MULTIFUNCTION PROTECTION

INGEPAC EF

User Manual

Ingeteam

UME_INGEPAC_EF_eng Rev.: A (07/11)

1. GENERAL DESCRIPTION

1.1 FUNCTIONAL DESCRIPTION

Table 1 shows the features available in each of the different models.

Table 1 Functions depending on model

	MD1B	MD0B	MD2B	MD3B
Common protection functions				
SOFT Switch onto fault			√	
27 Undervoltage	√	√	√	√
59 Overvoltage	√	√	√	√
59N Zero sequence overvoltage	√	√	√	√
47 V2 overvoltage protection	√	√	√	
Frequency (81M/m)	√	√	√	√
Frequency rate of change (81R)	√	√	√	√
3x50/51 (67)	√	√	√	√
50N/51N (67N)	√	√	√	√
50NS/51NS. (67NS) Sensitive neutral overcurrent		√	√	√
50G/51G. Grounding overcurrent		√	√	
67NA Isolated neutral directional		√	√	
67NC Compensated neutral directional		√	√	
46TOC (67Q), 46IOC(67Q)	√	√	√	√
46FA Open phase	√	√	√	√
50CSC Second harmonic restraint	√	√	√	√
37 Undercurrent		√	√	
49 Thermal image	√	√	√	√
32 Power units	√	√	√	√
78 Phase shift	√			
Field loss	√			
HCL	√	√	√	√
Cold load pickup	√	√	√	√
50V/51V monitoring	√	√	√	
87N Restricted earth		√	√	
Teleprotection				
Teleprotection (67/67Q)			√	
Monitoring Units				
68ZC Load encroachment			√	
68FF Fuse failure	√	√	√	√
Fault locator				
Fault locator for phase to ground lines		√	√	√
Breaker Monitoring				
k12 breaker monitoring per pole	√	√	√	√
Closing and trip circuit monitoring	√	√	√	√
Excessive number of trips	√	√	√	√
Open pole / Faulted line detector	√	√	√	√
Breaker status logic	√	√	√	√
Pole discordance			√	
Breaker				
50BF Basic breaker failure	√	√	√	√
Automatisms				
Synchronism	√	√	√	√
Recloser	√	√	√	√
Frequency recloser	√	√	√	√
Data acquisition functions				
Phase and neutral current measurements	√	√	√	√
Phase and synchronism voltage measurements	√	√	√	√
Real and reactive power	√	√	√	√
Real and reactive energy	√	√	√	√
Historical event, protection event and fault recording	√	√	√	√

Breaker monitoring	√	√	√	√
Oscillography	√	√	√	√
Historical reports	√	√	√	√

1.2 MODEL ENCODING

INGEPAC EF MODEL

M D - □ - □ - □ - □ - □ □ □ □ □ □ - □ □ - □ - □ □ □ □ □ □ A

MODEL	
67, 67N, 67SN, 67NA, 67NC, 50/51, 50N/51N, 50SN/51SN, 50G/51G, 67Q, 46BC, 37, 49, 59, 27, 59N, 47, 81O/u, 81R, 32, CLP, 50V/51V, 87N, 68FF, HCL, 25, 79, 79(81), 74TC/CC, 50BF, Fault Locator	0
67, 67N, 50/51, 50N/51N, 67Q, 46BC, 49, 59, 27, 59N, 47, 81O/u, 81R, 32, 40, 78, CLP, 50V/51V, 87N, 68FF, HCL, 25, 79, 79(81), 74TC/CC, 50BF	1
67, 67N, 67SN, 67IN, 67CN, 50/51, 50N/51N, 50SN/51SN, 50G/51G, 67Q, 46BC, 37, 49, 59, 27, 59N, 47, 81O/u, 81R, 32, CLP, 50V/51V, 87N, 68FF, 68ZC, HCL, SOTF, 25, 79, 79(81), POTT (67/67Q), 74TC/CC, 50BF, Fault Locator	2
67, 67N, 67SN, 50/51, 50N/51N, 50SN/51SN, 67Q, 46BC, 49, 59, 27, 59N, 81O/u, 81R, 32, CLP, 68FF, HCL, 25, 79, 79(81), 74TC/CC, 50BF, Fault Locator	3

EXTENDED CONTROL FUNCTIONS	
No	A
Yes	B

HOUSING		
1/2 chassis 19" 5U with configurable keyboard		A
1/2 chassis 19" 5U with predefined keyboard	Note 1	B
Chassis 19" 4U with configurable keyboard		C
Chassis 19" 4U with predefined keyboard	Note 1	D

POWER SUPPLY MODULE	
Single PS 85-300 Vdc+ 6DI 125 Vdc + 4DO	A
Single PS 85-300 Vdc+ 6DI 220 Vdc + 4DO	B

REAR SERIAL COMMUNICATION PORTS		
A	GFO	COM-1
B	PFO	COM-2
C	RS232C	COM-3
D	RS485	COM-4
X	No port	COM-5
		COM-6

REAR ETHERNET COMMUNICATION PORTS		
E	GFO	ETH-1
F	RJ45	ETH-2
X	No port	

TERMINALS		
Pyn type standard terminals		A
Closed terminals	Note 2	B
Closed terminals for analog inputs and pin type standard terminals for the rest		C

I/O BOARD CONFIGURATION BOARD SELECTION		(Note 3)
A	No board	Board 2 (Note 4)
B	11 DI (24V dc) + 9 DO	Board 3
C	11 DI (48 Vdc) +9 DO	Board 4 (Note 5)
D	11 DI (125 Vdc) + 9 DO	Board 5 (Note 5)
E	11 DI (220 Vdc) + 9 DO	Board 6 (Note 5)
F	32 DI (24 Vdc)	Board 7 (Note 5)
G	32 DI (48 Vdc)	
H	32 DI (125 Vdc)	
I	32 DI (220 Vdc)	
J	16 DI (24Vdc)-8 independent DO	
K	16 DI (48 Vdc)-8 independent DO	
L	16 DI (125 Vdc)-8 independent DO	
M	16 DI (220 Vdc)-8 independent DO	
N	16 DI (24 Vdc)- 16DO	
O	16 DI (48Vdc)- 16 DO	
P	16 DI (125 Vdc)- 16DO	
Q	16 DI (220 Vdc)- 16DO	
R	16 DI (24Vdc)-8 AI	
S	16 DI (48Vdc)-8 AI	
T	16 DI (125 Vdc)-8 AI	
U	16 DI (220 Vdc)-8 AI	
V	16 DI (24 Vdc)- 8 AI (4 isolated)	
W	16 DI (48Vdc)- 8 AI (4 isolated)	
X	16 DI (125 Vdc)- 8 AI (4 isolated)	
Y	16 DI (220 Vdc)- 8 AI (4 isolated)	

Note 1: Only selectable with extended control functions.
Note 2: The terminals for the power supply inputs are pyn type standard terminals.
Note 3:To know the order of the boards in the rack, consult the number of the terminals on the rear views of each chassis.
Note 4: In the 19" chassis, board 2 only available with pyn type standard terminals.
Note 5: Only available for 19" chassis.

1.3 USER INTERFACE

Local. The front board is equipped with:

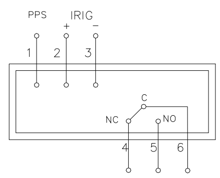
- 10-digit numerical keyboard with decimal point, plus R key
- 4 scroll keys: ↑ (Up), ↓ (Down), ← (Left), → (Right)
- 3 general keys ↵ (Enter), ESC (Escape), MENU
- Function keys depending on the model:
  - 5 function keys (I, O, DES, SEL, INF)
  - 7 function keys (I, O, F1...F5)
  - 12 function keys (I, O, DES, SEL, INF, F1...F7)
  - 16 function keys (I, O, F1...F14)
- 19 fully assignable LEDs
- 1 unit operation LED
- USB 2.0 front port for downloading reports and loading CID
- Front RJ45 port for communications

1.4 INTERCONNECTIONS

Interconnections depend on the modules selected. The connections associated to each of the modules are indicated, and thus the diagram will depend on the modules installed.

1.4.1 CPU

Figure 1 3-contact relay and IRIG-B



1.4.2 Power supply

The two options are a redundant power supply and a simple power supply with inputs/outputs.

Figure 2 Simple power supply

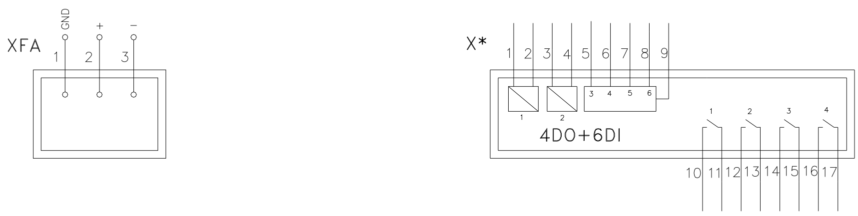


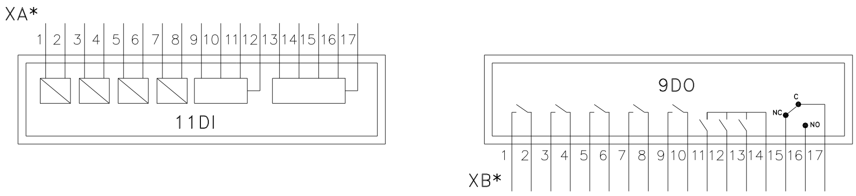
Figure 3 Double power supply

1.4.3 Input/output cards

The I/O modules available are:

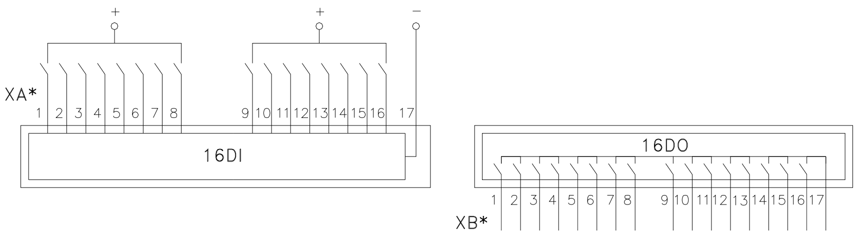
- Module 1 (Figure 4): Equipped with 11 digital inputs and 9 digital outputs grouped as follows:
  - Inputs: 4 independents + 3 with a common point + 4 with a common point.
  - Outputs: 5 independents + 3 with a common point + 1 switched (3 contacts).

Figure 4 Module 11 digital inputs and 9 digital outputs



- Module 2 (Figure 5): Equipped with 16 digital inputs and 16 digital outputs grouped as follows:
  - Inputs: 16 with a common point.
  - Outputs: 16 with a common point.

