 0.93
Ext. inverse (EIT) and IEC EIT/C: 0.13 to 15.47
IEEE moderately inverse: 0.42 to 51.86
IEEE very inverse: 0.73 to 90.57
IEEE extremely inverse: 1.24 to 154.32
IAC inverse: 0.34 to 42.08
IAC very inverse: 0.61 to 75.75
IAC extremely inverse: 1.08 to 134.4.
(3) Only for standardized tripping curves of the IEC, IEEE and IAC types.

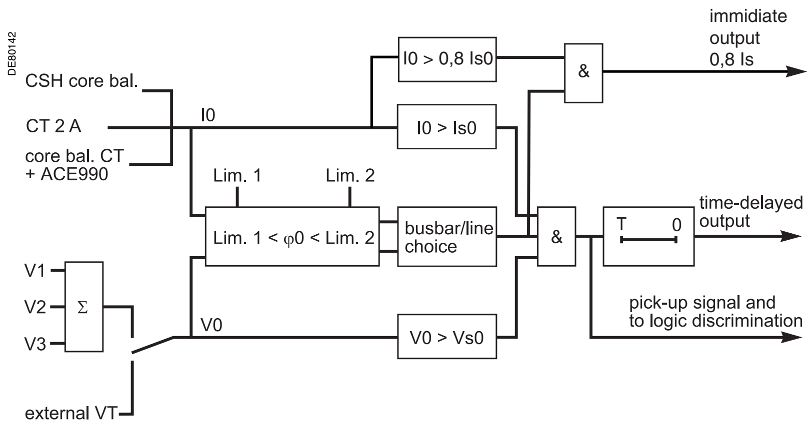
Directional earth fault - Type 3
ANSI Code 67N/67NC



Type 3 operation

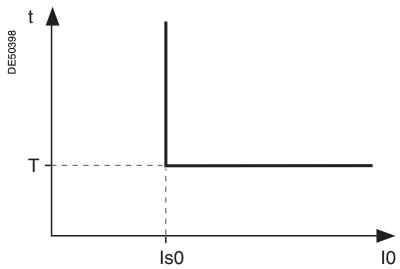
This protection operates like an earth fault protection function (ANSI 50N/51N) with an added angular direction criterion {*Lim.1*, *Lim.2*}.
It is suitable for distribution networks in which the neutral earthing system varies according to the operational mode.
The tripping direction may be set at the busbar end or line end.
The residual current is the current measured at the Sepam I0 input.
It has a definite time delay (DT constant).
By choosing an Is0 set point of 0, the protection function behaves like a neutral voltage displacement protection function (ANSI 59N).

Simplified schematic



Definite time operation

Is0 corresponds to the operating set point expressed in amps, and T corresponds to the protection operating delay.



Definite time protection principle.

Directional earth fault - Type 3
ANSI Code 67N/67NC

Type 3 characteristics

Measurement origin		
Setting range		I0 I'0 I0Σ (sum of the main phase channels)
Tripping zone start angle *Lim.1*		
Setting		0° to 359°
Resolution		1°
Accuracy		±3°
Tripping zone end angle *Lim.2*		
Setting		0° to 359° (1)
Resolution		1°
Accuracy		±3°
Tripping direction		
Setting		Line/busbar
Is0 set point		
Setting (2)	With CSH core balance CT (2 A rating)	0.1 A to 30 A
	With 1 A CT	0.005 In0 ⩽ Is0 ⩽ 15 In0 (min. 0.1 A)
	With core balance CT + ACE990 (range 1)	0.01 In0 ⩽ Is0 ⩽ 15 In0 (min. 0.1 A) (3)
Resolution		0.1 A or 1 digit
Accuracy		±5%
Drop-out/pick-up ratio		⩾ 95%
Vs0 set point		
Setting	On sum of 3 Vs	2% Unp ⩽ Vs0 ⩽ 80% Unp
	On external VT	0.6 % Unp ⩽ Vs0 ⩽ 80% Unp
Resolution		0.1% for Vs0 < 10% 1% for Vs0 ⩾ 10%
Accuracy		±5%
Drop-out/pick-up ratio		⩾ 95%
Time delay T		
Setting		instantaneous, 50 ms ⩽ T ⩽ 300 s
Resolution		10 ms or 1 digit
Accuracy		⩽ 3% or ±20 ms at 2 Is0
Characteristic times		
Operation time		pick-up < 40 ms at 2 Is0
		instantaneous < 55 ms at 2 Is0
Overshoot time		< 40 ms
Reset time		< 50 ms

Inputs

Designation	Syntax	Equations	Logipam
Reset protection	P67N_x_101	■	■
Inhibit protection	P67N_x_113	■	■

Outputs

Designation	Syntax	Equations	Logipam	Matrix
Instantaneous output (pick-up)	P67N_x_1	■	■	
Delayed output	P67N_x_3	■	■	■
Drop-out	P67N_x_4	■	■	
Instantaneous output (reverse zone)	P67N_x_6	■	■	
Protection inhibited	P67N_x_16	■	■	
Instantaneous output at 0.8 Is0	P67N_x_21	■	■	

***(1)** Tripping zone Lim.2-Lim.1 should be 10° or more.*
***(2)** For Is0 = 0, the protection function behaves like a neutral voltage displacement protection function (59N).*
***(3)** In0 = k . n where n = the core balance CT ratio and k = coefficient to be determined according to the wiring of the ACE990 (0.00578 ⩽ k ⩽ 0.04).*

Standard tripping zone setting (line end)

The settings below are given for the usual applications in different types of neutral earthing system.
The shaded boxes represent default settings.

	Isolated neutral	Impedant neutral	Directly earthed neutral
Lim.1 angle	190°	100°	100°
Lim.2 angle	350°	280°	280°

Loss of synchronism
ANSI code 78PS

Protection of synchronous motors and generators against loss of synchronism.

Operation
The loss of synchronism in synchronous motors and generators protection function is based on the value of the active power calculated on the stator winding.
The protection function is made up of three independent protection modules, based on:
- the internal angle calculation
- the equal-area criterion
- power swings.

Tripping is caused either by one of the above principles, or a combination of several of them, depending on the parameters set.

When using the loss of synchronism in synchronous motors protection function, only power swings should be used if the motor load instantaneous variations exceed 10 % of its rated power.

Current sensors
Current transformers must be:
- either type 5P20, with an accuracy burden of VATC > $RfIn^2$
  where VATC: CT rated burden
  In : secondary rated current of the CT
  Rf: wiring resistance
- or defined by a kneepoint voltage Vk ⩾ (RTC + Rf).20.In
  where RTC: CT internal resistance.

Calculating the internal angle
The algorithm is based on calculating variations in the rotor speed and the internal angle by resolving the fundamental equation relating to mechanical movements:

$$J \cdot \Omega_m \cdot \frac{d\Omega_m}{dt} = P_m - P_e$$

$$\Omega_m = \frac{d\theta_m}{dt} = \frac{d\delta}{dt} \times \frac{1}{np}$$

J: total moment of inertia (generator + turbine or motor + load)
Ωm: rotor speed
Pm: mechanical power (supplied by the turbine or taken by the motor load)
Pe: active electrical power (supplied by the generator or taken by the motor)
θm: mechanical internal angle of the synchronous machine
δ: electrical internal angle of the synchronous machine.

Calculating the internal angle

Protection tripping
The protection trips if the variation in the internal angle is higher than the configured set point for longer than the confirmation delay.

Initializing calculation
Calculation of variations in the rotor speed and the internal angle is initialized in the event of significant network disturbance:
- Either Pa = |Pm - Pe| is more than 25 % of the machine's rated power
- Or the positive sequence impedance enters the power swing polygon, defined using the machine transient reactance Xd'.

Stopping calculation
Calculation of variations in the rotor speed and the internal angle is interrupted either when the network returns to stability, or at the end of the first oscillation period of the mechanical movement (similarly to the equal-area criterion).

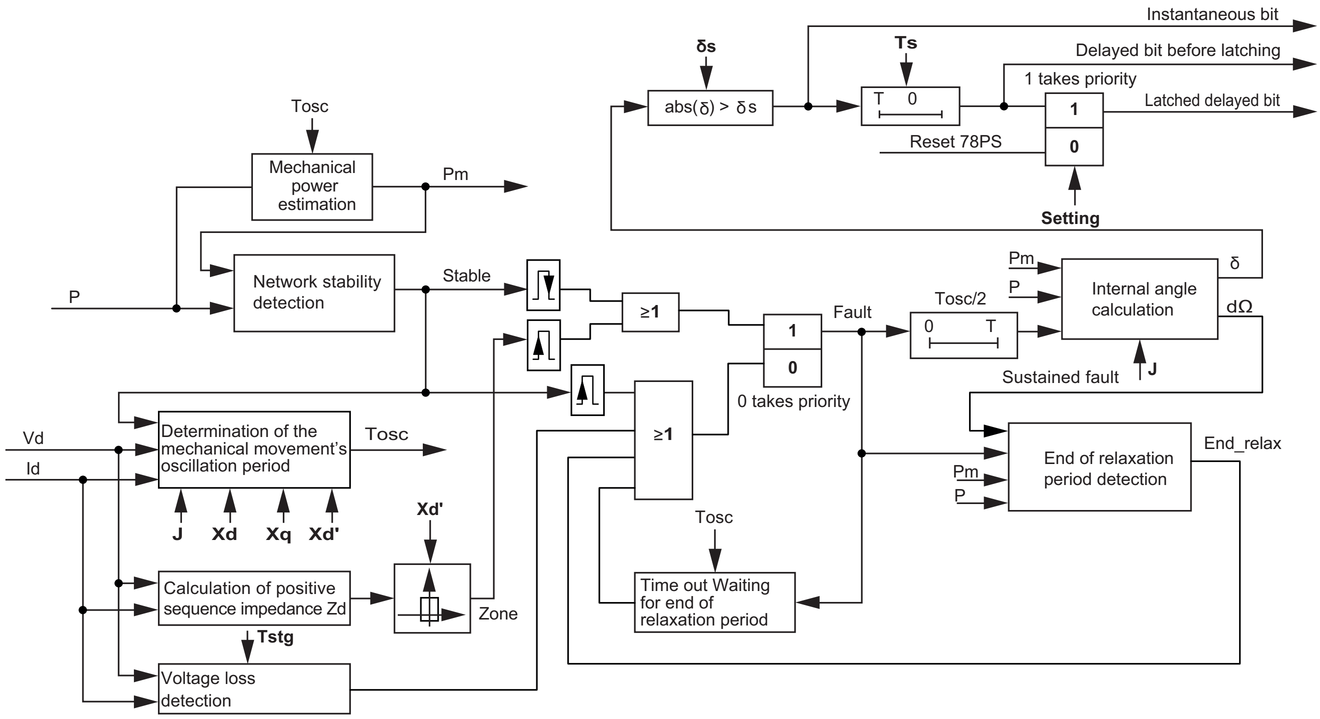
Calculating the mechanical power
The mechanical power Pm supplied by the turbine depends on the nature of the turbine and the type of speed governor. It is estimated by using a 2nd order low-pass filter at the mechanical movement's frequency of oscillation.
The mechanical power Pm taken by the motor + load assembly can vary quickly according to the driven mechanical load. Therefore in order to follow the mechanical power as closely as possible, it is estimated by using a 1st order low-pass filter at the mechanical movement's frequency of oscillation.

Determination of the frequency of oscillation Tosc
The mechanical movement's frequency of oscillation is determined periodically, before appearance of the disturbance, in order to take account of the initial internal angle and initial field voltage.

Synchronous machine parameters
Xd : synchronous reactance of the d axis (in pu)
Xd' : transient reactance of the d axis (in pu)
Xq : synchronous reactance of the q axis (in pu)
J : mechanical system moment of inertia (in kg.m²)
N : machine synchronous speed (in rpm)
These parameters are defined by the user in the "Particular characteristics" screen in the SFT2841 parameter-setting software.

Block diagram

DE81205



Loss of synchronism
ANSI code 78PS

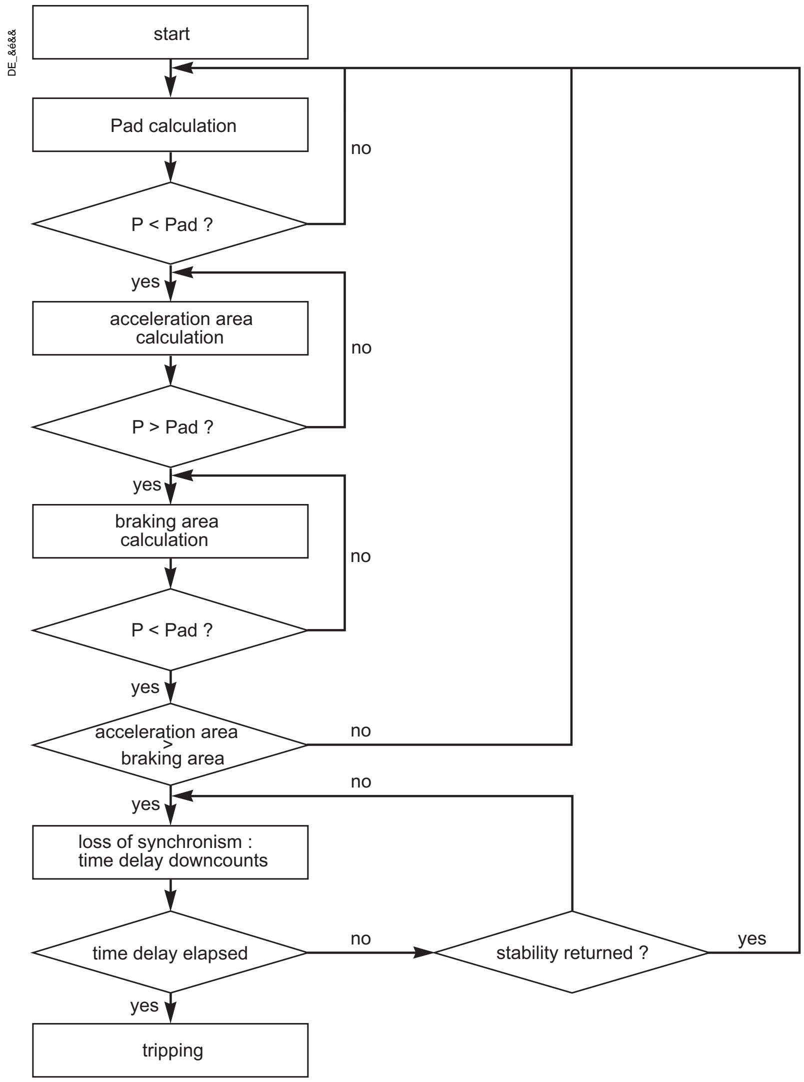
Equal-area criterion

The algorithm is based on calculating the acceleration area on appearance of a fault, then the braking area on disappearance of the fault.

Protection tripping

The trip order is given if the braking area is less than the acceleration area.
The function calculates in steady state the average over 4 seconds of active power, which corresponds to the mechanical power before the fault, Pad, supplied by the turbine or taken by the motor load.
Comparison of the areas is initialized when the active power differs from the mechanical power by more than 5 %.
A time delay can be used to postpone tripping. The protection function is reset if a return to stability is detected during this time delay.

Block diagram



3

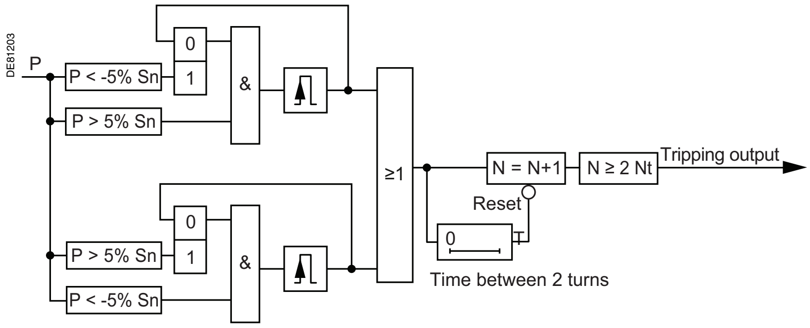
Loss of synchronism
ANSI code 78PS

IPower swings

The algorithm is based on detecting inversion of the active power sign.
A power swing corresponds to 2 consecutive inversions of the active power sign.
The protection trips when the number of power swings equals the configured set point.

A time delay is used to fix a maximum period between 2 power swings, in order to make the protection immune to low-frequency power swings.

Block diagram



Characteristics

Settings				
Choosing the type of trip				
Setting range	Internal angle calculation Internal angle and power swing calculation Equal-area criterion Power swing Equal-area criterion and power swing			
Internal angle calculation				
Stabilization delay				**Tstg**
Setting range	1 s ⩽ Tstg ⩽ 300 s			
Accuracy (1)	±2% or from -10 ms to +25 ms			
Resolution	100 ms or 1 digit			
Maximum internal angle variation				**δs**
Setting range	100 ° ⩽ δs ⩽ 1000 °			
Resolution (1)	10 °			
Confirmation delay				**Ts**
Setting range	0 ⩽ Ts ⩽ 300 ms			
Accuracy (1)	±2% or from -10 ms to +25 ms			
Resolution	10 ms or 1 digit			
Equal-area criterion				
Confirmation delay				**V**
Setting range	100 ms ⩽ T ⩽ 300 s			
Accuracy (1)	±2% or from -10 ms to +25 ms			
Resolution	10 ms or 1 digit			
Power swings				
Number of turns				**Nt**
Setting range	1 ⩽ Nt ⩽ 30			
Resolution	1			
Maximum time between 2 turns				**V**
Setting range	1 s ⩽ T ⩽ 300 s			
Resolution	1 s or 1 digit			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Reset protection	P78PS_1_101	■	■	
Inhibit protection	P78PS_1_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P78PS_1_1	■	■	
Time-delayed output	P78PS_1_3	■	■	■
Protection inhibited	P78PS_1_16	■	■	

(1) Under reference conditions (IEC 60255-6).

Help with parameter setting

Stabilization delay and oscillation period
The stabilization delay corresponds to the time it takes to estimate the mechanical power Pm, after circuit breaker closing.
The mechanical movement's oscillation period Tosc is calculated using the average of 4 values available every 500 ms.
As the mechanical movement's oscillation period is not available for 2 s after circuit breaker closing, the stabilization delay must be configured with a value between 4 and 5 times the mechanical movement's oscillation period defined by the following expression:

$$\mathbf{Tosc} = 2\pi \cdot \sqrt{\frac{\mathbf{2H}}{\mathbf{Ks} \cdot \omega}}$$

Where:
ω electrical network pulsation in rd/s
H: mechanical system inertia constant in seconds:

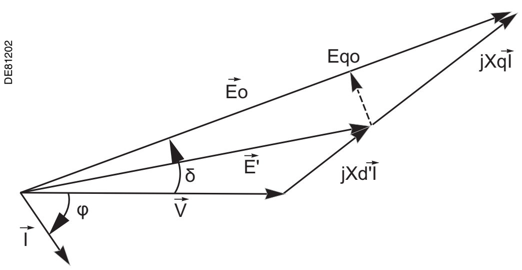
$$\mathbf{H} = \frac{\mathbf{J} \cdot (\omega / \mathbf{np})^2}{\mathbf{2} \cdot \mathbf{Sn}}$$

Ks: synchronizing coefficient in pu
np: number of pairs of poles
Sn: synchronous machine apparent power in VA

Synchronizing coefficient
The synchronizing coefficient Ks characterizes the ability of the synchronous machine to resynchronize itself. It depends on the synchronous machine's operating point before the fault appeared in the network. It is defined by the following expression:

$$\mathbf{Ks} = \frac{\mathbf{Eqo} \cdot \mathbf{V}}{\mathbf{Xd'}} \cdot \mathbf{cos}\delta + \mathbf{V}^2 \cdot \left(\frac{1}{\mathbf{Xq}} - \frac{1}{\mathbf{Xd'}}\right) \cdot \mathbf{cos2}\delta$$

Eqo: field voltage, in transient state, in pu of Vn
V: voltage at the machine terminals in pu of Vn
δ: synchronous machine's electrical internal angle in degrees



Vector representation of the machine's internal angle.

Field voltage
The field voltage in transient state Eqo is determined by the projecting the next vector on the q axis:

$$\vec{\mathbf{E}}' = \vec{\mathbf{V}} + \mathbf{j} \cdot \mathbf{Xd'} \cdot \vec{\mathbf{I}}$$

The direction of the q axis is defined by the vector:

$$\overrightarrow{\mathbf{E0}} = \vec{\mathbf{V}} + \mathbf{j} \cdot \mathbf{Xq} \cdot \vec{\mathbf{I}}$$

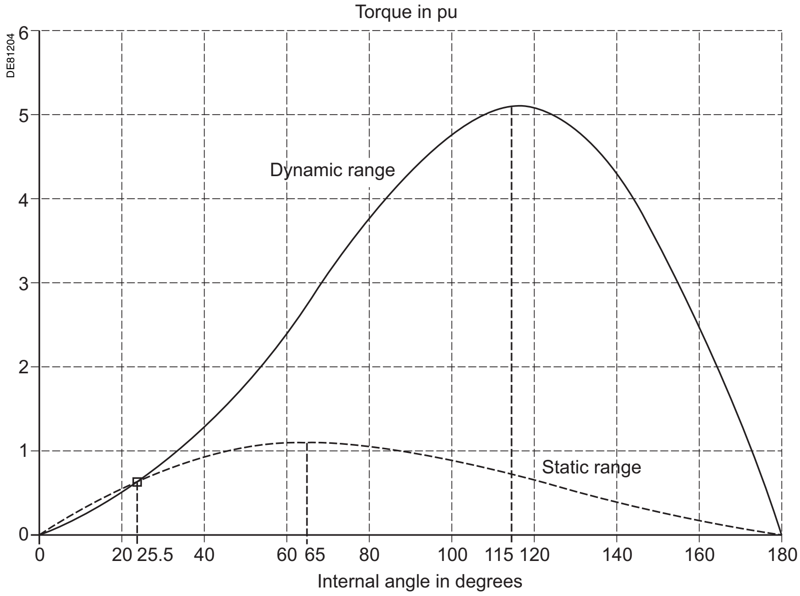
3

Example of parameter setting: 44 MVA / 11 kV generator

Input data
Xd = 1.67
Xq = 0.88
Xd' = 0.23
H = 10 seconds
The generator operating point is as follows:
V = 1 pu
I = 0.7 pu (φ = -20 °)

Calculation results
Eqo = 1.017 pu
δ = 25.55° (internal angle)
Pad = 0.658 pu (active power before fault)
Ks = 2.98
Tosc = 0.92 seconds

In this example, the initial internal angle is 25.55°. According to the graph below, we can see that the active power available when stationary cannot exceed 1.15 pu, whereas in transient state it can reach 5.24 pu.



Representation of the torque as a function of the internal angle in dynamic and static states.

Machine stability and internal angle
The synchronous machine will always be stable if the electrical torque drift is positive compared to the internal angle. In other words when on an ascending part of the Ce(δ) function.
Thus when stationary, the machine will always be stable in the above example, if the internal angle does not exceed 65°. Whereas in transient state, the internal angle can be as large as 115° without affecting the synchronous machine's stability.

Setting the power swing parameters
■ Maximum time between 2 rotations:
The maximum time between 2 rotations should be configured with a value higher than the mechanical movement's oscillation period Tosc.
■ Number of rotations:
The number of power swings is not directly linked to the number of rotations in the internal angle. Thus the number of rotations should be configured with a value higher than 2.

Setting the internal angle calculation parameters
■ Confirmation delay:
The confirmation delay should be configured with half the mechanical movement's oscillation period Tosc.
■ Maximum internal angle variation:
The majority of generators can tolerate, during a loss of synchronism, 2 rotations of their internal angle. Thus, in the absence of manufacturer data, the maximum internal angle variation should be configured with the value of 300° (corresponding to 1 rotation of the internal angle).

Recloser
ANSI code 79

Recloser with 1 to 4 cycles to clear transients or semi-permanent faults on overhead lines.

Definition

Reclaim time
The reclaim time is activated by a circuit breaker closing order given by the recloser.
If no faults are detected before the end of the reclaim time, the initial fault is
considered to have been cleared.
Otherwise a new reclosing cycle is initiated.
The delay must be longer than the longest reclosing cycle activation condition.

Safety time until ready
The safety time is activated by a manual circuit breaker closing order. The recloser is inhibited for the duration of the time.
If a fault occurs during this time, no reclosing cycles are initiated and the circuit breaker remains permanently open.

Dead time
Cycle n dead time is launched by
breaking device tripping order
given by the recloser during cycle n.
The breaking device remains open throughout the time.
At the end of the cycle n dead time, the n+1 cycle begins, and the recloser orders the closing of the circuit breaker.

Description

Automation device used to limit down time after tripping due to transient or semi-permanent faults on overhead lines. The recloser orders automatic reclosing of the breaking device after the time delay required to restore the insulation. Recloser operation is easy to adapt for different operating modes by parameter setting.

Initialization of the recloser
The recloser is ready to operate if all of the following conditions are met:
- "switchgear control" function activated and recloser in service (not inhibited by the recloser inhibition logic input)
- circuit breaker closed
- the safety time is not running
- none of the recloser inhibition conditions is true (e.g. trip circuit fault, control fault, SF6 pressure drop).

Recloser cycles
- case of a fault that is not cleared: following instantaneous or time-delayed tripping by the protection unit, activation of the dead time associated with the first active cycle. At the end of the dead time, a closing order is given, which activates the reclaim time. If the protection unit detects the fault before the end of the time delay, a tripping order is given and the following reclosing cycle is activated. after all the active cycles have been run, if the fault still persists, a final trip order is given, a message appears on the display.
- case of a cleared fault: Following a reclosing order, if the fault does not appear after the reclaim time has run out, the recloser reinitializes and a message appears on the display (see example 1).
- closing on a fault.

If the circuit breaker closes on a fault, or if the fault appears before the end of the safety time delay, the recloser is inhibited. A final trip message is issued.

Recloser inhibition conditions
The recloser is inhibited according to the following conditions:
- voluntary open or close order
- recloser put out of service
- receipt of a inhibition order on the logic input
- activation of the breaker failure, such as trip circuit fault, control fault, SF6 pressure drop
- opening of the circuit breaker by a protection unit that does not run reclosing cycles (e.g. frequency protection), by external tripping or by a function set up not to activate reclosing cycles.

In such cases, a final trip message appears.

Extension of the dead time
If, during a reclosing cycle, reclosing of the circuit breaker is impossible because breaker recharging is not finished (following a drop in auxiliary voltage, recharging time is longer), the dead time may be extended up to the time at which the circuit breaker is ready to carry out an "Open-Close-Open" cycle. The maximum time added to the dead time is adjustable (Twait_max). If, at the end of the maximum waiting time, the circuit breaker is still not ready, the recloser is inhibited (see example 5).

Recloser
ANSI code 79

Characteristics

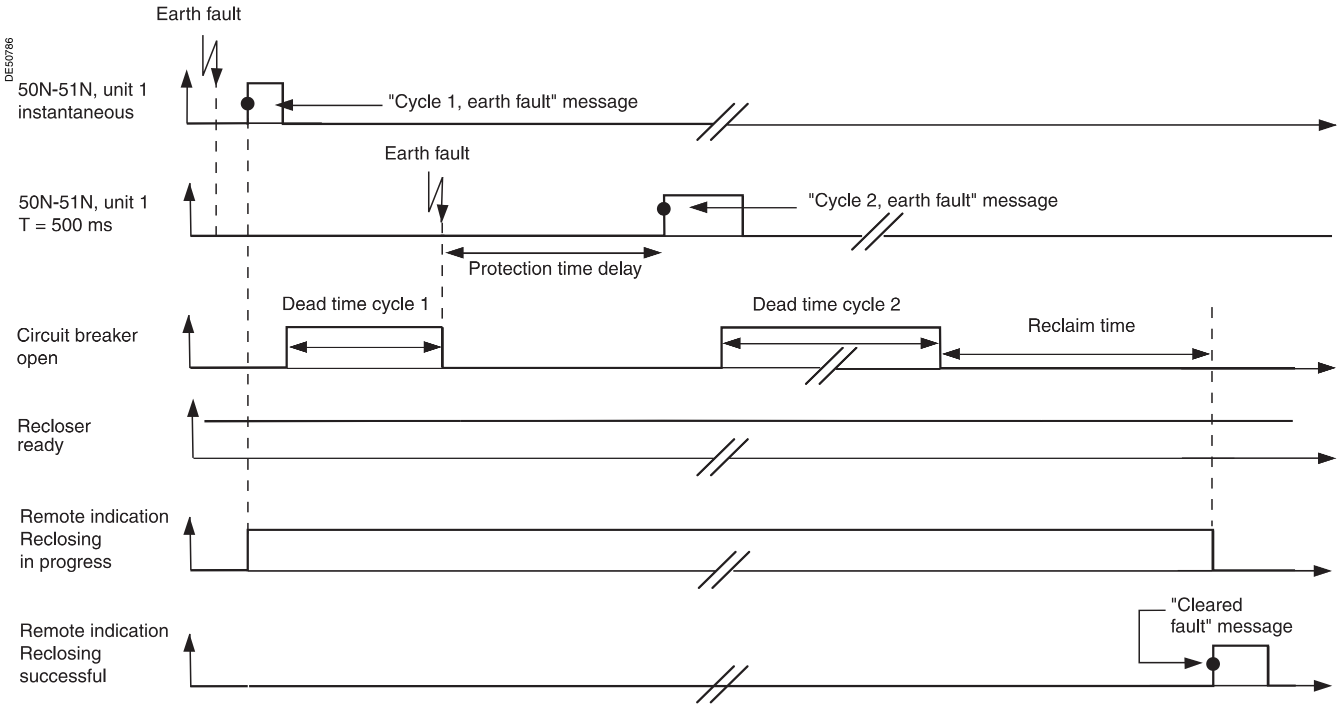
Settings		
Number of cycles		
Setting range		1 to 4
Activation of cycle 1		
Protection 50/51 units 1 to 4		inst. / delayed / no activation
Protection 50N/51N units 1 to 4		inst. / delayed / no activation
Protection 67 units 1 to 2		inst. / delayed / no activation
Protection 67N/67NC units 1 to 2		inst. / delayed / no activation
Logic equations or Logipam outputs V_TRIPCB		active/inactive
Activation of cycles 2, 3 and 4		
Protection 50/51 units 1 to 4		inst. / delayed / no activation
Protection 50N/51N units 1 to 4		inst. / delayed / no activation
Protection 67 units 1 to 2		inst. / delayed / no activation
Protection 67N/67NC units 1 to 2		inst. / delayed / no activation
Logic equations or Logipam outputs V_TRIPCB		active/inactive
Time delays		
Reclaim time		0.1 to 300 s
Dead time	Cycle 1	0.1 to 300 s
	Cycle 2	0.1 to 300 s
	Cycle 3	0.1 to 300 s
	Cycle 4	0.1 to 300 s
Safety time until ready		0 to 60 s
Maximum additional dead time		0.1 to 60 s
Accuracy (1)		±2 % or ±25 ms
Resolution		10 ms

Inputs			
Designation	**Syntax**	**Equations**	**Logipam**
Protection inhibition	P79_1_113	■	■

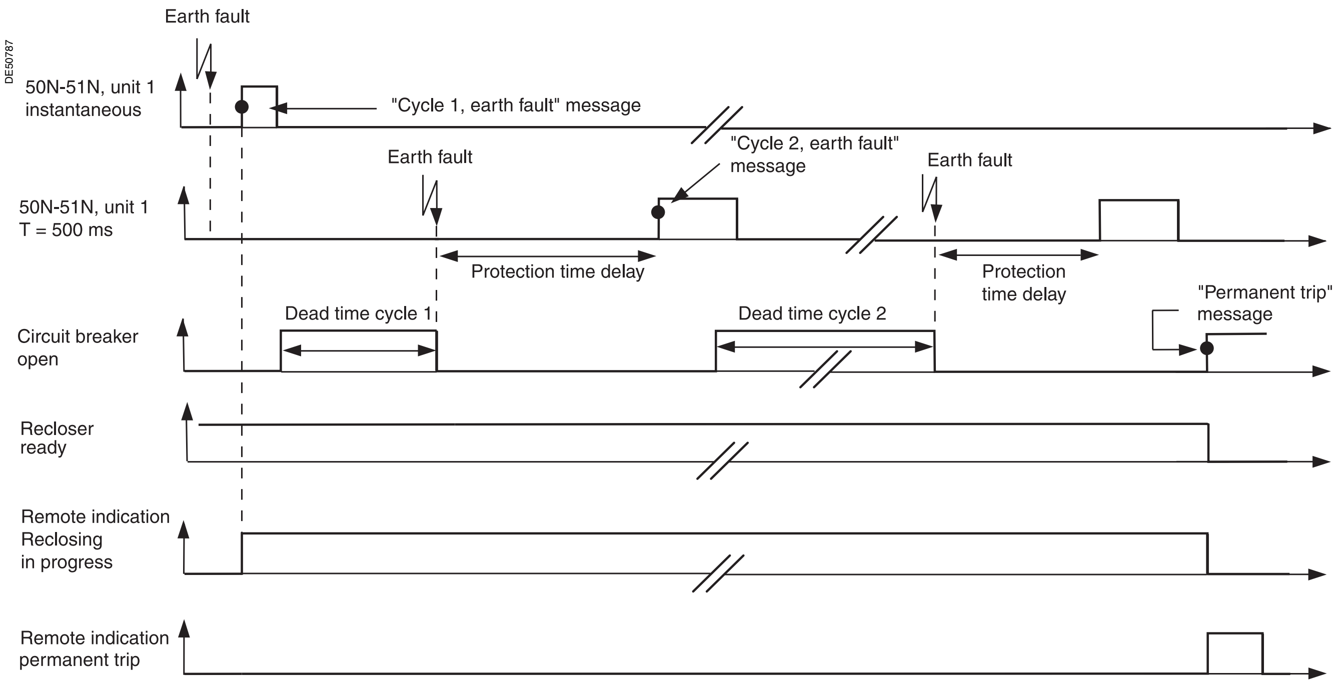
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Recloser in service	P79 _1_201	■	■	■
Recloser ready	P79 _1_202	■	■	■
Cleared fault	P79 _1_203	■	■	■
Final trip	P79 _1_204	■	■	■
Closing by recloser	P79 _1_205	■	■	
Reclosing cycle 1	P79 _1_211	■	■	■
Reclosing cycle 2	P79 _1_212	■	■	■
Reclosing cycle 3	P79 _1_213	■	■	■
Reclosing cycle 4	P79 _1_214	■	■	■

***(1)** Under reference conditions (IEC 60255-6).*

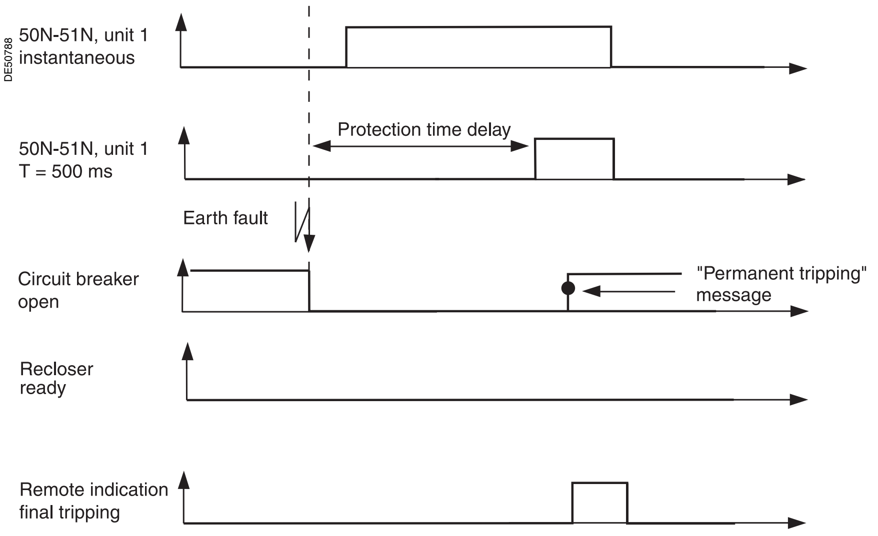
Example 1. Fault cleared after the second cycle



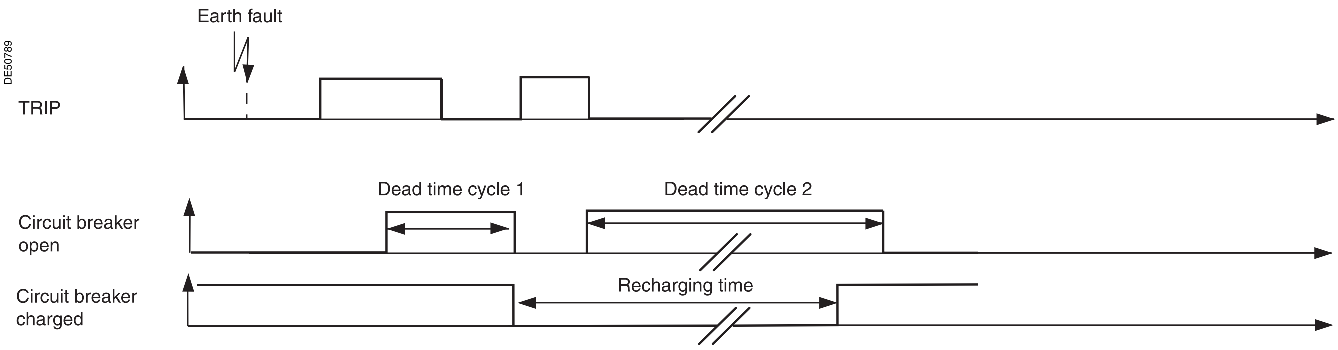
Example 2. Fault not cleared



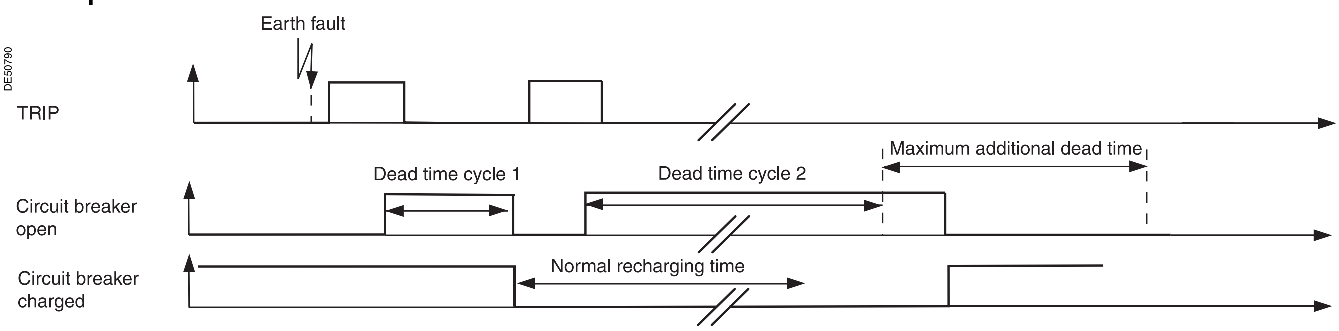
Example 3. Closing on a fault



Example 4. No extension of dead time



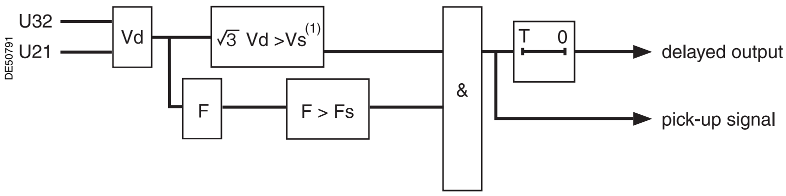
Example 5. Extension of dead time



Overfrequency
ANSI code 81H

Detection of abnormally high frequencies.

Description
Detection of abnormally high frequency compared to the rated frequency, to monitor power supply quality or protect a generator against overspeeds.
The frequency is calculated using voltage V1 or U21 when only one voltage is connected, otherwise the positive sequence voltage is used to procure greater stability. It is compared to the Fs set point.
The protection function is inhibited if the voltage used for calculations is under the adjustable set point Vs.
The protection includes a definite time delay T.

Block diagram


1) Or U21, or √3.V1 > Vs if only one TP.

Characteristics

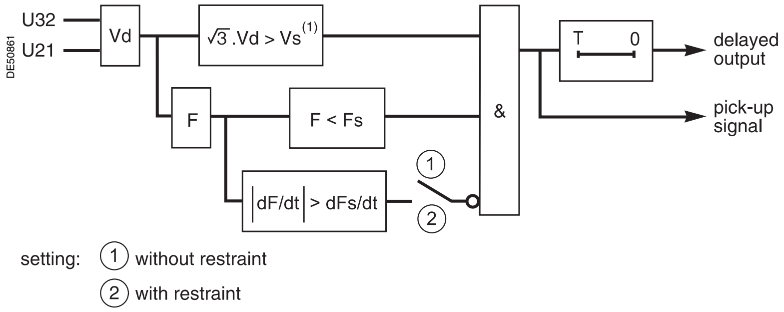
Settings				
Measurement origin				
Setting range	Main channels (U) / Additional channels (U’)			
Fs set point				
Setting range	49 to 55 Hz or 59 to 65 Hz			
Accuracy (1)	±0.01 Hz			
Resolution	0.01			
Pick up / drop out difference	0.05 Hz ± 0.015 Hz			
Time delay T				
Setting range	100 ms to 300 s			
Accuracy (1)	±2 % or ±25 ms			
Resolution	10 ms or 1 digit			
Advanced settings				
Vs set point				
Setting range	20 % Un to 90 % Un			
Accuracy (1)	2 %			
Resolution	1 %			
Characteristic times				
Operation time	Pick-up < 90 ms from Fs -0.5 Hz to Fs +0.5 Hz			
Overshoot time	< 50 ms from Fs -0.5 Hz to Fs +0.5 Hz			
Reset time	< 55 ms from Fs +0.5 Hz to Fs -0.5 Hz			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P81H_x_101	■	■	
Protection inhibition	P81H_x_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P81H_x_1	■	■	
Delayed output	P81H_x_3	■	■	■
Protection inhibited	P81H_x_16	■	■	

x: unit number.
***(1)** Under reference conditions (IEC 60255-6) and df/dt < 3 Hz/s.*

Underfrequency
ANSI code 81L

Detection of abnormally low frequency for load shedding using a metric frequency criterion.

Description
Detection of abnormally low frequency compared to the rated frequency, to monitor power supply quality. The protection may be used for overall tripping or load shedding.
The frequency is calculated using voltage V1 or U21 when only one voltage is connected, otherwise the positive sequence voltage is used to procure greater stability. It is compared to the Fs set point.
The protection function is inhibited if the voltage used for calculations is under the adjustable set point Vs.
Protection stability is ensured in the event of the loss of the main source and presence of remanent voltage by a restraint in the event of a continuous decrease of the frequency.
The protection includes a definite (DT) time delay T.

Block diagram


***1)** Or U21, or √3.V1 > Vs if only one TP.*

Characteristics

Settings				
Measurement origin				
Setting range	Main channels (U) / Additional channels (U')			
Fs set point				
Setting range	40 to 51 Hz or 50 to 61 Hz			
Accuracy (1)	±0.01 Hz			
Resolution	0.01			
Pick up / drop out difference	0.05 Hz ± 0.015 Hz			
Time delay T				
Setting range	100 ms to 300 s			
Accuracy (1)	±2 % or ±25 ms			
Resolution	10 ms or 1 digit			
Advanced settings				
Vs set point				
Setting range	20 % Un to 90 % Un			
Accuracy (1)	2 %			
Resolution	1 %			
Restraint on frequency variation				
Setting	With / without			
dFs/dt set point	1 Hz/s to 15 Hz/s			
Accuracy (1)	±1 Hz/s			
Resolution	±1 Hz/s			
Characteristic times				
Operation time	Pick-up < 90 ms from Fs +0.5 Hz to Fs -0.5 Hz			
Overshoot time	< 50 ms from Fs +0.5 Hz to Fs -0.5 Hz			
Reset time	< 55 ms from Fs -0.5 Hz to Fs +0.5 Hz			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P81L_x_101	■	■	
Protection inhibition	P81L_x_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P81L_x_1	■	■	
Delayed output	P81L_x_3	■	■	■
Protection inhibited	P81L_x_16	■	■	

x: unit number.
***(1)** Under reference conditions (IEC 60255-6) and df/dt < 3 Hz/s.*

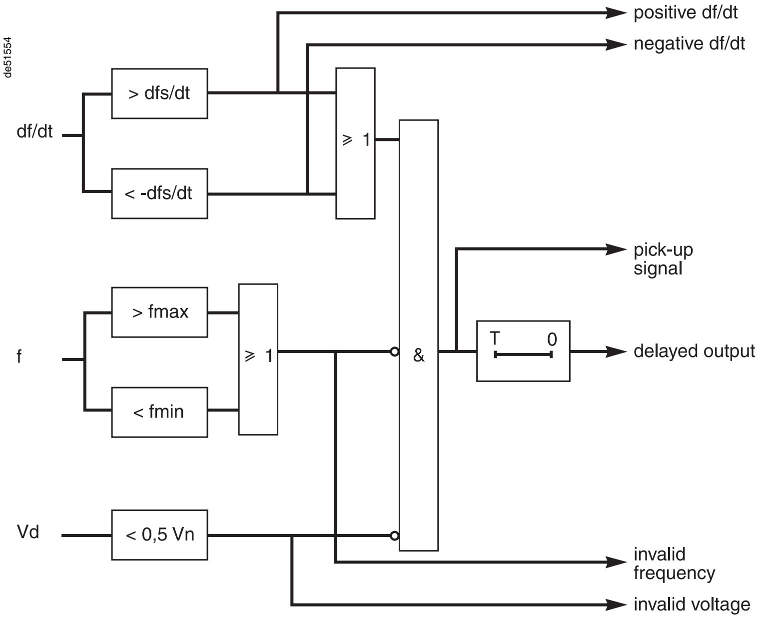
Rate of change of frequency
ANSI code 81R

Protection function based on the calculation of the frequency variation, used to rapidly disconnect a source supplying a network or to control load shedding.

Operation
The rate of change of frequency protection function is complementary to the under and overfrequency protection functions in detecting network configurations that require load shedding or disconnection.

The function is activated when the "rate of change of frequency" df/dt of the positive sequence voltage is higher than a set point. It includes a definite (DT) time delay.

The protection function operates if:
■ the positive sequence voltage is greater than 50 % of the rated phase-to-neutral voltage
■ the network frequency is between 42.2 Hz and 56.2 Hz for 50 Hz networks and between 51.3 Hz and 65 Hz for 60 Hz networks.

Block diagram


Characteristics

Settings				
dfs/dt set point				
Setting range	0.1 to 10 Hz/s			
Accuracy (1)	±5 % or ±0,1 Hz			
Resolution	0.01 Hz			
Drop out/pick up ratio	93 %			
Temporisation				
Setting range	0.15 to 300 s			
Accuracy (1)	±2 % or -10 at +25 ms			
Resolution	10 ms or 1 digit			
Characteristic times (1)				
Operation time	Pick-up < 150 ms (typically 130 ms)			
Overshoot time	< 100 ms			
Reset time	< 100 ms			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Protection reset	P81R_x_101	■	■	
Protection inhibition	P81R_x_113	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Instantaneous output (pick-up)	P81R_x_1	■	■	
Tripping output	P81R_x_3	■	■	■
Protection inhibited	P81R_x_16	■	■	
Invalid voltage	P81R_x_42	■	■	
Invalid frequency	P81R_x_43	■	■	
Positive df/dt	P81R_x_44	■	■	
Negative df/dt	P81R_x_45	■	■	

x: unit number.
***(1)** Under reference conditions (IEC 60255-6) and df/dt < 3 Hz/s.*

Rate of change of frequency
ANSI code 81R

Disconnection application

This function is used on incomers of installations that include generators that can operate in parallel with the distribution network.
The role of the function is to detect utility failures, i.e. operation of the generator as an autonomous isolated system. If the power flow from the utility prior to autonomous generator operation was not zero, the generator frequency changes.
The rate of change of frequency protection function detects autonomous generator operation more rapidly than conventional frequency protection functions.

Other disturbances such as short-circuits, load fluctuations and switching may cause changes of frequency. The low set point may be reached temporarily due to these disturbances and a time delay is necessary. In order to maintain the advantage of the speed of the rate of change of frequency protection in comparison to conventional frequency protection functions, a second, higher set point with a short time delay may be added.

The rate of change of frequency is actually not constant. Often, the rate of change of frequency is at its highest at the beginning of the disturbance after which it decreases. This extends the tripping time of frequency protection functions but does not affect the tripping time of the rate of change of frequency protection function.