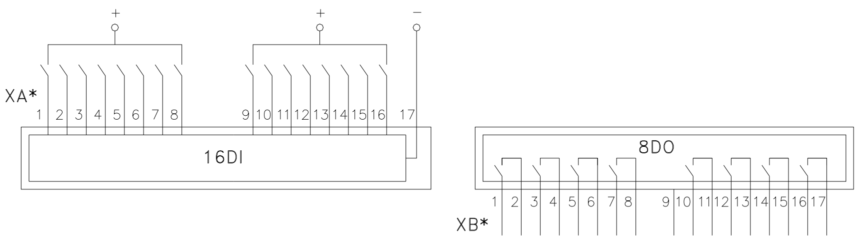
Figure 5 Module 16 digital inputs and 16 digital outputs



Module 3 (Figure 6): Equipped with 16 digital inputs and 8 digital outputs grouped as follows:

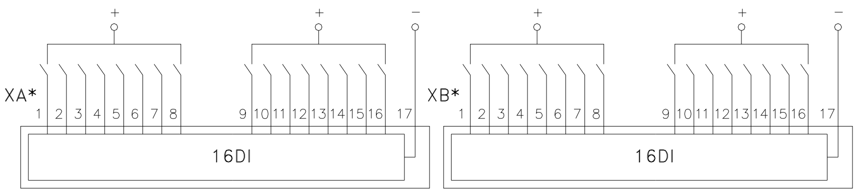
- Inputs: 16 with a common point.
- Outputs: 8 independent.

Figure 6 Module 16 digital inputs and 8 digital outputs



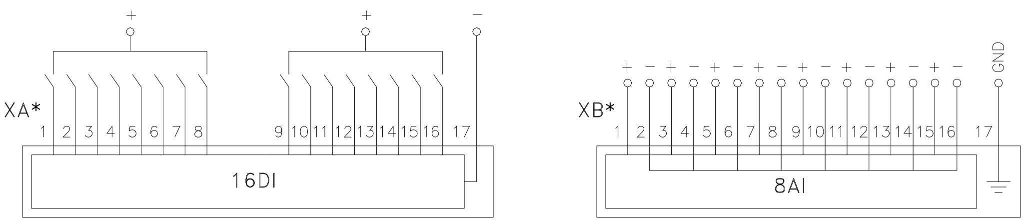
- Module 4 (Figure 7): Equipped with 32 digital inputs grouped as follows:
  - Inputs: 16 with a common point + 16 with a common point.

Figure 7 Module 32 inputs



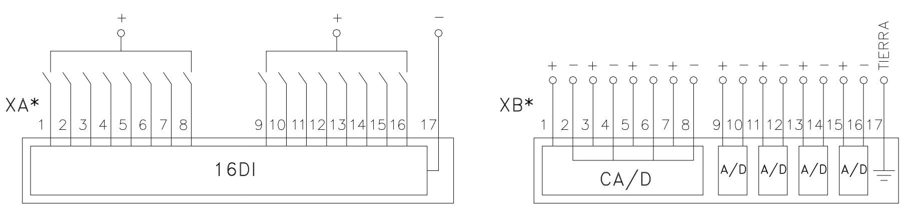
- Module 5 (Figure 8): Equipped with 16 digital inputs and 8 analogue inputs grouped as follows:
  - Inputs: 16 with a common point.
  - Analogue: 8 independent.

Figure 8 Module with 16 digital inputs and 8 analogue inputs



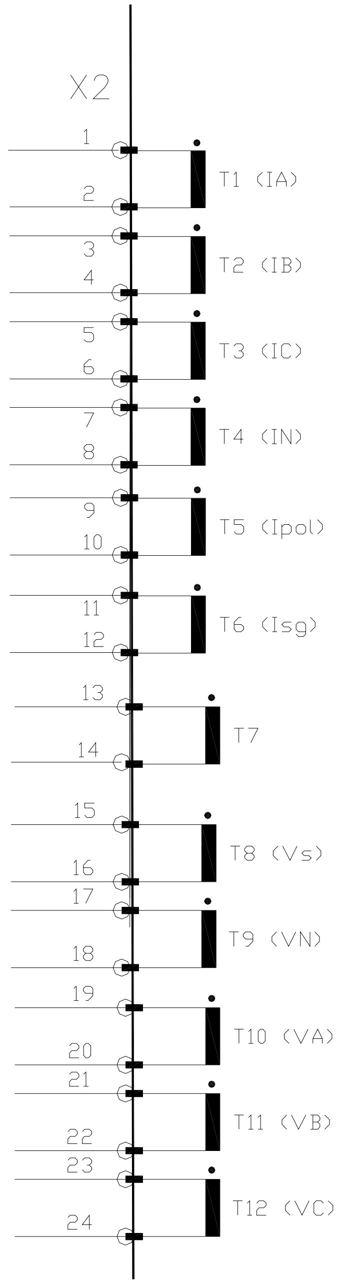
- Module 6 (Figure 9): Equipped with 16 digital inputs and 8 analogue inputs (4 isolated) grouped as follows:
  - Inputs: 16 with a common point.
  - Analogue: 8 independent.

Figure 9 Module with 16 digital inputs and 8 analogue inputs (4 isolated)



1.4.4 Analogue inputs

The following diagram shows the configuration of the analogue inputs:



1.4.4.1 Wiring diagrams

The following figures show different interconnection options for the analogue inputs, in accordance with the available inputs.

Figure 10 Wiring diagram Iphase, In, Ins, Ipol, Vphase, Vsyn

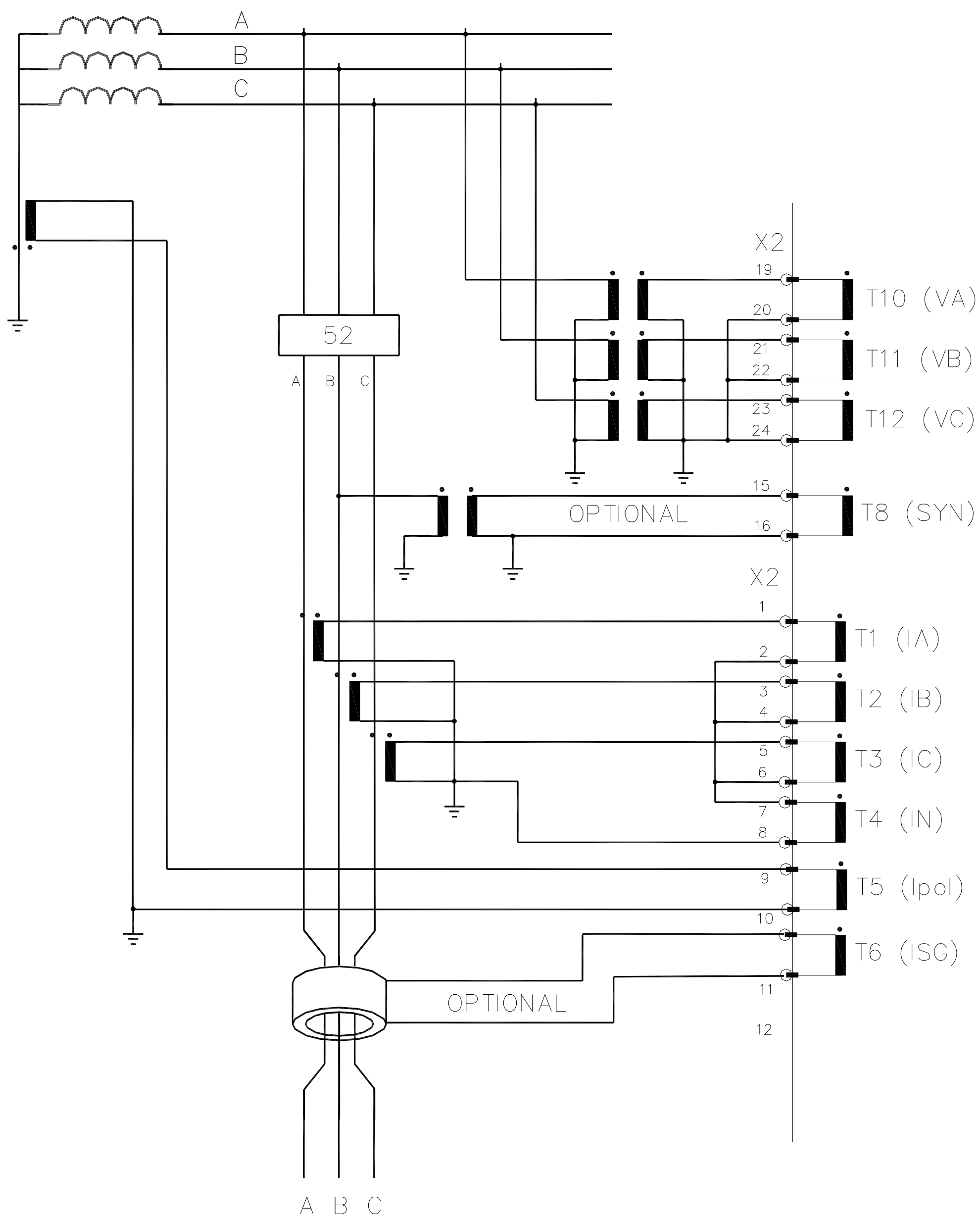


Figure 11 Wiring diagram Iphase, In, Ins, Vphase, Vsyn

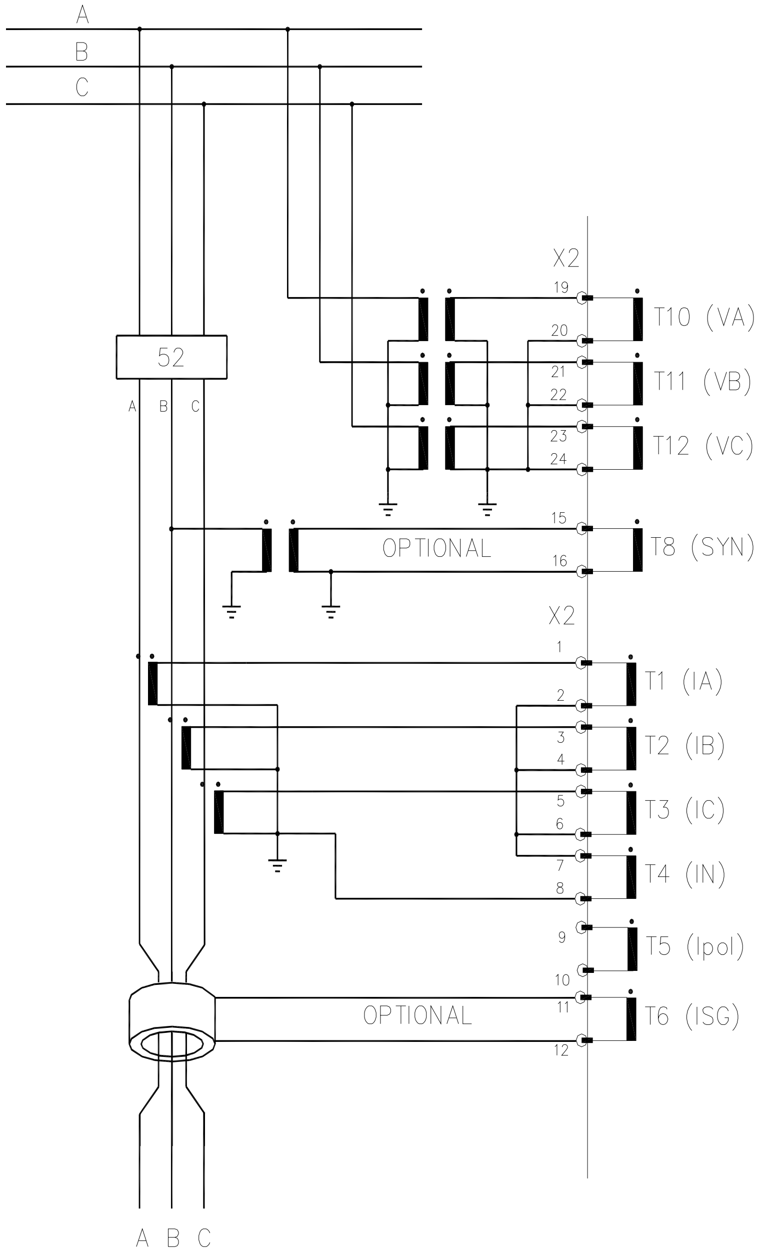


Figure 12 Wiring diagram Iphase, In, Ins, Ipol, Vphase, V0 and Vsyn

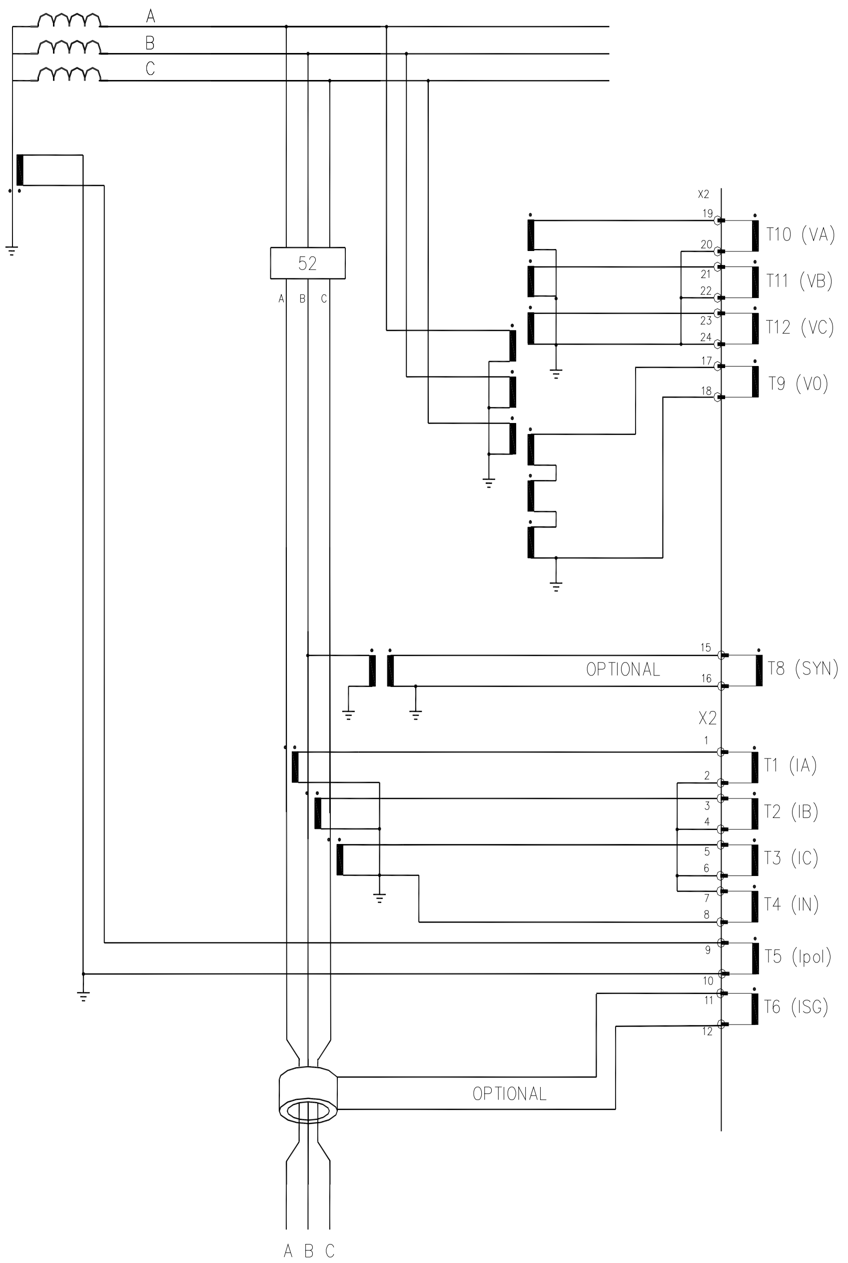
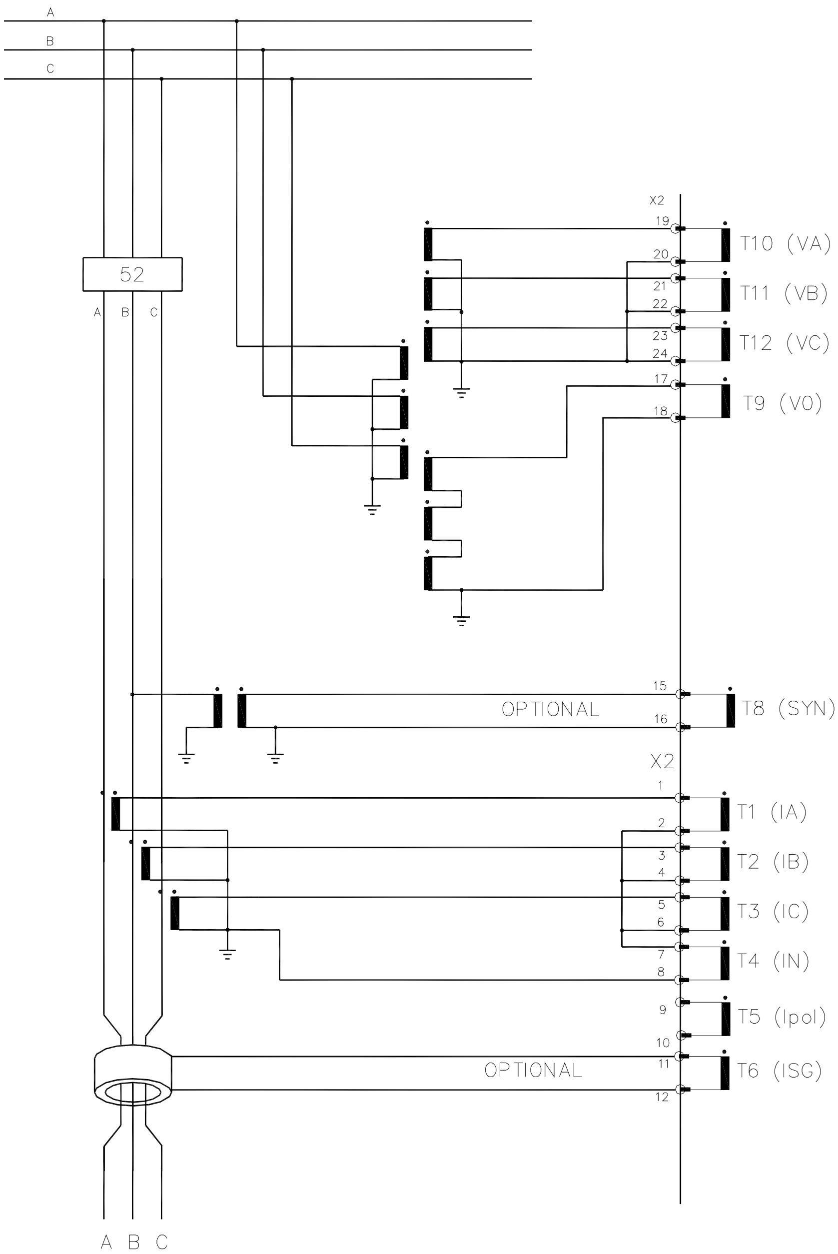


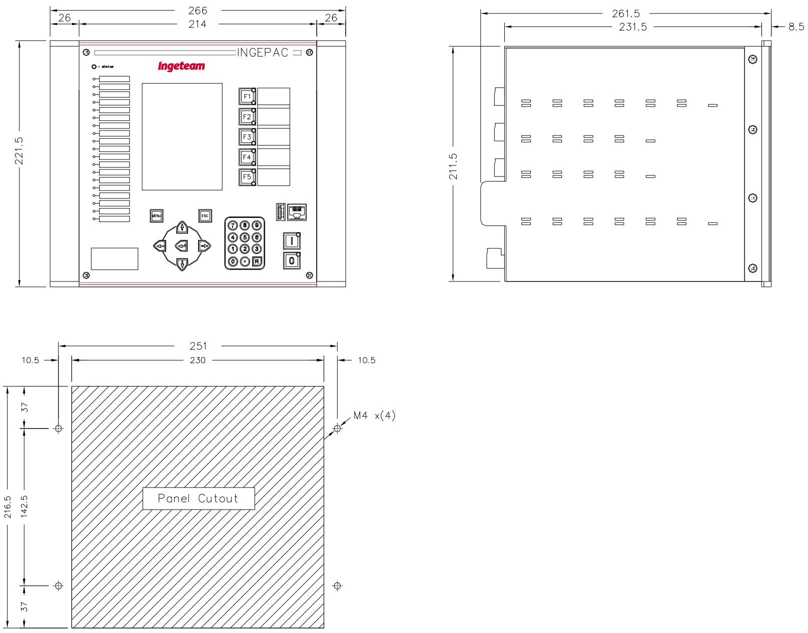
Figure 13 Wiring diagram Iphase, In, Ins, Vphase, V0 and Vsyn