Low set point setting

- Follow the utility's instructions, if there are any.
- If there are no utility instructions, proceed as follows:
  - if the maximum rate of change of frequency on the network under normal conditions is known, dfs/dt should be set above it.
  - if no information on the network is available, the low set point may be set according to generator data.

A good approximation of the rate of change of frequency after a utility failure resulting in a load variation ΔP is:

$$\frac{df}{dt} = \frac{\Delta P \times fn}{2 \times Sn \times H}$$

where Sn: rated power
fn: rated frequency
H: inertia constant

Typical value of the inertia constant (in MWs/MVA):

- $0.5 \leqslant H \leqslant 1.5$ for diesel and low-power generators ($\leqslant$ 2 MVA)
- $2 \leqslant H \leqslant 5$ for gas turbines and medium-power generators ($\leqslant$ 40 MVA)

$$H = \frac{J \times \Omega^2}{2 \times Sn}$$

where J: moment of inertia
Ω: machine speed

Examples

Rated power	2 MVA	20 MVA
Inertia constant	0.5 MWs/MVA	2 MWs/MVA
Power variation	0.1 MVA	1 MVA
df/dt	-2.5 Hz/s	-0.6 Hz/s

Low set point delay setting

For good protection stability during short-circuits or transient disturbances, the recommended time delay is 300 ms or more. If an automatic recloser is in service upstream of the installation, the detection of autonomous generator operation and the opening of the coupling circuit breaker must take place during the recloser isolation time.

High set point setting

The second set point may be chosen so that the rate of change of frequency tripping curve remains below the under and overfrequency protection curves.
If the frequency protection units are set to fn±0.5Hz and the low set point of the rate of change of frequency is T, the high set point may be set to 0.5/T.

High set point delay setting

No particular recommendantions.

Setting recommendations when no other information is available

Settings	Generator power	2 to 10 MVA	> 10 MVA
Low set point	dfs/dt	0.5 Hz/s	0.2 Hz/s
	T	500 ms	500 ms
High set point	dfs/dt	2.5 Hz/s	1 Hz/s
	T	150 ms	150 ms

Operating precautions:
When the generator connects to the network, power oscillations may occur until the generator becomes fully synchronized. The rate of change of frequency protection function is sensitive to this phenomenon, so it is advisable to inhibit the protection unit for a few seconds after circuit breaker closing.

Load shedding application

The rate of change of frequency protection function may also be used for load shedding in combination with underfrequency protection. In such cases, it is used on the installation busbars. Only negative frequency derivatives are to be used.

Two principles are available:
■ acceleration of load shedding:
The rate of change of frequency protection functions controls load shedding. It acts faster than underfrequency protection functions and the value measured (df/dt) is directly proportional to the load to be shed
■ load shedding inhibition:
This principle is included in underfrequency protection functions. It consists of activating the frequency variation restraint and does not call for implementation of the rate of change of frequency protection function.

Machine differential
ANSI code 87M

Phase-to-phase short-circuit protection for generators and motors.

Description

Phase-to-phase short-circuit protection, based on phase by phase comparison of the currents on motor and generator windings.
This function picks up if the difference in current is greater than the set point defined by:

- a percentage-based curve
- a differential curve (high set point).

Tripping restraint ensures stability due to:

- detection of an external fault or machine starting
- detection of CT saturation
- fast detection of CT loss
- detection of transformer energizing.

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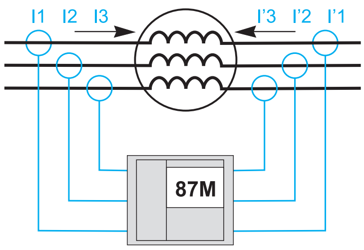

Percentage-based differential
The percentage-based tripping characteristic compares the through current to the differential current.
According to the current measurement convention, shown in the diagram and respecting the recommended wiring system, the differential and through currents are calculated by:

- differential current:

$$\mathbf{Idx} = \left|\vec{I}_x + \vec{I'}_x\right| \quad \text{where } x = 1, 2, 3$$

- through current

$$\mathbf{Itx} = \frac{\left|\vec{I}_x - \vec{I'}_x\right|}{2} \quad \text{where } x = 1, 2, 3$$

The percentage-based characteristic is made up to two half curves defined according to the following formulas:

- 1st half curve depending on the Is set point

$$\mathbf{Idx}^2 - \frac{\mathbf{Itx}^2}{32} > \mathbf{Is}^2 \quad \text{where } \mathbf{0} \leqslant \mathbf{Itx} \leqslant \sqrt{2}\,\mathbf{In} \text{ and } x = 1, 2, 3$$

- 2nd half curve

$$\frac{\mathbf{Idx}^2}{8} - \frac{\mathbf{Itx}^2}{32} > (\mathbf{0.05\ In})^2 \quad \text{where } \sqrt{2}\,\mathbf{In} < \mathbf{Itx} \text{ and } x = 1, 2, 3.$$

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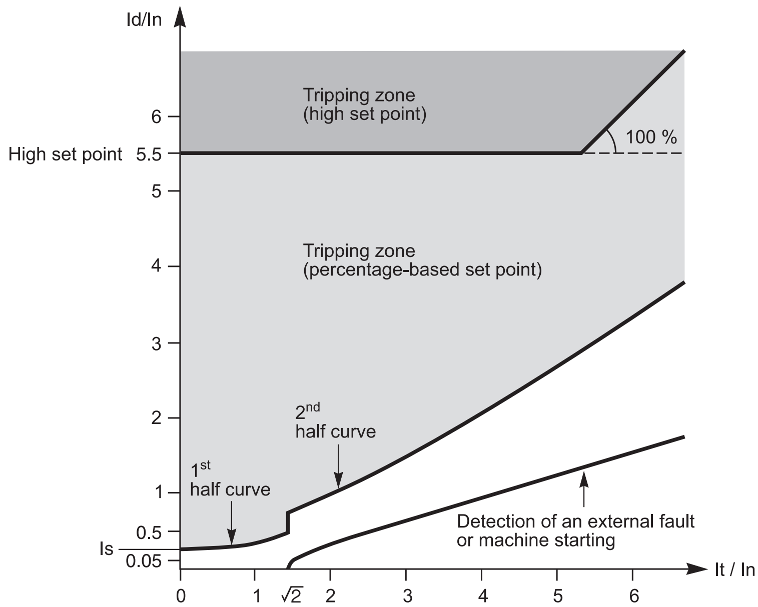


Differential high set point.
To avoid any delay for major asymmetrical faults, a differential high set point, without restraint, is used.
The characteristic of this set point is:

$$\mathbf{Idx} > \mathbf{5.5\ In} \quad \text{and} \quad \frac{\mathbf{Idx}}{\mathbf{Itx}} > \mathbf{1} \quad \text{where } x = 1, 2, 3$$

Machine differential
ANSI code 87M

Tripping restraints

■ Restraint for external faults or machine starting

During starting or an external fault, the through current is much higher than 1.5 In. As long as the CTs do not saturate, the differential current is low. This transient state is detected by the following characteristic:

$$\frac{\mathbf{Idx}^2}{\mathbf{2}} - \frac{\mathbf{Itx}^2}{\mathbf{32}} < -(\mathbf{0.25\ In})^2 \quad \text{where } x = 1, 2, 3$$

An external fault can be followed by a short, but high differential current, that is why a 200 ms restraint is used to ensure protection stability for this type of fault.

■ Restraint on CT saturation

CT saturation can result in a false differential current and nuisance tripping. The restraint analyses the asymmetry of the signals and restrains the tripping order if a CT is saturated.

■ Restraint on CT loss

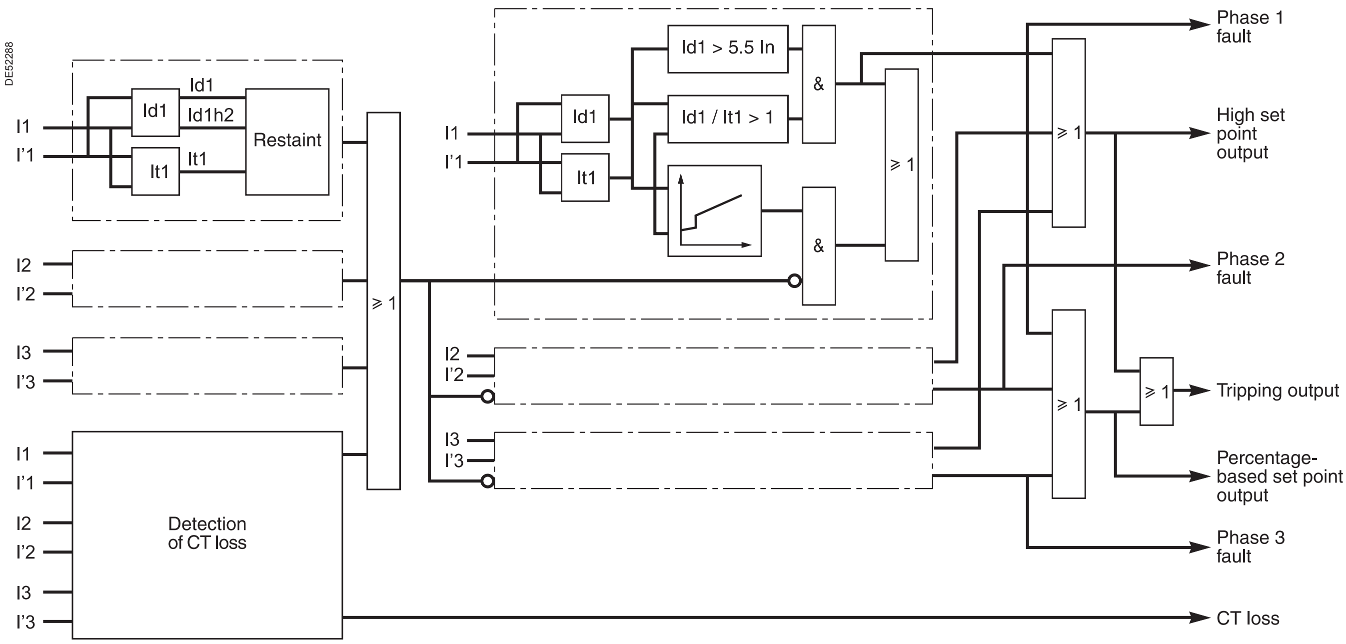
CT loss can result in a false differential current and nuisance tripping. This restraint is the means to detect a measurement that abnormally drops to zero (sample analysis).

■ Restraint on transformer energizing

this restraint ensures that the H2 level of the differential current is greater than 15 %:

$$\frac{\mathbf{Idxh2}}{\mathbf{Idx}} > \mathbf{0.15} \quad \text{where } x = 1, 2, 3.$$

Block diagram



CT loss can result in a false differential current and nuisance tripping. This restraint is activated if the following 3 criteria are met. The first two criteria identify the potentially defective CT; the third confirms the CT loss.

1) A residual current (SUM3I) is detected from one side of the windings and only one.
$|\vec{I}1 + \vec{I}2 + \vec{I}3| > Iso \oplus |\vec{I'}1 + \vec{I'}2 + \vec{I'}3| > Iso$ (Iso: internal threshold, non-adjustable)

2) The differential current is higher than the threshold Is on one phase and only one.
$Id1 > Is \oplus Id2 > Is \oplus Id3 > Is$

3) Abnormal number of zero value samples ($|ix| < 0.02 \times In$) is measured on the considered input.

The restraint is disabled if one criterion is not met.

$\oplus$ = Exclusive OR (XOR)

Machine differential
ANSI code 87M

3

Dimensioning phase-current sensors

Current transformers must be either:

- type 5P20, with an accuracy burden $VA_{CT} \geqslant Rw.in^2$
- or defined by a knee-point voltage $Vk \geqslant (R_{CT} + Rw).20.in$.

The equations apply to the phase current transformers placed on either side of the machine.
in is the CT rated secondary current.
R_{CT} is the CT internal resistance.
Rw is the resistance of the CT load and wiring.
The setting range of the Is set point depends on the rated values of the current sensors on the main channels I1, I2, I3 and the additional channels I'1, I'2, I'3. The setting range is the intersection of [0.05 In 0.5 In] with [0.05 I'n 0.5 I'n]. When the rated values are identical, the setting range is optimum. If there is no intersection, the function cannot be used.

Characteristics

Settings	
Is set point	
Setting range	In ≤ 20 A: max(0.1 In; 0.1 I'n) ⩽ Is ⩽ min(0.5 In; 0.5 I'n) In > 20 A: max(0.05 In; 0.05 I'n) ≤ Is ≤ max(0.5 In; 0.5 I'n)
Accuracy (1)	±5 % Is or ±0.4 % In
Resolution	1 A or 1 digit
Drop out/pick up ratio	93.5 % ±5 %
Pick-up of restraint on CT loss	
Characteristic times	
Operation time	Operation time of differential current function
Overshoot time	< 45 ms at 2 Is

Designation	Syntax	Equations	Logipam
Protection reset	P81L_x_101	■	■

Designation	Syntax	Equations	Logipam	Matrix
Protection output	P87M_1_3	■	■	■
Phase 1 fault	P87M_1_7	■	■	
Phase 2 fault	P87M _1_8	■	■	
Phase 3 fault	P87M _1_9	■	■	
Protection inhibited	P87M_1_16	■	■	
High set point	P87M_1_33	■	■	
Percentage-based set point	P87M_1_34	■	■	
CT loss	P87M_1_39	■	■	

(1) *Under reference conditions (IEC 60255-6).*

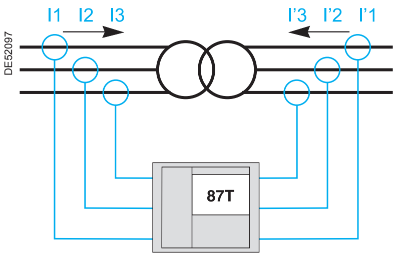
Phase-to-phase short-circuit protection for transformers and transformer-machine units (2 windings)

Operation

This protection function protects the zone between the sensors for the main currents I1, I2, I3 on the one hand and the sensors for the additional currents I'1, I'2, I'3 on the other.

It adjusts both the amplitude and phase of the currents in each winding according to the vector shift and the transformer rated power, as well as the set voltage and current values.

It then compares the matched currents phase by phase.



According to the current measurement convention shown in the diagram and respecting the recommended wiring system, the differential currents Id and through currents It are calculated using the matched currents Im and I'm.

- Differential current: $Idx = |\vec{I}xm + \vec{I'}xm|$ where x = 1, 2 or 3
- Through current: $Itx = max(|\vec{I}xm|, |\vec{I'}xm|)$ where x = 1, 2 or 3

The function picks up if the differential current of at least one phase is greater than the operating threshold defined by:

- a high adjustable differential current set point, without tripping restraint
- an adjustable percentage-based characteristic with two slopes
- a low adjustable differential current set point.

Stability is ensured by the following tripping restraints:

- a self-adaptive or conventional harmonic restraint
- a transformer-energization restraint
- a CT-loss restraint.

The high tripping set point is not restrained.

CT loss can result in a false differential current and nuisance tripping. This restraint is activated if the following 3 criteria are met. The first two criteria identify the potentially defective CT; the third confirms the CT loss.

1) At least one differential current is in the tripping zone according to the bias characteristic.

2) A residual current (SUM3I) is detected on a single winding.
A phase current measurement of this winding might be defective.

$$|\vec{I}1 + \vec{I}2 + \vec{I}3| > 0.3 \times \frac{S}{\sqrt{3} \times Un1} \oplus |\vec{I'}1 + \vec{I'}2 + \vec{I'}3| > 0.3 \times \frac{S}{\sqrt{3} \times Un2}$$

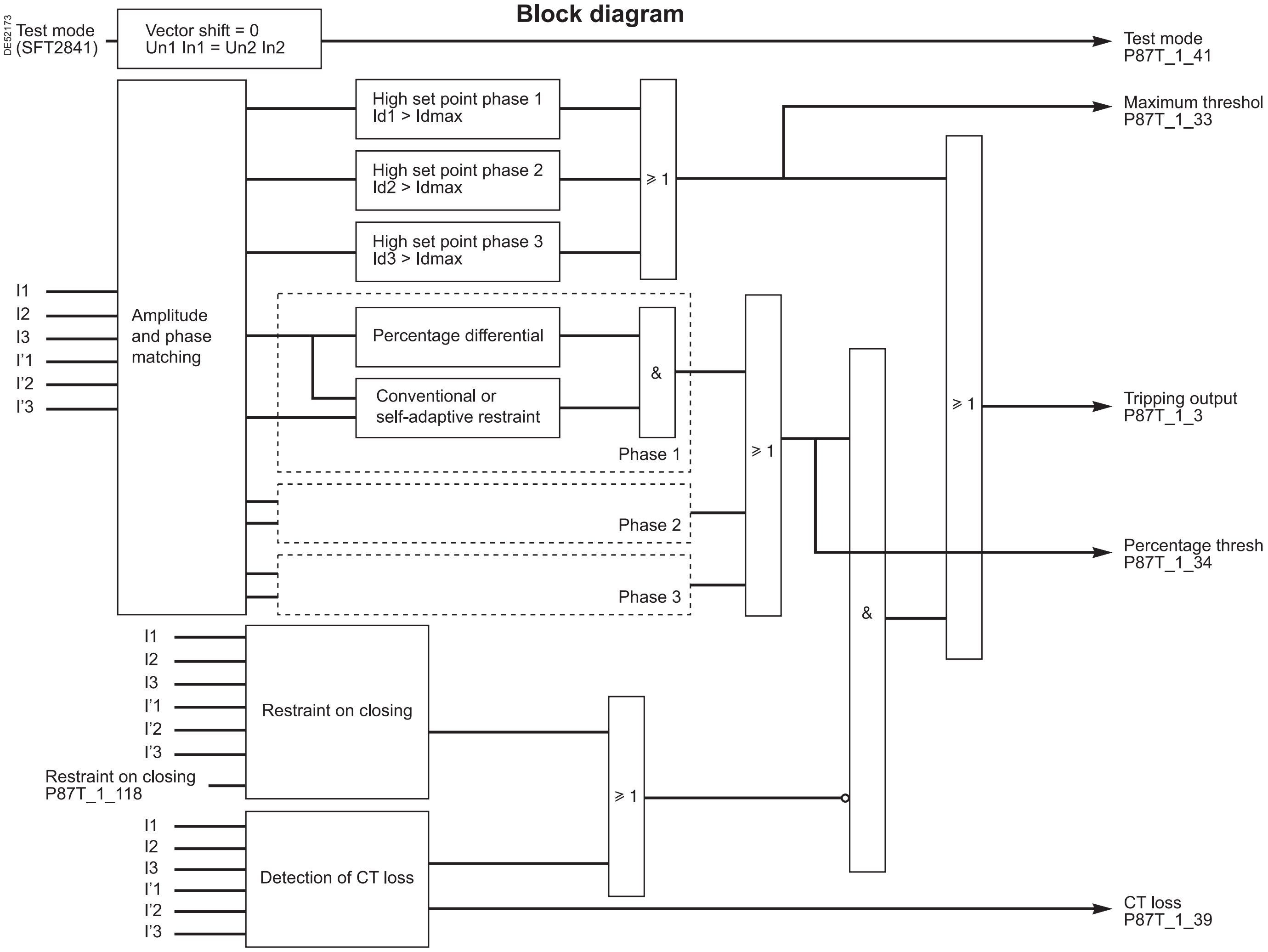
3) The magnitude of the positive sequence current is higher on the healthy winding than on the faulty one.

4) On the faulty winding, abnormal number of zero value samples ($|ix| < 0.02 \times In$) is measured on one phase and only one.

The restraint is disabled if one criterion is not met.

$\oplus$ = Exclusive OR (XOR)

Block diagram



Definitions

The terms winding 1 and winding 2 are used in the following manner:

- winding 1: corresponds to the circuit to which the main currents I1, I2, I3 and the voltage measurements V1, V2, V3 or U21, U32 are connected
- winding 2: corresponds to the circuit to which the additional currents I'1, I'2, I'3 are connected.

The transformer electrical parameters must be set on the "Particular characteristics" screen in the SFT2841 software:

- winding 1 voltage: Un1
- winding 2 voltage: Un2
- vector shift
- transformer rated power S.

To assist during the setup procedure, the screen shows:

- the transformer rated current value for windings 1 and 2: In1, In2
- the value set on the "CT-VT Sensors" screen for the base current Ib of winding 1
- the value calculated using the transformation ratio for the base current I'b of winding 2.

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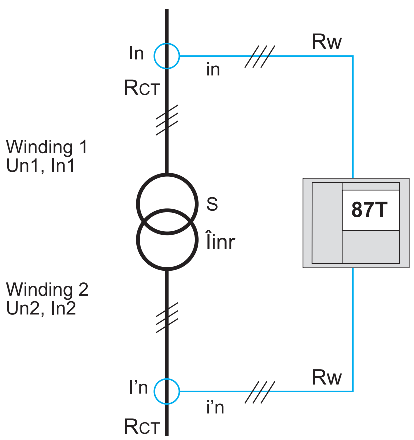


Matching

Principle

The currents in windings 1 and 2 cannot be compared directly due to the transformation ratio and the phase displacement introduced by the power transformer.
Sepam does not use matching CTs. Sepam uses the rated power and winding voltage data to calculate the transformation ratio and, therefore, to match current amplitude. The vector shift is used to match the phase currents.

Winding 1 current matching

Winding 1 is always matched in the same way, whatever the vector shift of the transformer. The matching is made by clearing the zero-sequence current in order to make the protection function immune to external earth faults.

$$\vec{I1m} = \frac{\vec{I1}}{In1} - \frac{\vec{I1} + \vec{I2} + \vec{I3}}{3In1}$$

$$\vec{I2m} = \frac{\vec{I2}}{In1} - \frac{\vec{I1} + \vec{I2} + \vec{I3}}{3In1}$$

$$\vec{I3m} = \frac{\vec{I3}}{In1} - \frac{\vec{I1} + \vec{I2} + \vec{I3}}{3In1}$$

Winding 2 current matching and vector shift

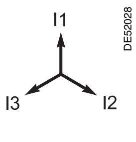
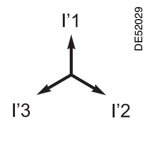
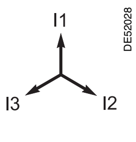
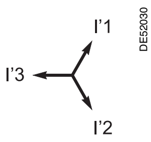
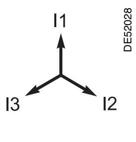
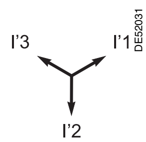
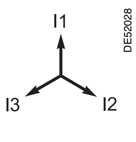
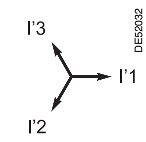
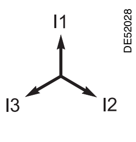
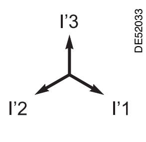
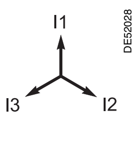
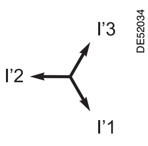
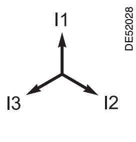
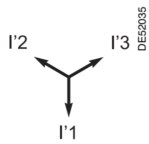
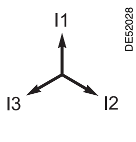
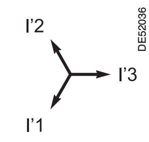
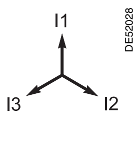
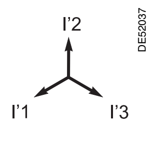
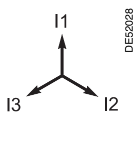
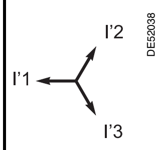
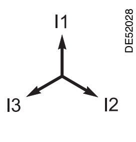
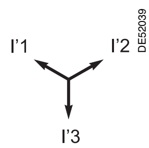
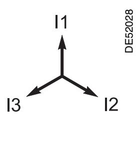
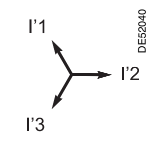
The matching of winding 2 affects the amplitude and phase and takes account of the vector shift of the transformer.
Standard IEC 60076-1 assumes that the vector shift is given for a transformer connected to a power source with a phase-rotation sequence of 123. Sepam uses this vector shift value for both 123 and 132 type networks.
It is, therefore, not necessary to complement this value by 12 for a 132 type network.
When the current sensor connections are correct, the vector shift matching to be made is the result of the phase-displacement measurement taken by Sepam between the currents in winding 1 and winding 2, divided by 30°.
The table on the next page contains vectorial diagrams and matching formulae based on the vector shift of the transformer for networks with type 123 phase-rotation sequences.

Notation

S: HV/LV transformer rated power
Un1: Winding 1 rated voltage
Un2: Winding 2 rated voltage
In1: Winding 1 rated current
In2: Winding 2 rated current
In: Winding 1 CT rated primary current
I'n: Winding 2 CT rated primary current
in: Winding 1 CT rated secondary current
i'n: Winding 2 CT rated secondary current
VA_{CT}: Current transformer accuracy burden
Rw: Resistance of the current transformer load (including wiring)
R_{CT}: Current transformer secondary resistance
FLP: Current transformer accuracy-limit factor
Vk: Current transformer knee-point voltage

Transformer differential
ANSI code 87T

Calculation of matched currents for winding 2

Vector shift	Winding 1	Winding 2	Matching
0			$\vec{I'}1rec = \frac{\vec{I'}1}{In2} - \frac{\vec{I'}1+\vec{I'}2+\vec{I'}3}{3In2}$ $\vec{I'}2rec = \frac{\vec{I'}2}{In2} - \frac{\vec{I'}1+\vec{I'}2+\vec{I'}3}{3In2}$ $\vec{I'}3rec = \frac{\vec{I'}3}{In2} - \frac{\vec{I'}1+\vec{I'}2+\vec{I'}3}{3In2}$
1			$\vec{I'}1rec = \frac{\vec{I'}1 - \vec{I'}2}{\sqrt{3}\,In2}$ $\vec{I'}2rec = \frac{\vec{I'}2 - \vec{I'}3}{\sqrt{3}\,In2}$ $\vec{I'}3rec = \frac{\vec{I'}3 - \vec{I'}1}{\sqrt{3}\,In2}$
2			$\vec{I'}1rec = -\frac{\vec{I'}2}{In2} + \frac{\vec{I'}1+\vec{I'}2+\vec{I'}3}{3In2}$ $\vec{I'}2rec = -\frac{\vec{I'}3}{In2} + \frac{\vec{I'}1+\vec{I'}2+\vec{I'}3}{3In2}$ $\vec{I'}3rec = -\frac{\vec{I'}1}{In2} + \frac{\vec{I'}1+\vec{I'}2+\vec{I'}3}{3In2}$
3			$\vec{I'}1rec = \frac{\vec{I'}3 - \vec{I'}2}{\sqrt{3}\,In2}$ $\vec{I'}2rec = \frac{\vec{I'}1 - \vec{I'}3}{\sqrt{3}\,In2}$ $\vec{I'}3rec = \frac{\vec{I'}2 - \vec{I'}1}{\sqrt{3}\,In2}$
4			$\vec{I'}1rec = \frac{\vec{I'}3}{In2} - \frac{\vec{I'}1+\vec{I'}2+\vec{I'}3}{3In2}$ $\vec{I'}2rec = \frac{\vec{I'}1}{In2} - \frac{\vec{I'}1+\vec{I'}2+\vec{I'}3}{3In2}$ $\vec{I'}3rec = \frac{\vec{I'}2}{In2} - \frac{\vec{I'}1+\vec{I'}2+\vec{I'}3}{3In2}$
5			$\vec{I'}1rec = \frac{\vec{I'}3 - \vec{I'}1}{\sqrt{3}\,In2}$ $\vec{I'}2rec = \frac{\vec{I'}1 - \vec{I'}2}{\sqrt{3}\,In2}$ $\vec{I'}3rec = \frac{\vec{I'}2 - \vec{I'}3}{\sqrt{3}\,In2}$
6			$\vec{I'}1rec = -\frac{\vec{I'}1}{In2} + \frac{\vec{I'}1+\vec{I'}2+\vec{I'}3}{3In2}$ $\vec{I'}2rec = -\frac{\vec{I'}2}{In2} + \frac{\vec{I'}1+\vec{I'}2+\vec{I'}3}{3In2}$ $\vec{I'}3rec = -\frac{\vec{I'}3}{In2} + \frac{\vec{I'}1+\vec{I'}2+\vec{I'}3}{3In2}$
7			$\vec{I'}1rec = \frac{\vec{I'}2 - \vec{I'}1}{\sqrt{3}\,In2}$ $\vec{I'}2rec = \frac{\vec{I'}3 - \vec{I'}2}{\sqrt{3}\,In2}$ $\vec{I'}3rec = \frac{\vec{I'}1 - \vec{I'}3}{\sqrt{3}\,In2}$
8			$\vec{I'}1rec = \frac{\vec{I'}2}{In2} - \frac{\vec{I'}1+\vec{I'}2+\vec{I'}3}{3In2}$ $\vec{I'}2rec = \frac{\vec{I'}3}{In2} - \frac{\vec{I'}1+\vec{I'}2+\vec{I'}3}{3In2}$ $\vec{I'}3rec = \frac{\vec{I'}1}{In2} - \frac{\vec{I'}1+\vec{I'}2+\vec{I'}3}{3In2}$
9			$\vec{I'}1rec = \frac{\vec{I'}2 - \vec{I'}3}{\sqrt{3}\,In2}$ $\vec{I'}2rec = \frac{\vec{I'}3 - \vec{I'}1}{\sqrt{3}\,In2}$ $\vec{I'}3rec = \frac{\vec{I'}1 - \vec{I'}2}{\sqrt{3}\,In2}$
10			$\vec{I'}1rec = -\frac{\vec{I'}3}{In2} + \frac{\vec{I'}1+\vec{I'}2+\vec{I'}3}{3In2}$ $\vec{I'}2rec = -\frac{\vec{I'}1}{In2} + \frac{\vec{I'}1+\vec{I'}2+\vec{I'}3}{3In2}$ $\vec{I'}3rec = -\frac{\vec{I'}2}{In2} + \frac{\vec{I'}1+\vec{I'}2+\vec{I'}3}{3In2}$
11			$\vec{I'}1rec = \frac{\vec{I'}1 - \vec{I'}3}{\sqrt{3}\,In2}$ $\vec{I'}2rec = \frac{\vec{I'}2 - \vec{I'}1}{\sqrt{3}\,In2}$ $\vec{I'}3rec = \frac{\vec{I'}3 - \vec{I'}2}{\sqrt{3}\,In2}$

Test mode

Two operating modes are available to facilitate maintenance and startup operations:

■ normal mode: the protection function controls the tripping and indication outputs based on the settings.
This is the standard operating mode

■ test mode: the protection function controls the tripping and indication outputs based on the test mode settings.
This mode can only be accessed via the SFT2841 software, once it has been connected and the Protection setting password entered.
The system returns to normal mode when the software is disconnected.

Transfer from normal mode to test mode can result in nuisance tripping if the protected transformer is energized.

Test mode settings:

■ $Un1 = \frac{S}{In \times \sqrt{3}}$

■ $Un2 = \frac{S}{I'n \times \sqrt{3}}$

■ vector shift = 0.

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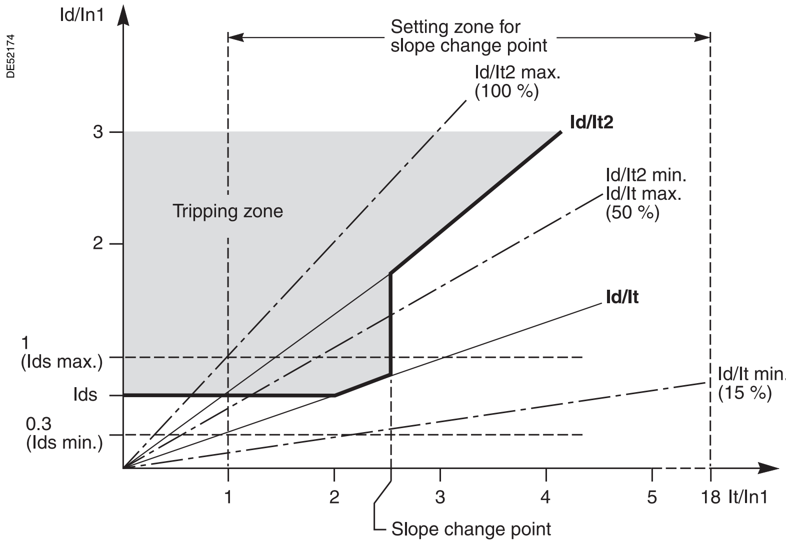
High set point
A non-restrained differential current set point will ensure fast tripping in the event of significant fault currents. This threshold must be set to a value higher than that of the inrush current.

Percentage-based curve
The percentage-based curve comprises a number of segments, which are defined as follows:
- a low set point (Ids)
- 2 straight lines crossing zero and with adjustable slopes (Id/It and Id/It2)
- the slope change point.

The curve must be set so that it can protect itself against current-sensor measurement errors and transformation errors, which can be attributed to the tap changer. Furthermore, the protection function must be made immune to power shunts on auxiliary windings.



Self-adaptive restraint
Self-adaptive restraint is particularly suitable for transformers where the peak inrush current in Amps is less than 8In1 or 8In2, depending on the winding by which the transformer is energized.

This neuronal network restraint ensures stability in the event of an external fault by analyzing the second- and fifth-harmonic factors, the differential currents and the through currents.
It ensures stability:
- in the event of the transformer closing
- in the event of an asymmetrical fault outside the zone, which saturates the current sensors
- in the event of the transformer being operated on a voltage supply, which is too high (overfluxing).

Detecting the presence of harmonics and taking into account the through and differential currents, the restraint automatically increases the low set point and the percentage-based slopes.
It is also more sensitive than the high set point. There is therefore no point in using the high set point when this restraint is active. Furthermore, as the restraint integrates the stabilization slope for high through currents, which can saturate the current sensors, slope Id/It2 does not have to be activated.

Conventional restraint
The conventional restraint comprises a second-harmonic set point for each phase and a fifth-harmonic set point for each phase.
The second-harmonic set point ensures that the protection function will not pick up in the event of the transformer closing or the current sensors becoming saturated.
The restraint can be global (cross-blocking: all three phases are restrained as soon as the harmonic in one phase exceeds the set point) or phase-specific (no cross-blocking: only the phase with a harmonic exceeding the set point is restrained).
Cross-blocking is recommended for transformers used in three-phase mode.
The fifth-harmonic set point ensures that the protection function will not pick up in the event of the transformer being connected to a voltage supply, which is too high.
The restraint can be global (i.e., all three phases are restrained) or phase-specific (only the phase with a harmonic exceeding the set point is restrained). Restraint without cross-blocking is recommended for normal operation.

Restraint on closing

In some cases, the harmonic content of the transformer inrush current is not sufficient to activate harmonic restraints. An additional restraint can be activated:
- when the through current exceeds an adjustable set point Isinr
- by an internal variable, P87T_1_118, controlled by logic equations or Logipam.

This restraint is applied to the percentage-based differential elements for an adjustable time period T. It is not applied to the high set point.

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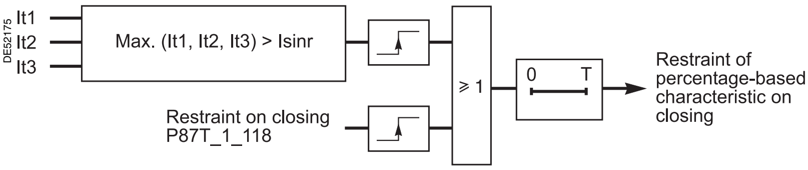
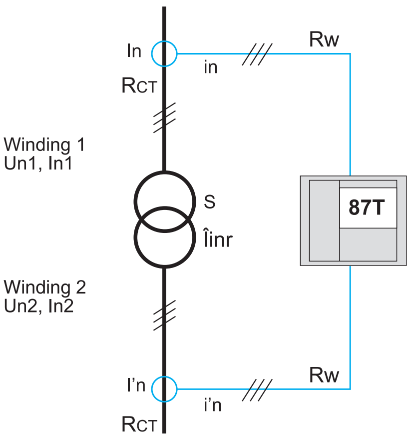


Restraint on CT loss

CT loss can distort the differential current and cause nuisance tripping. This restraint detects a measurement dropping to zero abnormally by analyzing sampled differential and through currents.

The CTs are dimensioned on the basis of the transformer inrush current, which differs according to the winding by which the transformer is energized.

DE52176



Dimensioning phase-current sensors

Calculating inrush currents

- Energization by winding 1:
  - Inrush current depends on the transformer rated current:

$$\hat{i}inr = \frac{\text{peak inrush current in Amps}}{In1.\sqrt{2}}$$

  - Inrush current depends on the CT rated current:

$$\hat{i}inr/TC = \frac{\text{peak inrush current in Amps}}{In.\sqrt{2}}$$

- Energization by winding 2:
  - Inrush current depends on the transformer rated current:

$$\hat{i}inr = \frac{\text{peak inrush current in Amps}}{In2.\sqrt{2}}$$

  - Inrush current depends on the CT rated current:

$$\hat{i}inr/TC = \frac{\text{peak inrush current in Amps}}{I'n.\sqrt{2}}$$

CT rated primary currents
The rated primary current of the current transformers is governed by the following rule:

- Winding 1 end: $0.1 \times \frac{S}{Un1 \times \sqrt{3}} \le In \le 2.5 \times \frac{S}{Un1 \times \sqrt{3}}$
- Winding 2 end: $0.1 \times \frac{S}{Un2 \times \sqrt{3}} \le I'n \le 2.5 \times \frac{S}{Un2 \times \sqrt{3}}$

Other characteristics of the CTs at the transformer energized end

- Scenario 1: $\hat{i}inr / TC < 6.7$

Only the following current transformers can be selected:

- Either type 5P20 with an accuracy burden of $VA_{CT} \ge Rw \cdot in^2$
- Or defined by a knee-point voltage $Vk \ge (R_{CT} + Rw).(20in)$

- Scenario 2: $\hat{i}inr / TC \ge 6.7$

Only the following current transformers can be selected:

- Either type 5P with an accuracy burden of $VA_{CT} \ge Rw \cdot in^2$

And an accuracy-limit factor $FLP \ge 3 \cdot \hat{i}inr / TC$

- Or defined by a knee-point voltage $k \ge (R_{CT} + Rw) \cdot 3 \cdot \hat{i}inr / TC \cdot in$

Other characteristics of the CTs at the transformer non-energized end
Only the following current transformers can be selected:

- Either type 5P20 with an accuracy burden of $VA_{CT} \ge Rw.in^2$
- Or defined by a knee-point voltage $Vk \ge (R_{CT} + Rw).20in$

Setting the Ids low set point

b: tap changer peak deviation [as a **%** of **Un**]
α: Composite error at the current sensor accuracy-limit current at the HV end [as a **%** of **In**]
β: Composite error at the current sensor accuracy-limit current at the LV end [as a **%** of **I'n**]

Referring to standard IEC 60044-1, the composite error at the accuracy-limit current is **5%** for type 5P CTs. For the CTs specified according to class Px, the maximum error is deemed to equal **5%**.

The minimum set point for Ids is found by adding together the errors below:

- Measurement: $100 \times \left[\frac{(100 + \beta)}{100} - \frac{(100 - \alpha)}{(100 + b)}\right]$
- Relay: **2 %**

Example: Transformer equipped with a tap changer of **-10%/+15%**.
Using type 5P CTs, the error on the current is:
$00 \times (105/100 - 95/115) + 2 = 24.4\ \%$

The Ids low set point should therefore be set to the minimum value of **30%**.

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Setting the first Id/It slope

b: tap changer peak deviation [as a % of Un]
α : Composite error at the current sensor accuracy-limit current at the HV end [as a **%** of **In**]
β: Composite error at the current sensor accuracy-limit current at the LV end [as a **%** of **I'n**]

Referring to standard IEC 60044-1, the composite error at the accuracy-limit current is **5%** for type 5P CTs. For the CTs specified according to class Px, the maximum error is deemed to equal **5%**.

The minimum slope for **Id/It** is found by adding together the errors below:

- Measurement: $100 \times \left[1 - \frac{(100-\alpha).100}{(100+b).(100+\beta)}\right]$
- Relay: **2%**
- Safety margin: **5%**

Example: Transformer equipped with a tap changer of **-10%/+15%**.
Using type 5P CTs, the error on the slope is:

$$00 \times (1 - 100 \times 95 / 115 / 105) + 2 + 5 = 28.3\ \%$$

The first **Id/It** slope should therefore be set to **28%**.

Setting the second-harmonic restraint set point

To ensure sufficient stability of the differential protection when the transformer closes, we recommend that the **second-harmonic restraint set point is set to 20%, with global restraint.**

Setting the fifth-harmonic restraint set point

To ensure stability of the protection function in the event of an abnormal increase in the voltage or a drop in the network frequency, we recommend that the **fifth-harmonic restraint set point is set to 35%, with phase-specific restraint.**

Setting the Idmax high set point

The Idmax set point is applied to the non-restrained differential current. It ensures that 87T protection function trips quickly.
The **Idmax** set point is set as follows: $\mathbf{Idmax} \geq \hat{i}inr$

Setting the second Id/It2 slope and the slope change point

The second slope on the percentage-based characteristic ensures sufficient stability of the protection in the event of an external fault resulting in the current sensors becoming saturated.

- The slope change point is set as a function of the value of the first **Id/It** slope and the transformer inrush current.

$$(\text{Slope change point}) \leq 2 + \frac{3}{4}(\hat{i}inr)^{4/3} \cdot \frac{(Id/It)}{100}$$

- The value of the second slope is:

$Id/It2 \geq 100 - 3.75 \cdot \hat{i}inr$ as a **%**, with a minimum at **75%**.

Setting the restraint on closing

This is inactive by default. It should only be used in exceptional cases, where the second harmonic is low on closing.
The decision to activate this restraint delays tripping of the 87T protection function by the value of the selected time delay, when there is a pre-existing closure on an internal fault.

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Characteristics

Settings		
Low set point Ids		
Setting range		30 % to 100 % of In1
Accuracy (1)		±2 %
Resolution		1 %
Drop-out/pick-up ratio		93.5 % ±5 %
Percentage-based characteristic Id/It		
Setting range		15 % to 50 %
Accuracy (1)		±2 %
Resolution		1 %
Drop-out/pick-up ratio		93.5 % ±5 %
Percentage-based characteristic Id/It2		
Setting range		None, 50 % to 100 %
Accuracy (1)		±2 %
Resolution		1 %
Drop-out/pick-up ratio		93.5 % ±5 %
Slope change point		
Setting range		None, In1 to 18 In1
Accuracy (1)		±5 %
Resolution		0.1 In1
Drop-out/pick-up ratio		93.5 % ±5 %
Test mode		
Setting range		Active/Not active
Advanced settings		
Selection of restraint		Conventional/Self-adaptive
Restraint on CT loss		
Setting range		Active/Not active
Restraint on closing		
Setting range		Active/Not active
Magnetization current set point Isinr	Setting range	1 % to 10 %
	Accuracy (1)	±5 %
	Resolution	1 %
	Drop-out/pick-up ratio	90 % ±5 % or 0.5 % In1
Time delay	Setting range	0 to 300 s
	Accuracy (1)	±2 % or -10 ms to +25 ms
	Resolution	10 ms
High set point Idmax		
Setting range	Conventional restraint	3 to 18 In1
	Self-adaptive restraint	None, 3 to 18 In1
Accuracy (1)		±2 %
Resolution		1 %
Drop-out/pick-up ratio		93.5 % ±5 %
Second-harmonic set point for conventional restraint		
Setting range		None, 5 to 40 %
Accuracy (1)		±5 %
Resolution		1 %
Drop-out/pick-up ratio		90 % ±5 %
Second-harmonic restraint for conventional restraint		
Setting range		Phase-specific/Global
Fifth-harmonic set point for conventional restraint		
Setting range		None, 5 to 40 %
Accuracy (1)		±5 %
Resolution		1 %
Drop-out/pick-up ratio		90 % ±5 %
Fifth-harmonic restraint for conventional restraint		
Setting range		Phase-specific/Global
Characteristic times		
Operating time high set point		< 45 ms at 2 Id
Operating time percentage-based curve		< 45 ms at 2 Id
Reset time		< 45 ms at 2 Id

Inputs

Designation	Syntax	Equations	Logipam
Protection reset	P87T_1_101	■	■
Protection inhibition	P87T_1_113	■	■
Restraint on closing	P87T_1_118	■	■

Outputs

Designation	Syntax	Equations	Logipam	Matrix
Protection output	P87T_1_3	■	■	■
Protection inhibited	P87T_1_16	■	■	-
High set point	P87T_1_33	■	■	-
Percentage-based threshold	P87T_1_34	■	■	-
CT loss	P87T_1_39	■	■	-
Test mode	P87T_1_41	■	■	-

***(1)** Under reference conditions (IEC 60255-6).*

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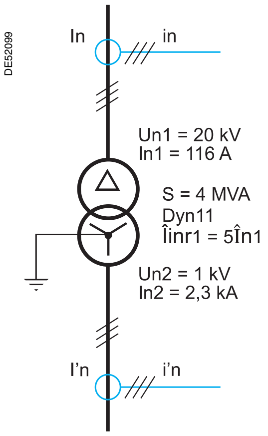

Example 1

■ The transformer is energized at the winding 1 end.
■ The inrush current is **820 A**.
■ This transformer does not feature a tap changer or an auxiliary winding.

Sensor selection
The rated currents of the windings are:

$$In1 = \frac{4MVA}{\sqrt{3}\cdot 20kV} = 115.5\ A \quad \text{and} \quad In2 = \frac{4MVA}{\sqrt{3}\cdot 1kV} = 2310A$$

The sensor rated current is selected at the next highest standardized values:
In = 150 A and **I'n = 3000 A.**

Inrush current:

$$\hat{i}inr = \frac{820}{115.5\sqrt{2}} = 5$$: depending on the transformer rated current

$$\hat{i}inr / TC = \frac{820}{150\sqrt{2}} = 3.9$$ depending on the CT rated current

■ Winding 1 end, $\hat{i}inr / TC < 6.7$: type 5P20 current transformers are suitable.
■ Winding 2 end, transformer not energized: type 5P20 current transformers are also suitable.

To sum up, the following sensors are selected:
■ Winding 1 end: **150A/1A**, 5P20
■ Winding 2 end: **3000A/1A**, 5P20

Setting the Ids low set point
Tap changer peak deviation: **b = 0** (no tap changer)
CT error, winding 1: α **= 5%**
CT error, winding 2: β **= 5%**

Measurement error: $100 \times \left[\frac{(100+\beta)}{100} - \frac{(100-\alpha)}{(100+b)}\right] = 10\ \%$

Relay error: **2%**
Total error = **12%**

Ids should be set to its minimum value of **30%**.

Setting the first Id/It slope

Measurement error: $100 \times \left[1 - \frac{(100-\alpha).100}{(100+b).(100+\beta)}\right] = 9.5\ \%$

Relay error: **2%**
Safety margin: **5%**
Total error: **16.5%**

Id/It should be set to the value of **17%**.

Selection of restraint $\hat{i}inr < 8$, the self-adaptive restraint is selected.

Thus the second slope on the percentage-based curve and the high set point are not necessary.

3

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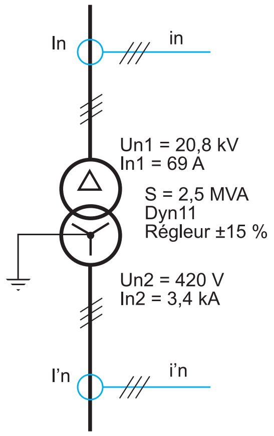


Example 2

- The transformer is energized at the winding 1 end.
- The inrush current is **942 A**.

Sensor selection
The rated currents of the windings are:

$$\mathbf{In1} = \frac{\mathbf{2.5\ MVA}}{\sqrt{3}\cdot\ \mathbf{20.8\ kV}} = \mathbf{69.4\ A} \text{ and } \mathbf{In2} = \frac{\mathbf{2.5\ MVA}}{\sqrt{3}\cdot\ \mathbf{0.42\ kV}} = \mathbf{3440\ A}$$

The sensor rated current is selected at the next highest standardized values:
In = 100 A and **I'n = 3500 A.**

Inrush current:

$$\hat{\mathbf{i}}\mathbf{inr} = \frac{\mathbf{942}}{\mathbf{69.4.}\sqrt{\mathbf{2}}} = \mathbf{9.6} \text{ : depending on the transformer rated current}$$

$$\hat{\mathbf{i}}\mathbf{inr}/\ \mathbf{TC} = \frac{\mathbf{942}}{\mathbf{100.}\sqrt{\mathbf{2}}} = \mathbf{6.66}\text{: depending on the CT rated current}$$

- Winding 1 end, $\hat{\mathbf{i}}\mathbf{inr}/\ \mathbf{TC} < \mathbf{6.7}$: type 5P20 current transformers are suitable.
- Winding 2 end, transformer not energized: type 5P20 current transformers are also suitable.