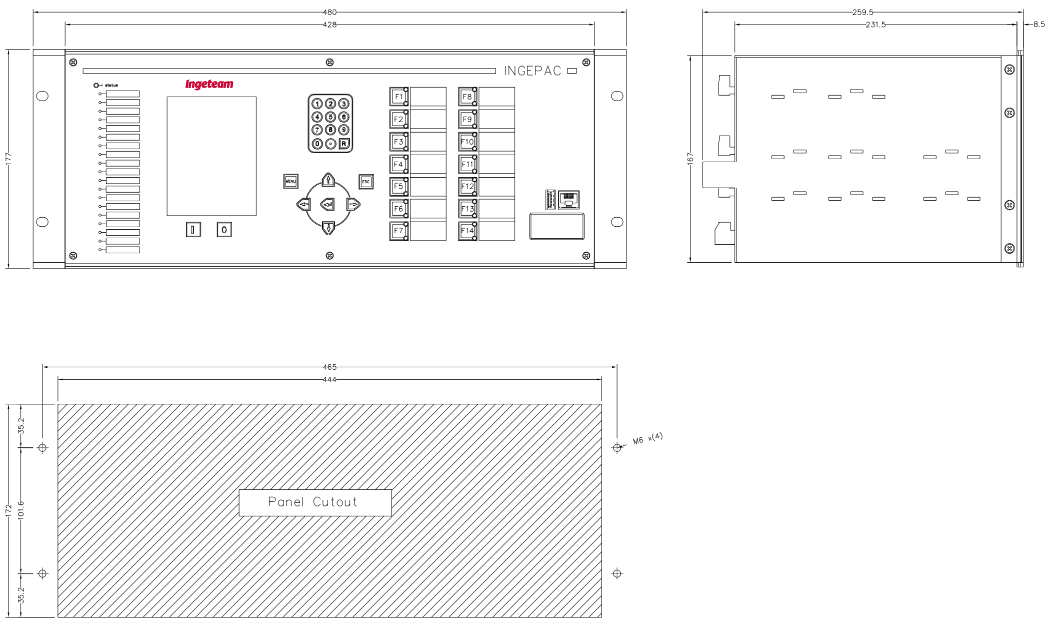
2. HARDWARE

2.1 CONSTRUCTION FEATURES

2.1.1 Half chassis (½ 19”)



2.1.2 19” chassis



2.2 REAR TERMINALS

The rear section will vary in accordance with the options selected for the unit. The following figures show various possible configurations.

2.2.1 Configuration options

The rear section options may vary depending on the options selected:

- Power supply unit. There are two options available:
  - Simple with inputs/outputs. Equipped with a 3-contact terminal with power supply with screw and a 17-contact terminal with screw (Figure 14).
  - Redundant. Equipped with two 3-contact terminals for each of the power supplies.
- Inputs/outputs cards. All the input/output modules have two 17-contact terminals with screw.
- CPU. Equipped with a 6-contact terminal with screw for the digital output of 3 contacts and the IRIG-B inputs. Equipped with different Ethernet and standard communications module options (Figure 1).
- Analogue. Equipped with two 12-contact terminals with screw.
- Communications. To choose between:
  - Ethernet: RJ45 and G.F.O.
  - Standard: RS232, RS485, G.F.O. and P.F.O.

Pin type or closed type terminals may be chosen for the analogue and input/output terminals.

2.2.2 Half chassis (½ 19”)

Different options which modify the view of the rear section may be selected (from top to bottom):

- Simple/redundant power supply
- 1 or 2 I/O modules
- Communication ports in the CPU
- Choose between analogue card, I/O module or nothing

Figure 14 shows rear section with the options:

- Simple power source with inputs/outputs
- 2 input/output cards
- CPU with communication ports:
  - Ethernet GFO + RJ45
  - Standard RS232+RS485+GFO+PFO
- Analogue card with up to 12 transformers

Figure 14 Rear section with analogue

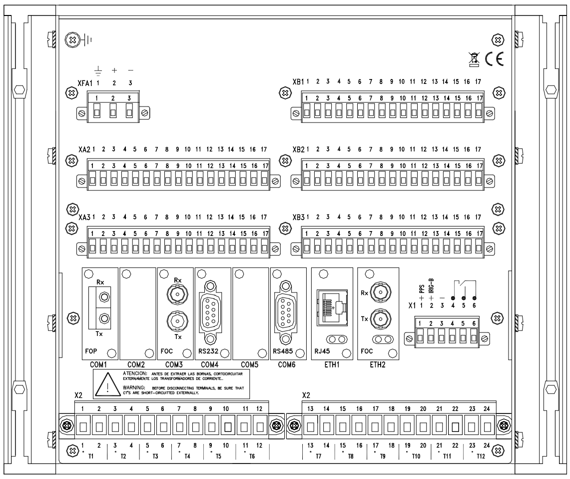
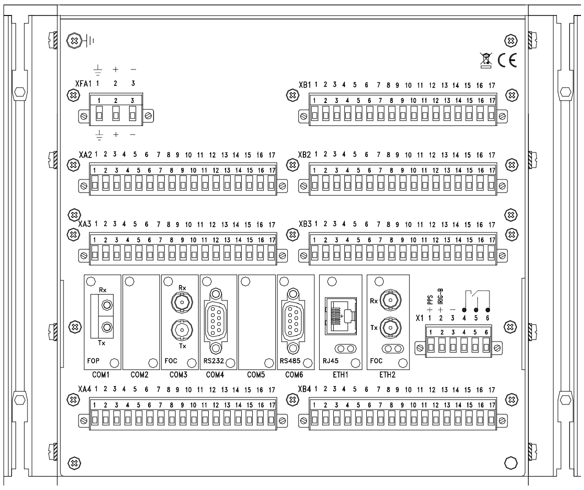


Figure 15 Rear section without analogue



2.2.3 19” chassis

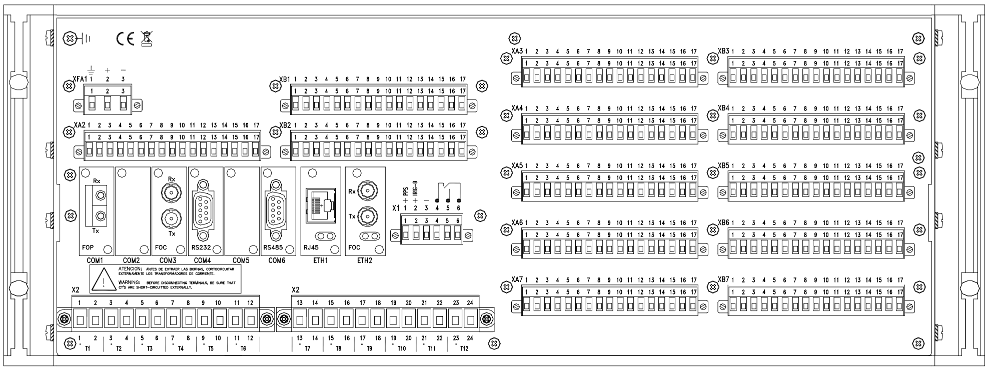
Different options which modify the view of the rear section may be selected (from top to bottom and left to right):

- Simple/redundant power supply
- 1 or no I/O modules
- Communication ports in the CPU
- Choose between analogue card, I/O module or nothing
- Number of I/O modules

In Figure 16 the next options can be seen:

- Simple power source with inputs/outputs
- 5 input/output cards
- CPU with communication ports:
    - Ethernet GFO + RJ45
    - Standard with 3 RS232 + 2 GFO + PFO
- Analogue card with up to 12 transformers

Figure 16 Rear section with analogue and simple source



2.3 FRONT INTERFACE

2.3.1 Half chassis (½ 19”)

There are two half-chassis front options (½ 19” and 5U):

- Configurable functional keys (Figure 17)
- Fixed functional keys (Figure 18).

The front interfaces are equipped with:

- Graphic display
- 19 general use LEDs with interchangeable labels
- 1 2-colour unit status LED
- Numeric keypad
- 7 operational keys
- Ethernet communication
- Master USB communication
- Depending on the model, the following are available:
  - 5 functional keys for selecting with interchangeable labels + 2 operational keys
  - 3 fixed function keys + 2 operational keys.

Figure 17 Configurable functional keys

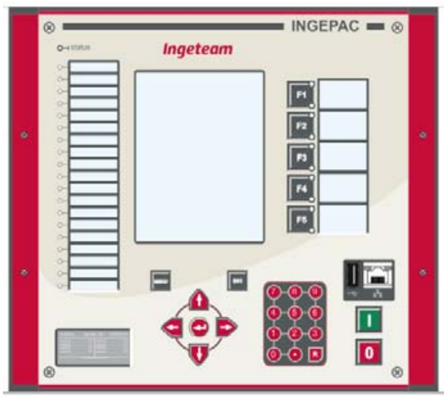
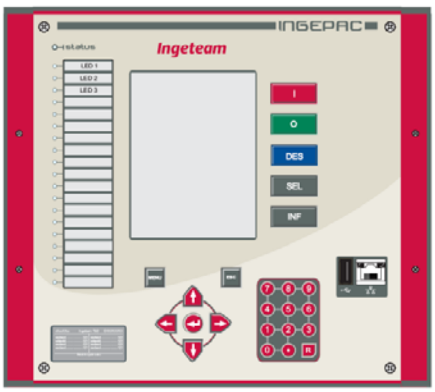


Figure 18 Fixed functional keys



2.3.2 19” chassis

There are two 19” and 4U chassis front options:

- Configurable functional keys (Figure 19)
- Fixed functional keys (Figure 20)

The front interfaces are equipped with:

- Graphic display
- 19 general use LEDs with interchangeable labels
- 1 2-colour unit status LED
- Numeric keypad
- 7 operational keys
- Ethernet communication
- Master USB communication
- Depending on the model, the following are available:
  - 14 functional keys for selecting with interchangeable labels + 2 operational keys
  - 3 fixed function keys + 2 operational keys + 7 functional keys with interchangeable labels for selecting.