Setting the Ids low set point
Tap changer peak deviation: **b = 15%**
CT error, winding 1: α **= 5%**
CT error, winding 2: β **= 5%**

$$\text{Measurement error: } \mathbf{100} \times \left[\frac{(\mathbf{100}+\beta)}{\mathbf{100}} - \frac{(\mathbf{100}-\alpha)}{(\mathbf{100}+\mathbf{b})}\right] = \mathbf{22.4\ \%}$$

Relay error: **2%**
Total error = **24.4%**

Ids should be set to its minimum value of **30%**.

Setting the first Id/It slope

$$\text{Measurement error: } \mathbf{100} \times \left[\mathbf{1} - \frac{(\mathbf{100}-\alpha)\mathbf{.100}}{(\mathbf{100}+\mathbf{b})\mathbf{.}(\mathbf{100}+\beta)}\right] = \mathbf{21.3\ \%}$$

Relay error: **2%**
Safety margin: **5%**
Total error: **28.3%**

Id/It should be set to the value of **29%**.

$\hat{\mathbf{i}}\mathbf{inr} > \mathbf{8}$, the conventional restraint is selected.

Setting the slope change point

$$\text{Point de changement de pente } = \mathbf{2} + \frac{\mathbf{3}}{\mathbf{4}}(\hat{\mathbf{i}}\mathbf{inr})^{\mathbf{4/3}}\mathbf{.}\frac{(\mathbf{Id/\ It})}{\mathbf{100}}$$

$$= \mathbf{6.4\ In1}$$

Setting the second slope

$$\mathbf{100} - (\mathbf{3.75}\cdot\ \hat{\mathbf{i}}\mathbf{inr}) = \mathbf{64\ \%}$$

Choose the minimum advised value: **Id/It2 = 75%**

Setting the Idmax high set point

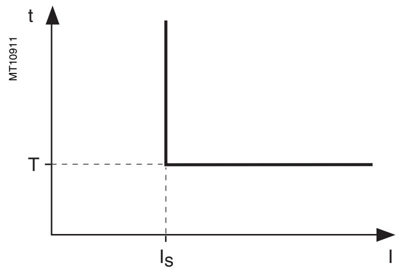
$$\mathbf{Idmax} = \hat{\mathbf{i}}\mathbf{inr} = \mathbf{9.6\ In1}$$

Setting the harmonic restraints
- Set point **H2 = 20%**, with global restraint
- Set point **H5 = 35%**, with phase-specific restraint

Presentation of tripping curve operation and settings for protection functions using:
- *definite time*
- *IDMT*
- *timer hold.*

Definite time protection

The tripping time is constant. The time delay is started when the set point is overrun.



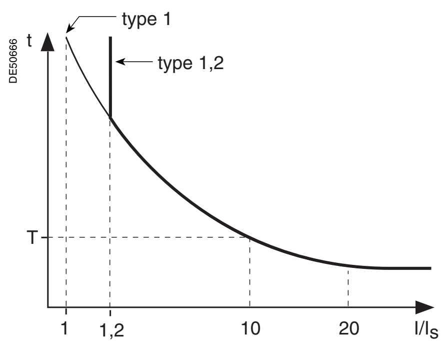
Definite time protection principle.

IDMT protection

The operation time depends on the protected value (phase current, earth fault current, etc.) in accordance with standards IEC 60255-3, BS 142 and IEEE C-37112.
Operation is represented by a characteristic curve, e.g.:
- t = f(I) curve for the **phase overcurrent** function
- t = f(I0) curve for the **earth fault** function.

The rest of the document is based on t = f(I); the reasoning may be extended to other variables I0, etc.
The curve is defined by:
- its type (standard inverse, very inverse, extremely inverse, etc.)
- current setting Is which corresponds to the vertical asymptote of the curve
- time delay T which corresponds to the operation time for I = 10 Is.

These 3 settings are made chronologically in the following order: type, Is current, time delay T.
Changing the time delay T setting by x % changes all of the operation times in the curve by x %.



IDMT protection principle.

The tripping time for I/Is values less than 1.2 depends on the type of curve selected.

Name of curve	Type
Standard inverse time (SIT)	1, 2
Very inverse time (VIT or LTI)	1, 2
Extremely inverse time (EIT)	1, 2
Ultra inverse time (UIT)	1, 2
RI curve	1
IEC inverse time SIT / A	1
IEC very inverse time VIT or LTI / B	1
IEC extremely inverse time EIT / C	1
IEEE moderately inverse (IEC / D)	1
IEEE very inverse (IEC / E)	1
IEEE extremely inverse (IEC / F)	1
IAC inverse	1
IAC very inverse	1
IAC extremely inverse	1

- when the monitored value is more than 20 times the set point, the tripping time is limited to the value corresponding to 20 times the set point.
- if the monitored value exceeds the measurement capacity of Sepam (40 In for the phase current channels, 20 In0 for the residual current channels), the tripping time is limited to the value corresponding to the largest measurable value (40 In or 20 In0).

Current IDMT tripping curves

Multiple IDMT tripping curves are offered, to cover most applications:

- IEC curves (SIT, VIT/LTI, EIT)
- IEEE curves (MI, VI, EI)
- commonly used curves (UIT, RI, IAC).

IEC curves

Equation

$$t_d(I) = \frac{k}{\left(\frac{I}{I_s}\right)^{\alpha} - 1} \times \frac{T}{\beta}$$

Curve type	Coefficient values		
	k	α	β
Standard inverse / A	0.14	0.02	2.97
Very inverse / B	13.5	1	1.50
Long time inverse / B	120	1	13.33
Extremely inverse / C	80	2	0.808
Ultra inverse	315.2	2.5	1

RI curve

Equation:

$$t_d(I) = \frac{1}{0.339 - 0.236\left(\frac{I}{I_s}\right)^{-1}} \times \frac{T}{3.1706}$$

IEEE curves

Equation

$$t_d(I) = \left(\frac{A}{\left(\frac{I}{I_s}\right)^{p} - 1} + B\right) \times \frac{T}{\beta}$$

Curve type	Coefficient values			
	A	B	p	β
Moderately inverse	0.010	0.023	0.02	0.241
Very inverse	3.922	0.098	2	0.138
Extremely inverse	5.64	0.0243	2	0.081

IAC curves

Equation

$$t_d(I) = \left(A + \frac{B}{\left(\frac{I}{I_s} - C\right)} + \frac{D}{\left(\frac{I}{I_s} - C\right)^2} + \frac{E}{\left(\frac{I}{I_s} - C\right)^3}\right) \times \frac{T}{\beta}$$

Curve type	Coefficient values					
	A	B	C	D	E	β
Inverse	0.208	0.863	0.800	-0.418	0.195	0.297
Very inverse	0.090	0.795	0.100	-1.288	7.958	0.165
Extremely inverse	0.004	0.638	0.620	1.787	0.246	0.092

Voltage IDMT tripping curves

Equation for ANSI 27 - Undervoltage

$$t_d(V) = \frac{T}{1 - \left(\frac{V}{V_s}\right)}$$

Equation for ANSI 59N - Neutral voltage displacement

$$t_d(V) = \frac{T}{\left(\frac{V}{V_s}\right) - 1}$$

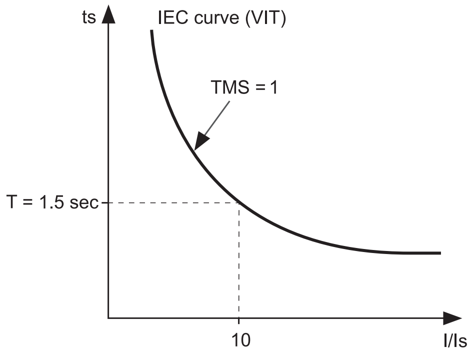
Voltage/frequency ratio IDMT tripping curves

Equation for ANSI 24 - Overfluxing (V/Hz)

Where G = V/f or U/f

$$t_d(G) = \frac{1}{\left(\frac{G}{G_s} - 1\right)^{p}} \times T$$

Curve type	p
A	0.5
B	1
C	2



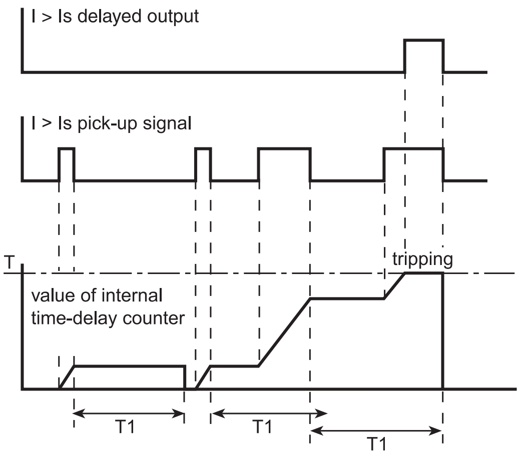
Example.

Setting of IDMT tripping curves, time delay T or TMS factor

The time delays of current IDMT tripping curves (except for customized and RI curves) may be set as follows:
- time T, operating time at 10 x Is
- TMS factor, factor shown as T/β in the equations on the left.

Example: $\mathbf{t(I)} = \dfrac{13.5}{\frac{I}{Is} - 1} \times \mathbf{TMS}$ where $\mathbf{TMS} = \dfrac{T}{1.5}$.

The IEC curve of the VIT type is positioned so as to be the same with TMS = 1 or T = 1.5 s.



Detection of restriking faults with adjustable timer hold.

Timer hold

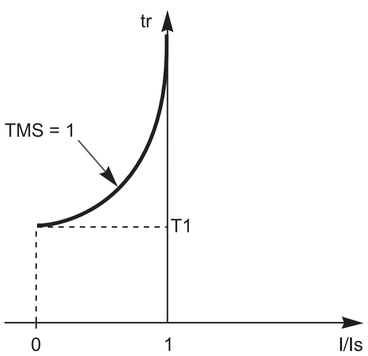
The adjustable timer hold T1 is used for:
- detection of restriking faults (DT curve)
- coordination with electromechanical relays (IDMT curve).
- Timer hold may be inhibited if necessary.

Equation for IDMT timer hold curve

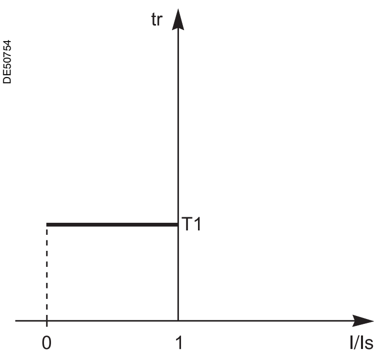
Equation: $\mathbf{t_r(I)} = \dfrac{T1}{1 - \left(\frac{I}{Is}\right)^2} \times \dfrac{T}{\beta}$ where $\dfrac{T}{\beta} = \mathbf{TMS}$.

T1 = timer hold setting (timer hold for I reset = 0 and TMS = 1)
T = tripping time delay setting (at 10 Is)

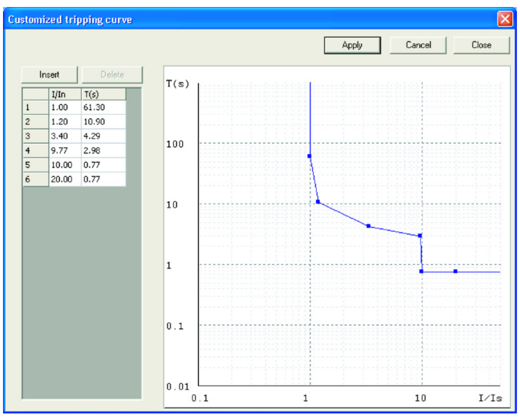
b = basic tripping curve value at $\dfrac{k}{10^{\alpha} - 1}$.



Timer hold dependent on current I.



Constant timer hold.



Customized tripping curve set using SFT2841 software.

Customized tripping curve

Defined point by point using the SFT2841 setting and operating software tool (application menu), this curve may be used to solve all special cases involving protection coordination or installation renovation.
It offers between 2 and 30 points whose coordinates must be:
- increasing on the I/Is axis
- decreasing on the t axis.

The two end points define the curve asymptotes.
There must be at least one point on the horizontal coordinate 10 I/Is. It serves as a reference point to set the function time delay by curve shifting.

Implementing IDMT curves: examples of problems to be solved.

Problem 1.
Given the type of IDMT, determine the Is current and time delay T settings.
Theoretically, the Is current setting corresponds to the maximum continuous current: it is generally the rated current of the protected equipment (cable, transformer).
The time delay T corresponds to operation at 10 Is on the curve. This setting is determined taking into account the constraints involved in discrimination with the upstream and downstream protection devices.
The discrimination constraint leads to the definition of point A on the operation curve (IA, tA), e.g. the point that corresponds to the maximum fault current for the downstream protection device.

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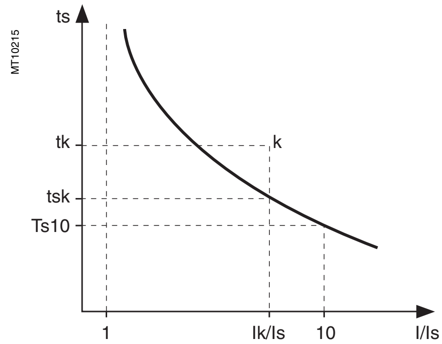
Problem 2.
Given the type of IDMT, the Is current setting and a point k (Ik, tk) on the operation curve, determine the time delay setting T.
On the standard curve of the same type, read the operation time tsk that corresponds to the relative current **Ik/Is** and the operation time Ts10 that corresponds to the relative current **I/Is = 10.**

The time delay setting to be used so that the operation curve passes through the point k (Ik, tk) is:

$$T = Ts10 \times \frac{tk}{tsk}$$

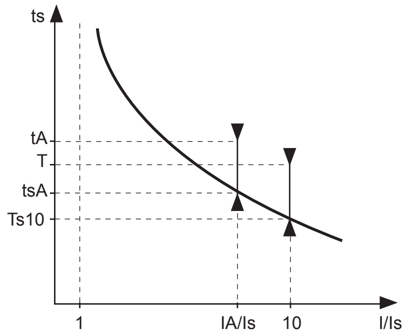


Another practical method:
the table below gives the values of **K = ts/ts10** as a function of **I/Is.**
In the column that corresponds to the type of time delay, read the value **K = tsk/Ts10** on the line for **Ik/Is.**
The time delay setting to be used so that the operation curve passes through point k (Ik, tk) is: **T = tk/k.**

Example
Data:
- type of time delay: standard inverse time (**SIT**)
- set point: Is
- a point k on the operation curve: k (3.5 Is; 4 s)

Question: What is the time delay T setting (operation time at 10 Is)?
Reading the table: **SIT** column, line **I/Is** = **3.5** therefore **K = 1.858**
Answer: The time delay setting is **T = 4/1.858 = 2.15 s**

Problem 3.
Given the Is current and time delay T settings for a type of time delay (standard inverse, very inverse, extremely inverse), find the operation time for a current value IA.
On the standard curve of the same type, read the operation time tsA that corresponds to the relative current IA/Is and the operation time Ts10 that corresponds to the relative current **I/Is = 10.**
The operation time tA for the current IA with the Is and T settings is **tA = tsA x T/Ts10.**



Another practical method:
the table below gives the values of **K = ts/Ts10** as a function of **I/Is.**
In the column that corresponds to the type of time delay, read the value **K = tsA/Ts10** on the line for **IA/Is,** the operation time tA for the current IA with the Is and T settings is **tA = K . T.**

Example
Data:
- type of time delay: very inverse time (**VIT**)
- set point: Is
- time delay T = 0.8 s.

Question: What is the operation time for the current IA = 6 Is?
Reading the table: VIT column, line I/Is = 6, therefore k = 1.8

Answer: The operation time for the current IA is t = 1.80 x 0.8 = 1.44 s.

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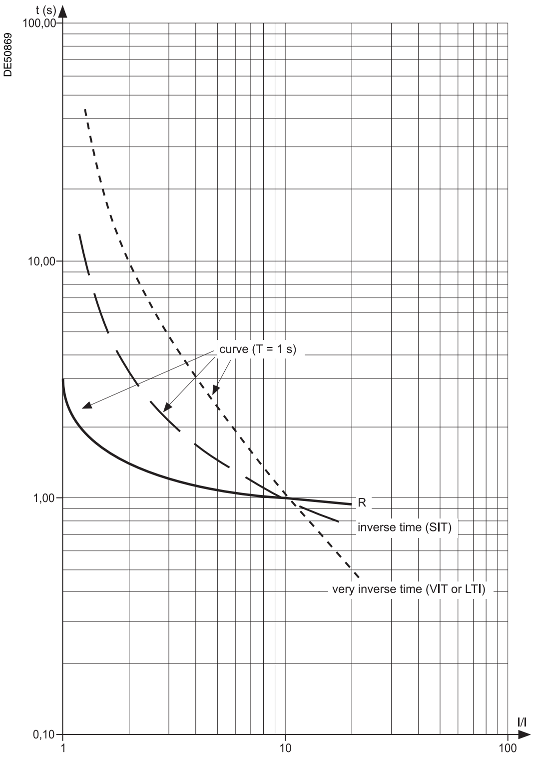
Table of K values

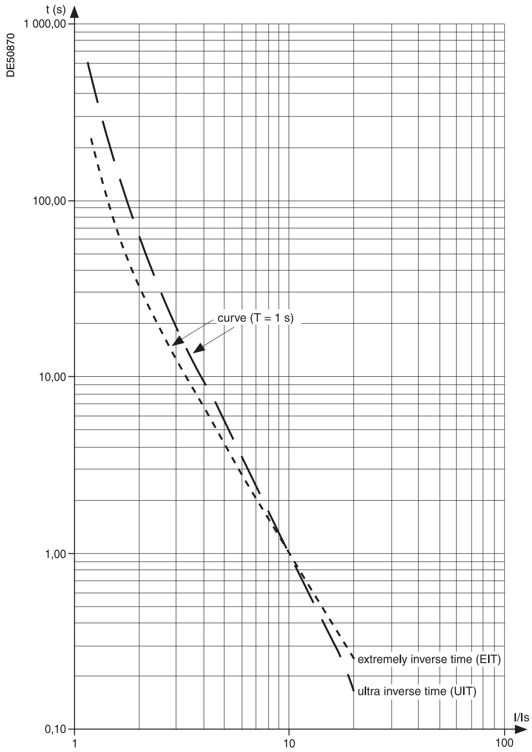
I/Is	SIT and IEC/A	VIT, LTI and IEC/B	EIT and IEC/C	UIT	RI	IEEE MI (IEC/D)	IEEE VI (IEC/E)	IEEE EI (IEC/F)	IAC I	IAC VI	IAC EI
1.0	∞ (1)	∞ (1)	∞ (1)	—	3.062	∞	∞	∞	62.005	62.272	200.226
1.1	24.700 (1)	90.000 (1)	471.429 (1)	—	2.534	22.461	136.228	330.606	19.033	45.678	122.172
1.2	12.901	45.000	225.000	545.905	2.216	11.777	65.390	157.946	9.413	34.628	82.899
1.5	5.788	18.000	79.200	179.548	1.736	5.336	23.479	55.791	3.891	17.539	36.687
2.0	3.376	9.000	33.000	67.691	1.427	3.152	10.199	23.421	2.524	7.932	16.178
2.5	2.548	6.000	18.857	35.490	1.290	2.402	6.133	13.512	2.056	4.676	9.566
3.0	2.121	4.500	12.375	21.608	1.212	2.016	4.270	8.970	1.792	3.249	6.541
3.5	1.858	3.600	8.800	14.382	1.161	1.777	3.242	6.465	1.617	2.509	4.872
4.0	1.676	3.000	6.600	10.169	1.126	1.613	2.610	4.924	1.491	2.076	3.839
4.5	1.543	2.571	5.143	7.513	1.101	1.492	2.191	3.903	1.396	1.800	3.146
5.0	1.441	2.250	4.125	5.742	1.081	1.399	1.898	3.190	1.321	1.610	2.653
5.5	1.359	2.000	3.385	4.507	1.065	1.325	1.686	2.671	1.261	1.473	2.288
6.0	1.292	1.800	2.829	3.616	1.053	1.264	1.526	2.281	1.211	1.370	2.007
6.5	1.236	1.636	2.400	2.954	1.042	1.213	1.402	1.981	1.170	1.289	1.786
7.0	1.188	1.500	2.063	2.450	1.033	1.170	1.305	1.744	1.135	1.224	1.607
7.5	1.146	1.385	1.792	2.060	1.026	1.132	1.228	1.555	1.105	1.171	1.460
8.0	1.110	1.286	1.571	1.751	1.019	1.099	1.164	1.400	1.078	1.126	1.337
8.5	1.078	1.200	1.390	1.504	1.013	1.070	1.112	1.273	1.055	1.087	1.233
9.0	1.049	1.125	1.238	1.303	1.008	1.044	1.068	1.166	1.035	1.054	1.144
9.5	1.023	1.059	1.109	1.137	1.004	1.021	1.031	1.077	1.016	1.026	1.067
10.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
10.5	0.979	0.947	0.906	0.885	0.996	0.981	0.973	0.934	0.985	0.977	0.941
11.0	0.959	0.900	0.825	0.787	0.993	0.963	0.950	0.877	0.972	0.957	0.888
11.5	0.941	0.857	0.754	0.704	0.990	0.947	0.929	0.828	0.960	0.939	0.841
12.0	0.925	0.818	0.692	0.633	0.988	0.932	0.912	0.784	0.949	0.922	0.799
12.5	0.910	0.783	0.638	0.572	0.985	0.918	0.896	0.746	0.938	0.907	0.761
13.0	0.895	0.750	0.589	0.518	0.983	0.905	0.882	0.712	0.929	0.893	0.727
13.5	0.882	0.720	0.546	0.471	0.981	0.893	0.870	0.682	0.920	0.880	0.695
14.0	0.870	0.692	0.508	0.430	0.979	0.882	0.858	0.655	0.912	0.868	0.667
14.5	0.858	0.667	0.473	0.394	0.977	0.871	0.849	0.631	0.905	0.857	0.641
15.0	0.847	0.643	0.442	0.362	0.976	0.861	0.840	0.609	0.898	0.846	0.616
15.5	0.836	0.621	0.414	0.334	0.974	0.852	0.831	0.589	0.891	0.837	0.594
16.0	0.827	0.600	0.388	0.308	0.973	0.843	0.824	0.571	0.885	0.828	0.573
16.5	0.817	0.581	0.365	0.285	0.971	0.834	0.817	0.555	0.879	0.819	0.554
17.0	0.808	0.563	0.344	0.265	0.970	0.826	0.811	0.540	0.874	0.811	0.536
17.5	0.800	0.545	0.324	0.246	0.969	0.819	0.806	0.527	0.869	0.804	0.519
18.0	0.792	0.529	0.307	0.229	0.968	0.812	0.801	0.514	0.864	0.797	0.504
18.5	0.784	0.514	0.290	0.214	0.967	0.805	0.796	0.503	0.860	0.790	0.489
19.0	0.777	0.500	0.275	0.200	0.966	0.798	0.792	0.492	0.855	0.784	0.475
19.5	0.770	0.486	0.261	0.188	0.965	0.792	0.788	0.482	0.851	0.778	0.463
20.0	0.763	0.474	0.248	0.176	0.964	0.786	0.784	0.473	0.848	0.772	0.450

***(1)** Values suitable only for IEC A, B and C curves.*

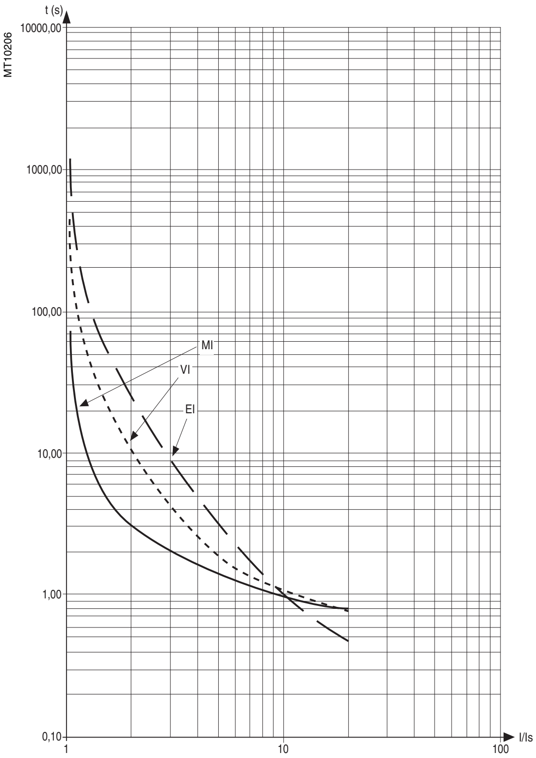
Standard inverse time SIT curve
Very inverse time VIT or LTI curve
RI curve



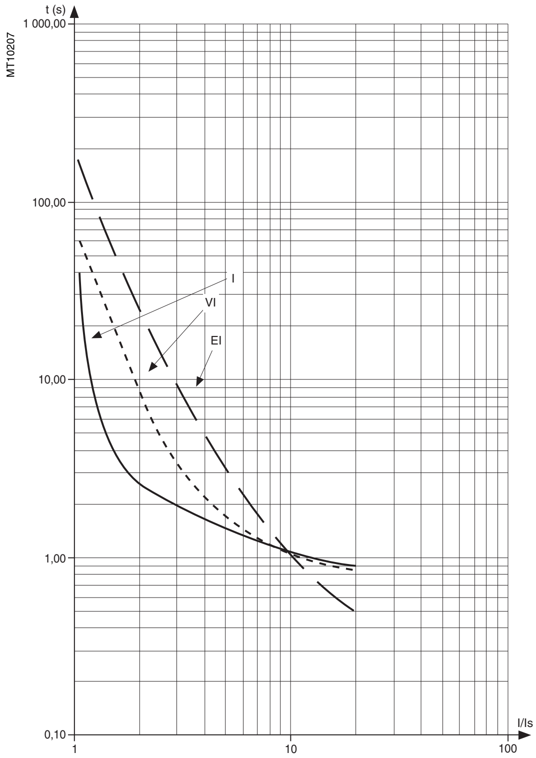
Extremely inverse time EIT curve
Ultra inverse time UIT curve



IEEE curves



IAC curves



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Contents

Description

Sepam performs all the control and monitoring functions required for electrical network operation:
■ the main control and monitoring functions are predefined and fit the most frequent cases of use. They are ready to use and are implemented by simple parameter setting after the necessary logic inputs / outputs are assigned.
■ the predefined control and monitoring functions can be adapted for particular needs using the SFT2841 software, which offers the following customization options:
□ logic equation editor, to adapt and complete the predefined control and monitoring functions
□ creation of personalized messages for local annunciation
□ creation of personalized mimic diagrams corresponding to the controlled devices
□ customization of the control matrix by changing the assignment of output relays, LEDs and annunciation messages
■ with the Logipam option, Sepam can provide the most varied control and monitoring functions, programmed using the SFT2885 programming software that implements the Logipam ladder language.

Operating principle

The processing of each control and monitoring function may be broken down into 3 phases:
■ acquisition of input data:
□ results of protection function processing
□ external logic data, connected to the logic inputs of an optional MES120 input / output module
□ local control orders transmitted by the mimic-based UMI
□ remote control orders (TC) received via the communication link
■ actual processing of the control and monitoring function
■ utilization of the processing results:
□ activation of output relays to control a device
□ information sent to the facility manager:
- by message and/or LED on the Sepam display and SFT2841 software
- by remote indication (TS) via the communication link
- by real-time indications on device status on the animated mimic diagram.

Wired logic inputs and outputs

The number of Sepam inputs / outputs must be adapted to fit the control and monitoring functions used.
The 5 outputs included in the Sepam series 80 base unit may be extended by adding 1, 2 or 3 MES120 modules with 14 logic inputs and 6 output relays.
After the number of MES120 modules required for the needs of an application is set, the logic inputs are assigned to functions. The functions are chosen from a list which covers the whole range of possible uses. The functions are adapted to meet needs within the limits of the logic inputs available. The inputs may also be inverted for undervoltage type operation.
A default input / output assignment is proposed for the most frequent uses.

PE50249

Maximum Sepam series 80 configuration with 3 MES120 modules: 42 inputs and 23 outputs.

GOOSE logic inputs and outputs

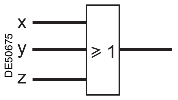
GOOSE logic inputs are used with the IEC 61850 communication protocol.
The GOOSE inputs are divided between the 2 GSE virtual modules with 16 logic inputs.
An example of implementing logic discrimination with GOOSE logic inputs is given on page 212.

Definition of symbols

This page gives the meaning of the symbols used in the block diagrams illustrating the different control and monitoring functions in this chapter.

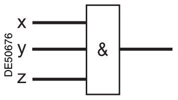
Logic functions

■ **"OR"**



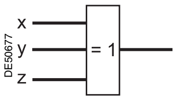
Equation: S = X + Y + Z.

■ **"AND"**



Equation: S = X x Y x Z.

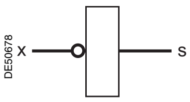
■ **exclusive "XOR"**



S = 1 if one and only one input is set to 1
(S = 1 if X + Y + Z = 1).

■ **Complement**

These functions may use the complement of one or more input values.

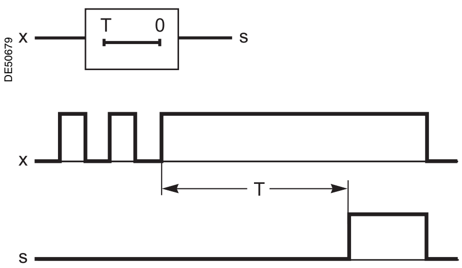


Equation: S = $\overline{X}$ (S = 1 if X = 0).

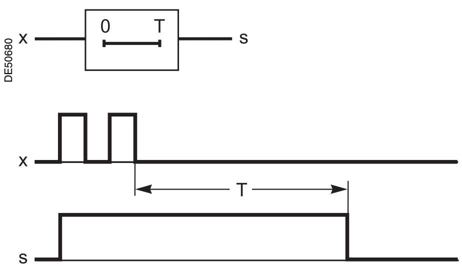
Delay timers

Two types of delay timers:

■ "on" delay timer: used to delay the appearance of a signal by a time T

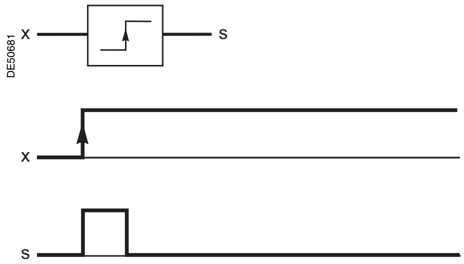


■ "off" delay timer: used to delay the disappearance of a signal by a time T.

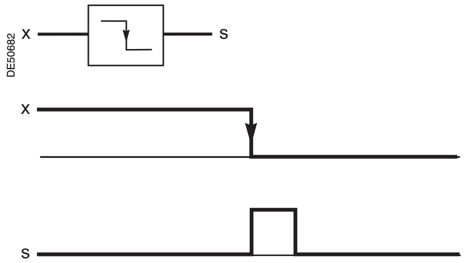


Pulse mode operation

■ "on" pulse: used to create a short-duration pulse (1 cycle) each time a signal appears



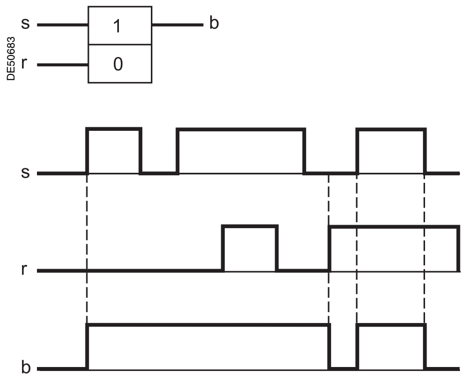
■ "off" pulse: used to create a short-duration pulse (1 cycle) each time a signal disappears.



Note: *the disappearance of a signal may be caused by an auxiliary power failure.*

Bistable functions

Bistable functions may be used to store values.



Equation: B = S + $\overline{R}$ x B.

Logic input / output assignment

Inputs and outputs may be assigned to predefined control and monitoring functions using the SFT2841 software, according to the uses listed in the table below.
The control logic of each input may be inverted for undervoltage type operation.
All the logic inputs, whether or not assigned to predefined functions, may be used for the customization functions according to specific application needs:
- in the control matrix (SFT2841 software), to connect an input to a logic output, a LED on the front of Sepam or a message for local indication on the display
- in the logic equation editor (SFT2841 software), as logic equation variables
- in Logipam (SFT2885 software) as input variables for the program in ladder language.

Logic output (Ox) assignment table

Functions	S80	S81	S82	S84	T81	T82 T87	M87	M81 M88	G87	G82 G88	B80	B83	C86	Assignment
Tripping / contactor control	■	■	■	■	■	■	■	■	■	■	■	■	■	O1
Inhibit closing	■	■	■	■	■	■	■	■	■	■	■	■	■	O2 by default
Closing	■	■	■	■	■	■	■	■	■	■	■	■	■	O3 by default
Watchdog	■	■	■	■	■	■	■	■	■	■	■	■	■	O5
Logic discrimination, blocking send 1	■	■	■	■	■	■	■	■	■	■	■	■	■	O102 by default
Logic discrimination, blocking send 2			■	■		■			■	■				O103 by default
Genset shutdown									■	■				Free
De-excitation									■	■				Free
Load shedding							■	■						Free
AT, closing of NO circuit breaker	■	■	■	■	■	■			■	■	■	■		Free
AT, closing of coupling	■	■	■	■	■	■			■	■	■	■		Free
AT, opening of coupling	■	■	■	■	■	■			■	■	■	■		Free
Tripping of capacitor step (1 to 4)													■	Free
Tripping of capacitor step (1 to 4)													■	Free

Note: *The logic outputs assigned by default may be freely reassigned.*

Assignment table for logic inputs (Ix) common to all applications

Functions	S80	S81	S82	S84	T81	T82 T87	M87	M81 M88	G87	G82 G88	B80	B83	C86	Assignment
Closed circuit breaker	■	■	■	■	■	■	■	■	■	■	■	■	■	I101
Open circuit breaker	■	■	■	■	■	■	■	■	■	■	■	■	■	I102
Synchronization of Sepam internal clock via external pulse	■	■	■	■	■	■	■	■	■	■	■	■	■	I103
Switching of groups of settings A/B	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
External reset	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Earthing switch closed	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Earthing switch open	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
External trip 1	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
External trip 2	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
External trip 3	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
End of charging position	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Inhibit remote control (Local)	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
SF6 pressure default	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Inhibit closing	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Open order	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Close order	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Phase VT fuse blown	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
V0 VT fuse blown	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
External positive active energy meter	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
External negative active energy meter	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
External positive reactive energy meter	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
External negative reactive energy meter	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Racked out circuit breaker	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Switch A closed	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Switch A open	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Switch B closed	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Switch B open	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Closing-coil monitoring	■	■	■	■	■	■	■	■	■	■	■	■	■	Free

Logic input / output assignment

Assignment table for logic inputs (Ix) common to all applications

Functions	S80	S81	S82	S84	T81	T82 T87	M87	M81 M88	G87	G82 G88	B80	B83	C86	Assignment
Data log activation	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Phase rotation direction 123	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Phase rotation direction 132	■	■	■	■	■	■	■	■	■	■	■	■	■	Free

Assignment table for logic inputs (Ix) by application

Functions	S80	S81	S82	S84	T81	T82 T87	M87	M81 M88	G87	G82 G88	B80	B83	C86	Assignment
Inhibit recloser	■	■	■	■										Free
Inhibit thermal overload		■	■	■	■	■	■	■	■	■			■	Free
Switching of thermal settings					■	■	■	■	■	■				Free
Blocking reception 1	■	■	■	■	■	■			■	■	■	■		Free
Blocking reception 2			■	■		■			■	■				Free
Buchholz trip					■	■		■		■				Free
Thermostat trip					■	■		■		■				Free
Pressure trip					■	■		■		■				Free
Thermistor trip					■	■	■	■	■	■				Free
Buchholz alarm					■	■		■		■				Free
Thermostat alarm					■	■		■		■				Free
Pressure alarm					■	■		■		■				Free
Thermistor alarm					■	■	■	■	■	■				Free
Rotor speed measurement							■	■	■	■				I104
Rotor rotation detection							■	■						Free
Motor re-acceleration							■	■						Free
Load shedding request							■	■						Free
Inhibit undercurrent							■	■						Free
Trigger Motor start report							■	■						Free
Authorize emergency restart							■	■						Free
Priority genset shutdown									■	■				Free
De-excitation									■	■				Free
Close enable (ANSI 25)	■	■	■	■	■	■			■	■	■	■		Free
Inhibit opposite-side remote control (local)	■	■	■	■	■	■			■	■	■	■		Free
Inhibit remote-control coupling (local)	■	■	■	■	■	■			■	■	■	■		Free
Coupling open	■	■	■	■	■	■			■	■	■	■		Free
Coupling closed	■	■	■	■	■	■			■	■	■	■		Free
Opposite side open	■	■	■	■	■	■			■	■	■	■		Free
Opposite side closed	■	■	■	■	■	■			■	■	■	■		Free
Selector set to Manual (ANSI 43)	■	■	■	■	■	■			■	■	■	■		Free
Selector set to Auto (ANSI 43)	■	■	■	■	■	■			■	■	■	■		Free
Selector set to Circuit breaker (ANSI 10)	■	■	■	■	■	■			■	■	■	■		Free
Selector set to Coupling (ANSI 10)	■	■	■	■	■	■			■	■	■	■		Free
Opposite-side circuit breaker disconnected	■	■	■	■	■	■			■	■	■	■		Free
Coupling circuit breaker disconnected	■	■	■	■	■	■			■	■	■	■		Free
Coupling close order	■	■	■	■	■	■			■	■	■	■		Free
Opposite-side voltage OK	■	■	■	■	■	■			■	■	■	■		Free
Inhibit closing of coupling	■	■	■	■	■	■			■	■	■	■		Free
Automatic closing order	■	■	■	■	■	■			■	■	■	■		Free
External closing order 1											■	■		Free
External closing order 2											■	■		Free
Additional phase voltage transformer fuse blown											■	■		Free
Additional V0 voltage transformer fuse blown												■		Free

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Logic input / output assignment

Assignment table for logic inputs (Ix) by application

Functions	S80	S81	S82	S84	T81	T82 T87	M87	M81 M88	G87	G82 G88	B80	B83	C86	Assignment
Capacitor step 1 open													■	Free
Capacitor step 1 closed													■	Free
Capacitor step 2 open													■	Free
Capacitor step 2 closed													■	Free
Capacitor step 3 open													■	Free
Capacitor step 3 closed													■	Free
Capacitor step 4 open													■	Free
Capacitor step 4 closed													■	Free
Step 1 opening order													■	Free
Step 2 opening order													■	Free
Step 3 opening order													■	Free
Step 4 opening order													■	Free
Step 1 closing order													■	Free
Step 2 closing order													■	Free
Step 3 closing order													■	Free
Step 4 closing order													■	Free
Step 1 external trip													■	Free
Step 2 external trip													■	Free
Step 3 external trip													■	Free
Step 4 external trip													■	Free
Capacitor step 1 VAR control													■	Free
Capacitor step 2 VAR control													■	Free
Capacitor step 3 VAR control													■	Free
Capacitor step 4 VAR control													■	Free
External capacitor step control inhibit													■	Free
Manual capacitor step control													■	Free
Automatic capacitor step control													■	Free

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Assignment table for GOOSE logic inputs (Gx) (IEC 61850) by application

Functions	S80	S81	S82	S84	T81	T82 T87	M87	M81 M88	G87	G82 G88	B80	B83	C86	Assignment
Blocking reception 1	■	■	■	■	■	■			■	■	■	■		Free
Blocking reception 2			■	■		■			■	■				Free
External trip 2	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Inhibit closing	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Load shedding request							■	■					■	Free
GOOSE reception fault	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
GOOSE reception indicator	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Other use	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
ACE850 presence	■	■	■	■	■	■	■	■	■	■	■	■	■	G516
Data log activation	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Phase rotation direction 123	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Phase rotation direction 132	■	■	■	■	■	■	■	■	■	■	■	■	■	Free
Trigger Motor start report							■	■						Free

Note: *GOOSE IEC 61850 logic inputs/outputs can only be used with the ACE850TP or ACE850FO communication interface and only with Sepam series 80.*

Logic input / output assignment

Standard logic input (Ix) assignment

The table below lists the logic input (Ix) assignments obtained with the SFT2841 configuration software by clicking on the "standard assignment" button.

Functions	Standard assignment	Application
Closed circuit breaker	I101	All
Open circuit breaker	I102	All
Blocking reception 1	I103	All except M8x
Blocking reception 2	I104	All except S80, S81, T81, M8x, B8x, C86
Close enable (ANSI 25)	I104	S80, S81, T81, B8x
SF6 pressure default	I105	All
Open order	I106	All
Close order	I107	All
Inhibit recloser	I108	S80, S81
Buchholz trip	I108	T8x, M88, G88
Thermostat trip	I109	T8x, M88, G88
Pressure trip	I110	T8x, M88, G88
Thermistor trip	I111	T8x, M88, G88
Buchholz alarm	I112	T8x, M88, G88
Thermostat alarm	I113	T8x, M88, G88
Pressure alarm	I114	T8x, M88, G88
Selector set to Circuit Breaker (ANSI 10)	I201	S8x, T8x, G8x, B8x
Selector set to Coupling (ANSI 10)	I202	S8x, T8x, G8x, B8x
Selector set to Auto (ANSI 43)	I203	S8x, T8x, G8x, B8x
Selector set to Manual (ANSI 43)	I204	S8x, T8x, G8x, B8x
Opposite side closed	I205	S8x, T8x, G8x, B8x
Opposite side open	I206	S8x, T8x, G8x, B8x
Opposite-side voltage OK	I207	S8x, T8x, G8x, B8x
Inhibit opposite side remote control (local)	I208	S8x, T8x, G8x, B8x
Automatic closing order	I209	S8x, T8x, G8x, B8x
Coupling open	I210	S8x, T8x, G8x, B8x
Coupling closed	I211	S8x, T8x, G8x, B8x
Inhibit closing of coupling	I212	S8x, T8x, G8x, B8x
Coupling close order	I213	S8x, T8x, G8x, B8x
Inhibit remote-control coupling (local)	I214	S8x, T8x, G8x, B8x

Standard GOOSE logic input (Gx) assignment

The table below lists the GOOSE logic input (Gx) assignments obtained with the SFT2841 configuration software by clicking on the "standard assignment" button.

Functions	Standard assignment	Application
Blocking reception 1	G401	All except M87, M81, M88, C86
Blocking reception 2	G402	S82, S84, T82, T87, G87, G82, G83
External trip 2	G403	All
Inhibit closing	G404	All

Any of 31 GOOSE logic inputs can be selected, from G401 to G416 and G501 to G515.

4

Switchgear control
ANSI code 94/69

Predefined circuit breaker or contactor control function.

Operation
The Switchgear control function can control the following types of breaking device:
■ circuit breakers with shunt trip or undervoltage coils
■ latching contactors with shunt trip coils
■ contactors with latched orders.

This function comprises two parts:
■ processing of internal switchgear control orders:
□ open [1], [2], [3]
□ close with or without synchro-check [6], [7], [8]
□ inhibit closing [4], [5]
■ execution of internal orders by control logic outputs according to the type of device to be controlled.

Processing of internal switchgear control orders
The Switchgear control function processes all breaking device closing and tripping conditions, based on:
■ protection functions (configured to trip the breaking device)
■ breaking device status data
■ remote control via the communication link
■ local control orders by logic input (Ix or Gx), or by mimic-based UMI
■ internal control orders created by logic equation or Logipam
■ specific predefined control functions for each application:
□ recloser
□ genset shutdown, de-excitation
□ load shedding
□ synchro-check
□ automatic transfer
□ capacitor step control.
The function also inhibits breaking device closing, according to the operating conditions.

Anti-pumping function
To prevent simultaneous breaking device open and close orders and to give priority to open orders, breaker device close orders are of the pulse type.

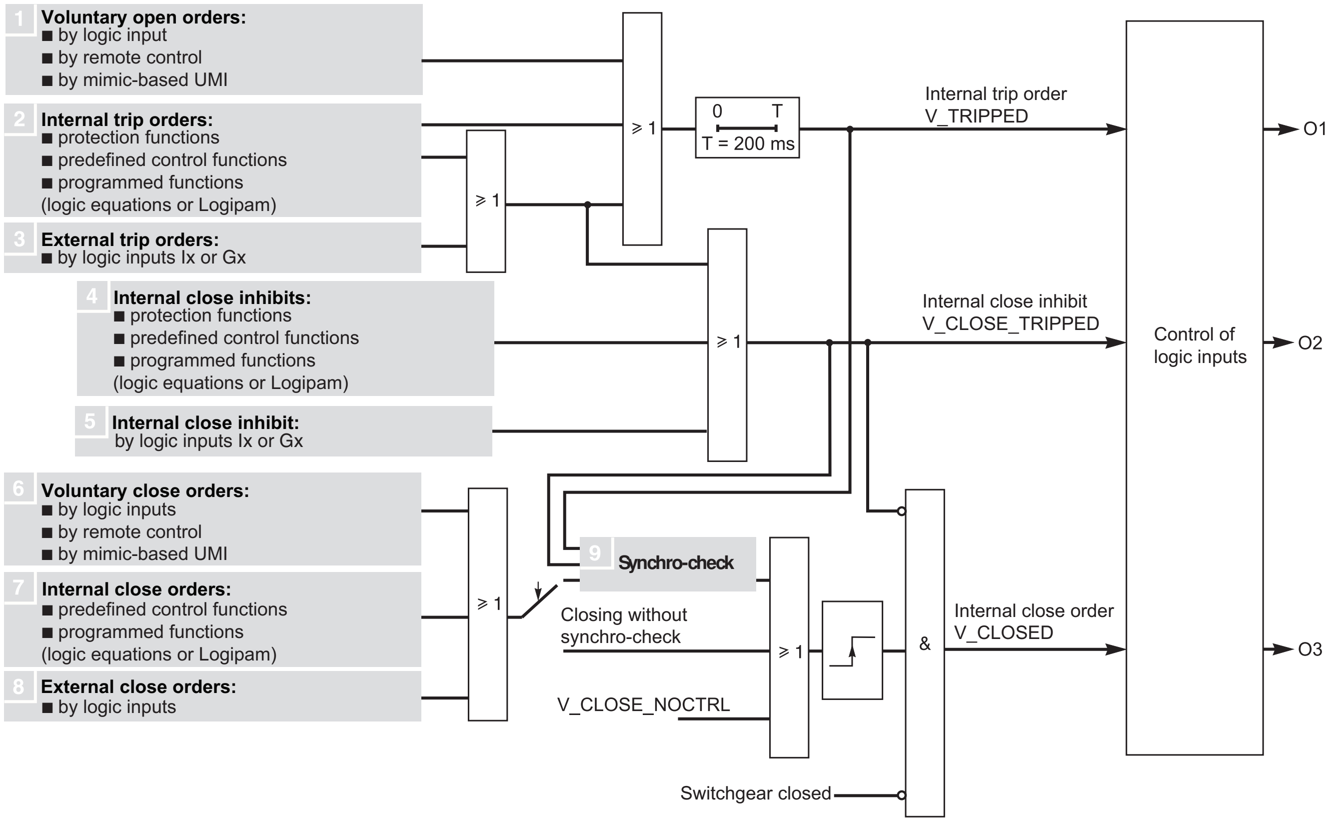
Switchgear control with lockout function (ANSI 86)
The ANSI 86 function traditionally performed by lockout relays may be ensured by Sepam using the Switchgear control function, with latching of all the tripping conditions (protection function outputs and logic inputs).
Sepam performs:
■ grouping of all the tripping conditions and breaking device control
■ latching of the tripping order, with inhibition of closing, until the cause of tripping disappears and is acknowledged by the user (see Latching / acknowledgement function)
■ indication of the cause of tripping:
□ locally by LEDs (Trip and others) and by messages on the display
□ remotely by remote indications (see Indications function).