Figure 19 Configurable functional keys

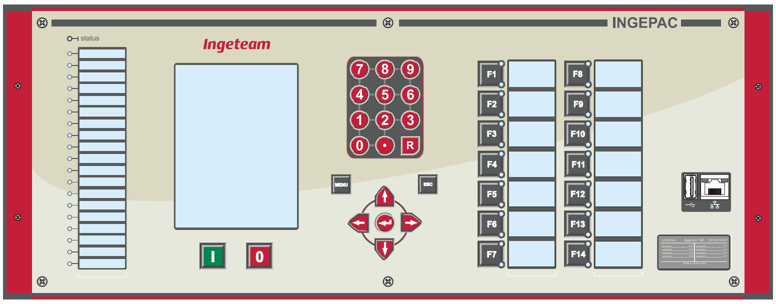
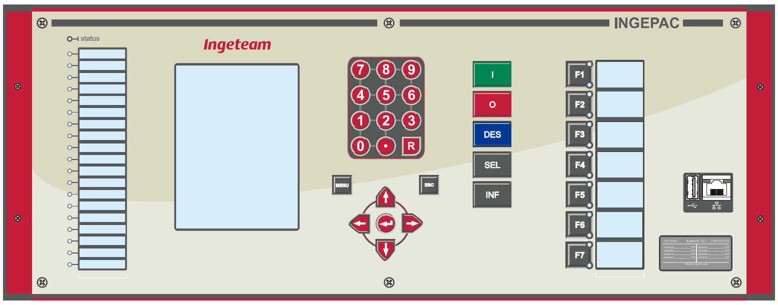


Figure 20 Fixed functional keys



2.4 TECHNICAL CHARACTERISTICS

2.4.1 Power supply voltage

125 Vdc models: 110Vdc-20% up to 250Vac + 10%:

- Operating range:
  - Direct: 85Vdc up to 300Vdc
  - Alternating: 85Vac up to 265Vac
- Burden. Depends on the cards connected.
  - 20W + 0,7W for each relay activated

2.4.2 Digital outputs

Independent standard and trip outputs:

- The characteristics of the independent contact outputs are as follows:
  - Permanent current: 8 A at 25ºC
  - Make: 30 A 1sec
  - Connection capacity 2500W at 250Vdc
  - Trip or Close capacity:

	200Vdc	125Vdc	48Vdc
With resistive load	1.0A	1.5A	2.0A
With inductive load L/R=40ms	0.7A	1.0A	1.5A

  - Operating time: 5ms activation and 8ms deactivation

Signal outputs:

- The characteristics of the 3-contact switched, common point signal outputs are:
  - Permanent current: 5 A at 25ºC
  - Make:
    - 30 A ½ sec.
    - 20 A 1 sec.
  - Trip or Close capacity:

	200Vdc	125Vdc	48Vdc
With resistive load	0.2A	0.4A	1.0A
With inductive load L/R=40ms	0.1A	0.2A	0.5A

  - Operating time: 8ms activation and deactivation

The compliance of the common point outputs is the same as that of the independent outputs. However, due to sharing a common point, only 2 relays can be activated simultaneously.

2.4.3 Digital inputs

The input burden is lower than 3mA at nominal voltage.

The inputs do not have polarity.

They have a fixed range with 4 nominal voltage options:

Rated V	Characteristics
24Vdc	Not activated below 9 Vdc. Activated above 12 Vdc. Maximum voltage 72 Vdc
48Vdc	Not activated below 32 Vdc. Activated above 37 Vdc. Maximum voltage 72 Vdc
125Vdc	Not activated below 82 Vdc. They are activated above 87 Vdc. Maximum voltage 300 Vdc
250Vdc	Not activated below 165 Vdc. Activated above 172 Vdc. Maximum voltage 300 Vdc

2.4.4 IRIG-B input and PPS

- Equipped with an input for synchronization by GPS, using IRIG-B time codes (Figure 21)
- Demodulated input (TTL levels).
- Cable type: 2-wire, shielded
- Insulation: 2000 V

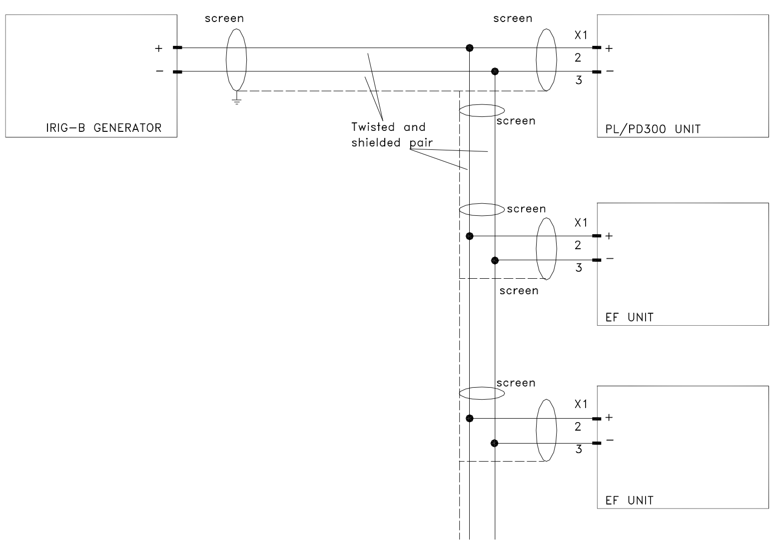
The input circuit is a 390 ohm serial resistance with an opto-isolator; for a 5 V signal, the approximate burden is 10 mA.

The number of units that can be connected in parallel to a generator depends on the output current supply capacity; a typical value is 70 mA, which would enable the connection of 6 units (although the length and the type of cable can also influence). The cable must be shielded and twisted.

There is a pulse per second (PPS) input for synchronization:

- Demodulated input (TTL levels).
- Cable type: 2-wire, shielded
- Insulation: 2000 V

Figure 21 Connection example



2.4.5 Current and voltage circuits

Phases, neutral and polarization. Single rated current 1/5 A.

- Measurement range: 0.02A to 200A.
- Thermal capacity
  - Permanent 20 A
  - Short duration 50 A (10 sec.)
    500 A (1 sec.)
  - Very short duration 1250 A (half cycle)
- Burden at In= 5 A <0.2VA
- Burden at In= 1 A <0.02VA

Sensitive neutral: Single rated current 0.025/1 A.

- Measurement range: 0.01A to 10A.
- Thermal capacity
  - Permanent 20 A
  - Short duration 50 A (10 sec.)
    500 A (1 sec.)
- Burden at In= 0.025 A <0.015 VA
- Burden at In= 1 A <0.02VA

Voltage:

- Measurement range: 1V to 200V.
- Rated voltages: 63.5/120 Vac
- Thermal capacity
  - Permanent 2 Un
  - Short duration 5 Un (1 sec.)
    3.5 Un (1 min)
- Burden at 63.5 V <0.015 VA
- Burden at 100 V <0.03 VA

2.4.6 Front communication

Ethernet via RJ45 cable

- RJ45 connector (female)
- Cable type: Shielded
- Cable length: 100 m maximum
- Baud rate: 10/100 Mb.
- Insulation 500V

USB

- USB 2.0 compatible version
- Master operating mode
- Speed: 480Mbps (high-speed), 12Mbps (full-speed) or 1.5Mbps (low-speed)
- Insulation 500V

2.4.7 Rear communications

2.4.7.1 Ethernet communication

Ethernet via RJ45 cable

- RJ45 connector (female)
- Cable type: Shielded
- Cable length: 100 m maximum
- Baud rate: 10/100 Mb.
- Insulation 500V

Ethernet via glass optical fiber

- ST connector
- Wavelength: 1300nm
- Permitted attenuation 8 db with glass fiber
- Multimode glass optical fiber: 62.5 /125 µm
- Maximum distance: 1.5km

2.4.7.2 Standard communications

Glass optical fiber

- ST connector
- Wavelength: 820nm
- Permitted attenuation: 8 db with 62.5 /125 µm glass fiber
- Multimode glass optical fiber: 62.5 /125 µm
- Maximum distance: 1.5km

Plastic optical fiber

- HP standard connector
- Wavelength: 660nm
- Permitted attenuation: 24.7db with 1mm plastic cable and 22db with 200 µm silica cable
- Maximum distance: 115m with 1mm plastic cable and 1.9km with 200 µm silica cable

RS232

- DTE 9 pin female D type
- Cable type: Shielded
- Cable length: 15 m maximum
- Insulation 500V

RS485

- DTE 9 pin female D type
- Cable type: Shielded crossed pair
- Cable length: 1.000 m maximum.
- Insulation 500V

2.5 ENVIRONMENTAL CONDITIONS

Operating temperature: -40 to +85ºC

Storage temperature: -40 to 85 ºC

Relative humidity: Up to 95% without condensation

2.6 TESTS

2.6.1 Climatic test

TEST	STANDARD
Low T. test, Cold -40ºC +/-3ºC 16 hours (Unit on)	IEC -60068-2-1: -40°C, 16 hours
Dry Heat test +85ºC +/-2ºC 16 hours (Unit on)	IEC -60068-2-2: +85°C, 16 hours
Humid heat +40ºC +/-2ºC, 93% HR +/-3% 16 hours (Unit off)	IEC -60068-2-78: +40°C, 16 hours
Humid heat, cyclical 95% HR +/-3%	IEC -60068-2-30: 95% HR 6 cycles, 20 to 55ºC
Thermal shock -20º/70ºC. 6 cycles of 2 h /cycle	IEC -60068-2-14: -20ºC/70ºC
External protection level: IP30	IEC60529: IP30

2.6.2 Insulation and electrical safety tests

TEST	STANDARD
Dielectric rigidity	IEC 60255-5: 2.5 kVac
Insulation resistance	IEC 60255-5: > 100 MΩ at 500Vdc.
Impulse voltage (shock wave)	IEC 60255-5: ±5kV MC ±5kV MD
Protective earthing continuity test	IEC 61131-2: 30 A ≤ 0.1Ω
Leakage current	IEC 60990

2.6.3 Electromagnetic tests

TEST	STANDARD
1MHz damped waves immunity test	IEC 60255-22-1: ±2.5kV MC ±2.5kV MD
Damped oscillatory waves immunity	IEC 61000-4-12: ±2.5kV MC ±2.5kV MD
Electrostatic discharges	IEC 61000-4-2: ±8kV/±15kV
Fast transient bursts	IEC 61000-4-4: ±4kV,5kHz
Voltage pulses (surge)	IEC 61000-4-5 ±4kV MC ±2kV MD
DC power supply variations and interruptions immunity test (micro-cuts)	IEC 61000-4-29 / IEC60255-11: 100% 300 ms 60% 1s 30% 1s
Ripple on d.c. input power port immunity test	IEC 61000-4-17 10% (50 and 100 Hz)
Harmonics	IEC 61000-4-7
Immunity to industrial frequencies	IEC 60255-22-7 Class B
Safety of equipment electrically connected to a telecommunication network	IEC62151:
Overvoltage Withstand Capability Test	IEEE C37.90-1 Fast transient ±4kV,2.5kHz Oscillatory: ±2.5kV
Electromagnetic radiation	IEEE C37.90-2 35 V/m
Electrostatic Discharge Test	IEEE C37.90-3 ±8kV/±15kV
Radio-electric emissions measurement	IEC 60255-25/EN55022/EN55011: Class A
Radiated radiofrequency fields immunity test	ENV 50204/EC 61000-4-3: 10V/m
Immunity to signals induced by radio-frequency	IEC 61000-4-6: 10Vrms
50 Hz magnetic fields immunity test	IEC 61000-4-8: 100 A/m 1000 A/m
Immunity to pulsing magnetic fields	IEC 61000-4-9: 1000 A/m
Damped oscillatory magnetic field immunity test	IEC 61000-4-10 100 A/m

2.6.4 Mechanical tests

Vibration and shock: status of the connected and operating unit during the operation:

TEST	STANDARD
Response to vibration:	IEC 60255-21-1: Class I
Response to shocks and jolts:	IEC 60255-21-2: Class I

Vibration and shock during transportation:

TEST	STANDARD
Seismic	IEC 60255-21-3: Class I

3. PROTECTION FUNCTIONS

3.1 GENERAL

This section lists all the protection functions. Those included in each model are listed in the functional description.