Closing with synchro-check [9]
The Synchro-check function checks the voltages upstream and downstream of a circuit breaker to ensure safe closing.
It is put into service by parameter setting.
For it to operate, one of the “Close enable” logic outputs of an MCS025 remote module must be connected to a Sepam logic input assigned to the Close enable function.
If it is necessary to close the circuit breaker without taking into account the synchronization conditions, this may be done by a logic equation or by Logipam via the V_CLOSE_NOCTRL input.

Control of logic outputs
Logic orders from the Switchgear control function are used to control the Sepam logic outputs that control breaking device opening and closing.
Logic output control is set up to match the device to be controlled, i.e. a circuit breaker or contactor.

Control of capacitor banks
The Sepam C86 Switchgear control function can control the breaking device and 1 to 4 capacitor step switches.
This particular function is described separately.

Block diagram

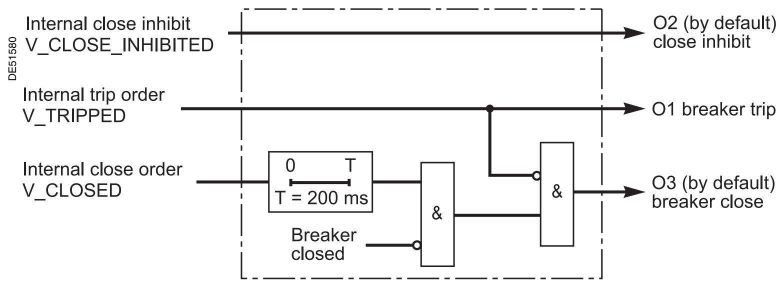


Control of logic outputs

Control of a circuit breaker or contactor with mechanical latching

The block diagram below represents the following parameter setting:

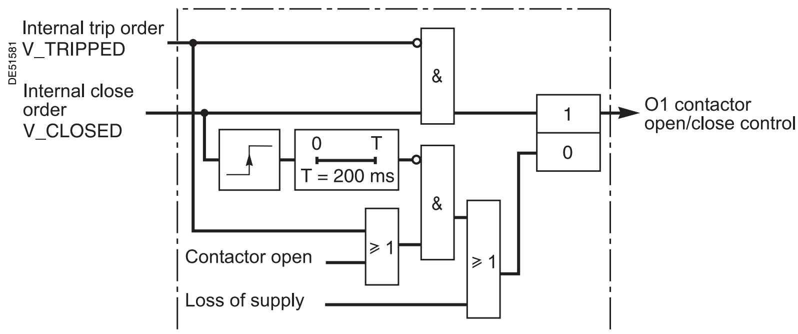
- type of switchgear = Circuit Breaker
- output O1 = trip
- output O2 = close inhibit
- output O3 = close.



Control of a contactor without mechanical latching

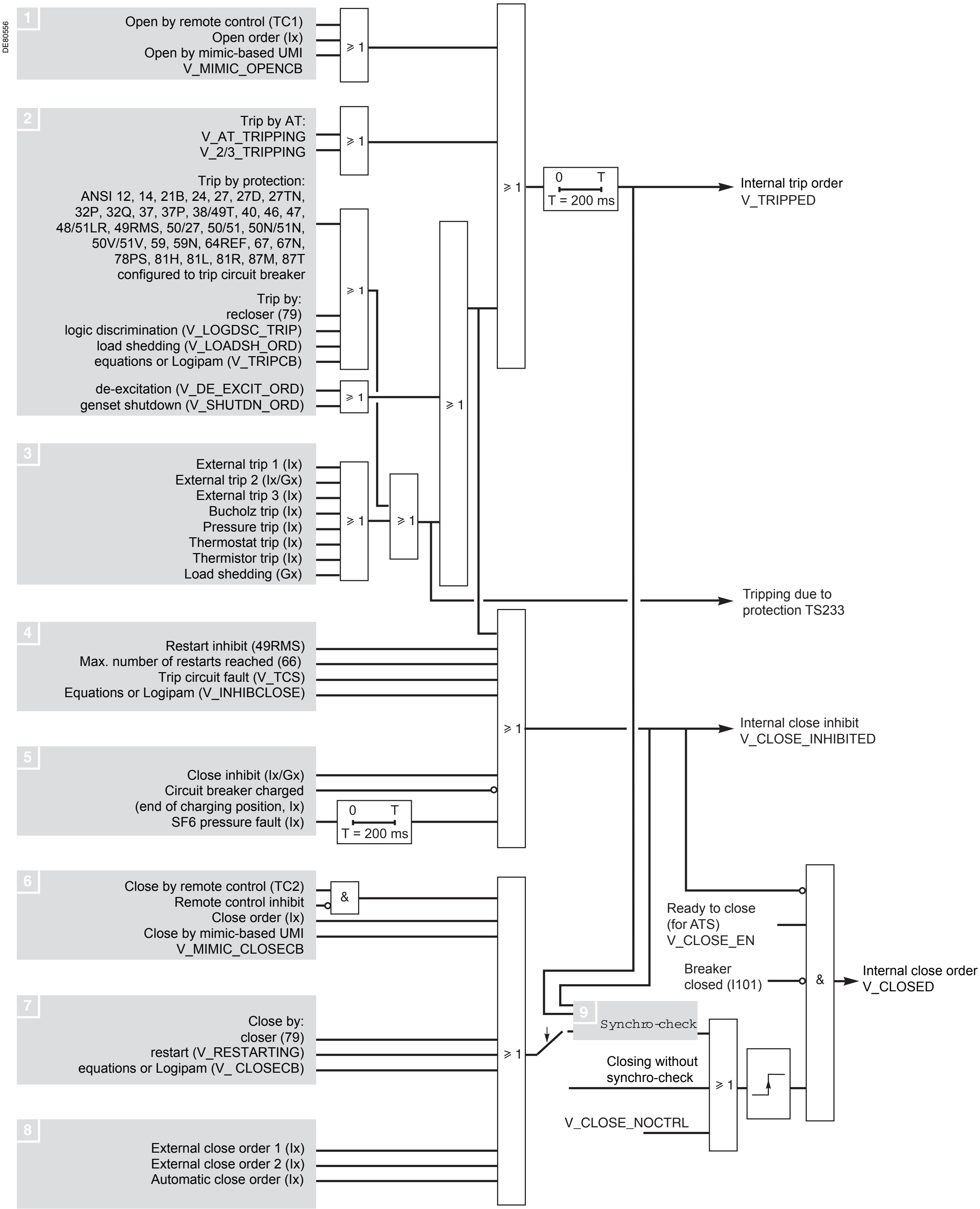
The block diagram below represents the following parameter setting:

- type of switchgear = Contactor
- output O1 = open / close.



Processing of internal switchgear control orders

Block diagram



Close enable by the Synchro-check function

Operation

The close request, made locally or remotely, is maintained by Sepam during the close request delay and triggers the appearance of a "SYNC.IN PROCESS" message. It is deactivated when a tripping order or circuit breaker inhibition order is received and triggers the "STOP SYNC." message.

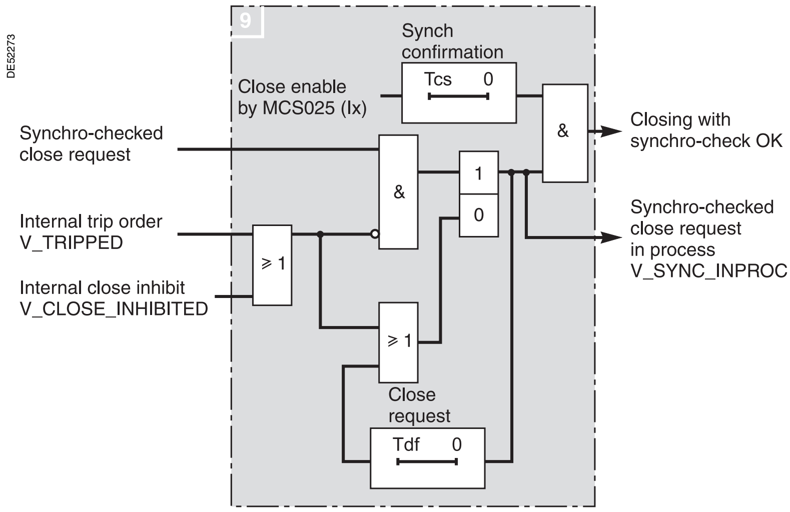
The closing order is given if the close enable is received before the close request delay runs out. When this is the case, the message "SYNC. OK" is displayed.

If the close enable is not received, the message "SYNC. FAILURE" is displayed. When possible and if the MCS025 remote module is connected by the CCA785 cord to the Sepam to which the close request has been made, an additional message indicates the type of synchronization failure:

- "SYNC. FAILED dU" for too high a voltage difference
- "SYNC. FAILED dF" for too high a frequency difference
- "SYNC. FAILED dPhi" for too high a phase difference.

An additional delay is used to confirm the close enable to guarantee that the closing conditions last long enough.

Block diagram



Parameter setting

The Switchgear control function is set up and adapted to match the type of breaking device to be controlled using the SFT2841 software.

"Control logic" tab

■ activation of the Switchgear control function
■ choice of the type of breaking device to be controlled: circuit breaker (by default) or contactor
■ activation of the Synchro-check function, if necessary.

"Logic I/Os" tab

■ assignment of the logic inputs required
■ definition of logic output behavior.

By default, the following outputs are used:

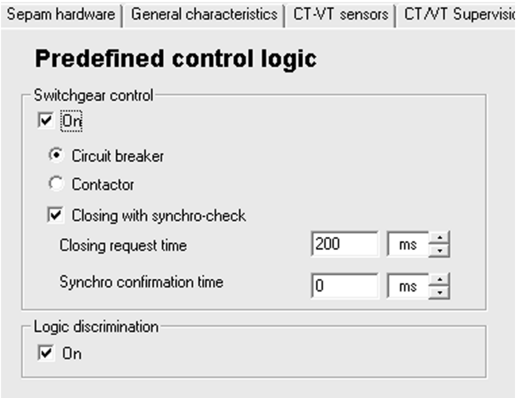
Logic output	Associated internal order	Circuit breaker coil
O1	Trip (V_TRIPPED)	Shunt trip coil
O2	Close inhibit (V_CLOSE_INHIBITED)	Undervoltage coil
O3	Close (V_CLOSED)	Shunt trip coil

■ the Trip order is always associated with output O1.
If output O1 is set up for pulse type operation, the pulse order duration may be set up
■ the optional Close inhibit and Close orders may be assigned to any logic output.

"Matrix" screen, "Logic" button

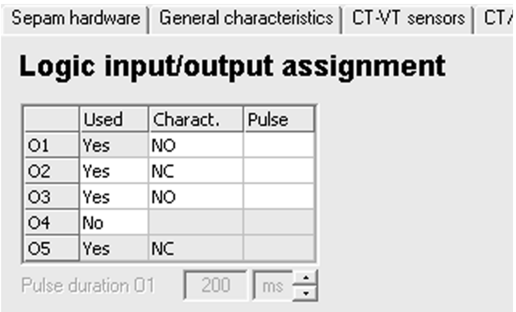
Modification of the default internal order assignment to outputs O2 and O3, if necessary.

PE50454



SFT2841: parameter setting of Switchgear control.

PE50455



SFT2841: default parameter setting of the logic outputs assigned to Switchgear control.

Switchgear control
ANSI code 94/69

Characteristics

Settings	
Switchgear control	
Setting range	On / Off
Type of device	
Setting range	Circuit breaker / Contactor
Tripping pulse duration (output O1)	
Setting range	200 ms to 300 s
Accuracy (1)	±2 % or from -10 ms to +25 ms
Resolution	10 ms or 1 digit
Closing with synchro-check	
Setting range	On / Off
Close request time delay Tdf	
Setting range	0 to 300 s
Accuracy (1)	±2 % or from -10 ms to +25 ms
Resolution	10 ms or 1 digit
Synchro confirmation time delay Tcs	
Setting range	0 to 300 s
Accuracy (1)	±2 % or from -10 ms to +25 ms
Resolution	10 ms or 1 digit

Inputs

Designation	Syntax	Equations	Logipam
Tripping, opening	V_TRIPCB	■	■
Inhibit closing	V_INHIBECLOSE	■	■
Closing	V_CLOSECB	■	■
Closing without synchro-check	V_CLOSE_NOCTRL	■	■

Outputs

Designation	Syntax	Equations	Logipam	Matrix
Switchgear control on	V_SWCTRL_ON		■	
Tripping, opening	V_TRIPPED	■	■	■
Inhibit closing	V_CLOSE_INHIBITED	■	■	■
Closing	V_CLOSED	■	■	■
Contactor control	V_CONTACTOR		■	■
Synchro-check on	V_SYNC_ON		■	■
Sychrochecked close request in process	V_SYNC_INPROC		■	■
Synchrochecked close request stop	V_SYNC_STOP		■	■
Synchrochecked close request successful	V_SYNC_OK		■	■
Synchrochecked close request failure	V_NOSYNC		■	■
Synchrochecked close request failure - Voltage difference too high	V_NOSYNC_DU		■	■
Synchrochecked close request failure - Frequency difference too high	V_NOSYNC_DF		■	■
Synchrochecked close request failure - Phase difference too high	V_NOSYNC_DPHI		■	■

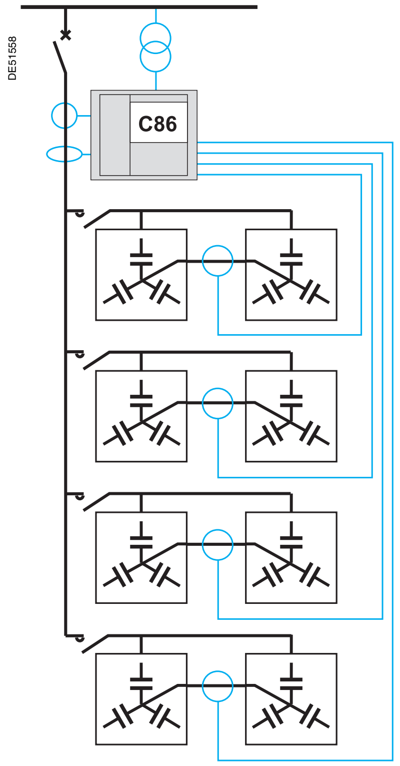
***(1)** Under reference conditions (IEC 60255-6).*

TS/TC equivalence for each protocol

Modbus	DNP3	IEC 60870-5-103	IEC 61850
TC	**Binary Output**	**ASDU, FUN, INF**	**LN.DO.DA**
TC1	BO0	20, 21, 1 (OFF)	CSWI1.Pos.ctlVal
TC2	BO1	20, 21, 1 (ON)	CSWI1.Pos.ctlVal
TS	**Binary Input**	**ASDU, FUN, INF**	**LN.DO.DA**
TS233	BI334	2, 160, 68	-

Capacitor bank switchgear control
ANSI code 94/69

Predefined function for the control of circuit breakers protecting capacitor banks and the switches of each capacitor bank step.
This function only concerns Sepam C86 units.

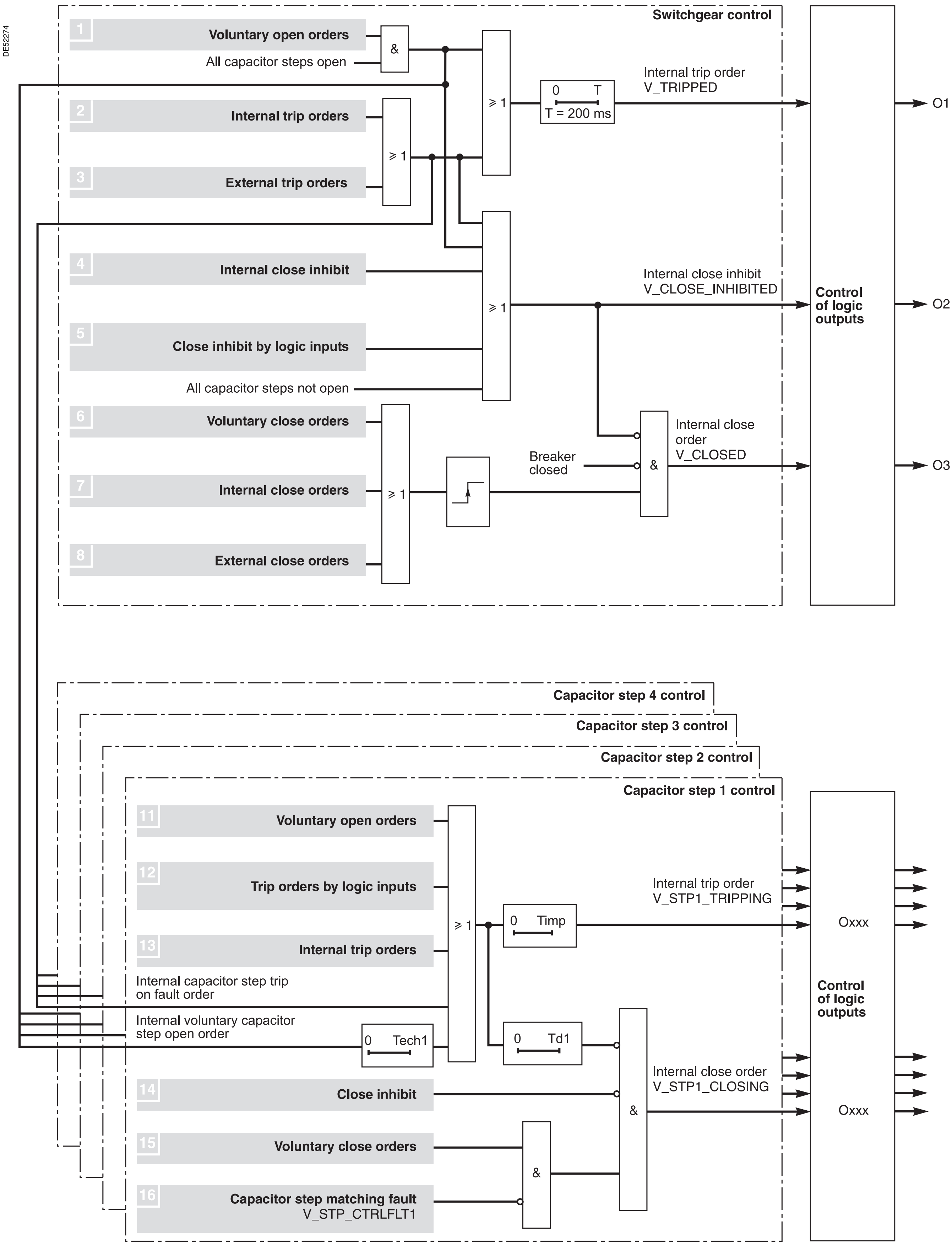


Example of a Sepam C86 application: circuit breaker protection of a 4-step capacitor bank.

Operation
The Sepam C86 Switchgear control function performs:
■ control of the circuit breaker protecting the capacitor bank (circuit breaker with shunt trip or undervoltage coil)
■ control of the capacitor bank step switches (maximum of 4 steps), with processing of:
□ voluntary manual control orders
□ automatic control orders, received from reactive-energy regulators

Control of logic outputs
The logic orders from the Switchgear control function are used to control the Sepam logic outputs which control:
■ opening and closing of the circuit breaker.
■ opening and closing of each capacitor step switch.
Logic output control is set up to match the type of device to be controlled, i.e. a circuit breaker or capacitor step switch.

Block diagram



Capacitor bank switchgear control
ANSI code 94/69

Control of the circuit breaker
This function comprises two parts:
■ processing of internal circuit breaker control orders:
□ open circuit breaker 1, 2, 3
□ close circuit breaker 6, 7, 8
□ inhibit circuit breaker closing 4, 5
■ execution of internal orders by control logic outputs according to the type of device to be controlled.

Processing of internal circuit breaker control orders
The Switchgear control function processes all the circuit breaker close and trip conditions, based on
■ protection functions (configured to trip the circuit breaker)
■ circuit breaker and capacitor step switch status data
■ remote control orders via the communication link
■ local control orders by logic input or mimic-based UMI
■ internal control orders created by logic equation or Logipam.
The function also inhibits circuit breaker closing according to the operating conditions.

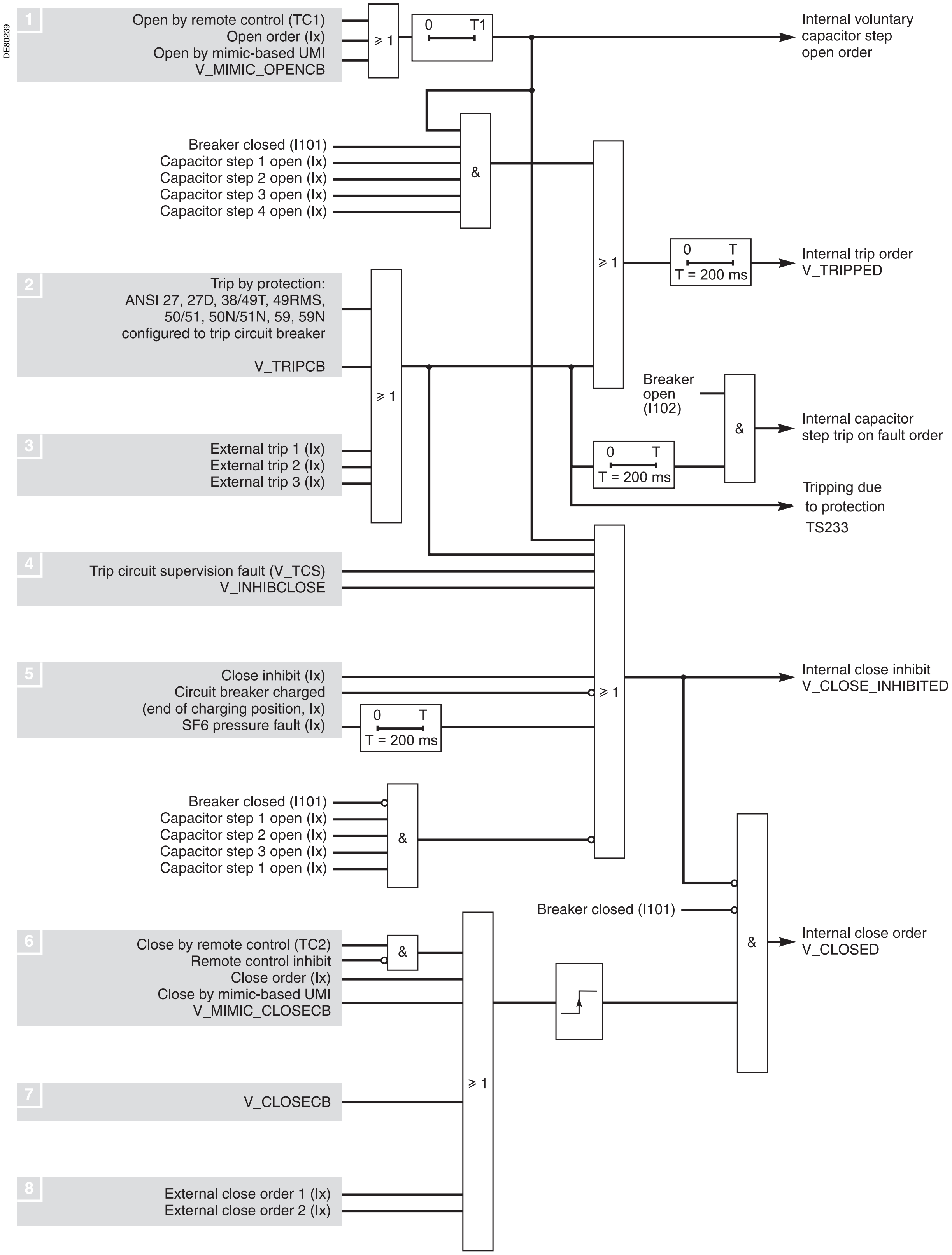
Circuit breaker opening
■ Voluntary open:
A circuit breaker open order triggers the staggered opening of capacitor step switches. This order is maintained for a time T1, the time required for the staggered opening of the capacitor step switches and the circuit breaker. The circuit breaker opens after all the capacitor step switches to avoid breaking the capacitive current.
■ Trip:
The protection functions (units configured to trip the circuit breaker and external protection units) send a tripping order to the circuit breaker. After the circuit breaker opens, an open order is sent to all the capacitor step switches at the same time.

Circuit breaker closing
The circuit breaker only closes if all the capacitor step switches are open.

Anti-pumping function
To prevent simultaneous breaking device open and close orders and to give priority to open orders, breaker device close orders are of the pulse type

Switchgear control with lockout function (ANSI 86)
The ANSI 86 function traditionally performed by lockout relays may be provided by Sepam using the Switchgear control function, with latching of all the tripping conditions (protection function outputs and logic inputs).
Sepam performs:
■ grouping of all the tripping conditions and circuit breaker control
■ latching of the tripping order, with inhibition of closing, until the cause of tripping disappears and is acknowledged by the user (see Latching / acknowledgement function)
■ indication of the cause of tripping:
□ locally by LEDs (Trip and others) and by messages on the display
□ remotely by remote indications (see Indications function).

Block diagram



Capacitor bank switchgear control
ANSI code 94/69

Capacitor step control

Automatic control
When the "Automatic capacitor step control" logic input is on, each step may be controlled automatically by the reactive energy regulator (VAR). In this case, one input per step is used to open and close one capacitor step switch:
- input in state 1: closing of capacitor step x switch
- input in state 0: opening of capacitor step x switch.

Manual control
When the "Manual capacitor step control" logic input is on, each step may be opened and closed manually:
- locally by specific logic inputs (one open input and one close input per step)
- remotely by remote control.

Inhibition of voluntary capacitor step control
Voluntary capacitor step switch control may be inhibited by a logic input. However, this input does not inhibit fault tripping or opening after circuit breaker opening.

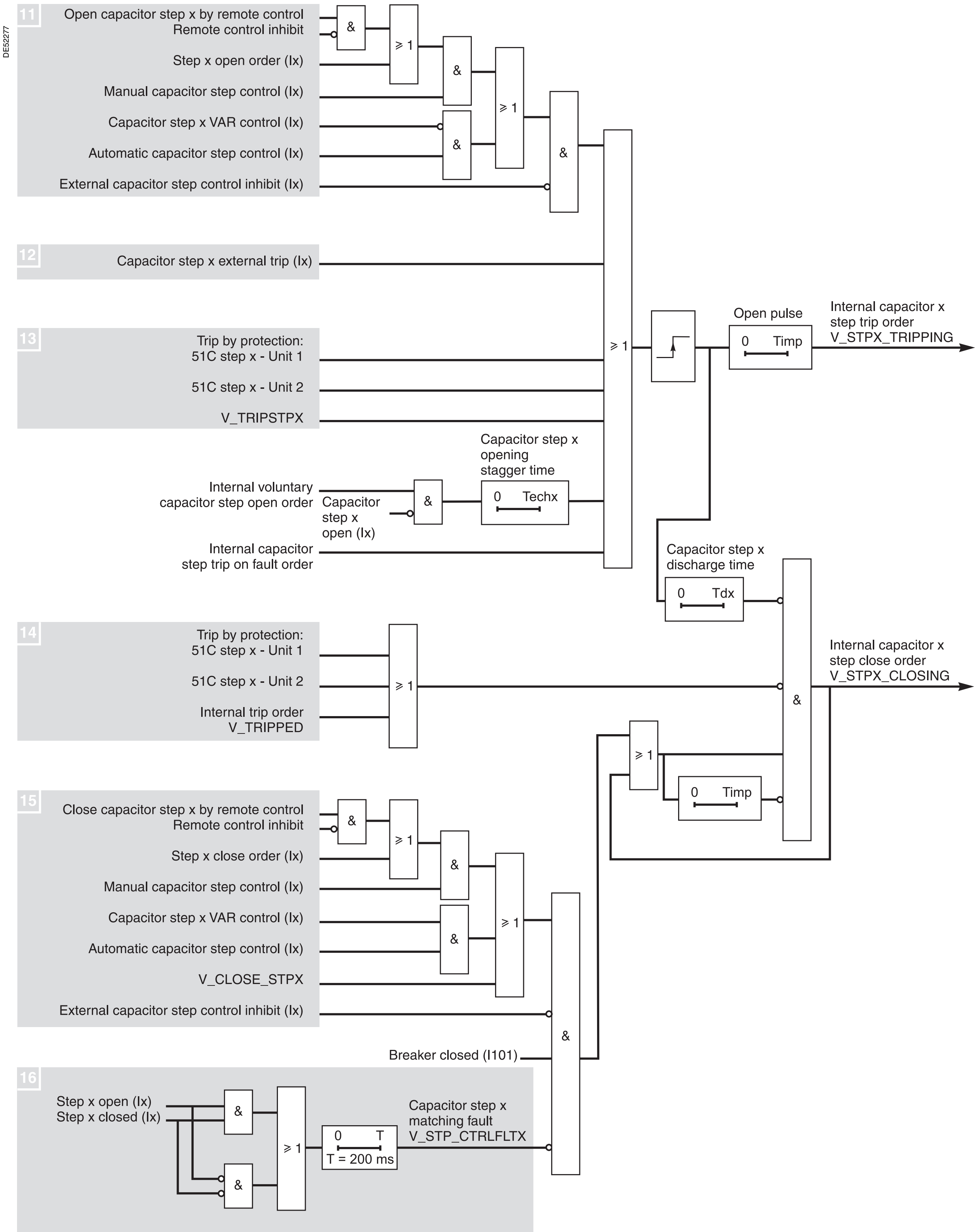
Capacitor step opening
Any opening of a capacitor step, whether voluntary or by tripping, activates a discharge time delay which inhibits closing to ensure that the step capacitors discharge correctly.
- voluntary open: manual or automatic capacitor step switch control order
- trip, triggered by:
  - ANSI 51C unbalance protection units associated with the capacitor step and configured to trip the step 13
  - "Tripping of step x" logic input (one input per capacitor step) 12
  - logic equation or Logipam 13.

Latched trip orders inhibit capacitor step closing until the orders are reset 14.
Open orders must be at least as long as the duration of open and close control pulses.

Capacitor step closing 15
Close orders are always voluntary, for manual and automatic control. They are as long as the duration of open and close control pulses.
Capacitor step switches only close after the capacitor step discharge time delay has run out and after the circuit breaker has closed, if there is no protection fault or inhibition.

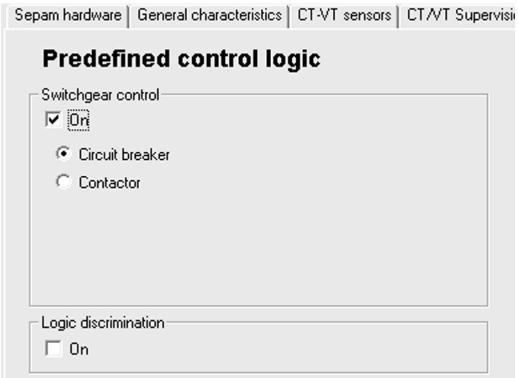
Capacitor step switch matching fault 16
This function checks that the capacitor step switch positions match, when the positions are set up on logic inputs (Ix).
In the event of a capacitor step switch matching fault, the switch close order is inhibited.

Block diagram



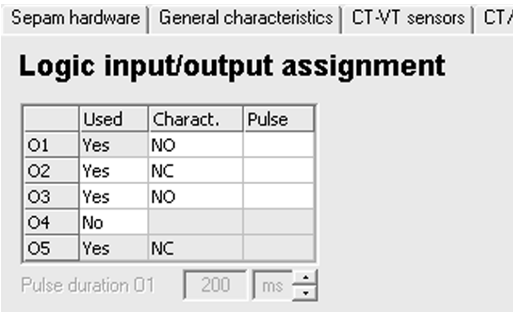
4

PE50456



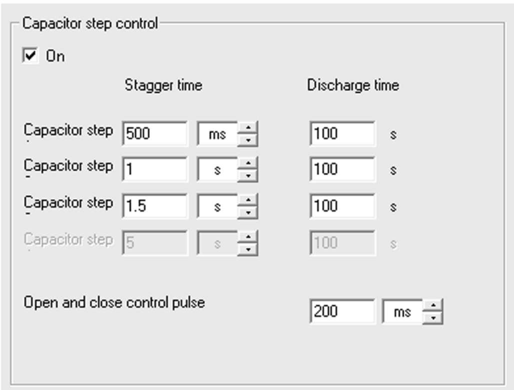
SFT2841: parameter setting of Switchgear control.

PE50455



SFT2841: default parameter setting of the logic outputs assigned to Switchgear control.

PE50457



SFT2841: parameter setting of the Capacitor step control function.

Parameter setting of circuit breaker control

The function is set up and adapted to match the type of circuit breaker to be controlled using the SFT2841 software.

"Control logic" tab

- activation of the Switchgear control function
- type of device to be controlled: Circuit breaker.

"Logic I/Os" tab

- assignment of the logic inputs required
- definition of logic output behavior.

By default, the following outputs are used:

Logic output	Associated internal order	Circuit breaker coil
O1	Trip (V_TRIPPED)	Shunt trip coil
O2	Close inhibit (V_CLOSE_INHIBITED)	Undervoltage coil
O3	Close (V_CLOSED)	Shunt trip coil

- the Trip order is always associated with output O1.

If output O1 is set up for pulse type operation, the pulse order duration may be set up.

- the optional Close inhibit and Close orders may be assigned to any logic output.

"Matrix" screen, "Logic" button

Modification of the default internal order assignment to outputs O2 and O3, if necessary.

Parameter setting of capacitor step control

The function is set up and adapted using the SFT2841 software.

"Particular characteristics" tab

Setup of the capacitor bank, with setting of the number of steps.

"Control logic" tab

Setup of capacitor step control:

- activation of the Capacitor step control function
- setting of capacitor step staggered opening times, capacitor step discharge times and capacitor step switch control pulse duration.

"Logic I/Os" tab

- assignment of the logic inputs required
- definition of the behavior of logic outputs assigned to capacitor step control.

4

Capacitor bank switchgear control
ANSI code 94/69

Characteristics

Settings				
Switchgear control				
Setting range	On / Off			
Type of device				
Setting range	Circuit breaker / Contactor			
Tripping pulse duration (output O1)				
Setting range	200 ms to 300 s			
Accuracy (1)	±2 % or from -10 ms to +25 ms			
Resolution	10 ms or 1 digit			
Control of capacitor banks				
Setting range	On / Off			
Staggered capacitor step opening time delay Techx (1 delay per step)				
Setting range	0 to 300 s			
Accuracy (1)	±2 % or from -10 ms to +25 ms			
Resolution	10 ms or 1 digit			
Capacitor step discharge time delay Tdx (1 delay per step)				
Setting range	0 to 300 s			
Accuracy (1)	±2 % or from -10 ms to +25 ms			
Resolution	10 ms or 1 digit			
Capacitor step open and close control pulse duration Timp				
Setting range	0 to 300 s			
Accuracy (1)	±2 % or from -10 ms to +25 ms			
Resolution	10 ms or 1 digit			

Inputs			
Designation	**Syntax**	**Equations**	**Logipam**
Tripping, opening	V_TRIPCB	■	■
Inhibit closing	V_INHIBECLOSE	■	■
Closing	V_CLOSECB	■	■
Capacitor step 1 tripping	V_TRIP_STP1		■
Capacitor step 2 tripping	V_TRIP_STP2		■
Capacitor step 3 tripping	V_TRIP_STP3		■
Capacitor step 4 tripping	V_TRIP_STP4		■
Capacitor step 1 closing	V_CLOSE_STP1		■
Capacitor step 2 closing	V_CLOSE_STP2		■
Capacitor step 3 closing	V_CLOSE_STP3		■
Capacitor step 4 closing	V_CLOSE_STP4		■

Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Switchgear control on	V_SWCTRL_ON		■	■
Tripping, opening	V_TRIPPED	■	■	■
Inhibit closing	V_CLOSE_INHIBITED	■	■	■
Closing	V_CLOSED	■	■	■
Contactor control	V_CONTACTOR		■	■
Capacitor bank control on	V_BANK_ON		■	■
Tripping of capacitor step 1	V_STP1_TRIPPING		■	■
Tripping of capacitor step 2	V_STP2_TRIPPING		■	■
Tripping of capacitor step 3	V_STP3_TRIPPING		■	■
Tripping of capacitor step 4	V_STP4_TRIPPING		■	■
Closing of capacitor step 1	V_STP1_CLOSING		■	■
Closing of capacitor step 2	V_STP2_CLOSING		■	■
Closing of capacitor step 3	V_STP3_CLOSING		■	■
Closing of capacitor step 4	V_STP4_CLOSING		■	■
Capacitor step 1 matching fault	V_STP1_CTRLFLT		■	■
Capacitor step 2 matching fault	V_STP2_CTRLFLT		■	■
Capacitor step 3 matching fault	V_STP3_CTRLFLT		■	■
Capacitor step 4 matching fault	V_STP4_CTRLFLT		■	■

***(1)** Under reference conditions (IEC 60255-6).*

TS/TC equivalence for each protocol

Modbus	DNP3	IEC 60870-5-103	IEC 61850
TC	**Binary Output**	**ASDU, FUN, INF**	**LN.DO.DA**
TC1	BO0	20, 21, 1 (OFF)	CSWI1.Pos.ctlVal
TC2	BO1	20, 21, 1 (ON)	CSWI1.Pos.ctlVal
TS	**Binary Input**	**ASDU, FUN, INF**	**LN.DO.DA**
TS233	BI334	2, 160, 68	-

Latching / acknowledgement

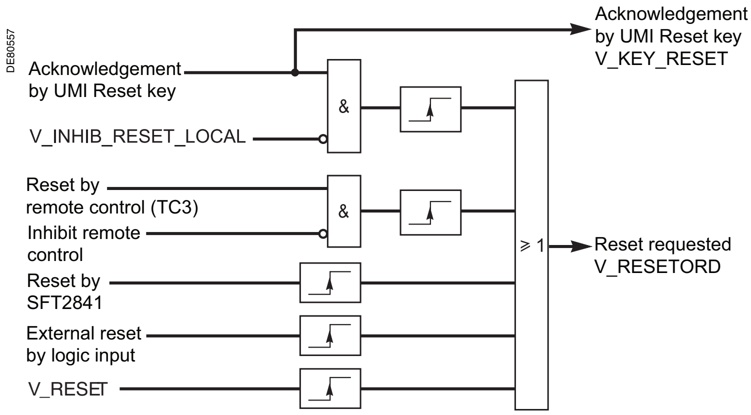
Operation

The tripping outputs of all the protection functions and all the logic inputs (Ix) may be latched individually.
Logic outputs may not be latched. Logic outputs set up as pulse-type outputs maintain pulse-type operation even when they are linked to latched data.
Latched data are saved in the event of an auxiliary power failure.
All latched data are acknowledged together, at the same time. Acknowledgement is done:

- locally on the UMI using the (reset) key
- or remotely via a logic input, the SFT2841 software or via the communication link
- or by logic equation or Logipam.

The remote indication TS5 remains present after latching operations until acknowledgement has taken place.
The Latching/acknowledgement function associated with the Switchgear control function may be used to perform the ANSI 86 Lockout relay function.

Block diagram



Characteristics

Inputs			
Designation	**Syntax**	**Equations**	**Logipam**
Inhibition of UMI Reset key	V_INHIB_RESET_LOCAL	■	■
Acknowledgement by logic equation or Logipam	V_RESET	■	■

Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Reset requested	V_RESET_ORD		■	
Acknowledgement by UMI Reset key	V_KEY_RESET		■	

TS/TC equivalence for each protocol

Modbus	DNP3	IEC 60870-5-103	IEC 61850
TS	**Binary Input**	**ASDU, FUN, INF**	**LN.DO.DA**
TS5	BI0	1, 160, 19	LLN0.LEDRs.stVal
TC	**Binary Output**	**ASDU, FUN, INF**	**LN.DO.DA**
TC3	BO2	20, 160, 19	LLN0.LEDRs.ctlVal

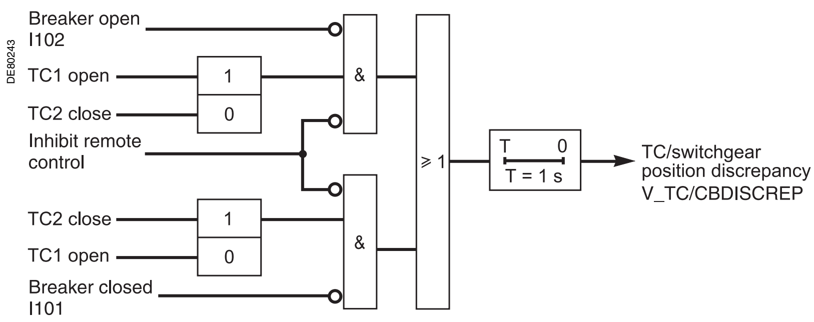
TC / switchgear position discrepancy Tripping

TC / switchgear position discrepancy

Operation

This function detects a discrepancy between the last remote control order received and the actual position of the circuit breaker or contactor.
The information is accessible in the matrix and via the remote indication TS3.

Block diagram



Characteristics

Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
TC/ switchgear position discrepancy	V_TC/CBDISCREP		■	

TS/TC equivalence for each protocol

Modbus	DNP3	IEC 60870-5-103	IEC 61850
TC	**Binary Output**	**ASDU, FUN, INF**	**LN.DO.DA**
TC1	BO0	20, 21, 1 (OFF)	CSWI1.Pos.ctlVal
TC2	BO1	20, 21, 1 (ON)	CSWI1.Pos.ctlVal
TS	**Binary Input**	**ASDU, FUN, INF**	**LN.DO.DA**
TS3	BI18	-	-

Tripping

Description

The information can be accessed via remote indication TS233.
It indicates whether a Sepam internal or external protection has tripped.

TS/TC equivalence for each protocol

Modbus	DNP3	IEC 60870-5-103	IEC 61850
TS	**Binary Input**	**ASDU, FUN, INF**	**LN.DO.DA**
TS233	BI334	2, 160, 68	-

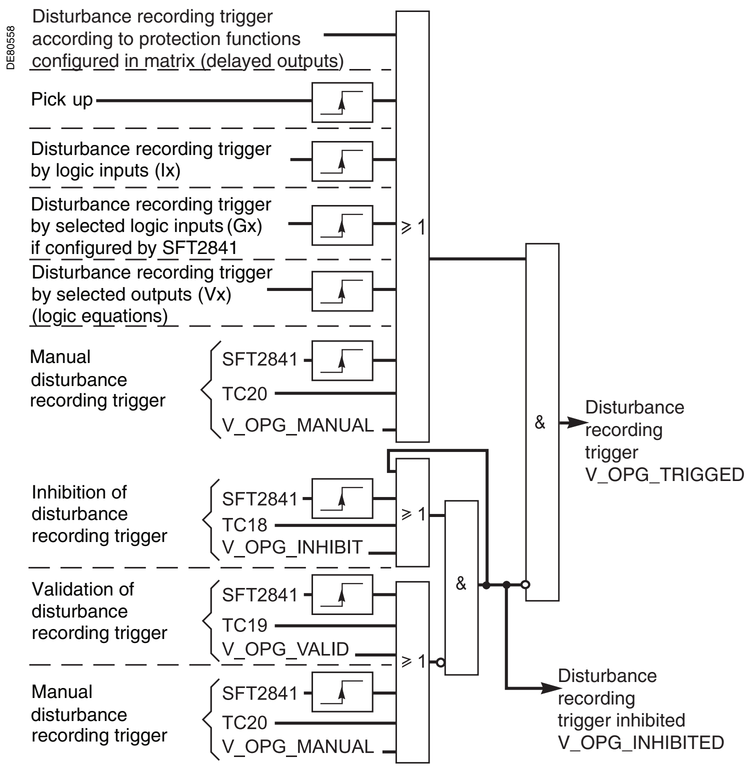
Disturbance-recording trigger

Operation

The recording of analog and logic signals may be triggered by different events, dependent on the control matrix parameter setting or manual action:
- triggering by the grouping of all pick-up signals of the protection functions in service
- triggering by the delayed outputs of selected protection functions
- triggering by selected logic inputs
- triggering by selected Vx outputs (logic equations)
- manual triggering by a remote control order (TC20)
- manual triggering via the SFT2841 software tool
- manual triggering by Logipam
- triggering by selected logic inputs (Gx) (if recording configured in SFT2841 software disturbance recording screen).

Disturbance recording may be:
- inhibited via the SFT2841 software or by remote control order (TC18) or by Logipam
- validated via the SFT2841 software or by remote control order (TC19) or by Logipam.

Block diagram



Disturbance-recording trigger

Characteristics

Inputs

Designation	Syntax	Equations	Logipam
Inhibits disturbance recording function	V_OPG_INHIBIT		■
Validates disturbance recording function	V_OPG_VALID		■
Manual trigger of disturbance recording function	V_OPG_MANUAL		■

Outputs

Designation	Syntax	Equations	Logipam	Matrix
Disturbance recording function triggered	V_OPG_TRIGGED		■	
Disturbance recording function inhibited	V_OPG_INHIBITED		■	■
Disturbance recording on	V_OPG_ON		■	

TS/TC equivalence for each protocol

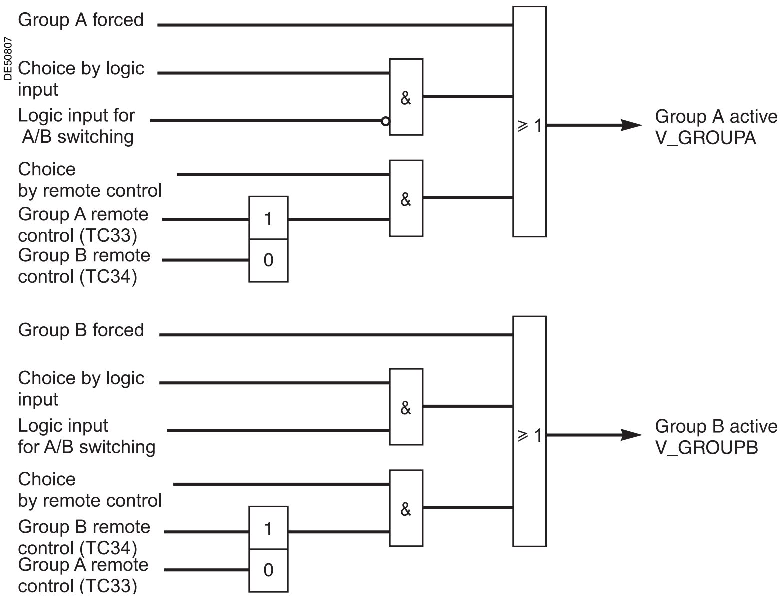
Modbus	DNP3	IEC 60870-5-103	IEC 61850
TC	**Binary Output**	**ASDU, FUN, INF**	**LN.DO.DA**
TC18	BO3	-	RDRE1.RcdInh.ctlVal
TC19	BO4	-	RDRE1.RcdInh.ctlVal
TC20	BO5	-	RDRE1.RcdTrg.ctlVal

Switching of groups of settings

Operation

There are two groups of settings, group A / group B, for the phase overcurrent, earth fault, directional phase overcurrent and directional earth fault protection functions. Switching from one group of settings to another makes it possible to adapt the protection characteristics to suit the electrical environment of the application (change of earthing system, changeover to local power generation, ...). The switching of settings is global and therefore applies to all the units of the protection functions mentioned above.
The groups of settings switching mode is determined by parameter setting:
- switching according to the position of a logic input (0 = group A, 1 = group B)
- switching by remote control order (TC33, TC34)
- forced group A or group B.

Block diagram



Characteristics

Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Group of settings A active	V_GROUPA		■	
Group of settings B active	V_GROUPB		■	

TS/TC equivalence for each protocol

Modbus	DNP3	IEC 60870-5-103	IEC 61850
TC	**Binary Output**	**ASDU, FUN, INF**	**LN.DO.DA**
TC33	BO8	20, 160, 23	LLN0.SGCB
TC34	BO9	20, 160, 24	LLN0.SGCB

Logic discrimination
Principle

Operation
This function considerably reduces the tripping time of the circuit breakers closest to the source and may be used for logic discrimination in closed ring networks.
It applies to the phase 50/51, directional phase overcurrent 67, earth fault 50N/51N and directional earth fault 67N overcurrent protections, definite time and IDMT.

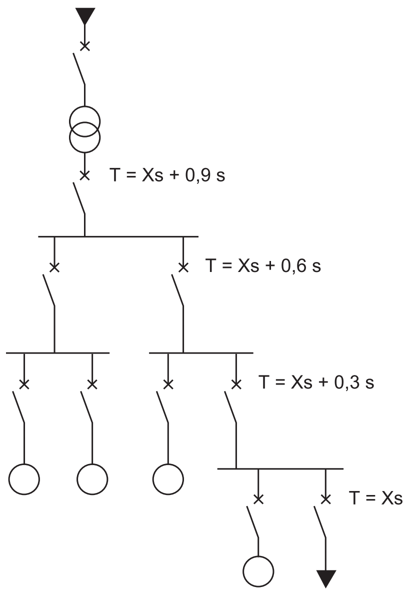
Sepam series 80 discrimination logic comprises 2 discrimination groups.
Each group includes:
- logic thresholds: protection units that send blocking signals (BSIG) and that may be prevented from tripping by the reception of blocking signals.
- time-based thresholds: protection units that may not be prevented from tripping by blocking signals and that do not send blocking signals. They are used as backup for the logic thresholds.

When a fault occurs:
- the logic thresholds detecting the fault send blocking signals
- the logic thresholds detecting the fault send a tripping order if they are not inhibited by blocking signals
- the time-based (backup) thresholds detecting the fault send a tripping order.

The sending of blocking signals lasts as long as it takes to clear the fault. If Sepam gives a tripping order, they are interrupted after a time delay that takes account of the breaking device operating time and the protection unit reset time. This system guarantees safety in downgraded operating situations (faulty wiring or switchgear).

Example: Radial distribution with use of time-based discrimination

DE50623

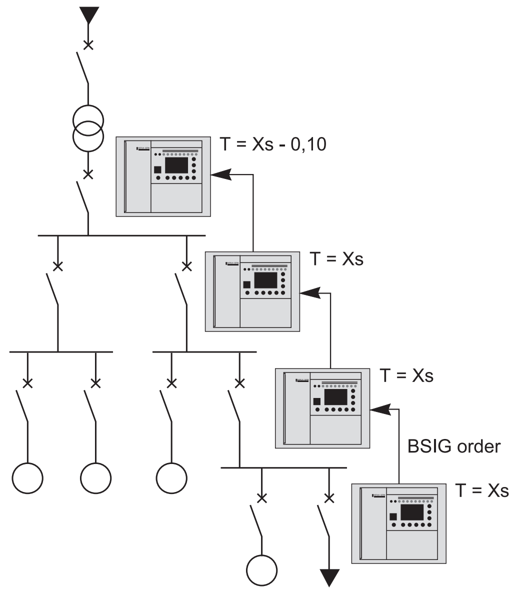


T: protection setting time. As an approximation for definite time curves, this is assumed to be equal to the protection tripping time.

The upstream protection units are typically delayed by 0.3 s to give the downstream protection units time to trip. When there are many levels of discrimination, the fault clearing time at the source is long.
In this example, if the fault clearing time for the protection unit furthest downstream is Xs = 0.2 s, the fault clearing time at the source is T = Xs + 0.9 s = 1.1 s.

Example: Radial distribution with use of logic discrimination

DE50809



T: protection setting time. As an approximation for definite time curves, this is assumed to be equal to the protection tripping time.

When a fault appears, the protection units that detect it inhibit the upstream protection units. The protection unit furthest downstream trips since it is not blocked by another protection unit. The delays are to be set in accordance with the device to be protected.
In this example, if the fault clearing time for the protection unit furthest downstream is Xs = 0.2 s, the fault clearing time at the source is T = Xs - 0.1 s = 0.1 s.

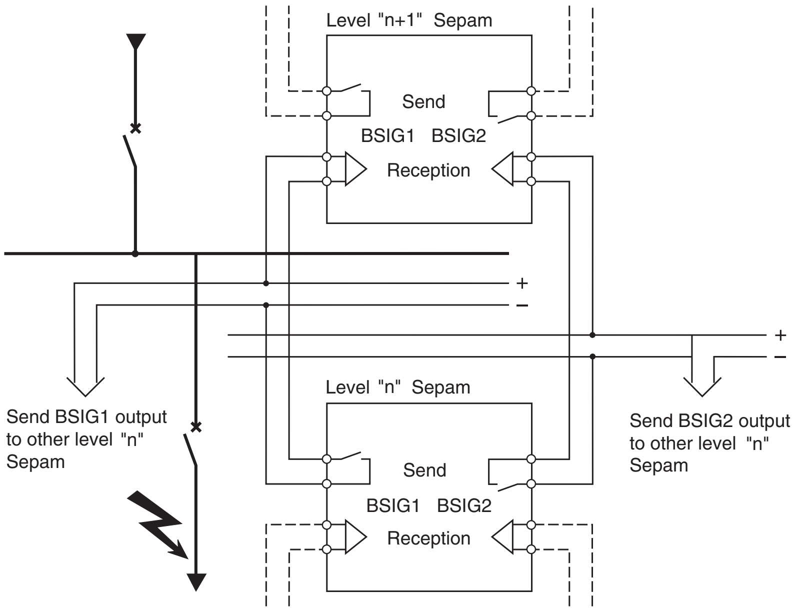
Logic discrimination
Principle

Operation with logic inputs/outputs (Ix/Ox)
The assignment of protection devices between logic thresholds and time-based thresholds depends on the application and the logic input/output settings.
The first logic group is active if one of the following two conditions is fulfilled:
- blocking reception 1 is assigned to a logic input (Ix) except for motors where this input does not exist
- blocking send 1 is assigned to an output (O102 by default).

The second logic group, when present in the application, is active if one of the following two conditions is fulfilled:
- blocking reception 2 is assigned to a logic input (Ix)
- blocking send 2 is assigned to an output (O103 by default).

The SFT2841 software indicates the type of thresholds, logic or time-based, according to the input/output settings.

DE80559



Logic discrimination using wired logic inputs and outputs (Ix and Ox)

The assignment of protection devices between the two discrimination groups is fixed and cannot be modified. When logic discrimination is used, it is important to check the concordance between the origin of the measurement and the logic discrimination group to which the unit is assigned.
By default, a single logic discrimination group has the same measurement origin. When several origins are possible, the main channels I1, I2, I3 and I0 are assigned by default to the first group and the additional channels I'1, I'2, I'3 and I'0 to the second.

Pilot wire test
The pilot wires may be tested using the output relay test function in the SFT2841 software.

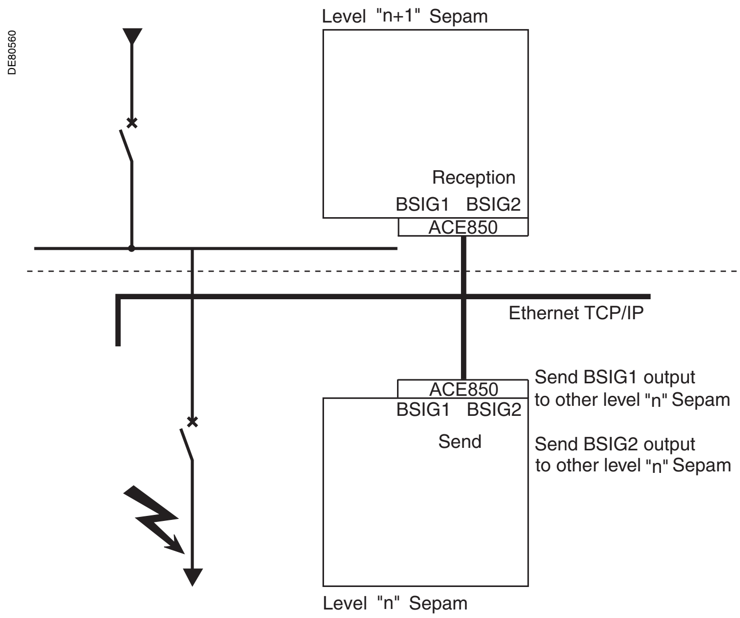
Logic discrimination
Principle

Operation with GOOSE messages and logic inputs (Gx)

Equipped with the ACE850 interface, Sepam series 80 can be used for logic discrimination with GOOSE logic inputs and the IEC 61850 protocol on Ethernet TCP/IP.

The first logic group is active if one of the following two conditions is fulfilled:
- blocking reception 1 is assigned to a GOOSE logic input (G401 by default), except for Sepams used in motor applications where this input does not exist
- blocking send 1 is created by sending a GOOSE logic discrimination blocking message over the Ethernet network.

The second logic group, when present in the application, is active if one of the following two conditions is fulfilled:
- blocking reception 2 is assigned to a GOOSE logic input (G402 by default)
- blocking send 2 is created by sending a GOOSE logic discrimination blocking message over the Ethernet network.



Logic discrimination using the IEC 61850 protocol and GOOSE logic inputs (Gx)

Logic discrimination

S80, S81, T81, B80 and B83 applications

Threshold assignment

Type of **protection**	**Unit number** Time-based	**Send logic** Group 1	Group 2	**Reception logic** Group 1	Group 2
50/51	3, 4, 5, 6, 7, 8	1, 2	-	1, 2	-
50N/51N	3, 4, 5, 6, 7, 8	1, 2	-	1, 2	-
67N(1)	2	1	-	1	-

(1) According to application.

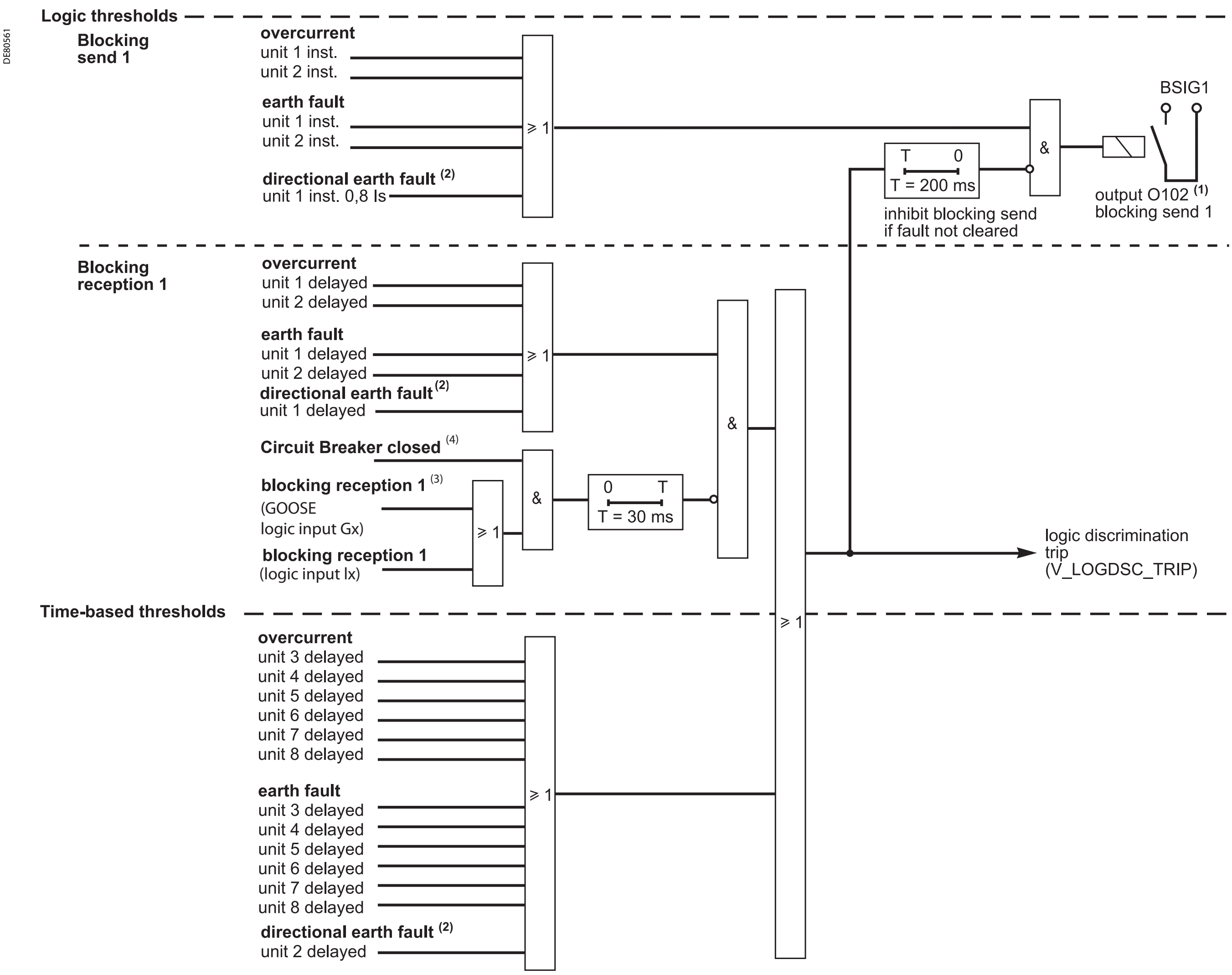
Characteristics

Settings				
Activity				
Setting range	On / Off			

Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Logic discrimination trip	V_LOGDSC_TRIP	■	■	■ (1)
Blocking send 1	V_LOGDSC_BL1	■	■	■
Logic discrimination on	V_LOGDSC_ON		■	

(1) *Only if switchgear control is not in service.*

Block diagram



(1) By default.
(2) According to application.
(3) If using the ACE850 communication interface and a GOOSE logic input (IEC 61850).
(4) Condition ignored (always = 1) if no input is assigned to Circuit Breaker closed.

Logic discrimination
M81, M87, M88 and C86 applications

Threshold assignment

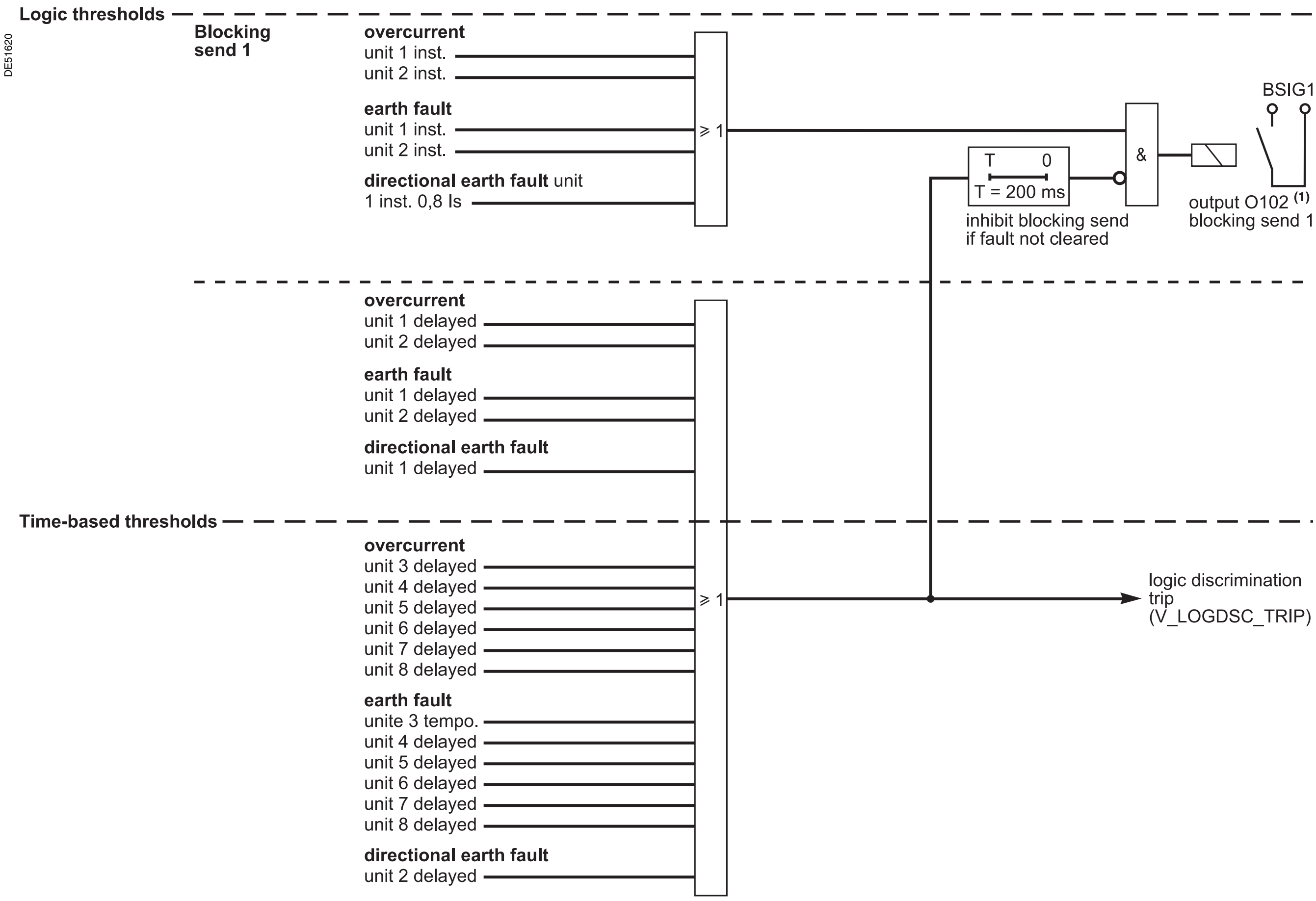
Type of protection	Unit number Time-based	Send logic Group 1	Send logic Group 2	Reception logic Group 1	Reception logic Group 2
50/51	3, 4, 5, 6, 7, 8	1, 2	-	-	-
50N/51N	3, 4, 5, 6, 7, 8	1, 2	-	-	-
67N	2	1	-	-	-

Characteristics

Settings				
Activity				
Setting range	On / Off			
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Logic discrimination trip	V_LOGDSC_TRIP		■	■ (1)
Blocking send 1	V_LOGDSC_BL1		■	■
Logic discrimination on	V_LOGDSC_ON		■	

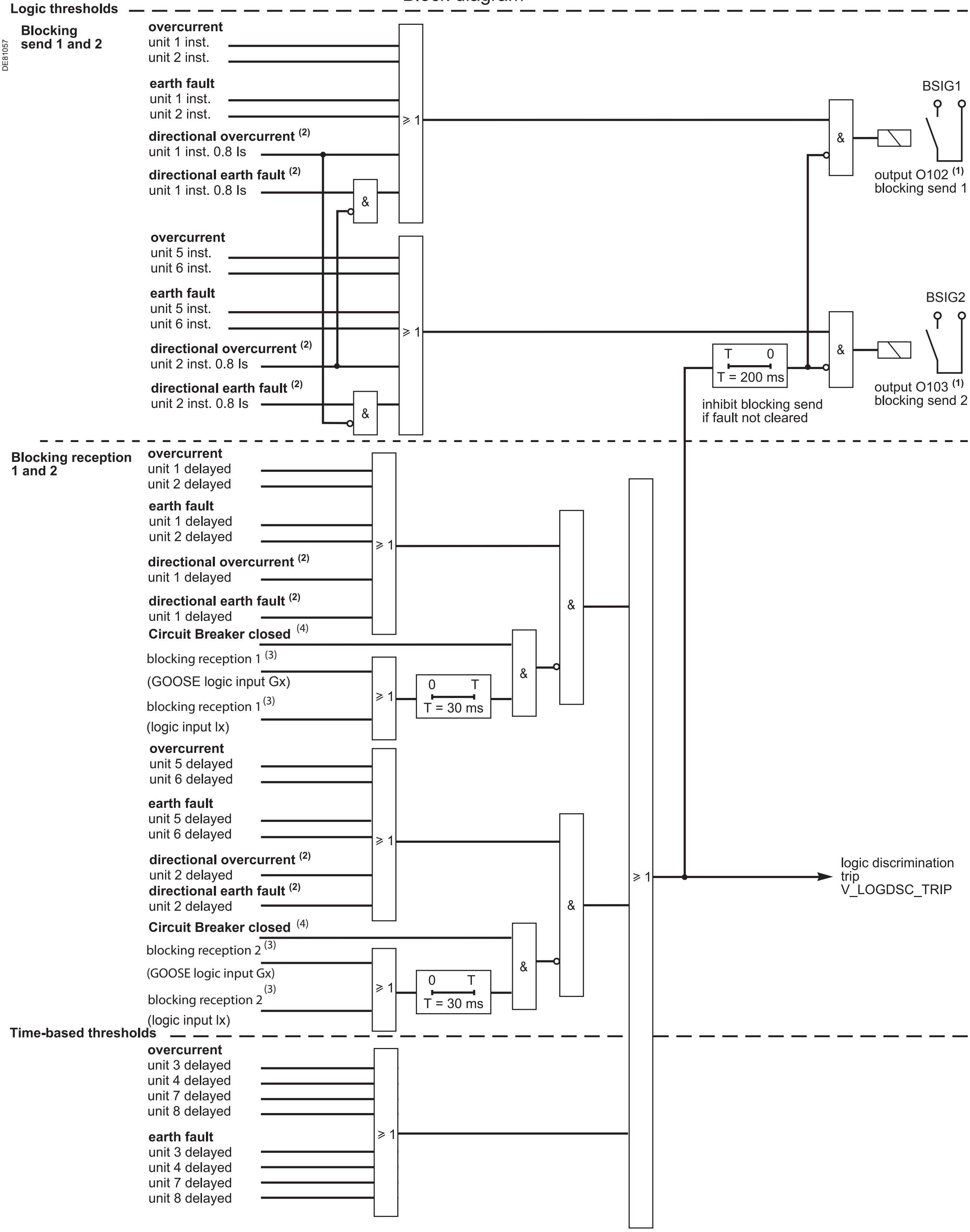
(1) Only if switchgear control is not in service.

Block diagram



Logic discrimination
S82, S84, T82, T87, G82, G87 and G88 applications

Block diagram



(1) By default.
(2) According to application.
(3) If using the ACE850 communication interface and a GOOSE logic input (IEC 61850).
(4) Condition ignored (always = 1) if no input is assigned to Circuit Breaker closed.

Logic discrimination
S82, S84, T82, T87, G82, G87 and G88 applications

Threshold assignment

Type of protection	Unit number				
	Time-based	Send logic		Reception logic	
		Group 1	Group 2	Group 1	Group 2
50/51	3, 4, 7, 8	1, 2	5, 6	1, 2	5, 6
50N/51N	3, 4, 7, 8	1, 2	5, 6	1, 2	5, 6
67 (1)	-	1	2	1	2
67N (1)	-	1	2	1	2

***(1)** According to application.*

Characteristics

Settings				
Activity				
Setting range	On / Off			
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Logic discrimination trip	V_LOGDSC_TRIP		■	■ (1)
Blocking send 1	V_LOGDSC_BL1		■	■
Blocking send 2	V_LOGDSC_BL2		■	■
Logic discrimination on	V_LOGDSC_ON		■	

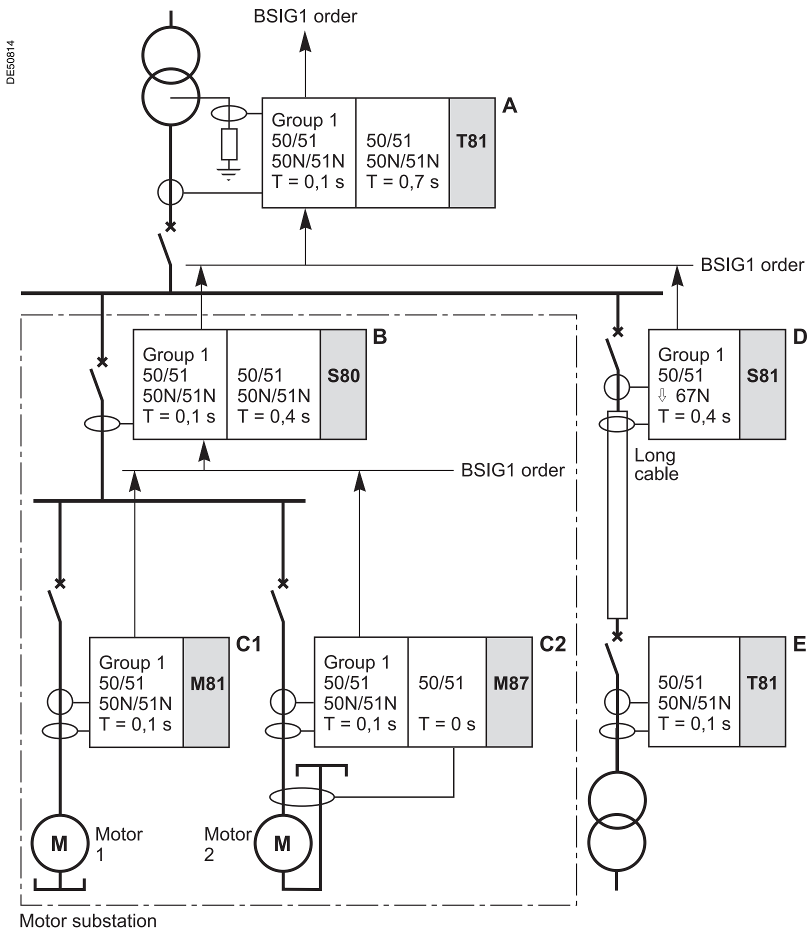
***(1)** Only if switchgear control is not in service.*

Logic discrimination
Example of setting: radial network

When a fault occurs in a radial network, the fault current flows through the circuit between the source and the location of the fault:
- the protection units upstream from the fault are triggered
- the protection units downstream from the fault are not triggered
- only the first protection unit upstream from the fault should trip.

Example of setting

A 20 kV installation, supplied by a transformer, comprises the main busbars which in turn supply a feeder to a motor substation and a long feeder to a distant MV/LV transformer. The installation is earthed via a resistor at the incoming transformer neutral point, which limits to the current to about 10 Amps.



⇧ : direction of protection function detection

▲ : direction of blocking signal orders

Logic discrimination
Example of setting: radial network

Based on a network coordination study, the installation relay settings are as follows:
- ■ incomer: Sepam T81 (relay A)
- □ busbar fault thresholds
50/51, 50N/51N: T =0.1 s (DT)
Logic discrimination group 1:
- blocked by relays B and D
- blocking send 1 to high voltage relays
- □ backup thresholds
50/51, 50N/51N: T = 0.7 s (DT)
Time-based thresholds
- ■ feeder to motor substation: Sepam S80 (relay B)
- □ busbar fault thresholds
50/51, 50N/51N: T = 0.1 s (DT)
Logic discrimination group 1:
- blocked by relays C1 and C2
- blocking send 1 to relay A
- □ backup thresholds
50/51, 50N/51N: T = 0.4 s (DT)
Time-based thresholds
- ■ **motor feeders:**
- ■ motor 1: Sepam M81 (relay C1)
- □ motor fault thresholds
50/51, 50N/51N: T = 0.1 s (DT)
Logic discrimination group 1:
- blocking send 1 to relay B
- ■ motor 2: Sepam M87 (relay C2)
- □ motor fault thresholds
- 50/51, 50N/51N: T = 0.1 s (DT)
  Logic discrimination group 1: blocking send 1 to relay B
  Measurement origin: I1, I2, I3
- 50/51 self-balancing differential scheme: T =0s (DT)
  Time-based threshold
  Measurement origin: I'1, I'2, I'3
- ■ transformer feeder
- □ cable fault thresholds
50/51, 67N: T = 0.4 s (DT)
Logic discrimination group 1:
- these thresholds are set time-wise in relation to relay E
- blocking send 1 to relay A.

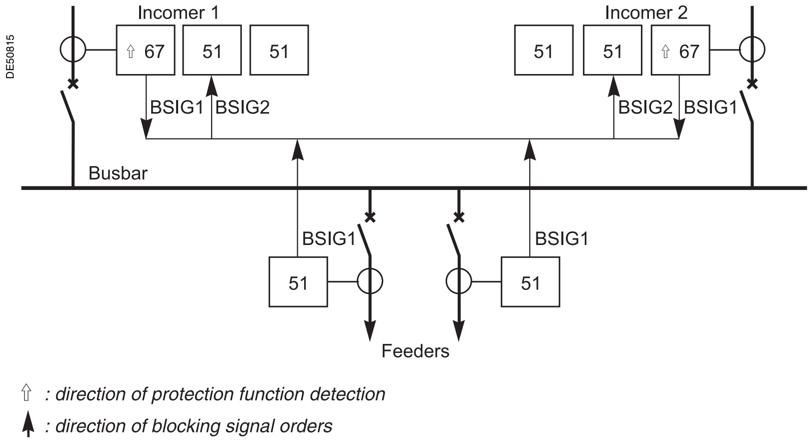
The logic input and output settings for all the relays concerned are:
- ■ blocking reception 1 on I103
- ■ blocking send 1 on O102

When using GOOSE logic inputs (IEC 61850), the input and output parameters are:
- ■ blocking reception 1: Each Sepam should subscribe to the GOOSE blocking message 1 gcbBasicGse (LDO/PTCR1/blklnd1) concerning it and then send this blocking GOOSE message to a GOOSE logic input (G401 by default for BSIG1).
- ■ blocking send 1: Each Sepam should generate a GOOSE blocking message called GOOSE Control Block standard which contains BSIG1 (gcbBasicGse (LDO/PTRC1/blklnd1)).

For more information, refer to the Sepam IEC 61850 communication user's manual, reference SEPED306024EN.

Logic discrimination
Example of setting: parallel incomers

Substations supplied by 2 (or more) parallel incomers may be protected using Sepam S82, T82 or G82, by a combination of directional phase (67) and earth fault (67N) protection functions, with the logic discrimination function.



To avoid both incomers tripping when a fault occurs upstream from one incomer, the incomer protection devices must operate as follows:
■ protection function 67 of the faulty incomer detects the fault current in the "line" direction, the protection tripping direction:
□ sends a blocking signal to inhibit the phase overcurrent protection functions (50/51) of both incomers
□ and initiates tripping of the incomer circuit breaker
■ protection function 67 of the fault-free incomer is insensitive to fault current in the "busbar" direction.

Example of setting
■ logic input/output assignment:
□ I104: blocking reception 2 - **Do not assign any inputs to blocking reception 1**
□ O102: blocking send 1
■ protection function 67 unit 1: tripping direction = line
□ instantaneous output: blocking send 1
□ delayed output: not blocked (no input assigned to blocking signal 1), circuit breaker tripping on faults upstream from incomer
■ protection function 50/51, unit 5:
□ delayed output:
- blocked by protection 67, unit 1 if there is a fault upstream from the incomer
- not blocked for busbar faults
- blocked for feeder faults
■ protection function 50/51, unit 3 as backup.

Logic discrimination
Example of setting: parallel incomers

Example of setting when using IEC 61850 GOOSE messages

■ blocking send 2: Each Sepam needing to provide the BSIG2 data should generate a GOOSE blocking send 2 message.
■ blocking reception 2: Each Sepam needing the BSIG2 data should subscribe to the GOOSE blocking send 2 message available over the Ethernet TCP/IP network, then wire this GOOSE blocking message on a GOOSE logic input (G402 by default for BSIG2). Do not assign the input to BSIG1.
■ blocking send 1: Each Sepam needing to provide the BSIG1 data should generate a GOOSE blocking send 1 message.
■ blocking reception 1: Each Sepam needing the BSIG1 data should subscribe to the GOOSE blocking send 1 message available over the Ethernet TCP/IP network, then wire this GOOSE blocking message on a GOOSE logic input (G401 by default for BSIG1).

No change on the protection settings:
■ protection function 67, unit 1: tripping direction = line
□ instantaneous output: blocking send 1
□ delayed output: not blocked (no input assigned to blocking signal 1), circuit breaker tripping on faults upstream from incomer
■ protection function 50/51, unit 5:
□ delayed output:
- blocked by protection 67, unit 1 if there is a fault upstream from the incomer
- not blocked for busbar faults
- blocked for feeder faults
■ protection function 50/51, unit 3 as backup.

Logic discrimination
Example of setting: closed ring network

Closed ring network protection may be provided by Sepam S82 or T82, which include the following functions:
- 2 units of directional phase (67) and earth fault (67N) protection functions:
  - one unit to detect faults in the "line" direction
  - one unit to detect faults in the "busbar" direction
- use of 2 discrimination groups:
  - sending of 2 blocking signals, according to the detected fault direction
  - reception of 2 blocking signals, to block the directional protection relays according to the detection direction.

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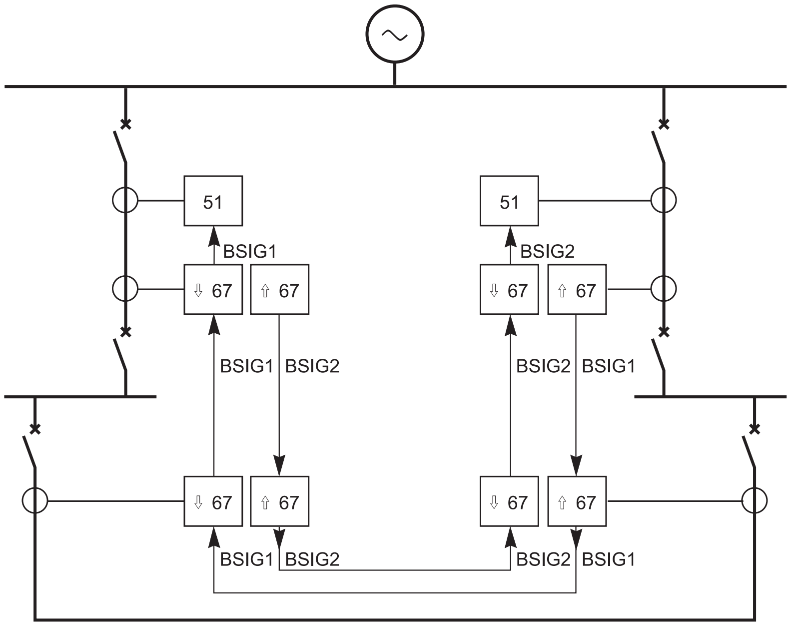


⇧, ⇩ : direction of protection function detection
: direction of blocking signal orders

With the combination of directional protection functions and the logic discrimination function, the faulty section may be isolated with a minimal delay by tripping of the circuit breakers on either side of the fault.

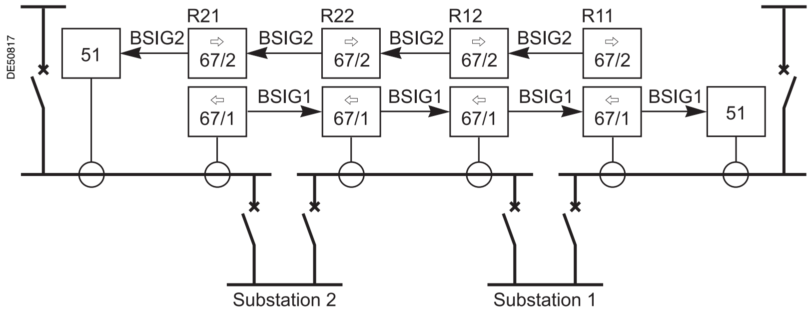
Blocking signals are initiated by both protection functions 67 and 67N.
Priority is given to protection function 67: when protection functions 67 and 67N detect faults in opposite directions at the same time, the blocking signal sent is determined by the direction of the fault detected by protection function 67.

The instantaneous output of protection functions 67 and 67N, activated at 80% of the Is threshold, is used to send blocking signals. This avoids uncertainty when the fault current is close to the Is threshold.

Logic discrimination
Example of setting: closed ring network

Example of setting:

Case of a closed ring with 2 substations, each of which comprises 2 Sepam S82 relays, marked R11, R12 and R21, R22.



⇨, ⇦ : *direction of protection function detection*
↑ : *direction of blocking signal orders*

Starting at one end of the ring, the detection direction of units 1 and 2 of the directional protection functions should be alternated between line and busbars.

Example of setting of the different Sepam relays linked to logic discrimination:

Substation 1	
Sepam S82 No. R11	**Sepam S82 No. R12**
■ Logic input/output assignment: I103: blocking reception 1 O102: blocking send 1 O103: blocking send 2	■ Logic input/output assignment: I103: blocking reception 1 I104: blocking reception 2 O102: blocking send 1 O103: blocking send 2
■ 67, 67N, unit 1: tripping direction = busbars ■ 67, 67N, unit 2: tripping direction = line	■ 67, 67N, unit 1: tripping direction = line ■ 67, 67N, unit 2: tripping direction = busbars
Substation 2	
Sepam S82 No. R22	**Sepam S82 No. R21**
■ Logic input/output assignment: I103: blocking reception 1 I104: blocking reception 2 O102: blocking send 1 O103: blocking send 2	■ Logic input/output assignment: I103: blocking reception 1 O102: blocking send 1 O103: blocking send 2
■ 67, 67N, unit 1: tripping direction = busbars ■ 67, 67N, unit 2: tripping direction = line	■ 67, 67N, unit 1: tripping direction = line ■ 67, 67N, unit 2: tripping direction = busbars

Load shedding

Operation

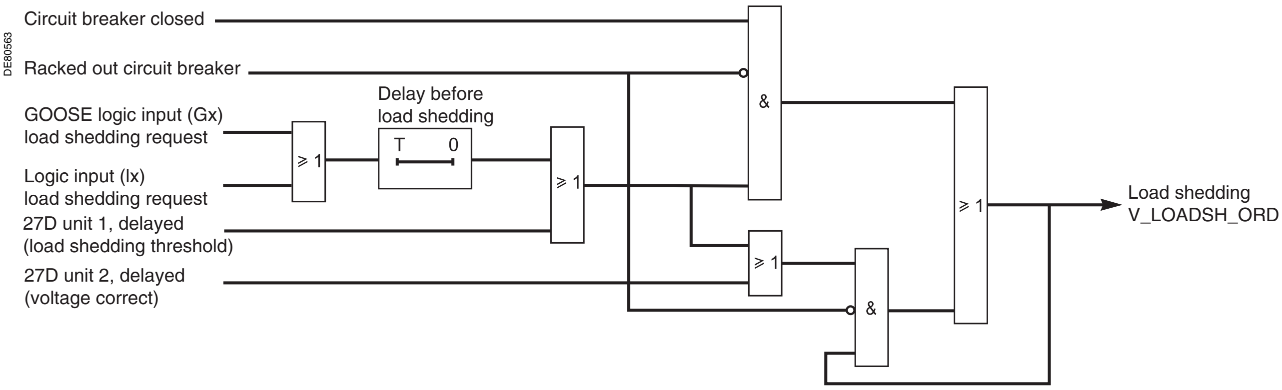
Motor load shedding is done to reduce the load on the electrical network so as to keep the voltage within an acceptable range.
Load shedding may be triggered:
- by an order from outside Sepam in the presence of a logic input assigned for the reception of load shedding orders. Orders may be delayed
- by a voltage dip detected by the delayed output of Sepam 27D protection unit 1 (typical setting 40% Un).

Load shedding triggers:
- tripping by the switchgear control function
- inhibition of closing as long as the load shedding order is maintained.

The load shedding order is maintained as long as one of the following three conditions is present:
- external order via logic input (Ix or Gx)
- positive sequence voltage less than load shedding voltage detected by 27D unit 1 threshold
- insufficient positive sequence voltage for a restart order to be given and detected by the delayed 27D unit 2 threshold. The time delay for the detection of correct voltage recovery must be shorter than the load shedding delay (27D unit 1) in order for the load shedding order to be maintained correctly. This unit is also used by the restart function.

The function may be validated by the switchgear closed and not racked out conditions.

Block diagram



Characteristics

Settings				
Activity				
Setting range	On / Off			
Delay before load shedding				
Setting range	0 to 300 s			
Accuracy (1)	±2 % or from -10 ms to +25 ms			
Resolution	10 ms or 1 digit			
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Load shedding order	V_LOADSH_ORD		■	■
Load shedding on	V_LOADSH_ON		■	

***(1)** Under reference conditions (IEC 60255-6).*

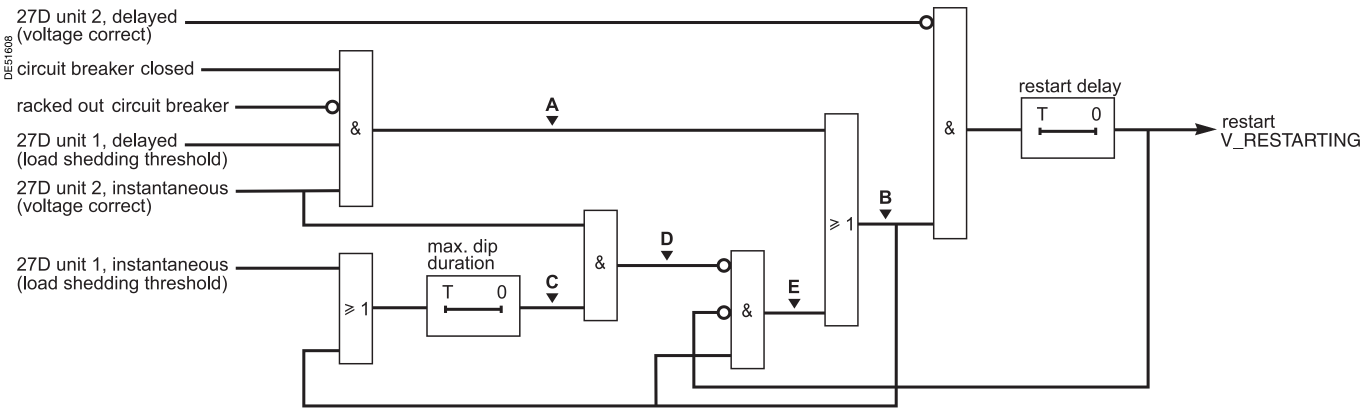
Restart

Operation

With this function, motors can be automatically restarted after a shutdown triggered by a voltage dip (load shedding).
The restart function is to be associated with the load shedding function It allows staggered restarting of process motors, as long as the voltage dip that caused load shedding was brief.
When tripping occurs due to a dip in the network supply voltage detected by 27D protection unit 1, two situations are possible:
- the voltage dip lasts for a period longer than the maximum voltage dip duration: tripping is final. External action is required for restart.
- the voltage dip lasts for a period shorter than the maximum dip duration: a restart order is given. Delayed restart allows motor restart orders to be staggered to avoid network overload.

The enabling of restart is detected after the delayed output of protection 27D unit 2 drops out. This threshold allows the return of voltage to be detected independently with respect to the load shedding threshold. The typical setting is 50 % Un.
The restart order is given by the switchgear control function.

Block diagram

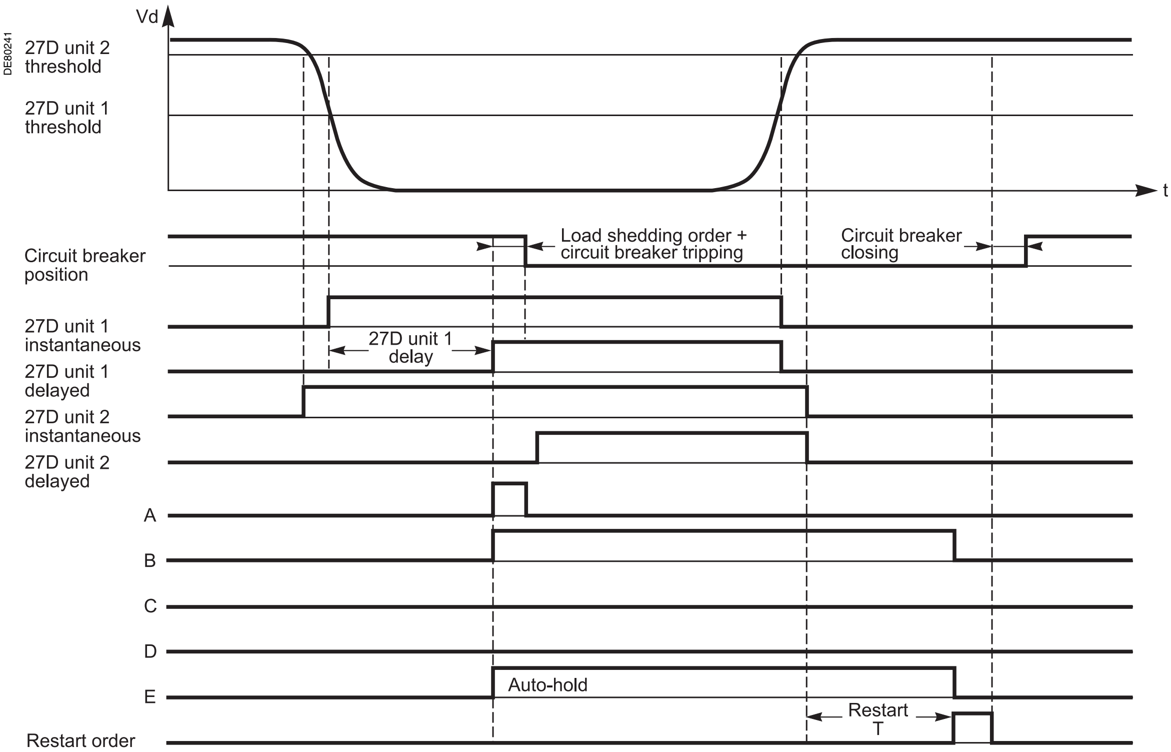


Characteristics

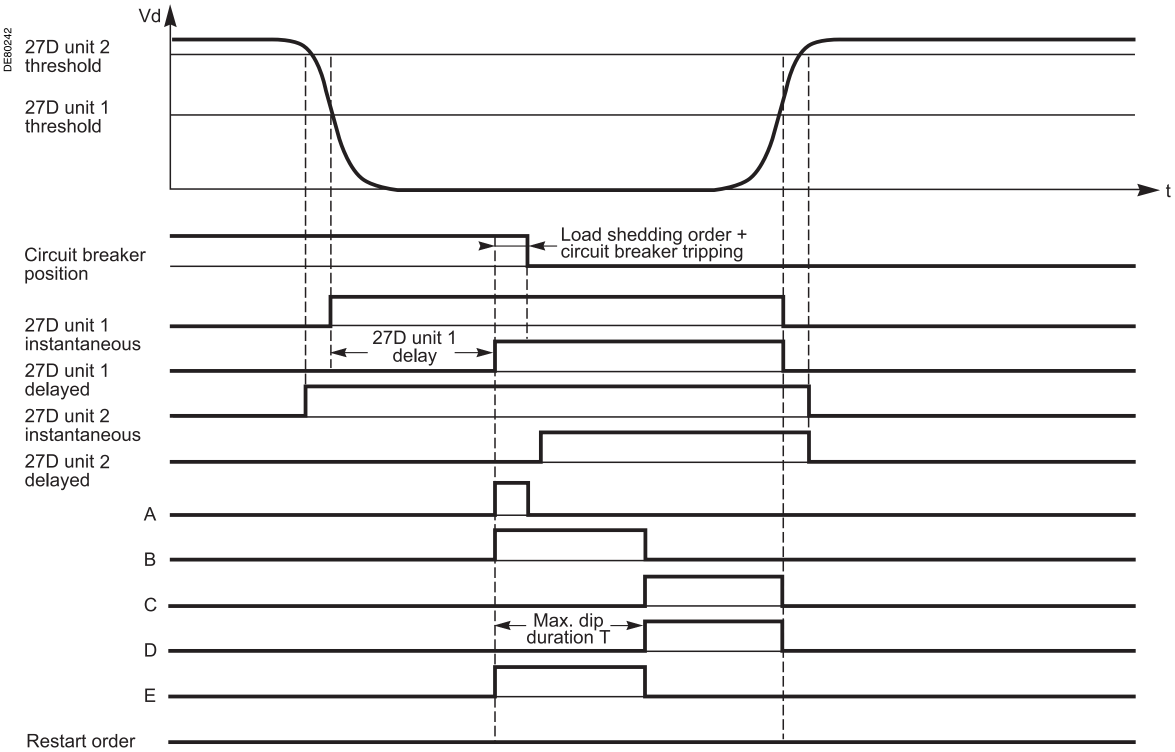
Settings				
Activity				
Setting range	On / Off			
Maximum voltage dip duration				
Setting range	0 to 300 s			
Accuracy (1)	±2 % or from -10 ms to +25 ms			
Resolution	10 ms or 1 digit			
Restart delay				
Setting range	0 to 300 s			
Accuracy (1)	±2 % or from -10 ms to +25 ms			
Resolution	10 ms or 1 digit			
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Restart order	V_RESTARTING		■	
Restart on	V_RESTART_ON		■	

(1) *Under reference conditions (IEC 60255-6).*

Example 1: Voltage dip with restart order



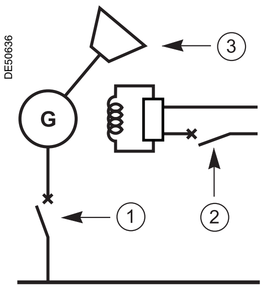
Example 2: Voltage dip without restart order



Generator shutdown and tripping

Operation

This function controls shutdown of the driving machine, tripping of the breaking device and interruption of the generator excitation supply in case of:
- detection of an internal generator fault
- receipt of a genset shutdown order on a logic input or via the communication link.