3.1.1 Commands

Certain commands enable actions to be taken on the protection functions. Each functions specific characteristics are listed in the corresponding section. This section lists the general functions. Table 2 shows the functions affected by the general commands.

The general protection commands are in the PROT/PTRC node, allowing the blocking/unblocking of the associated functions:

- DOrdPrBl Protection block. Affects all the protection functions.
- DOrdPhBl Phase block. Affects all the phase functions.
- DOrdInsBl Instantaneous block. Affects all the instantaneous functions.
- DOrdInsPhBl Instantaneous phase block. Affects all the phase instantaneous functions.
- DOrdTmPhBl Timed phase block. Affects all the timed phase functions.
- DOrdINBl Instantaneous neutral block. Affects all the neutral instantaneous functions.
- DOrdVBl Voltage block. Affects all the voltage functions.
- DOrdDirBl Directional block. Affects all the directional functions. Equivalent to giving directional permission.

Table 2 Command by functions

	DOrdPrBl	DOrdPhBl	DOrdInsBl	DOrdInsPhBl	DOrdTmPhBl	DOrdINBl	DOrdVBl
Current units							
Phase instantaneous (50)	√	√	√	√			
Phase timed (50)	√	√			√		
Neutral instantaneous (50)	√		√			√	
Neutral timed (50)	√						
Sensitive neutral instantaneous (50)	√		√			√	
Sensitive neutral timed (50)	√						
Ground instantaneous (50)	√		√			√	
Ground timed (50)	√						
Unbalance instantaneous	√		√				
Unbalance block	√						
46FA Open phase	√		√				
Isolated neutral	√		√			√	
Compensated neutral	√		√			√	
37 Undercurrent	√	√					
HCL phases	√	√					
HCL neutral	√						
50CSC Second harmonic restraint	√						
49 Thermal image	√						
Cold load pickup	√						
50V/51V monitoring	√						
Voltage units							
Phase overvoltage timed	√	√			√		√
Phase instantaneous overvoltage	√	√	√	√			√
Zero sequence overvoltage timed	√						√
Zero sequence instantaneous overvoltage	√		√			√	√

V2 overvoltage timed	√						√
V2 instantaneous overvoltage	√		√				√
Phase undervoltage timed	√	√			√		√
Phase instantaneous undervoltage	√	√	√	√			√
Frequency units							
Frequency (81M/m)	√						
Frequency rate of change (81R)	√						
Power units							
Minimum real power	√						
Maximum real power	√						
Real power inversion	√						
Reactive power inversion	√						
Minimum apparent power	√						
Maximum apparent power	√						
Remaining protection functions							
78 Phase shift	√						
Field loss	√						
87N Restricted earth	√						
Load encroachment	√						
Fuse failure	√						
SOFT Switch onto fault	√						
Line fault	√						
Breaker							
50BF Basic breaker failure	√						

3.2 CURRENT UNITS

3.2.1 General overcurrent description

3.2.1.1 Timed characteristics

When enabled and unblocked, the unit acts when the setting value is exceeded during the programmed time.

To reset, the current must fall below 95% of the setting value.

The different curve options are shown in the curve appendix.

The timed unit can be configured with a minimum response time, that is, a limit that prevents any unit from tripping below a minimum time when the trip time corresponding to the curve in use is met. This is done to prevent timed trips from being faster than instantaneous trips. It is configured with additional time setting, so that if it set to zero, there is no such limit.

The settings used in these functions (Table 3) are:

- Enabled. Indicates whether the function is enabled or not.
- Operation type. To be selected between:
  - "Trip" generates function trips.
  - "Pick up", in which the function generates a pick up but no trips.
  - "Instantaneous block 1". The timed unit's trip is blocked if the instantaneous unit 1 has picked up. The timed pick up is not deactivated.
  - "Instantaneous block 1 and 2". The timed unit's trip is blocked if the instantaneous unit 1 or 2 has picked up. The timed pick up is not deactivated.
  - "Instantaneous block 1, 2 and 3". The timed unit's trip is blocked if the instantaneous unit 1, 2 or 3 has picked up. The timed pick up is not deactivated.

- Start value (A). Set in secondary amps. It indicates the current value as of which the function is activated.

- Operating Curve Type Indicates the type of curve selected from the options:
  - ANSI-EI Extreme. Inverse (1)
  - ANSI-MI Very inverse (2)
  - ANSI-I Normal inverse(3)
  - ANSI-MODI Moderately inverse (4)
  - IEC-I Normal inverse (9)
  - IEC-MI Very inverse (10)
  - IEC-EI Extreme. Inverse (12)
  - IEC-IC Short inverse (13)
  - IEC-IL Long inverse (14)
  - IEC-MIEs Very inverse special (50)
  - User curves 1 (33)
  - User curves 2 (34)
  - User curves 3 (35)
  - User curves 4 (36)
  - Definite time (49)
- Time dial. Indicates the time curve within the selected characteristic.
- Operate/minimum time (ms). It has a different functionality depending on the type of curve selected:
  - When the selected curve is a definite time, it indicates the time during which the conditions for the tripping of the function must be met.
  - In the rest of the curve, it indicates the minimum response time. i.e., in order for a trip to be produced, the time employed will be greater between this setting and the time associated to the curve.
- Torque control. Selects the function’s directional type:
  - “NO”. Acts as non-directional.
  - “Forward”. Acts when the directional indicates forward.
  - “Reverse”. Acts when the directional indicates reverse.
- Behaviour with Fuse fail. Defines the function’s action if a fuse failure is detected.
  - "None". The fuse failure does not affect the function.
  - "Inhibit". The function acts as non-directional when a fuse failure is detected.
  - "Block". The function blocks, i.e., it does not act, when a fuse failure is detected.
  - "Enable". The function is enabled when a fuse failure is detected.
- Reset type. Allows the emulation of the induction operation. The following options are available:
  - "Instantaneous". If the current drops below 95% of the setting value, both the trip and pick up reset instantaneously.
  - "Timed". If the current drops below 95% of setting value, the trip drops out instantaneously, while the pick up reset time will depend on the selected curve (family and index) and the current. If a definite time curve is selected, the pick up will reset upon the completion of the time programmed for the pick up as of the moment in which it falls below the pick up current, regardless of the current value.
- Operating Quantity. Indicates the measurement used by the function:
  - "Phasor". Uses the fundamental measurement, without including harmonics.
  - "Rms". Uses the effective value, including harmonics.

- Blocking Input. Selects the signal which, when active, blocks the function.
- Time delay cancellation Input. Selects the signal which, when active, generates the instantaneous trips regardless of the setting time.
- General trip. Indicates if this unit produces general trip or not. For additional details, see section corresponding to the recloser (5.2.3).
- TripP:RL,RR,RL,R:1,2,3,4,MC. Indicates the trip and block permission in accordance with the recloser status: standby, blocked, safety time after reclosing, after closing. It is configured bit by bit; for additional details, see section corresponding to the recloser (5.2.4).
- Reclose perm.(R1,R2,R3,R4). Indicates whether each trip type can be reclosed or not, in accordance with the recloser's closing cycle (5.2.5).
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generate. If set to “YES”, the function’s specific mask is contemplated.

Table 3 Timed overcurrent unit settings

Data	Setting	Minimum	Maximum	Step	Remarks	Type
PTOCEna	Enabled				NO (0) YES (1)	enum
Optype	Operation type				TRIP (1) PICK UP (2) INST_1 LOCK (3) INST _1, INST_2 LOCK (4) INST_1, INST_2, INST_3 LOCK (5)	enum
StrVal	Start value (A)	0,02	150,0	0,01		float32
TmACrv	Operating Curve Type				ANSI-EI Extreme. Inverse (1) ANSI-MI Very inverse (2) ANSI-I Normal inverse(3) ANSI-MODI Moderately inverse (4) IEC-I Normal inverse (9) IEC-MI Very inverse (10) IEC-EI Extreme. Inverse (12) IEC-IC Short inverse (13) IEC-IL Long inverse (14) IEC-MIEs Very inverse special (50) User curves 1 (33) User curves 2 (34) User curves 3 (35) User curves 4 (36) Definite time (49)	enum
TmMult	Time dial	0,05	30,0	0,01	IEC	float32
OpDlTmms	Operate/minimum time (ms)	0	600000*	10		Int32
DirMod	Torque control				NO (0) Forward (1) Reverse (2)	enum
FFailBeh	Behaviour with Fuse fail action				Nothing (0) Inhibit (1) Block (2) Enable (3)	enum
RstTyp	Reset type				Instantaneous (0) Reset (1)	enum
MesTyp	Operating Quantity				Phasor (0) Rms (1)	enum
LogInBlk	Blocking Input					uint 32
LogInCaTm	Time delay cancellation Input					uint 32
GenTrip	General trip				NO (0) YES (1)	Boolean
TripPerm	TripP:RL,RR,RL,R:1,2,3,4,MC	0	255	1	Bit meaning (1)	ING
ReclPerm	Reclose perm.(R1,R2,R3,R4)	0	15		Bit meaning (2)	ING
MaskEna	Enable Events record				NO (0) / YES (1)	Boolean

In which:

Bit meaning (1)	Bit	Value
Reclose block	0	YES/NO
Trip permission 79 standby	1	YES/NO
Trip permission 79 blocked	2	YES/NO
Permission for trip in safety time following reclose 1	3	YES/NO
Permission for trip in safety time following reclose 2	4	YES/NO
Permission for trip in safety time following reclose 3	5	YES/NO
Permission for trip in safety time following reclose 4	6	YES/NO
Permission for trip in safety time following manual close	7	YES/NO

Bit meaning (2)	Bit	Value
Reclose permission 1	0	YES/NO
Reclose permission 2	1	YES/NO
Reclose permission 3	2	YES/NO
Reclose permission 4	3	YES/NO

3.2.1.2 Instantaneous characteristics

When enabled and unblocked, the unit acts when the setting value is exceed during the programmed time.

To reset, the current must fall below 95% of the setting value.