Generator shutdown and tripping involve:
(1) tripping of the circuit breaker connecting the machine to the network
(2) tripping of the excitation circuit breaker
(3) shutdown of the prime mover.

The combination of these three orders determines four types of shutdown and tripping orders:
- total shutdown (simultaneous tripping)
- generator tripping
- generator separation
- sequential tripping.

Total shutdown

This type of control function gives the following orders at the same time:
- a trip order to the generator coupling circuit breaker
- a trip order to the excitation circuit breaker
- a shutdown order to the prime mover.

This mode is reserved for internal faults in generators and transformers of generator-transformer units.

Generator tripping

This type of control function gives the following orders:
- a trip order to the generator coupling circuit breaker
- a trip order to the excitation circuit breaker.

The prime mover is not shut down.
This mode is reserved for power network faults and allows the generator to be quickly reconnected after the fault is cleared.

Generator separation

This type of control function gives the following order:
- a trip order to the generator coupling circuit breaker.

The machine remains excited and the prime mover is not shut down.
This mode is used to the isolate the machine from a network which no longer meets the coupling conditions (voltage, frequency, loss of power network).
The generator may continue to supply loads locally.

Sequential tripping

This type of control function gives the following orders on after the other:
- a trip order to the generator coupling circuit breaker
- a delayed trip order to the excitation circuit breaker
- a delayed shutdown order to the prime mover.

This mode is reserved for certain machines.

Sepam enables these operating modes by combining:
- switchgear control for tripping of the generator coupling circuit breaker
- de-excitation function for tripping of the excitation circuit breaker
- genset shutdown function to order the shutdown of the prime mover.

Function output delays are used for sequential tripping.

Typical parameter setting for industrial network generators

Protection functions	Circuit breaker tripping	Genset shutdown	De-excitation
12	■		
21B	■		
24	■	■	■
27	■		
32Q	■	■	■
37P	■		
40	■	■	■
46	■		
47	■		
49RMS	■		
50/27	■		
50/51	■		
50N/51N 50G/51G	■	■	■
50V/51V	■		
59	■		
59N	■	■	■
64G2/27TN (1)			
64REF	■	■	■
67	■	■	■
67N/NC	■	■	■
78PS	■		
81H	■		
81L	■		
81R	■		
87M	■	■	■
87T	■	■	■

(1) Generally initiates an alarm, but may otherwise initiate circuit breaker tripping, genset shutdown and de-excitation.

Operation

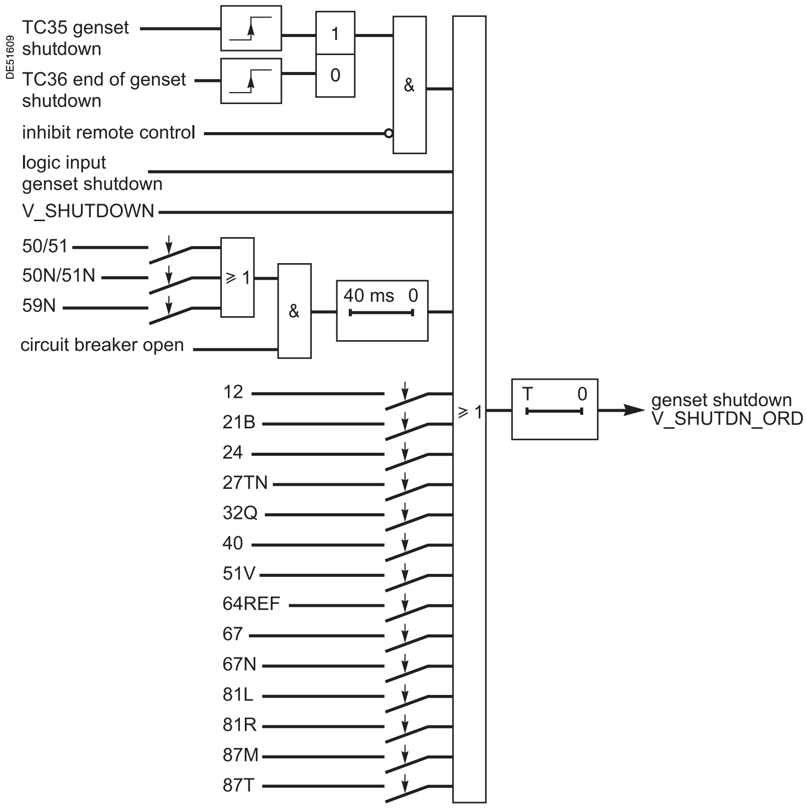
This function, available in generator applications, is used to shut down the genset:
- mechanical shutdown by shutting down the prime mover
- electrical shutdown by tripping the generator.

Genset shutdown may be initiated in the following ways:
- by a external shutdown order
  - remote control order if enabled
  - logic input if set up
- by logic equation or by Logipam to take into account all specific generator installation characteristics
- by delayed protection functions.

The protection functions concerned are those that detect internal faults in generators or transformers of generator-transformer units. They are divided into 2 groups: protection functions that contribute to shutdown regardless of the circuit breaker position and those whose contribution is dependent on the circuit breaker position:
- protection functions unrelated to circuit breaker position 12, 21B, 24, 27TN, 32Q, 40, 51V, 64REF, 67, 67N, 81L, 87M, 87T
- protection functions dependent on circuit breaker position 50/51, 50N/51N, 59N. The delayed, unlatched outputs of these protection units activate shutdown, only if the circuit breaker is open.

Participation in the function is to be set individually in the protection setting tabs of the SFT2841 software for each protection unit that can take part in genset shutdown.
At the same time, the function gives a tripping order via switchgear control to disconnect the generator from the power network. It must be associated with a logic output in the matrix to initiate genset shutdown.

Block diagram



Characteristics

Settings				
Activity				
Setting range	On / Off			
Selection of protection functions activating genset shutdown				
Setting range per protection unit	Enabled / disabled			
Genset shutdown time delay				
Setting range	0 to 300 s			
Accuracy (1)	±2 % or from -10 ms to +25 ms			
Resolution	10 ms or 1 digit			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Genset shutdown	V_SHUTDOWN	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Genset shutdown	V_SHUTDN_ORD		■	■
Genset shutdown on	V_SHUTDN_ON		■	

(1) Under reference conditions (IEC 60255-6).

TS/TC equivalence for each protocol

Modbus	DNP3	IEC 60870-5-103	IEC 61850
TC	**Binary Output**	**ASDU, FUN, INF**	**LN.DO.DA**
TC35	BO15	20, 21, 102 (ON)	-
TC36	BO16	20, 21, 102 (OFF)	-

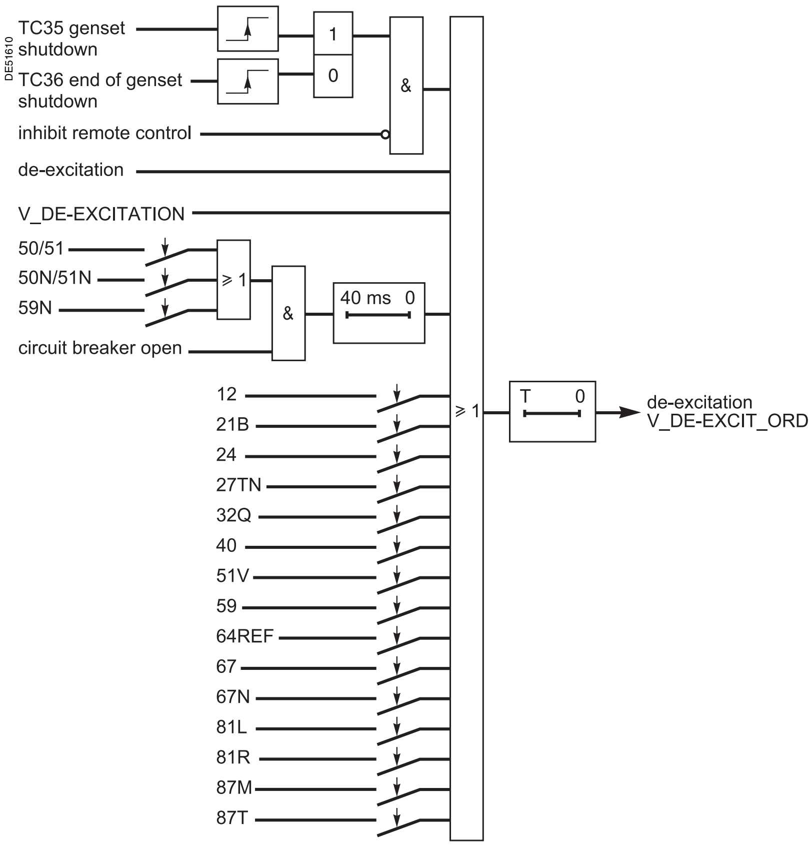
Generator shutdown and tripping
De-excitation

Operation
This function, available in generator applications, is used to quickly cut off the power supply to an internal fault when the generator is disconnected from the network:
- de-excitation of the generator
- electrical shutdown by tripping.

De-excitation may be initiated in the following ways:
- by an order
  - remote control order if enabled
  - logic input if set up
- by logic equation or by Logipam to take into account all specific generator installation characteristics
- by delayed protection functions.

The protection functions concerned are those that detect internal faults in generators or transformers of generator-transformer units. They are divided into 2 groups: protection functions that contribute to de-excitation regardless of the circuit breaker position and those whose contribution is dependent on the circuit breaker position:
- protection functions unrelated to circuit breaker position 12, 21B, 24, 27TN, 32Q, 40, 51V, 59, 64REF, 67, 67N.81L, 87M, 87T
- protection functions dependent on circuit breaker position 50/51, 50N/51N, 59N. The delayed, unlatched outputs of these protection units trigger de-excitation only if the circuit breaker is open.

Participation in the function is to be set individually in the protection function setting tabs of the SFT2841 software for each protection unit that can take part in de-excitation.
At the same time, the function gives a tripping order via switchgear control to disconnect the generator from the power network. It must be associated with a logic output in the control matrix to initiate the de-excitation order.

Block diagram


Characteristics

Settings				
Activity				
Setting range	On / Off			
Selection of protection functions activating de-excitation				
Setting range per protection unit	Enabled / disabled			
De-excitation time delay				
Setting range	0 to 300 s			
Accuracy (1)	±2 % or from -10 ms to +25 ms			
Resolution	10 ms or 1 digit			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
De-excitation	V_DE-EXCITATION	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
De-excitation	V_DE-EXCIT_ORD		■	■
De-excitation on	V_DE-EXCIT_ON		■	

(1) Under reference conditions (IEC 60255-6).

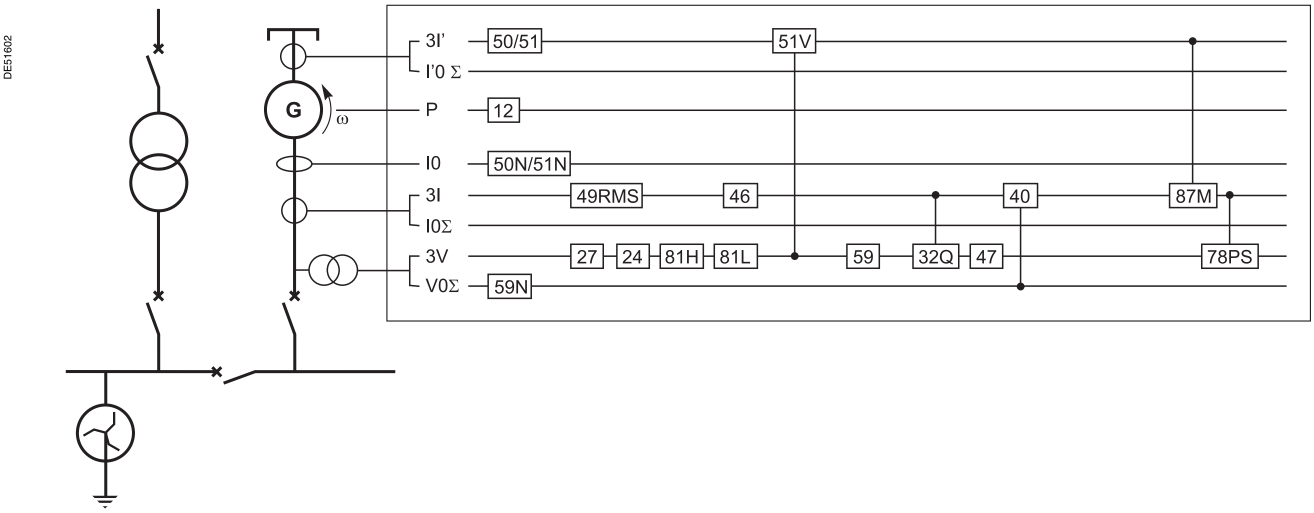
TS/TC equivalence for each protocol

Modbus	DNP3	IEC 60870-5-103	IEC 61850
TC	**Binary Output**	**ASDU, FUN, INF**	**LN.DO.DA**
TC35	BO15	20, 21, 102 (ON)	-
TC36	BO16	20, 21, 102 (OFF)	-

Generator shutdown and tripping
Example

Installation description

The electrical installation consists of busbars to which the following are connected:
- an incomer supplied by a 10 MVA transformer
- a 3.15 MVA power generator



In normal operation, the generator and transformer are coupled to the busbars. The generator provides backup power to the installation in the absence of the transformer power supply. The installation is earthed by a neutral point coil connected to the busbars. When the generator is not coupled to the network, its neutral is isolated. When faults occur, the generator is over-excited for 3 seconds. Its fault current is equal to 3 times its rated current. After the 3 seconds have elapsed, the fault current drops to 0.5 times the rated current.

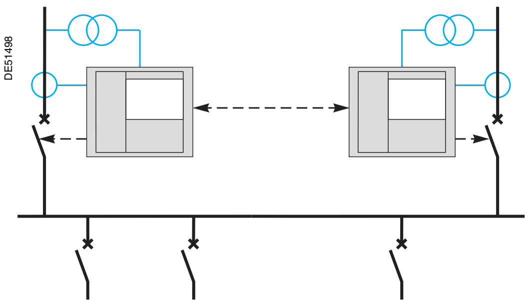
The generator is protected:
- against network electrical short-circuits by a phase overcurrent protection function 50/51 and a backup protection function 50V/51V
- against internal faults in generators by a generator differential protection function 87M.
- against earth faults by an earth fault protection function 50N/51N when the generator is coupled to the busbars and by a neutral voltage displacement protection function when it is not coupled
- against overloads by a thermal overload protection function 49RMS
- against unbalance by a negative sequence / unbalance protection function 46
- against frequency variations by underfrequency and overfrequency protection functions 81L and 81H
- against voltage variations by undervoltage and overvoltage protection functions 27 and 59
- against field loss by a protection function 40
- against loss of synchronization of the main network by a protection function 78PS.

Setting of genset shutdown and de-excitation

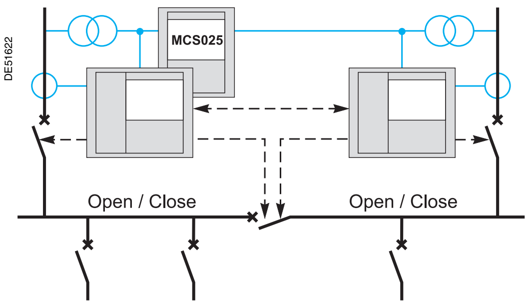
The participation of these protection functions in circuit breaker tripping, genset shutdown and de-excitation depends on the type of faults detected:
- circuit breaker tripping against network faults:
  - 50/51, 50V/51V, 50N/51N, 49RMS, 46, 81L, 81H, 27, 59, 78PS
- genset shutdown for prime mover faults and internal faults:
  - 50/51, 87M, 59N, 40
- de-excitation for internal faults:
  - 50/51, 87M, 59N, 40.

Shutdown is total and not sequential. The genset shutdown and de-excitation time delays are zero.

Automatic transfer



Automatic "one out of two" transfer.



Automatic "two out of three" transfer with synchro-check managed by Sepam series 80.

Description

The automatic transfer function is used to transfer busbar supply from one source to another.
The function reduces busbar supply interruptions, thereby increasing the service continuity of the network supplied by the busbars.

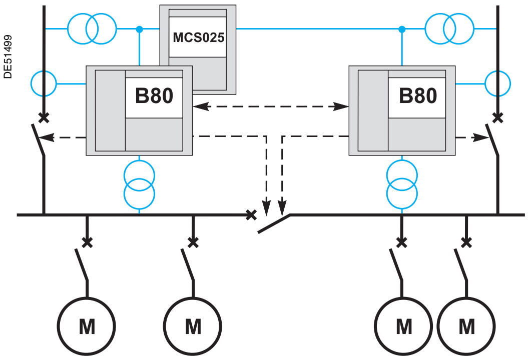
Automatic transfer performs:
■ automatic transfer with interruption if there is a loss of voltage or a fault upstream
■ manual transfer and return to normal operation without interruption, with or without synchro-check
■ control of the coupling circuit breaker (optional)
■ selection of the normal operating mode
■ the necessary logic to ensure that at the end of the sequence, only 1 circuit breaker out of 2 or 2 out of 3 are closed.

Automatic "one out of two" or "two out of three" transfer

The operation and implementation of the automatic transfer function depend on the type of substation:
■ automatic "one out of two" transfer is suitable for dual-incomer substations without coupling
■ automatic "two out of three" transfer is suitable for dual-incomer substations with coupling.
These two applications are described separately to make them easier to understand.

The automatic transfer function is symmetrical:
■ hardware symmetry: dual-incomer substations, with 2 incoming circuit breakers, and each incomer is protected by a Sepam series 80 unit
■ functional symmetry: automatic transfer is distributed between the two Sepam series 80 units protecting the two incomers.
Each of the functions is therefore described from the viewpoint of one of the two incomers, the other incomer being referred to as the "opposite side" incomer.

Automatic transfer



Automatic "two out of three" transfer with synchro-check managed by Sepam B80.

Equipment used

Sepam protection relay

Each incomer is protected by a Sepam series 80 unit.
At least two MES120 modules need to be added to each Sepam.
The synchro-check function (ANSI 25) is performed by an optional MCS025 module connected to one of the two Sepam units.

For busbars with motors, it is necessary to check the remanent voltage on the busbars during automatic transfer.
2 solutions are proposed:
■ protection of the two incomers with Sepam B80:
□ to measure the 3 phase voltages upstream of the circuit breaker and detect the loss of phase voltage
□ to measure 1 additional phase voltage on the busbars and detect the presence of remanent voltage
■ protection of the two incomers with another type of Sepam series 80, and checking of remanent voltage on the busbars with Sepam B21.

Local control of automatic transfer

Local control of automatic transfer requires the following components:
■ 1 "NO circuit breaker" selector (ANSI 10), 2 or 3-position selector which designates the circuit breaker that remains open at the end of voluntary transfer without interruption
■ 1 optional "Manual / Auto" selector (ANSI 43)
□ in Auto mode, automatic transfer is enabled
□ in Manual mode, automatic transfer is disabled
□ when this optional selector is not included, all the automatic transfer functions are enabled.
■ 1, 2 or 3 optional "Local / Remote" selectors (one selector for the function or one selector per circuit breaker)
□ in Remote mode, automatic transfer on voltage loss is enabled and the other functions are disabled
□ in Local mode, automatic transfer on voltage loss is disabled and the other functions are enabled
□ when these optional selectors are not included, all the automatic transfer functions are enabled.
■ 2 or 3 optional pushbuttons with LEDs (one pushbutton per circuit breaker):
□ "Breaker closing" pushbutton
□ "Closing ready" LED.

Automatic "one out of two" transfer
Operation

Definition
Automatic "one out of two" transfer is suitable for substations with busbars supplied by two incomers with no coupling.
Automatic transfer comprises two functions:
- automatic transfer with busbar supply interruption
- voluntary return to normal without busbar supply interruption.

The 2 functions are described separately below.

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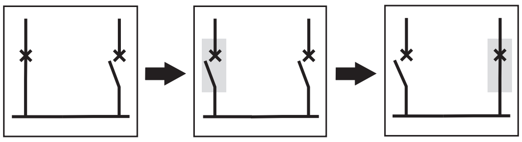


Automatic transfer with supply interruption
Description
The function is used to transfer busbar supply from one source to the other, after the detection of voltage loss or a fault upstream of the source.

Automatic source transfer takes place in two steps:
- tripping of the circuit breaker triggered by the detection of the loss of voltage or an external trip order (trip order from upstream protection units): loss of busbar supply
- closing of the opposite side circuit breaker to resupply the busbars (when motors are connected to the busbars, it is necessary to check for remanent voltage on the busbars using the ANSI 27R Remanent undervoltage function).

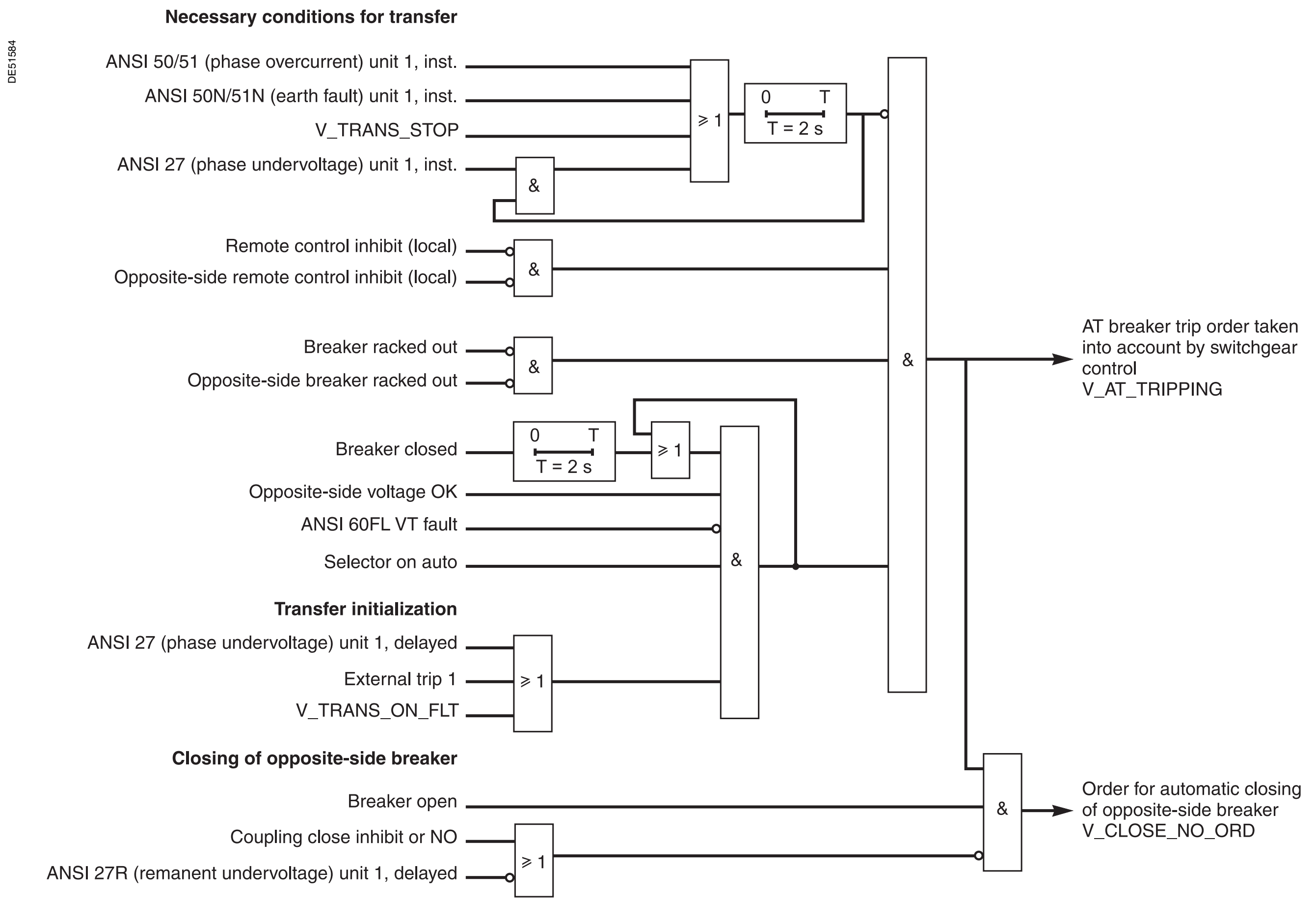
Compulsory transfer conditions
These conditions are always required to enable transfer:
- the incoming circuit breaker is closed
- no phase-to-phase fault detected by the incomer on the busbars or downstream
- no phase-to-earth fault detected by the incomer on the busbars or downstream
- voltage OK on the opposite incomer.

Optional transfer conditions
These conditions are required when the associated optional functions are enabled:
- the "Auto / Manual" selector is in the Auto position
- the 2 "Local / Remote" selectors are in the Remote position
- the 2 incoming circuit breakers are racked in
- no VT fault detected by the VT Supervision function (ANSI 60FL), to avoid transfer on the loss of voltage transformers
- no inhibition of transfer by V_TRANS_STOP by logic equations or by Logipam.

Initialization of transfer
Three events may trigger automatic transfer:
- loss of voltage detected on the incomer by the Phase undervoltage function (ANSI 27)
- or detection of a fault by the protection units upstream of the incomer, with intertripping order on the "External tripping 1" logic input
- or V_TRANS_ON_FLT, initialization of transfer by logic equations or by Logipam.

Automatic "one out of two" transfer
Operation

Block diagram



Closing of opposite side circuit breaker

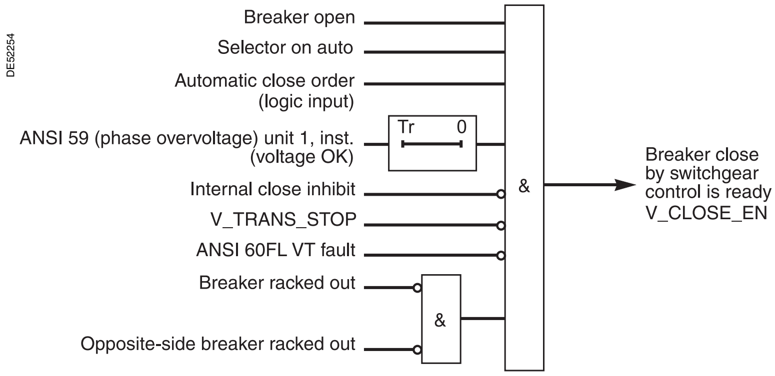
The following conditions are required to order the closing of the opposite side circuit breaker:

- the circuit breaker is open
- no opposite side circuit breaker inhibit close conditions
- no remanent voltage on the busbars (checking necessary when motors are connected to the busbars).

The opposite side circuit breaker closing order is transmitted by a Sepam logic output to a logic input of the opposite side Sepam.

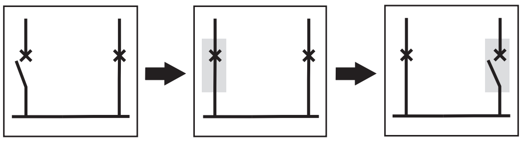
It is taken into account by the Switchgear control function of the opposite side Sepam.

Block diagram (Opposite side Sepam)



Automatic "one out of two" transfer
Operation

DE51017



Voluntary return to normal without interruption

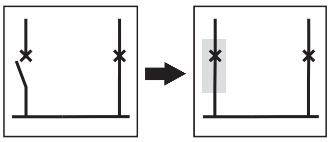
Description
The voluntary return to normal without interruption involves two separate control functions:
■ closing of the open incoming circuit breaker, with or without synchro-check: the two incoming circuit breakers are closed
■ then opening of the normally open circuit breaker, designated by the "NO circuit breaker" selector.
These two functions may also be used to transfer the busbar supply source without any interruption.

Compulsory transfer conditions
These conditions are always required to enable transfer:
■ the incoming circuit breaker is open
■ the voltage is OK upstream of the incoming circuit breaker.

Optional transfer conditions
These conditions are required when the associated optional functions are enabled:
■ the "Auto / Manual" selector is in the Manual position
■ the 2 "Local / Remote" selectors are in the Local position
■ the 2 incomer circuit breakers are racked in
■ no VT fault detected by the VT Supervision function (ANSI 60FL), to avoid transfer on the loss of voltage transformers
■ no inhibition of transfer by V_TRANS_STOP by logic equations or by Logipam.

Initialization of the return to normal
■ voluntary incoming circuit breaker close order.

DE51509



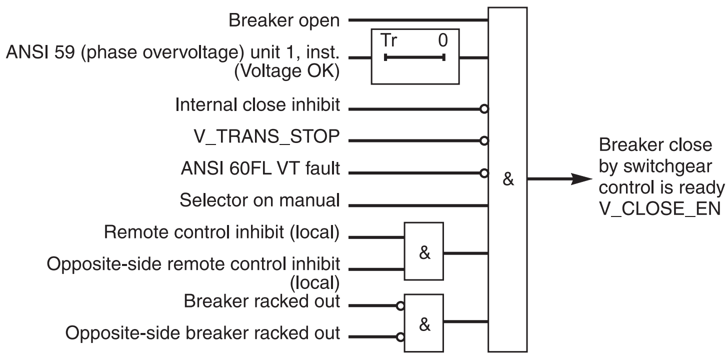
Closing of the open circuit breaker

Description
Circuit breaker closing is ensured by the Switchgear control function, with or without synchro-check.

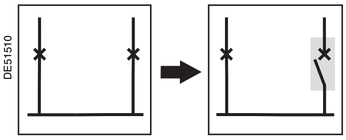
The AT function checks that all the required conditions are met and indicates to the user that the return to normal is possible.

Block diagram

DE52253



Automatic "one out of two" transfer
Operation

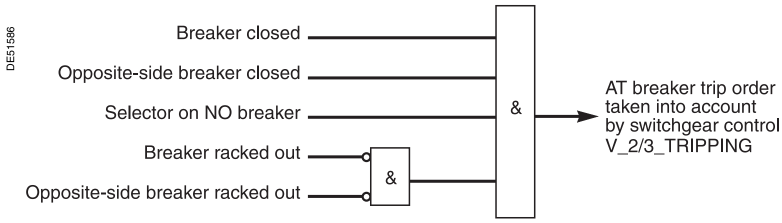


Opening of the normally open circuit breaker

Description

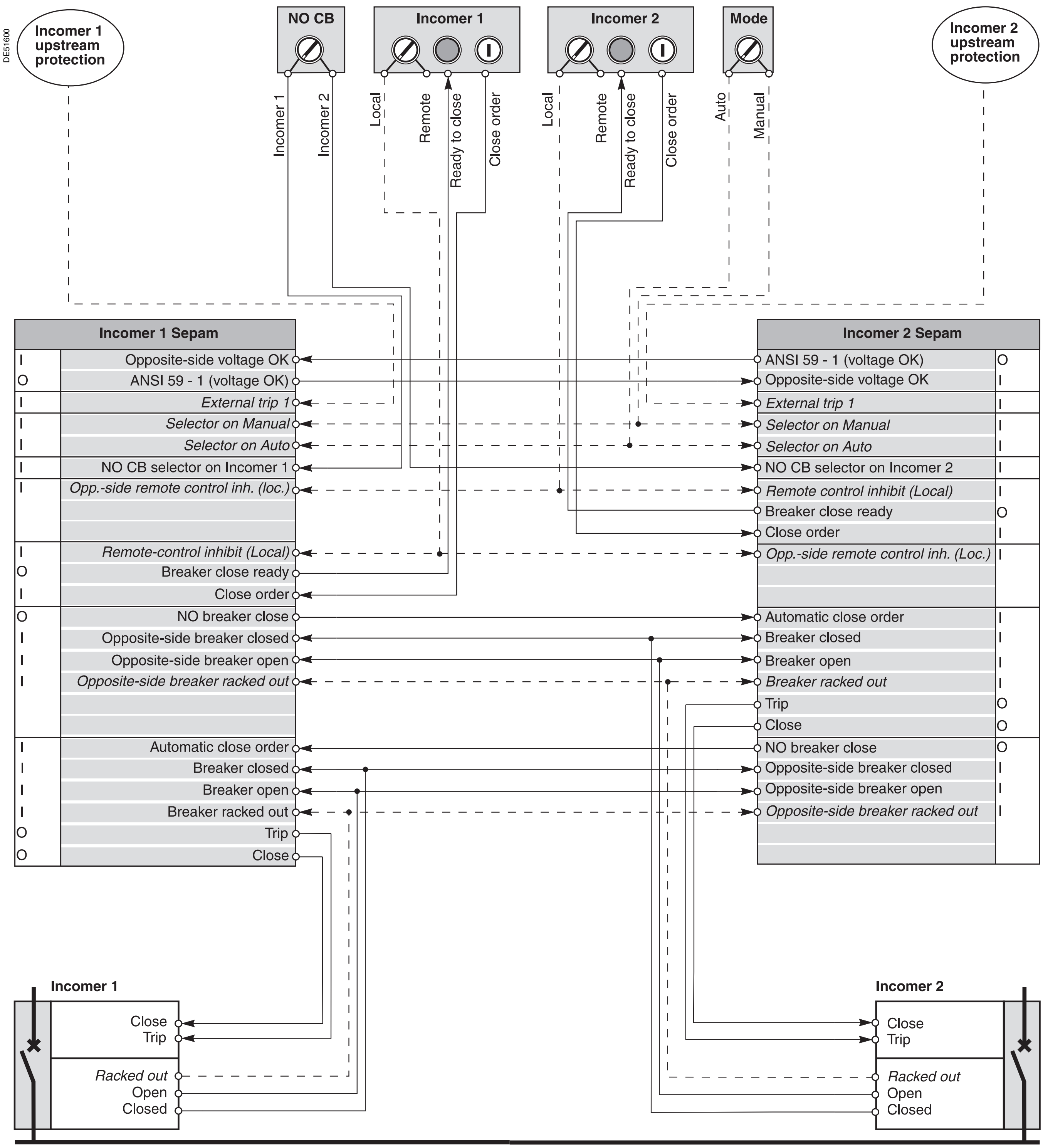
This function controls the opening of the circuit breaker designated as being normally open by the position of the "NO circuit breaker" selector, when the two incomer circuit breakers are closed.
It guarantees, for all the automatic control sequences that put the two sources in parallel, that at the end of the transfer, only one circuit breaker out of the two is closed.
The open order is taken into account by the Switchgear control function.

Block diagram



Automatic "one out of two" transfer
Implementation

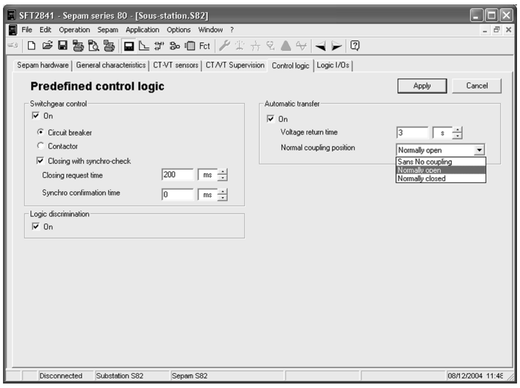
Connection



– – – – – – : *optional wiring.*

Automatic "one out of two" transfer
Implementation

PE50458



SFT2841: parameter setting of predefined control logic.

Parameter setting of predefined control functions

The Automatic transfer function is set up at the same time as the Switchgear control function in the "Control logic" tab of the SFT2841 software.

Switchgear control function

- activation of the Switchgear control function
- activation of the Synchro-check function if necessary.

Automatic transfer function

- activation of the Automatic transfer function and adjustment of associated parameters:
  - voltage return time Tr (typically 3 s)
  - normal coupling position: no coupling.

VT supervision function

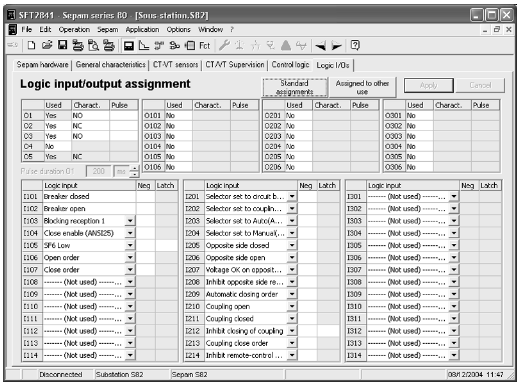
The VT supervision (ANSI 60FL) is to be activated if necessary.

Protection function setting

Protection functions	Use	Setting information
Phase undervoltage (ANSI 27) Unit 1	Initialization of automatic transfer on detection of voltage loss.	Voltage set point: 60% Unp Delay: 300 ms
Phase overcurrent (ANSI 50/51) Unit 1, instantaneous output	Detection of downstream phase fault, to inhibit automatic transfer.	To be set according to discrimination study (the most sensitive set point).
Earth fault (ANSI 50N/51N) Unit 1, instantaneous output	Detection of downstream earth fault, to inhibit automatic transfer.	To be set according to discrimination study (the most sensitive set point).
Phase overvoltage (ANSI 59) Unit 1	Detection of phase voltage upstream of the circuit breaker. To be assigned to a Sepam logic output in the control matrix.	Voltage set point: 90% Unp Delay: 3 s
Optional protection functions	**Use**	**Setting information**
Remanent undervoltage (ANSI 27R) Unit 1	Detection of no remanent voltage on the busbars to which the motors are connected.	Voltage set point: 30% Unp Delay: 100 ms

Automatic "one out of two" transfer
Implementation

PE50459



SFT2841: standard assignment of the inputs required for the AT function.

Logic input assignment

The logic inputs required for the AT function are to be assigned in the SFT2841 "Logic I/Os" screen.
The "Standard assignments" button proposes an assignment of the main inputs required for the AT function. The other inputs are to be assigned manually.

Logic output assignment in the control matrix

The assignment of the logic outputs required for the AT function takes place in 2 steps:

■ declaration of the required logic outputs "Used", indicating the control mode of each output, in the SFT2841 "Logic I/Os" screen
■ assignment of each predefined output associated with the AT function to a Sepam logic output in the SFT2841 "Control matrix" screen.

The predefined outputs associated with the AT function are as follows:

"Protection" button	Description	Use
59 - 1	Delayed output of the Phase overvoltage function (ANSI 59) Unit 1	Indication for the opposite side Sepam: the voltage is OK upstream of the incoming circuit breaker.
"Logic" button	**Description**	**Use**
NO circuit breaker closing	Predefined output V_CLOSE_NO_ORD of the AT function	Automatic closing order of opposite side circuit breaker.
Breaker closing ready	Predefined output V_CLOSE_EN of the AT function	LED indication: the return to normal conditions are met (neglecting the synchro-check)

4

Automatic "one out of two" transfer
Characteristics

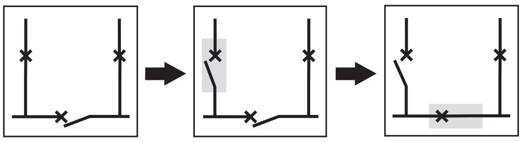
Setting				
Activity				
Setting range	On / Off			
Voltage return time				
Setting range	0 to 300 s			
Accuracy (1)	±2 % or from -10 ms to +25 ms			
Resolution	10 ms or 1 digit			
Normal coupling position				
Setting range	No coupling / Normally open / Normally closed			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Transfer order on fault	V_TRANS_ON_FLT	■	■	
Transfer off order	V_TRANS_STOP	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Automatic transfer on	V_TRANSF_ON		■	■
Tripping by 2/3 or 1/2 logic	V_2/3_TRIPPING		■	■
Tripping by automatic transfer	V_AT_TRIPPING		■	■
NO circuit breaker closing	V_CLOSE_NO_ORD		■	■
Breaker closing ready	V_CLOSE_EN		■	■

***(1)** Under reference conditions (IEC 60255-6).*

Automatic "two out of three" transfer
Operation

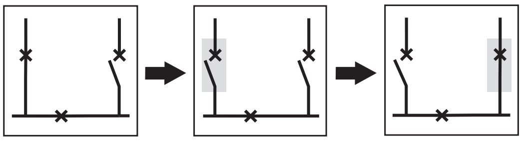
Definition
Automatic "two out of three" transfer is suitable for substations with busbars supplied by two incomers and with coupling.
Automatic transfer comprises two functions:
■ automatic transfer with busbar supply interruption
■ voluntary return to normal without busbar supply interruption.
The 2 functions are described separately below.

DE51511



Automatic transfer with normally open coupling.

DE51514



Automatic transfer with normally closed coupling.

Automatic transfer with supply interruption
Description
The function is used to transfer busbar supply from one source to the other, after the detection of voltage loss or a fault upstream of the source.

Automatic source transfer takes place in two steps:
■ tripping of the circuit breaker triggered by the detection of the loss of voltage or an external trip order (trip order from upstream protection units): loss of busbar supply
■ closing of the normally open circuit breaker to resupply the busbars. According to the parameter setting, the normally open circuit breaker may be one of the following:
□ the coupling circuit breaker, when coupling is normally open
□ the opposite side circuit breaker, when coupling is normally closed.
When motors are connected to the busbars, it is necessary to check for remanent voltage on the busbars using the Remanent undervoltage function (ANSI 27R).

Compulsory transfer conditions
These conditions are always required to enable transfer:
■ the incoming circuit breaker is closed
■ according to the coupling setup:
□ the opposite side circuit breaker is closed and the coupling circuit breaker is open, when coupling is normally open (NO coupling)
□ or the opposite side circuit breaker is open and the coupling circuit breaker is closed, when coupling is normally closed (NC coupling)
■ no phase-to-phase fault detected by the incomer on the busbars or downstream
■ no phase-to-earth fault detected by the incomer on the busbars or downstream
■ voltage OK on the opposite incomer.

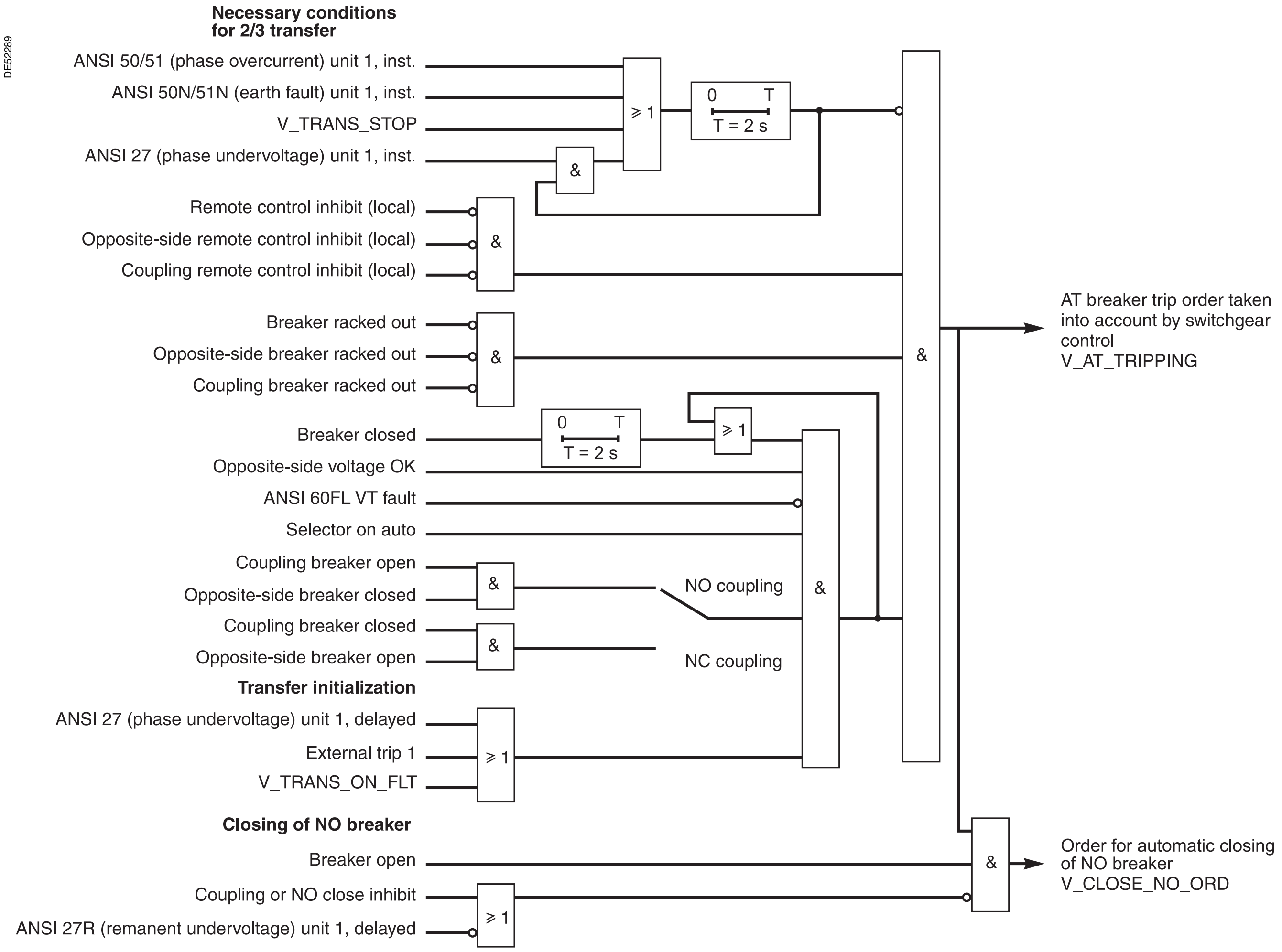
Optional transfer conditions
These conditions are required when the associated optional functions are enabled:
■ the "Auto / Manual" selector is in the Auto position
■ the 3 "Local / Remote" selectors are in the Remote position
■ the 3 circuit breakers are racked in
■ no VT fault detected by the VT Supervision function (ANSI 60FL), to avoid transfer on the loss of voltage transformers
■ no inhibition of transfer by V_TRANS_STOP by logic equations or by Logipam.

Initialization of transfer
Three events may trigger automatic transfer:
■ loss of voltage detected on the incomer by the Phase undervoltage function (ANSI 27)
■ or the detection of a fault by the protection units upstream of the incomer, with intertripping order on the "External tripping 1" logic input
■ or V_TRANS_ON_FLT, initialization of transfer by logic equations or by Logipam.

4

Automatic "two out of three" transfer
Operation

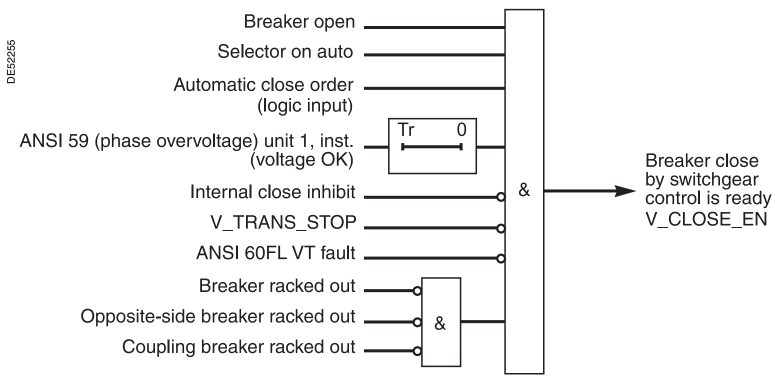
Block diagram



Closing of the normally open circuit breaker
The following conditions are required to order the closing of the normally open circuit breaker:
- the incoming circuit breaker is open
- no normally open circuit breaker inhibit close conditions
- no remanent voltage on the busbars (checking necessary when motors are connected to the busbars.)

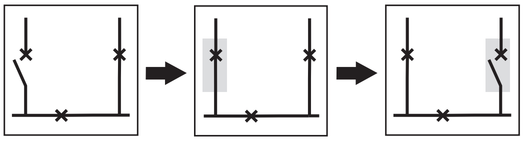
If the normally open circuit breaker is the opposite side circuit breaker:
the NO circuit breaker closing order is transmitted by a Sepam logic output to a logic input of the opposite side Sepam where it is taken into account by the Switchgear control function (see block diagram below).
If the normally open circuit breaker is the coupling circuit breaker:
the NO circuit breaker closing order is transmitted by a Sepam logic output to close the circuit breaker directly, without any intermediary.

Block diagram (Opposite side Sepam)



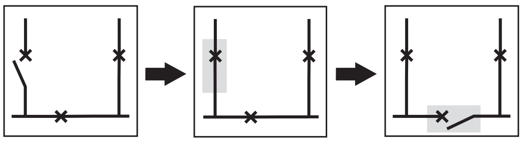
Automatic "two out of three" transfer
Operation

DE51512



Voluntary return to normal with normally closed coupling.

DE51631



Voluntary return to normal with normally open coupling.

Voluntary return to normal without interruption

Description
The voluntary return to normal without interruption involves two separate control functions:
- closing of the open circuit breaker, with or without synchro-check: the 3 circuit breakers are closed
- then opening of the normally open circuit breaker, designated by the "NO circuit breaker" selector.