The settings used in these functions (see Table 4) are:

- Enabled. Indicates whether the function is enabled or not.
- Operation type. To be selected between:
  - “Trip” generates function trips.
  - “Pick up”, in which the function generates a pick up but no trips.
- Start value (A). Set in secondary amps. It indicates the current value as of which the function is activated.
- Operate Delay time (ms). Indicates the time during which the conditions for the tripping of the function must be met.
- Torque control. Selects the function’s directional type:
  - “NO”. Acts as non-directional.
  - “Forward”. Acts when the directional indicates forward.
  - “Reverse”. Acts when the directional indicates reverse.
- Behaviour with Fuse failure. Defines the function’s action if a fuse failure is detected.
  - "None". The fuse failure does not affect the function.
  - "Inhibit". The function acts as non-directional when a fuse failure is detected.
  - "Block". The function blocks, i.e., it does not act, when a fuse failure is detected.
  - "Enable". The function is enabled when a fuse failure is detected.
- Operating Quantity. Indicates the measurement used by the function:
  - "Phasor". Uses the fundamental measurement, without including harmonics.
  - "Rms". Uses the effective value, including harmonics.
- Blocking Input. Selects the signal which, when active, blocks the function.
- Time delay cancellation Input. Selects the signal which, when active, generates the instantaneous trips regardless of the setting time.
- General trip. Indicates if this unit produces general trip or not. For additional details, see section corresponding to the recloser (5.2.3).

- TripP:RL,RR,RL,R:1,2,3,4,MC. Indicates the trip and block permission in accordance with the recloser status: standby, blocked, safety time after reclosing, after closing. It is configured bit by bit; for additional details, see section corresponding to the recloser (5.2.4).
- Reclose perm.(R1,R2,R3,R4). Indicates whether each trip type can be reclosed or not, in accordance with the recloser's closing cycle (5.2.5).
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generate. If set to “YES”, the function’s specific mask is contemplated.

Table 4 Instantaneous overcurrent unit settings

Data	Setting	Minimum	Maximum	Step	Remarks	Type
PIOCEna	Enabled				NO (0) YES (1)	enum
Optype	Operation type				TRIP (1) PICK UP (2)	enum
StrVal	Start value (A)	0,02	150,0	0,01		float32
OpDlTmms	Operate Delay time (ms)	0	600000*	10		Int32
DirMod	Torque control				NO (0) Forward (1) Reverse (2)	enum
FFailBeh	Behaviour with Fuse fail				Nothing (0) Inhibit (1) Block (2) Enable (3)	enum
MesTyp	Operating Quantity				Phasor (0) Rms (1)	enum
LogInBlk	Blocking Input					uint 32
LogInTIn	Time delay cancellation input					uint 32
GenTrip	General trip				NO (0) YES (1)	Boolean
TripPerm	TripP:RL,RR,RL,R:1,2,3,4,MC	0	255	1	Bit meaning (1)	ING
ReclPerm	Reclose perm.(R1,R2,R3,R4)	0	15		Bit meaning (2)	ING
MaskEna	Enable Events record				NO (0) / YES (1)	Boolean

In which:

Bit meaning (1)	Bit	Value
Reclose block	0	YES/NO
Trip permission 79 standby	1	YES/NO
Trip permission 79 blocked	2	YES/NO
Permission for trip in safety time following reclose 1	3	YES/NO
Permission for trip in safety time following reclose 2	4	YES/NO
Permission for trip in safety time following reclose 3	5	YES/NO
Permission for trip in safety time following reclose 4	6	YES/NO
Permission for trip in safety time following manual close	7	YES/NO

Bit meaning (2)	Bit	Value
Reclose permission 1	0	YES/NO
Reclose permission 2	1	YES/NO
Reclose permission 3	2	YES/NO
Reclose permission 4	3	YES/NO

3.2.2 Directional characteristics

The overcurrent units have a setting (torque control) for selecting the unit's directionality:

- No: the unit acts as non-directional.
- Forward: the unit acts as directional in a forward direction.
- Reverse: the unit acts as directional in a reverse direction.

There are logical trip direction inversion inputs that allow the different units' trip direction to be inverted.

There are logical "function X directional inhibition" inputs that allow the directional units to which they are applied to be converted into non-directional. These inputs allow for a unit's conversion into non-directional in the case of a fuse failure, for example.

The inverse sequence unit can be employed in phases and in neutral.

3.2.2.1 Phase directional

The operation can be selected among: quadrature, direct (S1) and direct+inverse (S1+S2). Each mode has its own settings.

This function's general settings and those applied in the quadrature and direct sequence criteria are in the PROT/PDIR1 node:

- Directional method. Indicates the directional criterion used.
  - "Quadrature". Analyzes each phase independently.
  - "Quadrature 2 of 3". Analyzes each phase independently. However, in order to grant permission it must see the direction in at least two phases.
  - "Direct sequence". Analyzes the direct sequence.
  - "Inverse and direct sequence". Analyzes the inverse and direct sequence.
- Torque angle (°). Indicates the directional angle. Applies to quadrature and direct sequence.
- Minimum V polarization. Indicates the minimum voltage for polarization; the direction cannot be reliably determined below this value.
- Directional Zone amplitude. Indicates the angle covered by the trip zone.
- Trip permission with low Vpol. Indicates the functioning of the directional when the polarization voltage is below the threshold. If set to YES, it enables an overcurrent trip if the memorized polarization voltage is lower than the minimum polarization voltage; if set to NO, the overcurrent trip is not allowed under those conditions.
- Phase directional inversion. Selects the signal which, when active, inverts the trip direction.
- Phase directional blocking. Selects the signal which, when active, blocks the function. When the directional is blocked, it is issues permission for the trip.
- Enable Events record. Allows the generation of protection events associated to the function. If set to "NO", the function's protection events are not generate. If set to "YES", the function's specific mask is contemplated.

Table 5. Phase directional settings

Data	Setting	Minimum	Maximum	Step	Remarks	Type
PolQty	Directional method				Quadrature Quadrature 2 of 3 Direct sequence Inverse and direct sequence	enum
	Quadrature and direct sequence					
ChrAng	Torque angle (°)	0	360	1		float32
Vpol	V minimum V polarization	1	200	0,1		float32
Amp	Directional Zone amplitude	90	170	1		float32
EnaOpn	Trip Permission with low Vpol				YES/NO	Boolean
LogInInvDir	Phase directional inversion					Int32
LogInBlDir	Phase directional blocking					Int32
MaskEna	Enable Events record				NO (0) / YES (1)	Boolean

The minimum polarization current is considered as 50% of the minimum setting of the three timed phase units (51).

- The quadrature and direct sequence units settings, commands and outputs.
- PROT/PDIR1 node
- Settings and logical inputs. There are 6 settings tables. For details see Table 5.
- Commands:
  - “DOrdBlk”: Function block and unblocking.
  - “DOrdInvDir”. Inverts the directional’s trip direction.
- Outputs: Table 6 shows the function’s output data.
  - 67 Forward X. The detected direction indicates forward. It is independent for each phase.
  - 67 Reverse X. The detected direction indicates reverse. It is independent for each phase.
  - Polarization failure X. Indicates that the direction has not been detected due to a polarization failure. It is independent for each phase.
  - Phase directional inhibition. Indicates that the directional is inhibited.
  - Phase direction inversion. Indicates that the direction is opposite to the setting.

Table 6 Phase directional outputs (quadrature and direct sequence)

Signal	Data	Attribute
67-Forward A	Fw67	phsA
67-Forward B	Fw67	phsB
67-Forward C	Fw67	phsC
67-Reverse A	Rv67	phsA
67-Reverse B	Rv67	phsB
67-Reverse C	Rv67	phsC
Polarization Failure A	FailPol	phsA
Polarization Failure B	FailPol	phsB
Polarization Failure C	FailPol	phsC
Phase Directional Inhibition	BlkDir	general
Phase Direction Inversion	InvDir	general

3.2.2.1.1 Quadrature

For the detection of directionality in phases, the polarization voltage corresponds to the quadrature connection (90º), in which each phase's current is compared with the phase to phase voltage between the other two phases (see Figure 22).

Phase Ia	$\mathrm{Spol} = \mathrm{Vbc}$	$\mathrm{Sop} = \mathrm{Ia} \cdot e^{-j\cdot\left(\frac{\pi}{2}-\mathrm{MTA\_FASES}\right)\cdot\frac{\pi}{180}}$
Phase Ib	$\mathrm{Spol} = \mathrm{Vca}$	$\mathrm{Sop} = \mathrm{Ib} \cdot e^{-j\cdot\left(\frac{\pi}{2}-\mathrm{MTA\_FASES}\right)\cdot\frac{\pi}{180}}$
Phase Ic	$\mathrm{Spol} = \mathrm{Vab}$	$\mathrm{Sop} = \mathrm{Ic} \cdot e^{-j\cdot\left(\frac{\pi}{2}-\mathrm{MTA\_FASES}\right)\cdot\frac{\pi}{180}}$

Signals forward when lang(Spol)-ang(Sop)l<90º

The "2 out of 3" means that the unit only signals forward if this direction is seen in 2 phases. Avoid cases in which, with a reverse fault, certain of the phases detected a forward fault (e.g., weak in-feed). In the case of weak in-feed due to the breaking of a transformer, there is only zero sequence current circulation and therefore the three phases detect the same current. In this case, one of the 3 phases will detect the fault in the opposite direction to the other two.

It operates as three single phase units in which polarization voltages are the phase to phase voltages of the healthy phases. These may be obtained by calculation or by transformer measurement, depending on whether the voltage setting type indicates that the signals entered are phase to ground voltages (calculation) or phase to phase voltages (measurement).

In the case of an ABC phase sequence, polarization is effected with Vab, Vbc and Vac, for Ic, Ia and Ib. In the case of a CBA phase sequence, polarization is effected with Vba, Vcb and Vac, for Ic, Ia and Ib.

There is a 5º zone between the non-trip zone and the trip zone in which the current directional status is maintained.

This unit's signals are independent for each of the phases (see Table 6).

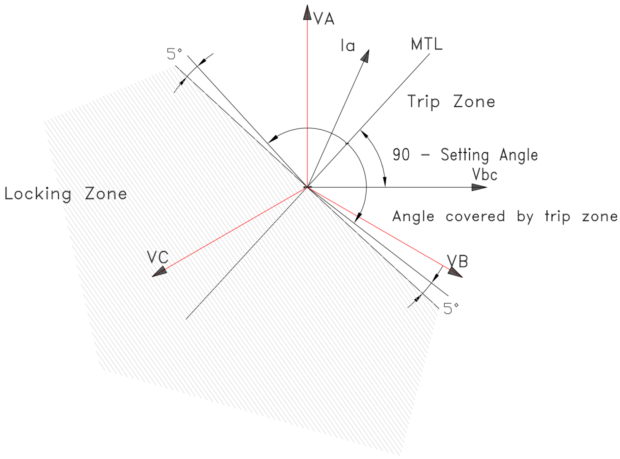
Memory

The current quadrature voltage is used. If it falls below the Vpol threshold, the value memorized in accordance with the memory management explained in the polarization memory monitoring is used. It is also affected by the serial compensation logic in so far that if it is set to YES the memorized voltage is used as of the moment in which a fault or a voltage inversion is detected.

Trip permission with low Vpol

The directional block is used when the polarization voltage is below a threshold (VPOL_FASES) or the operating current is below another threshold (Iphase < (IMIN_FASES)). "Phase x polarization fault" is indicated. If the trip permission without polarization V is set to YES, the trip is permitted. If set to NO, it is blocked.