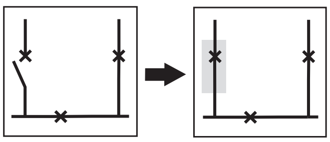
These two functions may also be used to transfer the busbar supply source without any interruption.

Compulsory transfer conditions
These conditions are always required to enable transfer:
- the incoming circuit breaker is open
- the opposite side circuit breaker and the coupling circuit breaker are closed
- The voltage is OK upstream of the incoming circuit breaker. This voltage is detected either by function ANSI 59, or by a processing operation in Logipam using V_TRANS_V_EN.

Optional transfer conditions
These conditions are required when the associated optional functions are enabled:
- the "Auto / Manual" selector is in the Manual position
- the 3 "Local / Remote" selectors are in the Local position
- the 3 circuit breakers are racked in
- no VT fault detected by the VT Supervision function (ANSI 60FL), to avoid transfer on the loss of voltage transformers
- no inhibition of transfer by V_TRANS_STOP by logic equations or by Logipam.

Initialization of the return to normal
- voluntary incoming circuit breaker close order.

DE51513



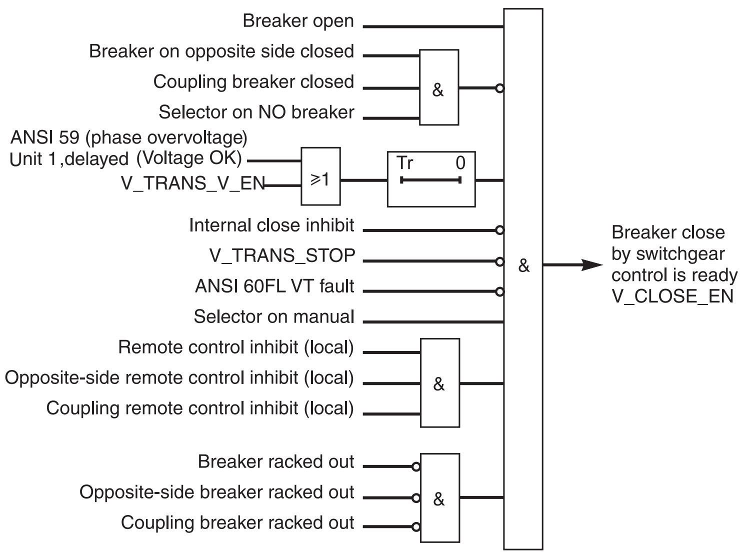
Closing of the open circuit breaker

Description
Circuit breaker closing is ensured by the Switchgear control function, with or without synchro-check.

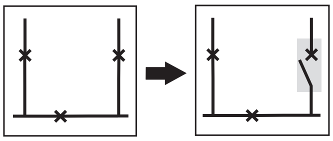
The AT function checks that all the required conditions are met and indicates to the user that the return to normal is possible.

Block diagram

DE80146

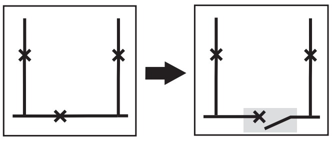


Automatic "two out of three" transfer
Operation



DE51529

Normally closed coupling.



Normally open coupling.

Opening of the normally open circuit breaker

Description

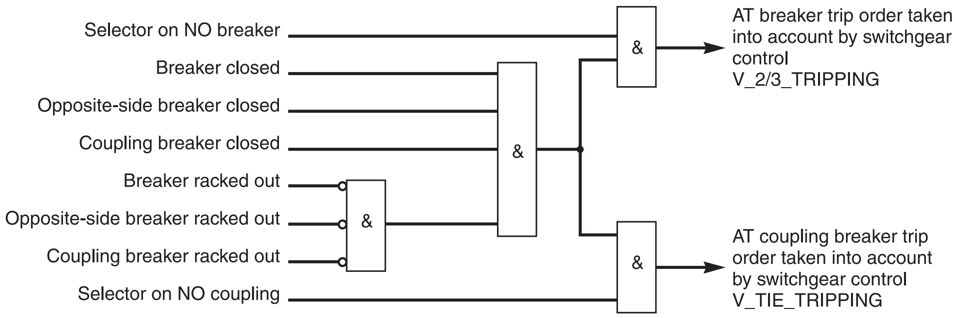
This function controls the opening of the circuit breaker designated as being normally open by the position of the "NO circuit breaker" selector, when the three circuit breakers are closed.

It guarantees, for all the automatic control sequences that put the two sources in parallel, that at the end of the transfer, only two circuit breakers out of the three are closed.

The open order is taken into account by the Switchgear control function.

Block diagram

DE51589



Automatic "two out of three" transfer
Operation

Coupling closing

Description
The voluntary closing of the coupling circuit breaker without interruption involves two separate control functions:
■ closing of the coupling circuit breaker, with or without synchro-check: the 3 circuit breakers are closed
■ then opening of the normally open circuit breaker, designated by the "NO circuit breaker" selector.

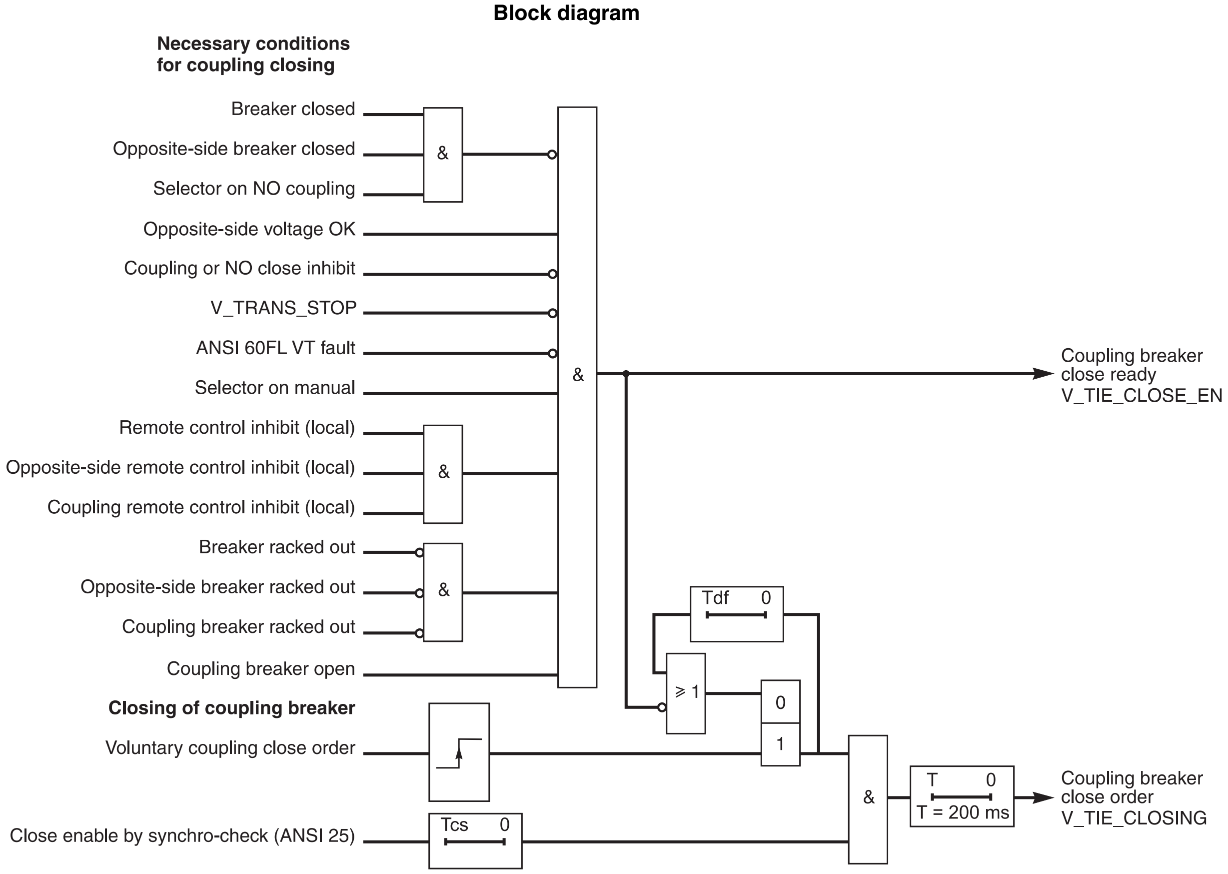
Compulsory transfer conditions
These conditions are always required to enable transfer:
■ the opposite side voltage is OK
■ the 3 following conditions are not fulfilled simultaneously:
□ the incoming circuit breaker is closed
□ the opposite side circuit breaker is closed
□ the coupling circuit breaker is the normally open circuit breaker (NO coupling).

Optional transfer conditions
These conditions are required when the associated optional functions are enabled:
■ the "Auto / Manual" selector is in the Manual position
■ the 3 "Local / Remote" selectors are in the Local position
■ the 3 circuit breakers are racked in
■ no VT fault detected by the VT Supervision function (ANSI 60FL), to avoid transfer on the loss of voltage transformers
■ no inhibition of transfer by V_TRANS_STOP by logic equations or by Logipam.

Initialization of coupling closing
Voluntary coupling circuit breaker close order.

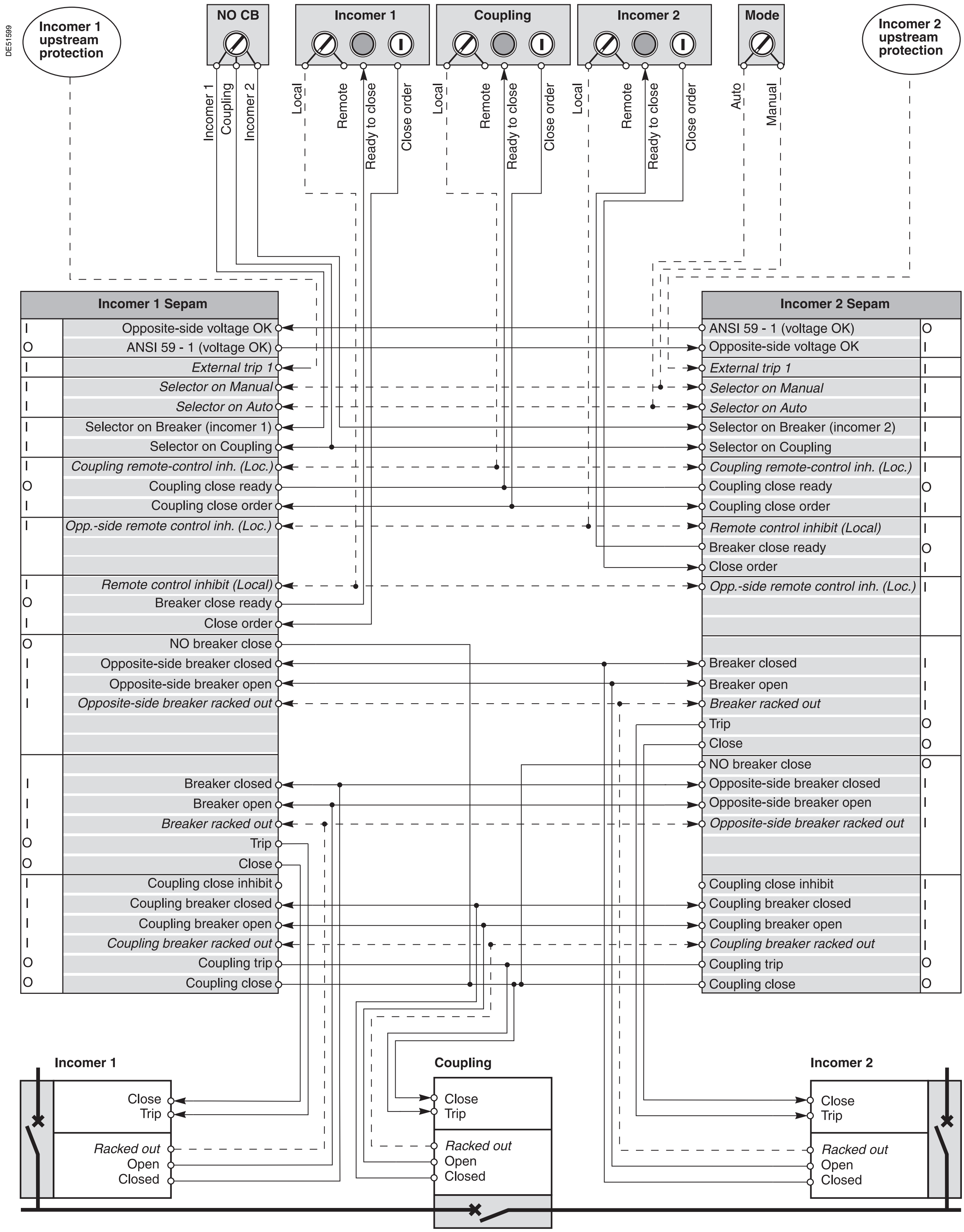
Block diagram

DE52257



Automatic "two out of three" transfer
Implementation

Connection for normally open coupling

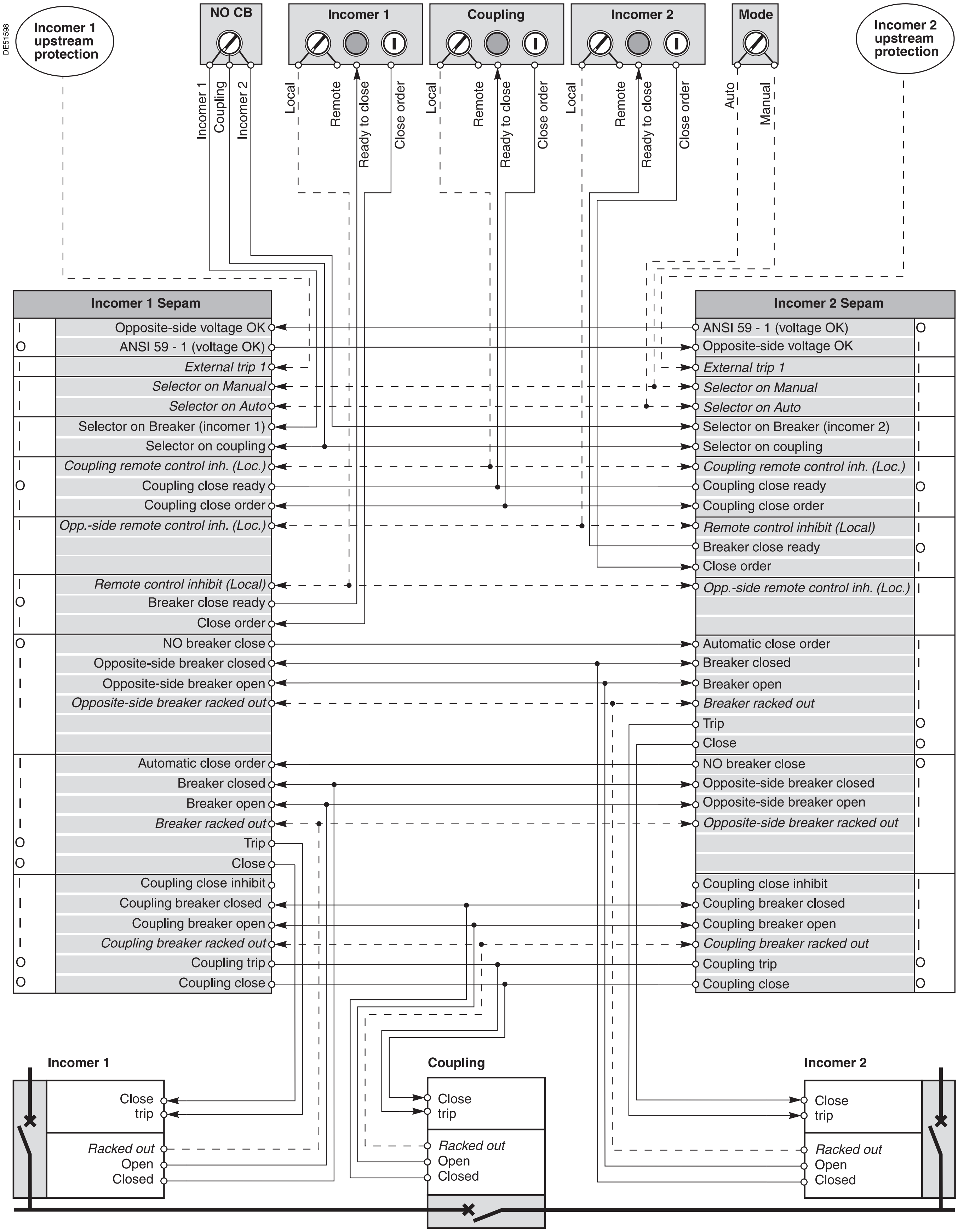


– – – – – – : *optional wiring.*

4

Automatic "two out of three" transfer
Implementation

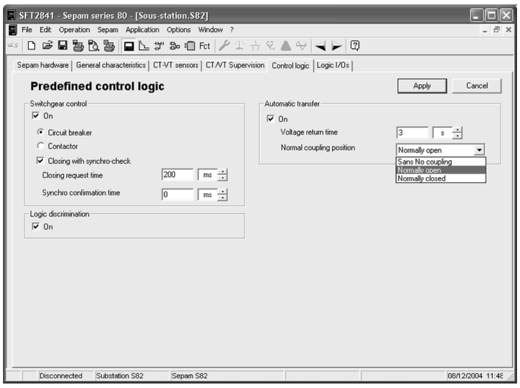
Connection for normally closed coupling



– – – – – – – : optional wiring.

Automatic "two out of three" transfer
Implementation

PE50458



SFT2841: parameter setting of predefined control logic.

Parameter setting of predefined control functions

The Automatic transfer function is set up at the same time as the Switchgear control function in the "Control logic" tab of the SFT2841 software.

Switchgear control function

■ activation of the Switchgear control function
■ activation of the Synchro-check function if necessary.

Automatic transfer function

■ activation of the Automatic transfer function and adjustment of associated parameters:
□ voltage return time Tr (typically 3 s)
□ normal coupling position: normally open or normally closed, according to the network operating mode.

VT supervision function

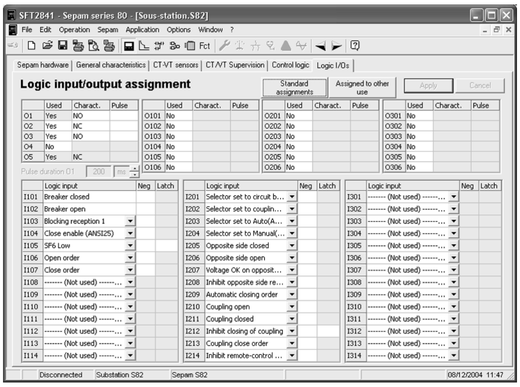
The VT supervision (ANSI 60FL) is to be activated if necessary.

Protection function setting

Protection functions	Use	Setting information
Phase undervoltage (ANSI 27) Unit 1	Initialization of automatic transfer on detection of voltage loss.	Voltage set point: 60% Unp Delay: 300 ms
Phase overcurrent (ANSI 50/51) Unit 1, instantaneous output	Detection of downstream phase fault, to inhibit automatic transfer.	To be set according to discrimination study (the most sensitive set point).
Earth fault (ANSI 50N/51N) Unit 1, instantaneous output	Detection of downstream earth fault, to inhibit automatic transfer.	To be set according to discrimination study (the most sensitive set point).
Phase overvoltage (ANSI 59) Unit 1	Detection of phase voltage upstream of the circuit breaker. To be assigned to a Sepam logic output in the control matrix.	Voltage set point: 90% Unp Delay: 3 s
Optional protection functions	**Use**	**Setting information**
Remanent undervoltage (ANSI 27R) Unit 1	Detection of no remanent voltage on the busbars to which the motors are connected.	Voltage set point: 30% Unp Delay: 100 ms

Automatic "two out of three" transfer
Implementation

PE50459



SFT2841: standard assignment of the inputs required for the AT function.

Logic input assignment

The logic inputs required for the AT function are to be assigned in the SFT2841 "Logic I/Os" screen.
The "Standard assignments" button proposes an assignment of the main inputs required for the AT function. The other inputs are to be assigned manually.

Logic output assignment in the control matrix

The assignment of the logic outputs required for the AT function takes place in 2 steps:

- declaration of the required logic outputs "Used", indicating the control mode of each output, in the SFT2841 "Logic I/Os" screen
- assignment of each predefined output associated with the AT function to a Sepam logic output in the SFT2841 "Control matrix" screen.

The predefined outputs associated with the AT function are as follows:

"Protection" button	Description	Use
59 - 1	Delayed output of the Phase overvoltage function (ANSI 59) Unit 1	Indication for the opposite side Sepam: voltage OK upstream of the incoming circuit breaker.
"Logic" button	**Description**	**Use**
NO circuit breaker closing	Predefined output V_CLOSE_NO_ORD of the AT function	Automatic closing order of normally open circuit breaker.
Coupling closing	Predefined output V_TIE_CLOSING of the AT function	Coupling circuit breaker close order.
Coupling tripping	Predefined output V_TIE_OPENING of the AT function	Coupling circuit breaker open order.
Breaker closing ready	Predefined output V_CLOSE_EN of the AT function	LED indication: the return to normal conditions are met. (neglecting the synchro-check)
Coupling closing ready	Predefined output V_TIE_CLOSE_EN of the AT function	LED indication: the coupling close conditions are met. (neglecting the synchro-check)

Automatic "two out of three" transfer
Characteristics

Setting				
Activity				
Setting range	On / Off			
Voltage return time				
Setting range	0 to 300 s			
Accuracy (1)	±2 % or from -10 ms to +25 ms			
Resolution	10 ms or 1 digit			
Normal coupling position				
Setting range	No coupling / Normally open / Normally closed			
Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	
Transfer order on fault	V_TRANS_ON_FLT	■	■	
Transfer off order	V_TRANS_STOP	■	■	
Voltage OK upstream of the incoming circuit breaker	V_TRANS _ V_EN		■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Automatic transfer on	V_TRANSF_ON		■	
Tripping by 2/3 or 1/2 logic	V_2/3_TRIPPING		■	■
Tripping by automatic transfer	V_AT_TRIPPING		■	■
NO circuit breaker closing	V_CLOSE_NO_ORD		■	■
Breaker closing ready	V_CLOSE_EN		■	■
Coupling tripping	V_TIE_OPENING		■	■
Coupling closing ready	V_TIE_CLOSE_EN		■	■
Coupling closing	V_TIE_CLOSING		■	■
Coupling closing with synchro-check failed	V_TIESYNCFAIL		■	■

***(1)** Under reference conditions (IEC 60255-6).*

Triggering the Motor start report (MSR)

Operation

This function is only found in motor applications. It is used to record values specific to motors, during the starting phase.

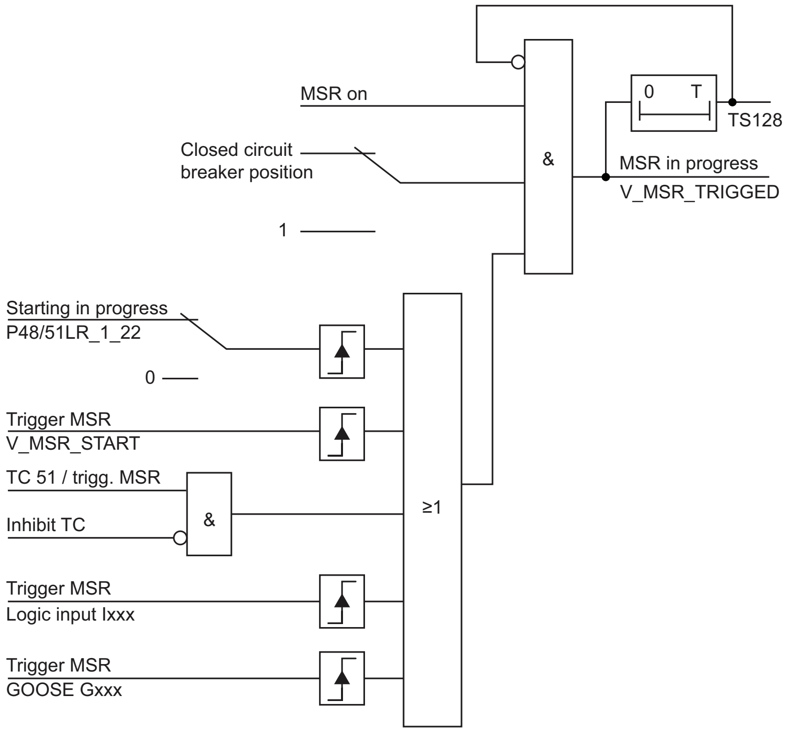
While there is no recording in progress, recording can be triggered by:

- the "starting in progress" output of the 48/51LR protection function
- the V_MSR_START output from the Logipam or the logic equation editor
- the remote control order TC51
- the "Trigger MSR" logic input
- the "Trigger MSR" GOOSE logic input

Recording can be conditional upon the closed circuit breaker position.

Block diagram

DE81267



Characteristics

Inputs

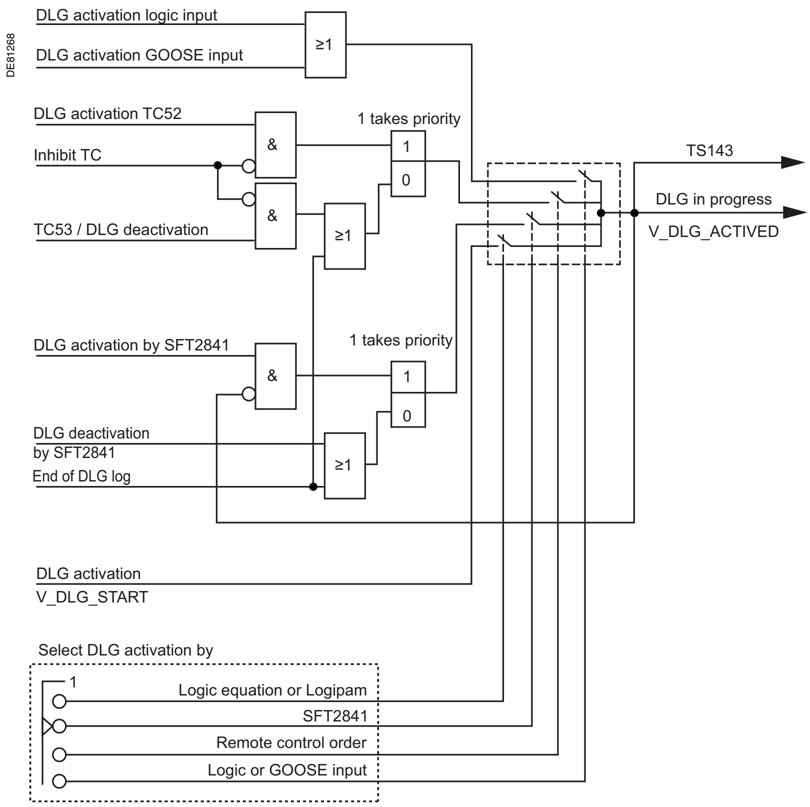
Designation	Syntax	Equations	Logipam	Matrix
Trigger MSR	V_MSR_START	■	■	

Outputs

Designation	Syntax	Equations	Logipam	Matrix
MSR triggered	V_MSR_TRIGGED	■	■	

Activating / Deactivating the Data log function (DLG)

Operation
This function is found in all applications.
Depending on the chosen parameter setting, activation and deactivating the log of selected electrical values can be achieved by:
- logic input or GOOSE type IEC 61850 logic input
- Logipam or logic equation editor
- remote control order
- SFT2841 software.

Block diagram


Characteristics

Inputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
DLG activation	V_DLG_START	■	■	
Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
DLG in progress	V_DLG_ACTIVED	■	■	

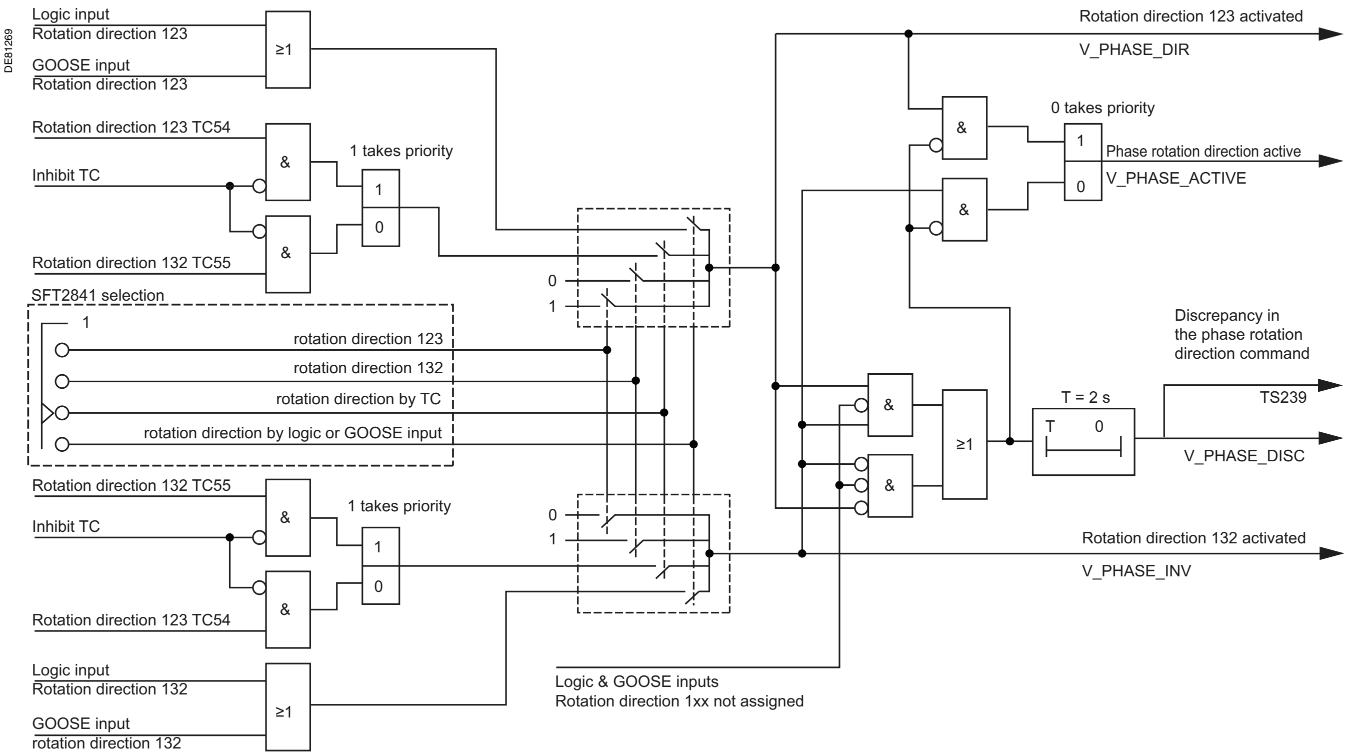
Change of phase rotation direction

Operation

This function is found in all applications.
The change of phase rotation direction can be triggered by:
- logic input or GOOSE type IEC 61850 logic input
- remote control order (TC)

The phase rotation direction can be defined as:
- positive sequence (123)
- negative sequence (132)

Block diagram



Characteristics

Outputs				
Designation	**Syntax**	**Equations**	**Logipam**	**Matrix**
Discrepancy in the phase rotation direction	V_PHASE_DISC	■	■	
Phase rotation direction 123 activated	V_PHASE_DIR	■	■	
Phase rotation direction 132 activated	V_PHASE_INV	■	■	
Phase rotation direction active	V_PHASE_ACTIVE	■	■	

⚠ WARNING

WARNING: protection functions inhibited for 350 ms.
Form the time it receives the change phase rotation direction request, Sepam cannot protect the electrical network for 350 ms.
This inhibition of protection functions **can result** in death or serious injury.

Local indication
ANSI code 30

Operation
Events may be indicated locally on the front panel of Sepam by:
- appearance of a message on the display
- switching on of one of the 9 yellow LEDs.

Message type indication
Predefined messages
All the messages connected to the standard Sepam functions are predefined and available in two language versions:
- in English, factory-set messages, not modifiable
- in the local language, according to the version delivered.

The language version is chosen at the time of Sepam parameter setting.
The messages are visible on the Sepam display and on the SFT2841 Alarms screen.
The number and type of predefined messages depend on the type of Sepam. The table below gives the complete list of all predefined messages.

Functions			English	Local language (e.g. French)
Control and monitoring	**ANSI code**			
External trip (1 to 3)			EXT. TRIP (1 to 3)	DECLT.EXT. (1 à 3)
Buchholz trip			BUCHH/GAS TRIP	BUCHH/GAZ DECL^{T}
Buchholz alarm			BUCHHOLZ ALARM	BUCHH ALARME
Thermostat trip			THERMOS^{T}. TRIP	THERMOS^{T}.DECL^{T}.
Thermostat alarm			THERMOS^{T}. ALARM	THERM^{OT}.ALARME
Pressure trip			PRESSURE TRIP	PRESSION DECL^{T}
Pressure alarm			PRESSURE ALARM	PRESSION ALARME
Thermistor alarm			THERMISTOR AL.	THERMISTOR AL.
Thermistor trip			THERMISTOR TRIP	THERMISTOR DECL.
Control fault			CONTROL FAULT	DEFAUT COMMANDE
Load shedding			LOAD SHEDDING	DÉLESTAGE
Genset shutdown			GENSET SHUTDOWN	ARRÊT GROUPE
De-excitation			DE-EXCITATION	DÉSEXCITATION
Tripping order by automatic transfer			AUTO TRANSFER	AUTO TRANSFER
Phase rotation direction command complementarity fault			ROTATION DISC CMD	DISC CDE ROTATION
Diagnosis	**ANSI code**			
SF6 fault			SF6 LOW	BAISSE SF6
MET148-2 No 1 RTD fault			RTD'S FAULT MET1 (1)	DEF SONDE MET1 (1)
MET148-2 No 2 RTD fault			RTD'S FAULT MET2 (1)	DEF. SONDE MET2 (1)
VT supervision	60FL	Phase VT supervision	VT FAULT	DEFAUT TP
		Residual VT supervision	VT FAULT Vo	DEFAUT TP Vo
CT supervision	60	Main CT supervision	CT FAULT	DEFAUT TC
		Additional CT supervision	CT' FAULT	DEFAUT TC'
Trip circuit supervision (TCS) fault or mismatching of open/closed position contacts	74		TRIP CIRCUIT	CIRCUIT DECL^{T}
Closing circuit fault			CLOSE CIRCUIT	CIRCUIT ENCL^{T}
Capacitor step matching fault			COMP. FLT. STP (1 to 4)	DEF. COMP. GR (1 à 4)
Cumulative breaking current monitoring			ΣI^2BREAKING >>	ΣI^2 COUPES
Battery monitoring			BATTERY LOW (1)	PILE FAIBLE (1)
Auxiliary power supply monitoring		Low threshold	LOW POWER SUP.	ALIM. SEUIL BAS
		High threshold	HIGH POWER SUP.	ALIM. SEUIL HAUT

(1) RTD FAULT, BATTERY LOW messages: refer to the maintenance chapter.

Local indication
ANSI code 30

Functions			English	Local language (e.g. French)
Protection	**ANSI code**			
Overspeed	12		OVERSPEED	VITESSE >>
Underspeed	14		UNDERSPEED	VITESSE <<
Underimpedance	21B		UNDERIMPEDANCE	IMPEDANCE <<
Overfluxing (V/Hz)	24		OVERFLUXING	SURFLUXAGE
Synchro-check	25	Synchrochecked close request in process	SYNC.IN PROCESS	SYNC. EN COURS
		Synchrochecked close request successful	SYNC. OK	SYNC. REUSSIE
		Closing failed, out-of-sync	SYNC. FAILURE	ECHEC SYNC.
		Closing failed, out-of-sync, cause dU	SYNC. FAILED dU	ECHEC SYNC. dU
		Closing failed, out-of-sync, cause dPHI	SYNC. FAILED dPhi	ECHEC SYNC. dPhi
		Closing failed, out-of-sync, cause dF	SYNC. FAILED dF	ECHEC SYNC. dF
		Stop closing with synchro-check	STOP SYNC.	STOP SYNC.
		Coupling closing with synchro-check failed	TIE SYNC. FAILED	ECHEC COUPLAGE
Undervoltage	27		UNDERVOLTAGE (1)	TENSION << (1)
Positive sequence undervoltage	27D	Positive sequence undervoltage	UNDERVOLTAGE.PS	TENSION Vd <<
		Reverse rotation	ROTATION -	ROTATION -
Third harmonic undervoltage	27TN/64G2		100% STATOR	100% STATOR
Active overpower	32P		OVER P	P >>
Reactive overpower	32Q		OVER Q	Q >>
Phase undercurrent	37		UNDER CURRENT	COURANT <<
Phase underpower	37P		UNDER POWER	P <<
Temperature monitoring	38/49T	Alarm	OVER TEMP. ALM	T° ALARME
		Tripping	OVER TEMP. TRIP	T° DECL^{T}
Field loss	40		FIELD LOSS	PERTE EXCITATION
Negative sequence / unbalance	46		UNBALANCE I	DESEQUILIBRE I
Negative sequence overvoltage	47		UNBALANCE U	DESEQUILIBRE U
Excessive starting time, locked rotor	48/51LR	Excessive starting time	LONG START	DEMARRAGE LONG
		Locked rotor in normal operation	ROTOR BLOCKING	BLOCAGE ROTOR
		Locked rotor on start	ST^{RT} LOCKED ROT^{R}	BLOC ROTOR DEM
Thermal overload	49RMS	Alarm	THERMAL ALARM	ECHAUF^{T}.ALARME
		Tripping	THERMAL TRIP	ECHAUF^{T}.DECL$^{T.}$
		Inhibit closing	START INHIBIT	DEMARRAGE INHIBE
Breaker failure	50BF		BREAKER FAILURE	DEF. DISJONCT.
Inadvertent energization	50/27		INADV. ENERGIZ.	SS TENSION ACC.
Phase overcurrent	50/51		PHASE FAULT (2)	DEFAUT PHASE (2)
Earth fault	50N/51N		EARTH FAULT	DEFAUT TERRE
Voltage-restrained overcurrent	50V/51V		O/C V REST (2)	DEF. PHASE RET. U (2)
Capacitor bank unbalance	51C		UNBAL. STP (1 to 4)	DES. GRADIN (1 à 4)
Overvoltage	59		OVERVOLTAGE (1)	TENSION >> (1)
Neutral voltage displacement	59N		Vo FAULT	DEFAUT Vo
Restricted earth fault	64REF		RESTRIC. EARTH FAULT	TERRE RESTREINTE
Starts per hour	66		START INHIBIT	DEMARRAGE INHIBE
Directional phase overcurrent	67		DIR. PHASE FAULT (2)	DEFAUT PHASE DIR. (2)
Directional earth fault	67N/67NC		DIR. EARTH FAULT	DEFAUT TERRE DIR.
Pole slip	78PS		POLE SLIP	PERTE SYNCHRO.
Recloser	79	Cycle x	CYCLE (1 to 4) (3)	CYCLE (1 à 4) (3)
		Reclosing successful	CLEARED FAULT	DEFAUT ELIMINE
		Permanent trip	FINAL TRIP	DECL^{T} DEFINITIF
Overfrequency	81H		OVER FREQ.	FREQUENCE >>
Underfrequency	81L		UNDER FREQ.	FREQUENCE <<
Rate of change of frequency	81R		ROCOF	DERIV. FREQ
Machine differential	87M		DIFFERENTIAL	DIFFERENTIELLE
Transformer differential	87T		DIFFERENTIAL	DIFFERENTIELLE

(1) *With indication of the faulty phase, when used with phase-to-neutral voltage.*
(2) *With indication of the faulty phase.*
(3) *With indication of the protection unit that has initiated the cycle (phase fault, earth fault, ...).*

Local indication
ANSI code 30

Personalized user messages
100 additional messages may be created using the SFT2841 software to link a message to a logic input or the result of a logic equation, for example, or to replace a predefined message by a user message.

User message editor in SFT2841
The user message editor is included in the SFT2841 software and may be accessed in connected or disconnected mode from the control matrix screen:
- display the "Event" tab on the screen: the user messages appear
- double-click on one of the messages displayed to activate the user message editor.

User message editor functions
- creation and modification of user messages:
  - in English and the local language
  - by text input or importing of an existing bitmap file (*.bmp) or by point to point drawing
- deletion of user messages
- assignment of predefined or user messages to an event defined in the control matrix:
  - from the control matrix screen, "Events" tab, double-click on the event to be linked to a new message
  - select the new predefined or user message from the messages presented
  - "assign" it to the event.

The same message may be assigned to several events, with no limitations.

Message display in SFT2841
- The predefined messages are stored in Sepam's memory and are displayed in connected mode. In disconnected mode, the last messages stored in Sepam connected mode are displayed.
- The user messages are saved with the other Sepam parameters and protection settings and are displayed in connected and disconnected modes.

Message processing on the Sepam display
When an event occurs, the related message appears on the Sepam display.
The user presses the (clear) key to clear the message and enable normal consultation of all the display.
The user must press the (reset) key to acknowledge latched events (e.g. protection outputs).
The list of messages remains accessible in the alarm history (⚠ key), in which the last 16 messages are stored. The last 250 messages may be consulted with the SFT2841 software.
To delete the messages stored in the alarm history:
- display the alarm history on the display
- press the (clear) key.

LED indication
The 9 yellow LEDs on the front of Sepam are assigned by default to the following events:

LED	Event	Name on label on front panel
LED 1	Tripping of protection 50/51 unit 1	I>51
LED 2	Tripping of protection 50/51 unit 2	I>>51
LED 3	Tripping of protection 50N/51N unit 1	Io > 51N
LED 4	Tripping of protection 50N/51N unit 2	Io >> 51N
LED 5		Ext
LED 6		
LED 7	Circuit breaker open (I102)	0 Off
LED 8	Circuit breaker closed (I101)	I On
LED 9	Tripping by circuit breaker control	Trip

The default parameter setting may be personalized using the SFT2841 software:
- LEDs are assigned to events in the "LEDs" tab of the control matrix screen
- editing and printing of personalized labels are proposed in the general characteristics screen.

Local control

PE80330

Local control using the mimic-based UMI

Description

Switchgear may be controlled locally using Sepam series 80 units equipped with the mimic-based UMI.
The control functions available are:
- selection of the Sepam control mode
- viewing of device status on the animated mimic diagram
- local control of the opening and closing of all the devices controlled by Sepam

Selection of the Sepam control mode

A key-switch on the front of the mimic-based UMI is used to select the Sepam control mode. Three modes are available: Remote, Local or Test.

In Remote mode:
- remote control orders are taken into account
- local control orders are disabled, with the exception of the circuit breaker open order.

Remote mode is indicated by the variable V_MIMIC_REMOTE = 1.

In Local mode:
- remote control orders are disabled, with the exception of the circuit breaker open order.
- local control orders are enabled.

Local mode is indicated by the variable V_MIMIC_LOCAL = 1.

Test mode should be selected for tests on equipment, e.g. during preventive maintenance operations:
- all functions enabled in Local mode are available in Test mode
- no time-tagged events are sent by the communication link.

Test mode is indicated by the variable V_MIMIC_TEST = 1.

The Logipam programming software can be used to customize control-mode processing.

Mimic diagram and symbols

A mimic diagram or single-line diagram is a simplified diagram of an electrical installation. It is made up of a fixed background on which symbols and measurements are placed.
The mimic diagram editor integrated in the SFT2841 software may be used to personalize and setup mimic diagrams.

The symbols making up the mimic-diagram constitute the interface between the mimic-based UMI and the other Sepam control functions.
There are three types of symbols:
- fixed symbol: represents the electrotechnical devices that are neither animated or controlled, e.g. a transformer
- animated symbol with one or two inputs: represents the electrotechnical devices that change on the mimic diagram, depending on the symbol inputs, but cannot be controlled via the Sepam mimic-based UMI.
This type of symbol is used for switch-disconnectors without remote control, for example.
- controlled symbol with one or two inputs/outputs: represents the electrotechnical devices that change on the mimic diagram, depending on the symbol inputs, and can be controlled via the Sepam mimic-based UMI.
This type of symbol is used for circuit breakers, for example.
The symbol outputs are used to control the electrotechnical device:
  - □ directly via the Sepam logic outputs
  - □ by the switchgear control function
  - □ by logic equations or the Logipam program.

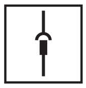
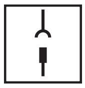
Local control

Symbol animation

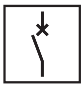
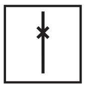
Depending on the value of their inputs, symbols change. A graphic representation corresponds to each state. Animation is carried out automatically by changing the symbol each time the state changes.
The symbol inputs must be assigned directly to the Sepam inputs indicating the position of the symbolized switchgear.

Animated symbols with one input
"Animated -1 input" and "Controlled -1 input/output" symbols are animated symbols with one input. The value of the input determines the state of the symbol:
- input set to 0 = inactive
- input set to 1 = active

This type of symbol is used for simple presentation of information, for example the racked out position of a circuit breaker.

Symbol inputs	Symbol state	Graphic representation (example)
Input = 0	Inactive	
Input = 1	Active	

Animated symbols with two inputs
"Animated - 2 inputs" and "Controlled - 2 inputs/outputs" symbols are animated symbols with two inputs, one open and the other closed.
This is the most common situation in representing switchgear positions.
The symbol has three states, i.e. three graphic representations: open, closed and unknown.
The latter is obtained when the inputs are not matched, in which case it is impossible to determine the position of the switchgear.

Symbol inputs	Symbol state	Graphic representation (example)
Input 1 (open) = 1 Input 2 (closed) = 0	Open	
Input 1 (open) = 0 Input 2 (closed) = 1	Closed	
Input 1 (open) = 0 Input 2 (closed) = 0	Unknown	
Input 1 (open) = 1 Input 2 (closed) = 1	Unknown	

Local control using a symbol

"Controlled - 1 input/output" and "Controlled - 2 inputs/outputs" symbols are used to control the switchgear corresponding to the symbol via the Sepam mimic-based UMI.

Control symbols with two outputs
"Controlled - 2 inputs/outputs" symbols have two control outputs for opening and closing of the symbolized device.
An order on the mimic-based UMI sends a 300 ms pulse on the controlled output.

Control symbols with one output
"Controlled - 1 input/output" symbols have one control output. The output remains in the last state to which it was ordered.
A new order results in a change in the output state.

Inhibition of orders
"Controlled - 1 input/output" and "Controlled - 2 inputs/outputs" symbols have two inhibition inputs that, when set to 1, block opening and closing orders. This makes it possible to create interlocking systems or other order-disabling systems that are taken into account by the UMI.

Local control

Symbol inputs/outputs

Depending on the desired operation of the mimic-based UMI, Sepam variables must be assigned to the inputs of animated symbols and the inputs/outputs of controlled symbols.

Sepam variables assigned to symbol inputs

Sepam variables		Name	Use
Logic inputs		Ixxx	Symbol animation directly based on device positions
Outputs of predefined functions	Switchgear control	V_CLOSE_INHIBITED	Circuit-breaker operation disabled
	Position of key on the front panel of Sepam	V_MIMIC_LOCAL, V_MIMIC_REMOTE, V_MIMIC_TEST	Representation of key position Operation disabled depending on the control mode
	Logic equations or Logipam program	V_MIMIC_IN_1 to V_MIMIC_IN_16	Representation of Sepam internal status conditions Cases where operation is disabled

Sepam variables to be assigned to symbol outputs

Sepam variables		Name	Use
Logic outputs		Oxxx	Direct control of devices
Inputs of predefined functions	Switchgear control	V_MIMIC_CLOSE_CB V_MIMIC_OPEN_CB	Circuit-breaker control using the switchgear-control function via the mimic-based UMI
	Logic equations or Logipam program	V_MIMIC_OUT1 to V_MIMIC_OUT16	Order processing by logic functions: interlocking, order sequence, etc.

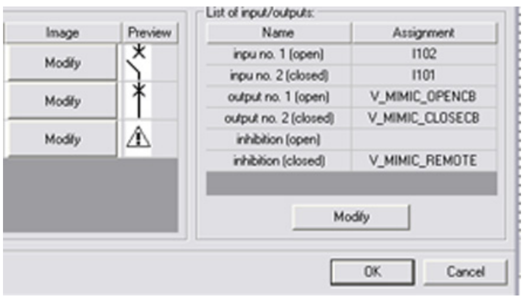
Block diagram

The block diagrams below present the functions ensured by the controlled symbols, based on two examples.
Voluntary user control orders (selection of the device to be controlled in the mimic diagram and action on a control key) are represented in the block diagrams by the following icons:

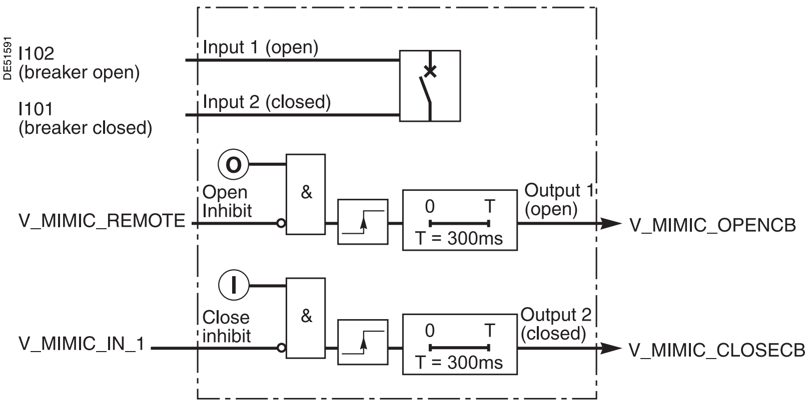
(O) : open order

(I) : close order

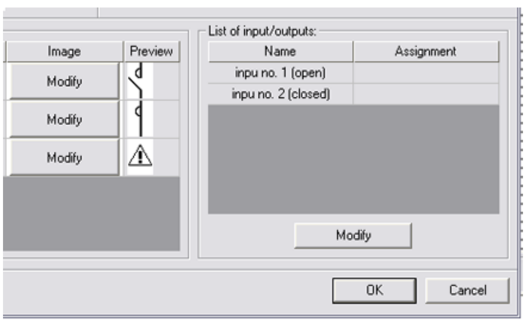
Local control using symbols with two outputs



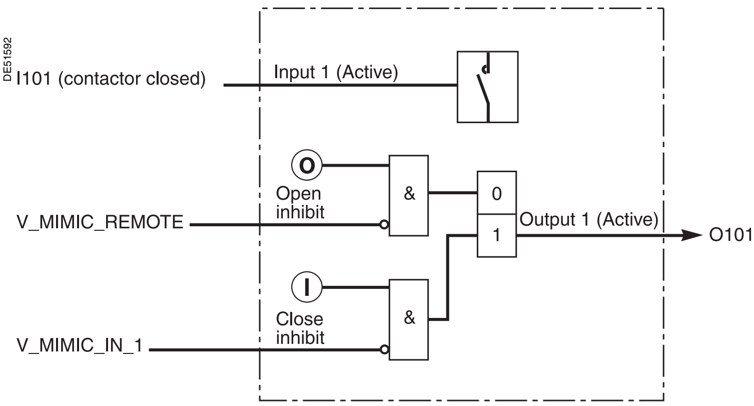
SFT2841: example of the logic input / output assignment of a symbol with two outputs.



Local control using a symbol with one output



SFT2841: example of the logic input / output assignment of a symbol with one output.



Control matrix

Description

The control matrix is used for simple assignment of the logic outputs and LEDs to data produced by the protection functions, control logic and logic inputs.
Each column creates a logic OR between all the lines selected.
The matrix may also be used to display the alarms associated with the data.
It guarantees the consistency of the parameter setting with the predefined functions.
The following data are managed in the control matrix and may be set using the SFT2841 software tool.

Control matrix inputs

"Protection" button	Meaning	Comments
All application protection functions	Protection tripping output and additional outputs when applicable	
"Inputs" button		
Logic inputs I101 to I114	According to configuration	If first MES120 module is configured
Logic inputs I201 to I214	According to configuration	If second MES120 module is configured
Logic inputs I301 to I314	According to configuration	If third MES120 module is configured
"Equations" button	**Meaning**	**Comments**
V1 to V20	Logic equation editor outputs	
"Logipam" button	**Meaning**	**Comments**
MAT001 to MAT128	Logipam output variables to the control matrix	Only the variables actually used in the Logipam program are displayed
"Logic" button	**Meaning**	**Comments**
Switchgear control		
Closing	Closing by switchgear control function	By default on O3. Only available if switchgear control is in circuit breaker mode
Tripping	Tripping by switchgear control function	Forced on O1, if switchgear control is in circuit breaker mode
Inhibit closing	Inhibition by switchgear control function	By default on O2. Only available if switchgear control is in circuit breaker mode
Contactor control	Contactor control	Forced on O1, if switchgear control is in circuit breaker mode
Pick-up	Logic OR of the instantaneous output of all protection units with the exception of protection units 38/49T, 48/51LR, 49RMS, 64G2/27TN, 66.	
Drop-out	A protection unit time delay counter has not yet gone back to 0.	
Logic discrimination		
Logic discrimination trip	Tripping order sent by logic discrimination function	Only when logic discrimination function is used without switchgear control function
Blocking send 1	Sending of blocking signal to next Sepam in logic discrimination chain 1	By default on O102.
Blocking send 2	Sending of blocking signal to next Sepam in logic discrimination chain 2	By default on O103
Motor/generator control		
Load shedding	Sending of a load shedding order	Motor application
Genset shutdown	Sending of a prime mover shutdown order	Generator application
De-excitation	Sending of a de-excitation order	Generator application
Recloser		
Recloser in service	The recloser is in service	
Reclosing successful	The recloser has successfuly reclosed	Pulse type output
Permanent trip	The circuit breaker is permanently open after the reclosing cycles	Pulse type output
Recloser ready	The recloser is ready to operate	
Recloser cycle 1	Cycle 1 in progress	
Recloser cycle 2	Cycle 2 in progress	
Recloser cycle 3	Cycle 3 in progress	
Recloser cycle 4	Cycle 4 in progress	
Closing by recloser	A closing order is given by the recloser	
"GOOSE" button	**Meaning**	**Comments**
Logic inputs G401 to G416 and G501 to G516	According to configuration	Only with ACE850 configured

Control matrix

"Logic" button	Meaning	Comments
Diagnosis		
TCS fault	Trip circuit fault	
CCS fault	Closing circuit fault	
TC / breaker position discrepancy	Discrepancy between the last state ordered by the remote monitoring and control system and the position of the circuit breaker	
Breaker monitoring	A circuit breaker or contactor open or close order has not been executed	
Reverse phase rotation	Reverse voltage rotation due to a wiring error	
Additional-phase reverse rotation	Reverse rotation of additional phase voltages due to a wiring error	
Disturbance recording inhibited	Disturbance recording inhibited	
Cumulative breaking current monitoring	Overshooting of the cumulative breaking current set point	
Low auxiliary voltage threshold	The auxiliary voltage is below the low threshold	
High auxiliary voltage threshold	The auxiliary voltage is above the high threshold	
Low battery fault	Battery low or absent	
MET148-2 No 1 fault MET148-2 No 2 fault	Hardware problem on an MET 148-2 module (module 1 or 2) or on an RTD	
Watchdog	Monitoring of Sepam operation	Always on O5 if used
CT supervision		
Main CT fault	I current input CT fault	
Additional CT fault	I' current input CT fault	
VT supervision		
Main VT fault, phase channel	V voltage input phase VT fault	
Main VT fault, residual channel	V0 voltage input residual VT fault	
Additional VT fault, phase channel	V' voltage input phase VT fault	
Additional VT fault, residual channel	V'0 voltage input residual VT fault	
Synchro-check		
Closing with synchro-check	Circuit breaker close request with synchro-check by the ANSI 25 function has been initiated	Switchgear control with synchro-check function
Closing with synchro-check completed	Breaker closing with synchro-check by the ANSI 25 function successful	Switchgear control with synchro-check function
Closing failed, out-of-sync	Synchronism conditions too short to enable breaker closing	Switchgear control with synchro-check function
Closing failed, out-of-sync, cause dU	Breaker closing inhibited because sources are out-of-sync due to an excessive voltage difference	Switchgear control with synchro-check function
Closing failed, out-of-sync, cause dPHI	Breaker closing inhibited because sources are out-of-sync due to an excessive phase difference	Switchgear control with synchro-check function
Closing failed, out-of-sync, cause dF	Breaker closing inhibited because sources are out-of-sync due to an excessive frequency difference	Switchgear control with synchro-check function
Stop closing with synchro-check	A synchrochecked circuit breaker close request has been interrupted	Switchgear control with synchro-check function
Automatic transfer		
Coupling closing with synchro-check failed	The coupling close request initiated by automatic transfer has failed because the sources are out-of-sync	
Tripping by automatic transfer	Breaker tripping initiated by automatic transfer (tripping is performed by the switchgear control function)	
Tripping by 2/3 or 1/2 logic	Breaker tripping initiated by 2/3 or 1/2 logic (tripping is performed by the switchgear control function)	
NO circuit breaker closing	Normally open circuit breaker close order for automatic transfer function	
Breaker closing ready	Indication that breaker closing is possible to return to normal operation	
Coupling closing	Coupling closing order for automatic transfer function	
Coupling closing ready	Indication that coupling closing is possible to return to normal operation	
Coupling tripping	Coupling tripping order for automatic transfer function	
Control of capacitor banks		
Tripping of capacitor step x	Capacitor step x tripping output	
Closing of capacitor step x	Capacitor step x closing output	
Capacitor step x position fault	Capacitor step x positions mismatched	
Automatic capacitor step control	Capacitor steps in automatic control mode	
Manual capacitor step control	Capacitor steps in manual control mode	

Logic equations

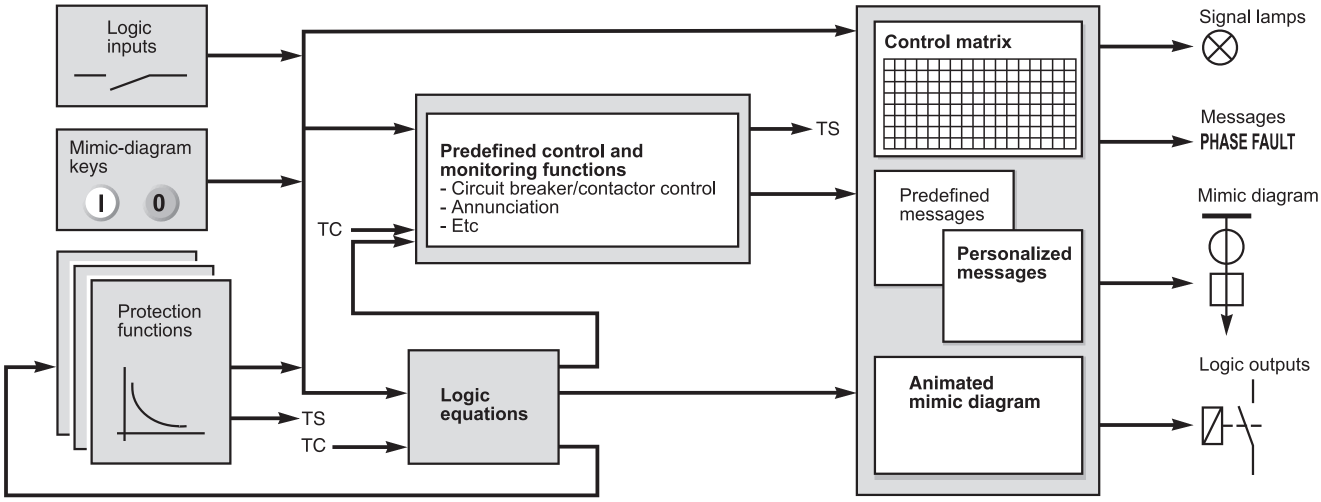
Adaptation of the predefined control and monitoring functions by the addition of simple logic functions.

Use

This function may be used to configure simple logic functions by combining data received from the protection functions, logic inputs, remote control orders or the mimic-based UMI.
GOOSE logic inputs (Gx) available with the IEC 61850 protocol are not managed.
By using logic operators (AND, OR, XOR, NOT) and timers, new processing operations and indications may be added to the existing ones.
The logic functions produce outputs that may be used:

- in the matrix to control output relays, switch on a LED or display new messages
- in the protection functions to create, for example, new inhibit or reset conditions
- in the main predefined control and monitoring functions to complete processing operations or add new cases of tripping or genset shutdown, for example
- for mimic diagram animation.

DE81063



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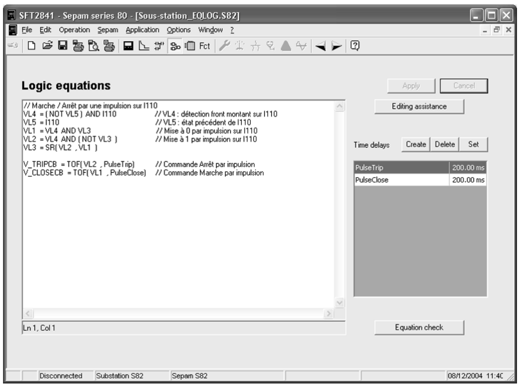
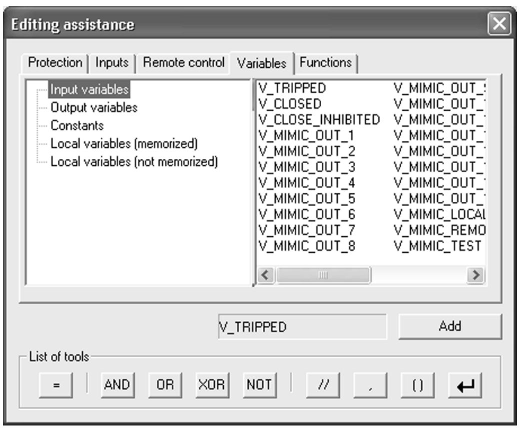


SFT2841: logic equation editor.

PE50461



SFT2841: data input assistance tool.

Logic function configuration

Logic functions are entered in text format in the SFT2841 equation editor. Each line includes a logic operation, the result of which is assigned to a variable.

Example:
V1 = P5051_2_3 OR I102.
The variable V1 is assigned the result of the logic OR operation involving the value from protection function 50/51 and logic input I102.

The variables may be used for other operations or as outputs to produce actions in the control matrix, protection functions or predefined control and monitoring functions.
A program is a series of lines executed sequentially every 14 ms.
A data input assistance tool provides quick access to each of the equation editor operators and variables.

Description of operations

Operators

- **=**: assignment of a result

V2 = VL3 //V2 is assigned the value of VL3

- **NOT**: logic inversion

VL1 = NOT VL2 // VL1 is assigned the opposite logic state of VL2

- **OR**: logic OR

V1 = VL3 OR I103 // V1 is assigned state 1 if VL3 or I03 are in state 1

- **AND**: logic AND

VV3 = VL2 AND VV1 // VV3 is assigned state 1 if VL2 and VV3 are in state 1

- **XOR**: exclusive OR

V3 = VL1 XOR VL2 // V3 is assigned state 1 if only one of the variables VL1 or VL2 is in state 1.
This is equivalent to **V3 = (V1 AND (NOT V2)) OR (V2 AND (NOT V1))**

- **//**: commentary

The characters on the right are not processed

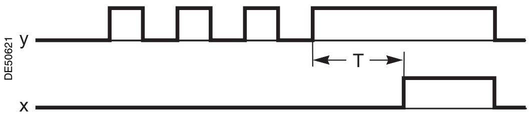
- **(,)**: the operations may be grouped between brackets to indicate the order in which they are carried out

V1 = (VL3 OR VL2) AND I213.

Functions

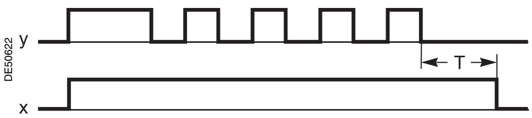
■ x = **SR**(y, z): bistable with priority to Set
x is set to 1 when y is equal to 1
x is set to 0 when z is equal to 1 (and y is equal to 0)
otherwise x is not changed.
V1 = SR(I104, I105) // I104 sets V1 to 1, I105 sets V1 to 0

■ **LATCH**(x, y, …): latching of variables x, y, ...
The variables are maintained constantly at 1 after being initially set. They are reset to 0 when Sepam is reset (reset button, external input or remote control order).
The LATCH function accepts as many parameters as the number of variables that the user wishes to latch.
It applies to the entire program, whatever the position of LATCH in the program. For easier reading, it is advisable to put it at the start of the program.
LATCH(V1, VL2, VV3) // V1, VL2 and VV3 are latched, ie. once they are set to 1, only a Sepam reset can set them back to 0



*x = **TON**(y, t).*

■ x = **TON**(y, t): "on" delay timer
The variable x goes to 1 t ms after variable y goes to 1.
V1 = TON(I102.2000) // used to filter input I102 which must be present for
// 2 s to be taken into account in V1

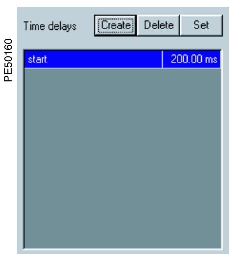


*x = **TOF**(y, t).*

■ x = **TOF**(y, t): "off" delay timer.
The variable x goes to 0 t ms after variable y goes to 0.
VL2 = TOF(VL1, 100) // VL2 stays at 1 for 100 ms after VL1
// goes back to 0

■ x = **PULSE**(s, i, n): time-tagger
Used to generate n periodic pulses, separated by an interval i as of the starting time s
s is expressed in hours:minutes:seconds
i is expressed in hours:minutes:seconds
n is a whole number (n = -1: repeated until the end of the day).
V1 = PULSE (8:30:00, 1:0:0.4) will generate 4 pulses at 1-hour intervals at 8 h 30, 9 h 30, 10 h 30 and 11 h 30. This will be repeated every 24 hours.
The pulses last for a 14 ms cycle. V1 is assigned the value of 1 during the cycle.
If necessary, V1 may be extended using the **TOF, SR** or **LATCH** functions.

Timer values



SFT2841: timer editor.

A timer editor is used to give a name and value to each timer. The name may then be used in the **TON** and **TOF** functions. The timer value may therefore be adjusted without changing the program content.
V1 = TON (VL1, start) // start set to 200 ms in the timer editor.

Maximum number of functions

The number of time delays (**TON**, **TOF**) and time-taggers (**PULSE**) is globalized and may not be more than 16.
There is no limitation for the **SR** and **LATCH** functions.

Description of variables

■ input variables: they come from the protection functions, logic inputs or predefined control functions. They may only appear on the right of the = sign
■ output variables: they are produced by the equation editor to generate actions in the matrix, protection functions or predefined control functions
■ local variables: they are intended for intermediary calculations and are not available outside the logic equation editor.

Logic equations

Input variables

Type	Syntax	Example, meaning
Logic inputs	Ixxx	I101: input 1 of MES120 No 1 module I312: input 12 of MES120 No 3 module
Protection function outputs	Pnnnn_x_y nnnn: ANSI code x: unit y: data	P50/51_2_1: Protection 50/51, unit 2, delayed output. The protection function output data numbers are given in the characteristics of each function and may be accessed using the data input assistance tool.
Remote control orders	TC1 to TC64	Pulse type value (duration of one 14 ms cycle) of remote control orders received
Predefined control function outputs	V_TRIPPED	Tripping order present at switchgear control function output
	V_CLOSE_INHIBITED	Inhibit closing order present at switchgear control function output
	V_CLOSED	Closing order present at switchgear control function output
Phase rotation direction management functions output	V_PHASE_DIR	The phase rotation direction 123 command is active
	V_PHASE_INV	The phase rotation direction 132 command is active
	V_PHASE_DISC	The phase rotation direction commands are not complementary after more than 2 s
Mimic-based UMI outputs	V_MIMIC_OUT_1 to V_MIMIC_OUT_16	Variables that may be assigned to the mimic diagram symbol outputs and that change values when control orders are transmitted from the mimic-based UMI
	V_MIMIC_LOCAL V_MIMIC_TEST, V_MIMIC_REMOTE	Position of the key on the mimic-based UMI

Output variables

Type	Syntax	Example, meaning
Outputs to matrix	V1 to V20	They may initiate LEDs, logic outputs or messages in the matrix.
Protection function inputs	Pnnnn_x_y nnn: ANSI code x: unit y: data	P50N/51N_6_113: Protection 50N/51N, unit 6, inhibit order. The protection function output data numbers are given in the characteristics of each function and may be accessed using the data input assistance tool.
Predefined control function inputs	V_TRIPCB	Tripping of circuit breaker (contactor) by the switchgear control function. Used to adapt tripping and recloser activation conditions.
	V_INHIBCLOSE	Inhibition of circuit breaker (contactor) closing by the switchgear control function. Used to add circuit breaker (contactor) inhibit closing conditions.
	V_CLOSECB	Closing of circuit breaker (contactor) by the switchgear control function. Used to generate a circuit breaker (contactor) close order based on a particular condition.
	V_SHUTDOWN	Shutdown of genset prime mover. Used to adapt cases of genset shutdown
	V_DE_EXCITATION	Generator de-excitation Used to adapt cases requiring generator de-excitation
	V_FLAGREC	Data saved in disturbance recording. Used to save a specific logic state in addition to those already present in disturbance recording.
	V_RESET	Sepam reset
	V_CLEAR	Clearing of alarms present
	V_INHIBIT_RESET_LOCAL	Inhibition of Sepam reset by UMI Reset key.
	V_CLOSE_NOCTRL	Breaking device closing enabled without synchro-check. Used to adapt the Switchgear control function
	V_TRIP_STP1 to V_TRIP_STP4	Tripping of capacitor steps 1 to 4. Used to adapt the Capacitor step control function
	V_CLOSE_STP1 to V_CLOSE_STP4	Closing of capacitor steps 1 to 4. Used to adapt the Capacitor step control function
	V_TRANS_ON_FLT	Automatic transfer order on fault. Used to adapt automatic transfer
	V_TRANS_STOP	Stopping automatic transfer Used to adapt automatic transfer
	V_DLG_START	Data log function activation
	V_MSR_START	Start an MSR

Local variables, constants

Type	Syntax	Example, meaning
Local variables stored	VL1 to VL31	The values of these variables are saved in the event of an auxiliary power outage and are restored when Sepam starts again.
Local variables not stored	VV1 to VV31	The values of these variables are not saved in the event of an auxiliary power outage. They are assigned the value of 0 when Sepam starts.
Constants	K_1, K_0	Value not modifiable K_1: always 1 K_0: always 0

Logic equations

Processing in the event of auxiliary power outage
All the variables, with the exception of the variables VVx, are saved in the event of a Sepam auxiliary power outage. The states of the variables are restored when the power is recovered, allowing the states produced by **LATCH**, **SR** or **PULSE** type memory operators to be saved.

Special cases
■ brackets must be used in expressions that comprise different **OR, AND, XOR or NOT** operators:
□ **V1 = VL1 AND I12 OR P27/27S_1_1. //** expression incorrect
□ **V1 = (VL1 AND I12) OR P27/27S_1_1. //** expression correct
□ **V1 = VL1 OR I12 OR P27/27S_1_1. //** expression correct
■ protection input/output variables (Pnnn_x_y) may not be used in the **LATCH** function
■ function parameters may not be expressions:
□ **VL3 = TON ((V1 AND V3), 300) //** expression incorrect
□ **VL4 = V1 AND V3**
□ **VL3 = TON (VL4, 300) //** correct.

Use limit
The number of operators and functions (**OR, AND, XOR, NOT, =, TON, TOF, SR, PULSE** is limited to 200.

Examples of applications

■ **latching of recloser permanent trip signal**
By default, this signal is of the pulse type at the recloser output. If required by operating conditions, it may be latched as follows:
LATCH (V1) // V1 may be latched
V1 = P79_1_204 // recloser "permanent trip" output.
V1 may then control a LED or output relay in the matrix.

■ **latching of a LED without latching the protection function**
Certain operating conditions call for the latching of indications on the front panel of Sepam, without latching of the tripping output O1.
LATCH (V1, V2) // V1 and V2 may be latched
V1 = P50/51_1_1 OR P50/51_3_1 // tripping, units 1 and 3 of protection 50/51
V2 = P50/51_2_1 OR P50/51_4_1 // tripping, units 2 and 4 of protection 50/51
V1 and V2 must be configured in the matrix to control 2 front panel LEDs.

■ **circuit breaker tripping if input I113 is present for more than 300 ms**
V_TRIPCB = TON (I113, 300).

■ **live line work (example 1)**
If work is underway with power on (indicated by input I205), the relay behavior is to be changed as follows:
1 – circuit breaker tripping by the instantaneous output of protection 50/51 unit 1 or 50N/51N unit 1 AND if input I205 is present:
V_TRIPCB = (P50/51_1_1 OR P50N/51N_1_1) AND I205
2 – Inhibit recloser:
P79_1_113 = I205

■ **live line work (example 2)**
The user wishes to inhibit protection functions 50N/51N and 46 by an input I204:
P50N/51N_1_113 = I204
P46_1_113 = I204

■ **validation of a 50N/51N protection function by logic input I210**
A 50N/51N protection function with a very low threshold must only initiate tripping of the circuit breaker if it is validated by an input. The input comes from a relay which gives a very accurate measurement of the neutral point current:
V_TRIPCB = P50N/51N_1_3 AND I210

■ **inhibition of circuit breaker closing if thermal alarm thresholds are overrun**
The temperature protection function 38/49T supplies 16 alarm bits. If one of the first three bits is activated (1 state), the user wishes to inhibit circuit breaker closing
V_INHIBCLOSE = P38/49T_1_10 OR P38/49T_2_10 OR P38/49T_3_10

■ **remote control order to inhibit protection 50/51 unit 1**
VL1=SR(TC63,TC64) // TC63 set inhibition, TC64 reset inhibition
P50/51_1_113 = VL1 // VL1 is stored in the event of an auxiliary power outage.

Customized functions using Logipam

The SFT2885 programming software (Logipam) can be used to enhance Sepam by programming specific control and monitoring functions.

Only the Sepam series 80 with a cartridge containing the Logipam SFT080 option can run the control and monitoring functions programmed by Logipam.

Operating principle

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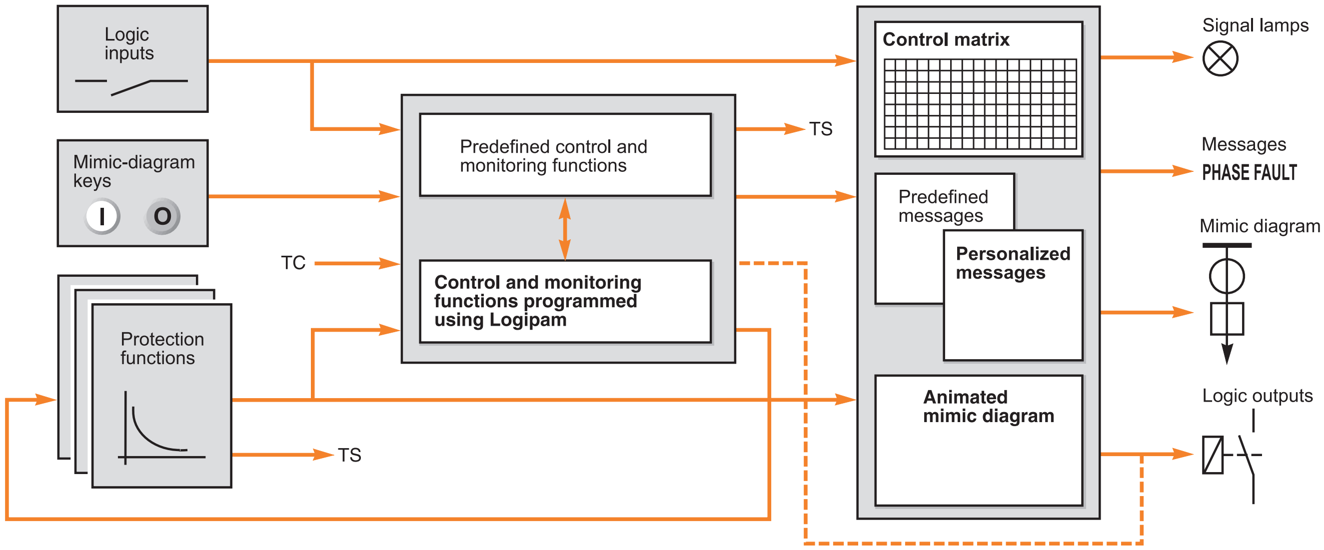
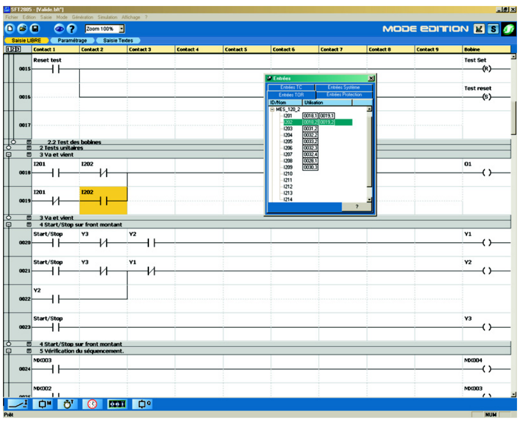


PE50257



SFT2885: Logipam programming software.

Logipam programming software

The Logipam SFT2885 programming software can be used to:
- adapt predefined control and monitoring functions
- program specific control and monitoring functions, either to replace the predefined versions or to create completely new functions, to provide all the functions required by the application.

It is made up of:
- a ladder-language program editor used to address all Sepam data and to program complex control functions
- a simulator for complete program debugging
- a code generator to run the program on Sepam.

The ladder-language program and the data used can be documented and a complete file can be printed.

Offering more possibilities than the logic-equation editor, Logipam can be used to create the following functions:
- specific automatic transfer functions
- motor starting sequences.

It is not possible to combine the functions programmed by Logipam with functions adapted by the logic-equation editor in a given Sepam.

The Logipam program uses the input data from:
- protection functions
- Ix logic inputs
- GOOSE logic inputs (Gx) available with the IEC 61850 protocol
- remote control orders
- local control orders transmitted by the mimic-based UMI.

The result of Logipam processing may then be:
- assigned to a logic output, directly or via the control matrix
- assigned to a LED or message via the control matrix
- transmitted by the communication link, as a new remote indication
- used by the predefined control and monitoring functions
- used to inhibit or reset a protection function.

Self-tests and fail-safe position

Presentation

The reliability of a device is the property that allows its users to have well-placed confidence in the service it delivers.

For a Sepam protection relay, operational reliability consists of ensuring the safety and availability of the installation. This means avoiding the following 2 situations:

■ Nuisance tripping of the protection

Continuity of the electrical power supply is as vital for a manufacturer as it is for an electricity distribution company. Nuisance tripping caused by the protection can result in considerable financial losses. This situation affects the availability of the installation.

■ Failure of the protection to trip

The consequences of a fault that is not eliminated can be catastrophic. For safety of operation, the protection relay must detect faults in the power supply as quickly as possible, using discrimination. This situation affects the safety of the installation.

Self-tests and monitoring functions

On initialization and cyclically during operation, Sepam runs a series of self-tests. These self-tests are designed to detect any failure in its internal and external circuits so as to ensure Sepam's reliability. These failures are classified into 2 categories, major failures and minor failures:

■ A major failure reaches the hardware resources used by the protection functions (program memory and analog input for example).

This type of failure risks resulting in failure to trip on a fault or nuisance tripping. In this case, Sepam must go into the fail-safe position as quickly as possible.

■ A minor failure affects Sepam's peripheral functions (display, communication except for ACE969-2 and ACE850).

This type of failure does not prevent Sepam from protecting the installation and providing continuity of service. Sepam then operates in downgraded mode.

The classification of failures into 2 categories improves both safety and availability of the installation.

The possibility of a Sepam major failure must be taken into account when selecting the trip command type to maximize availability or safety of the installation (see "Selecting the trip command" page 316).

In addition to the self-tests, the user can activate monitoring functions to improve the installation monitoring:

■ VT supervision (ANSI code 60FL)
■ CT supervision (ANSI code 60)
■ Trip circuit and closing circuit supervision (ANSI code 74)
■ Auxiliary power supply supervision

These functions send an alarm message to the Sepam display unit and a data item is automatically available to the communication to alert the user.

Self-tests and fail-safe position

Self-tests

The self-tests are run when Sepam is initialized and/or during its operation.

List of self-tests which place Sepam in the fail-safe position

Failures which have caused this are deemed to be major ones.

Function	Test type	Execution period
Power supply		
	Power supply presence	During operation
CPU		
	Embedded software	During operation
	Processor	On initialization and during operation
	RAM memories	On initialization and during operation
Program memory		
	Checksum	On initialization and during operation
Parameter memory		
	Checksum	On initialization
Analog inputs		
	Acquisition consistency	During operation
	Infinite gain	During operation
Logic outputs		
	Relay driver	On initialization and during operation
Connection		
	CCA630, CCA634, CCA671, CCT640	On initialization and during operation
	MES120	On initialization and during operation
	E Connector (phase voltage inputs, residual voltage and current inputs)	On initialization and during operation

List of self-tests which do not place Sepam in the fail-safe position

Failures which have caused this are deemed to be minor ones.

Function	Test type	Execution period
UMI		
	Module presence	On initialization and during operation
	Memory	On initialization
	Software	During operation
Analog output		
	Module presence	On initialization and during operation
Temperature inputs		
	Module presence	On initialization and during operation
Battery voltage		
	Minimum value check	During operation

Self-tests and fail-safe position

Fail-safe position

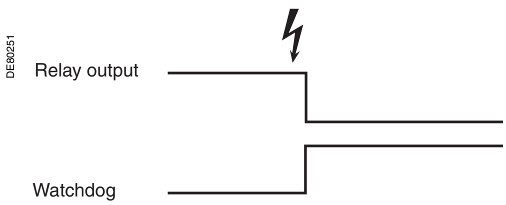
When Sepam is in working order, it runs self-tests continuously. Detection of a major failure places Sepam in the fail-safe position.

State of Sepam in the fail-safe position

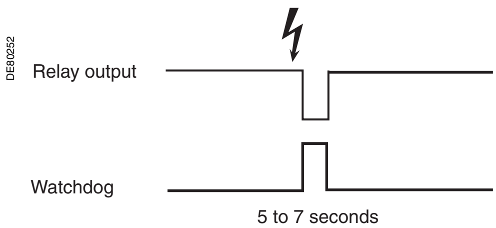
- All the output relays are forced to the idle state
- All protection functions are inhibited
- The watchdog output indicates failure (output in the idle state)
- A red LED on the Sepam front panel is on and a diagnostic message appears on the Sepam display unit (see "Local indication" page 300).

How Sepam deals with failures

- Minor failure: Sepam switches to downgraded operation.
The failure is indicated on the Sepam display unit and also by the communication. Sepam continues to protect the installation.
- Major failure: Sepam switches to the fail-safe position and attempts a restart during which it again runs its self-tests. There are 2 possible scenarios:
  - The internal failure is still present. It is a permanent failure. Intervention on Sepam is required. Only removing the cause of the failure, followed by de-energizing and then energizing Sepam, will allow the unit to exit the fail-safe position.
  - The internal failure is no longer present. It is a transient failure. Sepam restarts so that it can continue to protect the installation. Sepam has been in the fail-safe position for 5 to 7 s.



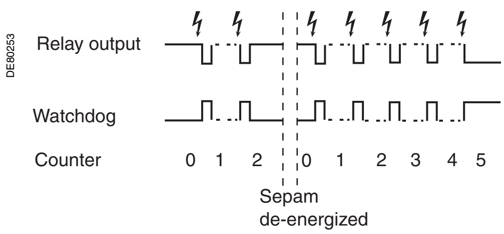
Permanent internal failure.



Transient internal failure.

Limiting the number of transient failure detections

Each time a transient internal failure appears, Sepam increments an internal counter. The fifth time the failure occurs, Sepam is placed in the fail-safe position. De-energizing Sepam reinitializes the failure counter. This mechanism can be used to avoid keeping a Sepam running that is subject to repeated transient failures.



Repeated transient internal failures.

Self-tests and fail-safe position

Selecting the trip command and examples of use

An analysis of the operational reliability of the whole installation should determine whether availability or safety of this installation should be prioritized if Sepam is in the fail-safe position. This information is used to determine the choice of trip command as outlined in the table below.

NOTICE

RISK OF UNPROTECTED INSTALLATION
Always connect the watchdog output to a monitoring device when the selected trip command does not result in the installation tripping when Sepam fails.

Failure to follow these instructions can result in equipment damage.

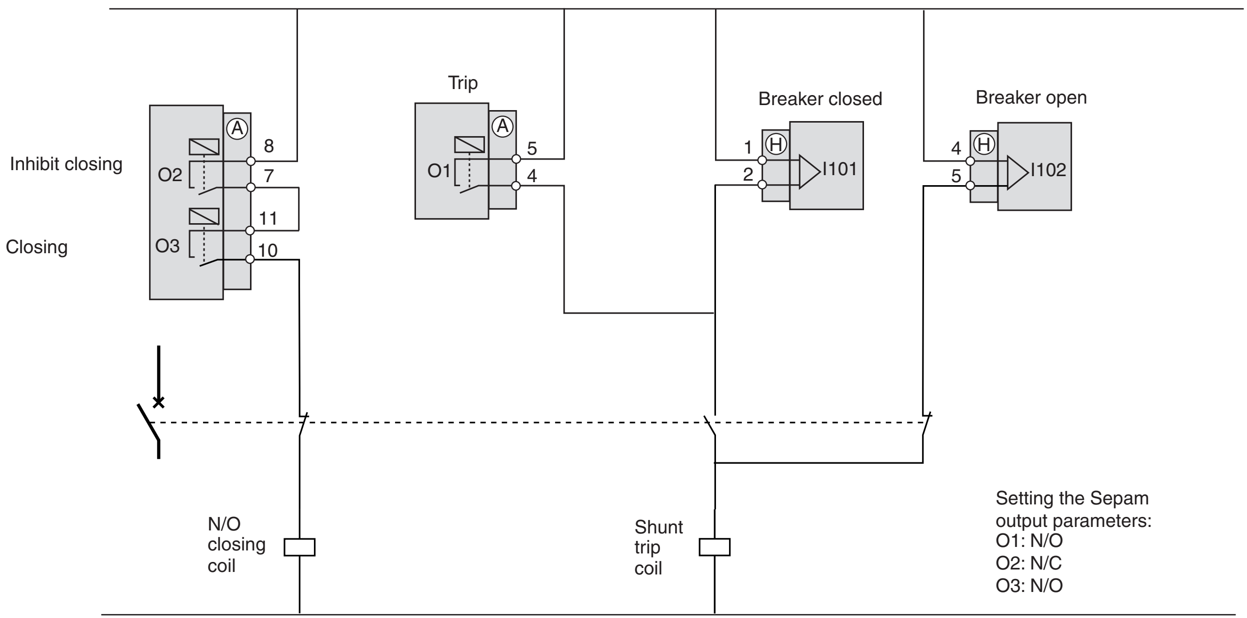
Selecting the trip command

Diagram	Control	Event	Trip	Advantage	Disadvantage
1	Shunt trip breaker or mechanical latching contactor	Sepam failure or loss of the auxiliary power supply	No	Availability of the installation	Installation not protected until remedial intervention (1)
2	Breaker with undervoltage trip coil (fail-safe)	Sepam failure or loss of the auxiliary power supply	Yes	Safety of the installation	Installation not available until remedial intervention
3	Breaker with undervoltage trip coil (not fail-safe)	Sepam failure	No	Availability of the installation	Installation not protected until remedial intervention (1)
		Loss of auxiliary power supply	Yes	Safety of the installation	Installation not available until remedial intervention
4	Contactor without coil latching (permanent order)	Sepam failure or loss of the auxiliary power supply	Yes	Safety of the installation	Installation not available until remedial intervention

***(1)** It is essential to use the watchdog, see the warning notice opposite.*

Example of use with shunt trip coil (diagram 1)

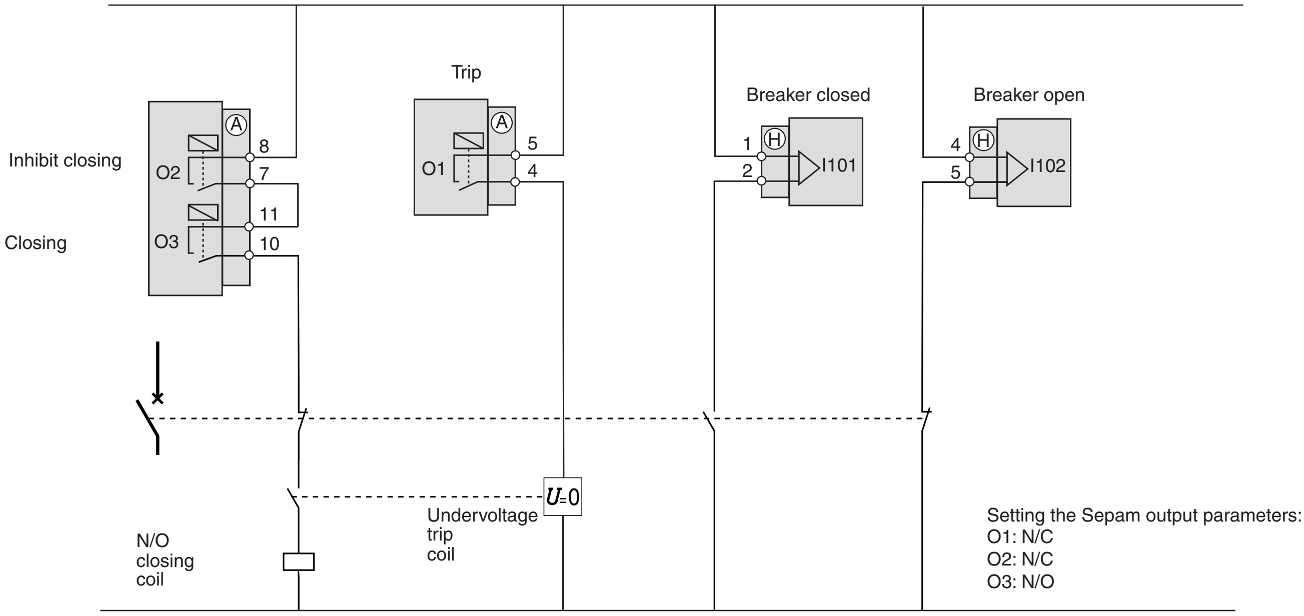
DE80254



Self-tests and fail-safe position

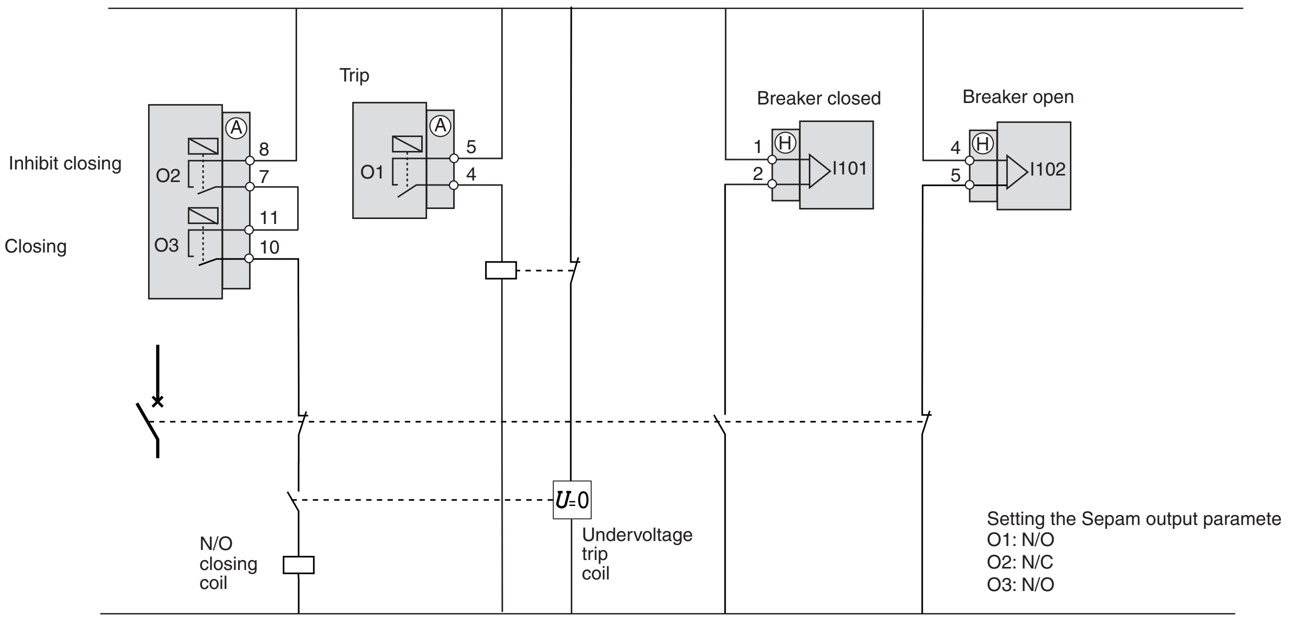
Example of use with undervoltage trip coil with fail-safe condition (diagram 2)

DE80255



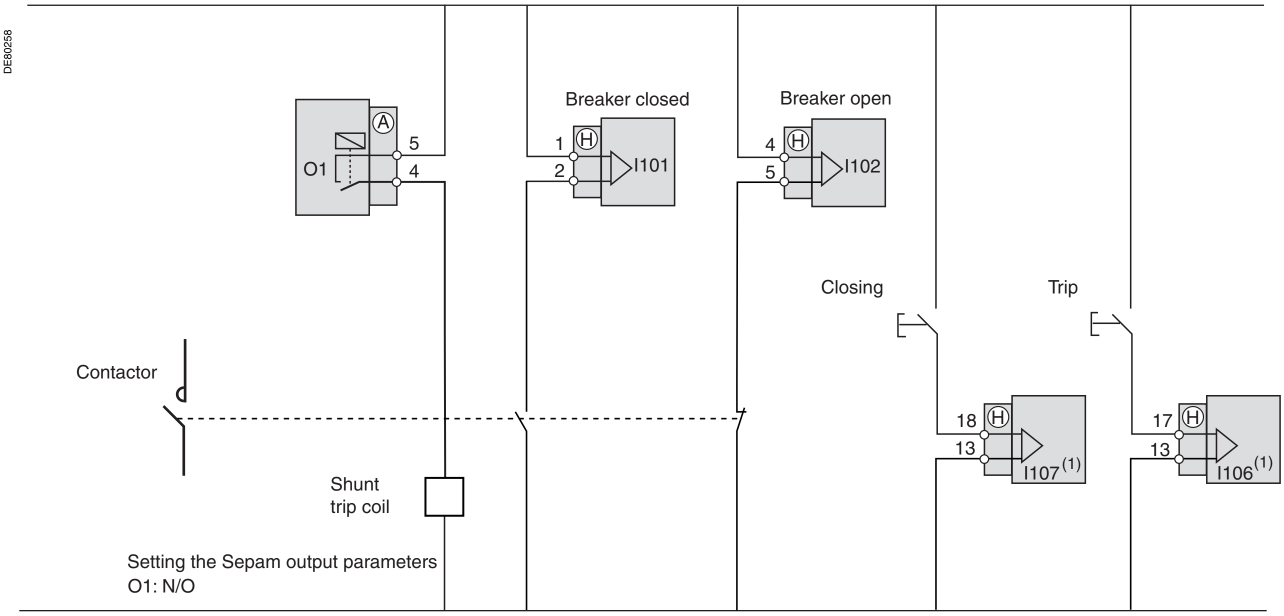
Example of use with undervoltage trip coil without fail-safe condition (diagram 3)

DE80256



Self-tests and fail-safe position

Example of use with contactor under permanent order command (diagram 4)



***(1)** Standard assignments, can be modified.*

Using the watchdog

The watchdog is extremely important in the monitoring system, as it indicates to the user that the Sepam protection functions are working correctly. When Sepam detects an internal failure, an LED flashes automatically on the Sepam front panel regardless of whether the watchdog output is connected correctly. If the watchdog output is not correctly connected to the system, this LED is the only way of knowing that Sepam has failed. We therefore strongly recommend connecting the watchdog output at the highest level of the installation so that an effective alarm is generated when necessary. For example, an audible alarm or flashing alarm lamp can be used to warn the operator.

Watchdog output status	No failure detected	Failure detected
Watchdog output connected correctly to the control system	The protection functions are in working order	■ The protection functions are not working. ■ Sepam is in the fail-safe position. ■ The Sepam alarm LED flashes. ■ The watchdog output activates a system alarm. ■ The operator is warned that he needs to intervene.
Watchdog output not connected	The protection functions are in working order	■ The protection functions are not working. ■ Sepam is in the fail-safe position. ■ The Sepam alarm LED flashes. ■ The need of maintenance is detected only if an operator controls the front panel of the digital relay.

Notes

4

Notes

4

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