Figure 22 Phase directional (Quadrature)



3.2.2.1.2 Direct sequence

The direction is determined by comparison between the positive sequence voltage and current (see Figure 23).

$$S1pol = V1$$

$$S1op = I1 \cdot e^{j \cdot MTA\_FASES \frac{\pi}{180}}$$

It signals forward when |ang(S1pol)-ang(S1op)|<90º

90-angle setting > arg(I1)-arg(V1)>270-angle setting

There is a 5º zone between the non-trip zone and the trip zone in which the current directional status is maintained.

This unit's signals are the same as those of the quadrature, with the difference that the three phases are always given simultaneously (see Table 6).

Memory

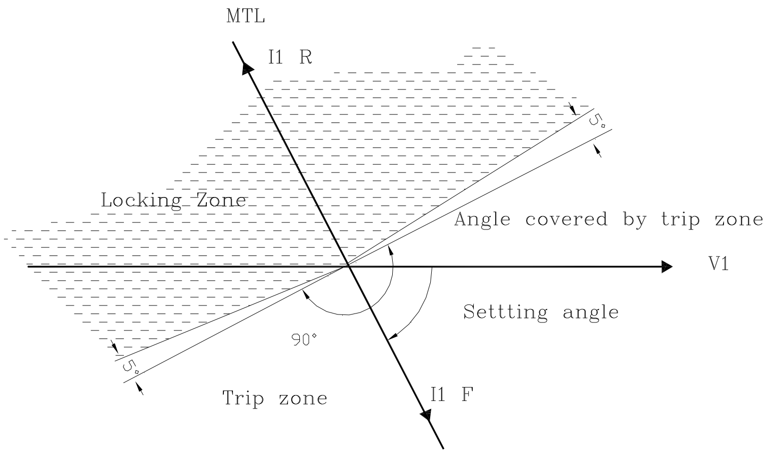
The memory management explained in the Polarization memory monitoring is used. If the voltage falls below VPOL_FASES, the voltage is memorized during the programmed time. It is also affected by the serial compensation logic in so far that if it is set to YES the memorized voltage is used as of the moment in which a fault is detected.

Trip permission with low Vpol

The directional block is used when the V1 polarization voltage is below a threshold (VPOL_FASES) or the operating current is below another threshold (Iphase< (IMIN_FASES)). "Phase A, B and C polarization fault" is indicated.

If the V1 polarization voltage is below the threshold (VPOL_FASES) and the trip permission without polarization V is set to YES, the trip is permitted. If set to NO, it is blocked.

Figure 23 Phase directional (Direct sequence)



3.2.2.1.3 Inverse and direct sequence

Both methods are used to determine the direction, first by analyzing the inverse sequence:

- If the inverse sequence indicates the direction, the direct sequence is not consulted.
- If the inverse sequence indicates a polarization failure, the direct sequence is consulted.

3.2.2.2 Inverse sequence

It is used both in phase and neutral directional.

The direction is determined by comparison between the negative sequence voltage and current, with I2 superior to a threshold and V2 superior to a threshold (see Figure 24)

$$S2pol = -3 \cdot V2$$

$$S2op = 3 \cdot I2 \cdot e^{j \cdot MTA\_S2 \cdot \frac{\pi}{180}}$$

It signals forward when larg(S2po)-arg(S2opl)l is less than 90º

Inverse sequence polarization failure

If the inverse sequence polarization voltage (S2pol) is less than a threshold (Setting "Vpol_S2"), or if the inverse sequence current is below a threshold (3I2<IMIN_IN_S2 or 3I2<IMIN_I1_S2xI1/100), "Inverse sequence polarization fault" is indicated.

This function's general settings and those applied in the quadrature and direct sequence criteria are in the PROT/S2PDIR1 node:

- Torque angle (º). Indicates the directional angle.
- DIrectional Zone amplitude (º). Indicates the angle covered by the trip zone.
- Minimum V polarization. Indicates the minimum voltage for polarization; the direction cannot be reliably determined below this value.
- I2 minimum operation x I1. Percentage of I1 Indicates the minimum value of I2 in relation to I1.

- I2 minimum operation x In. Percentage of rated I. Indicates the minimum value of I2 in relation to rated I.
- Permission without polarization V. Indicates the functioning of the directional when the polarization voltage is below the threshold. If set to YES, it enables an overcurrent trip if the memorized polarization voltage is lower than the minimum polarization voltage; if set to NO, the overcurrent trip is not allowed under those conditions.
- Blocking Input. Selects the signal which, when active, blocks the function. When the directional is blocked, it is issues permission for the trip.
- Logical inversion input. Selects the signal which, when active, inverts the trip direction.
- Enable Events record. Allows the generation of protection events associated to the function. If set to "NO", the function's protection events are not generate. If set to "YES", the function's specific mask is contemplated.

Table 7 Inverse sequence directional settings

Data	Setting	Minimum	Maximum	Step	Remarks	Type
ChrAng	Torque angle (°)	0	360	1		float32
Amp	Directional Zone amplitude (°)	90	170	1		float32
Vpol	Minimum V polarization	1	200	0,1		float32
BlkValI1	Minimum I2 / I1 (%)	1	100	1	Value % of I1	float32
BlkValIn	Minimum I1 / Irated (%)	1	100	1	Value % of In	float32
LogInInvDir	Neg.Seq.Directional inversion					Int32
LogInBIDir	Blocking input					Int32
MaskEna	Enable Events record				NO (0) / YES (1)	Boolean

The quadrature and direct sequence units settings, commands and outputs:

- PROT/S2PDIR1 node
- Settings and logical inputs. There are 6 settings tables. See Table 7.
- Commands:
  - "DOrdBlk": Function block and unblocking.
  - "DOrdInvDir". Inverts the directional's trip direction
- Outputs:
  - 67N-S2 Forward. The detected direction indicates forward.
  - 67N-S2 Reverse. The detected direction indicates reverse.
  - Polarization Failure S2. Indicates that the direction has not been detected due to a polarization failure.
  - S2 directional inhibition. Indicates that the directional is inhibited.
  - S2 direction inversion. Indicates that the direction is opposite to the setting.

Table 8 Inverse sequence directional outputs

Signal	Data	Attribute
67N-S2 Forward	Fw67S2	general
67N-S2 Reverse	Rv67S2	general
Polarization Failure S2	FailS2	general
S2 Directional Inhibition	BlkDir	general
S2 Direction Inversion	InvDir	general

Figure 24 Inverse sequence directional

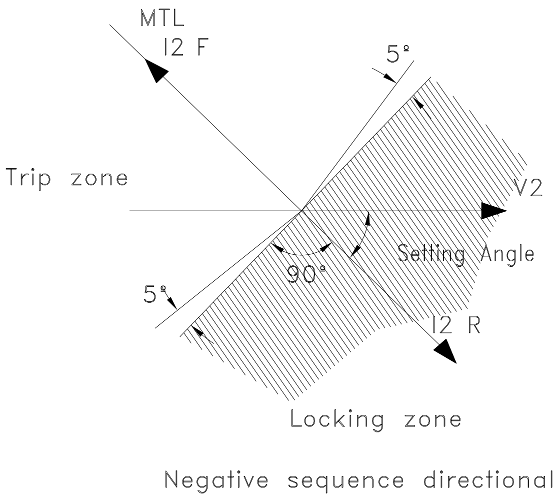
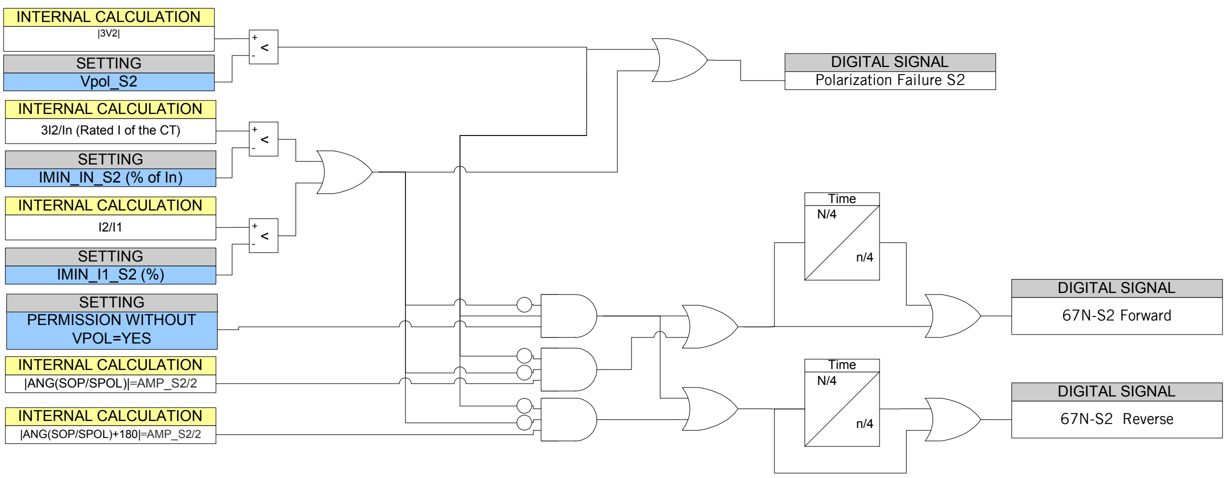


Figure 25 Inverse sequence directional scheme



3.2.2.3 Polarization memory monitoring

It is used in the polarization of the phase directional (direct sequence and quadrature).

Allows the memorized voltage to be used during the configured time when the current voltage is not apt.

This unit don´t have settings:

- Minimum V1. Indicates the minimum V1 value for employing the memorized voltage. It is set at 10V.
- V1 maintenance time. Indicates the time during which the memorized voltage is used in the polarization by direct sequence. It is set at 30 cycles.
- Minimum Vc. Indicates the minimum quadrature voltage for employing the memorized voltage. It is set at 30V.
- Vc maintenance time. Indicates the time during which the memorized voltage is used in the polarization by quadrature. It is set at 30 cycles.

This unit's operating scheme is:

- If V1> VPOL_FASES is met during at least 4 cycles, the memorized voltage is captured once again.
- V1men is then update to the V1 value registered 3 cycles previously. Thus, in the moment in which the conditions for using it are met, the value registered 3 cycles previously will be taken.
- The 67-50/51 units are normally polarized without memory. The memorized voltage is used in the moment in which the current V1 voltage drops below VPOL_FASES. The memorized voltage must exceed VPOL_FASES in order to be used. The memory time is indicated in the maintenance time setting.

The direct sequence voltage and the quadrature voltages are analyzed separately (Vab, Vbc and Vac).

The function's logic diagram is shown in Figure 26 (direct sequence) and Figure 27 (quadrature).

Figure 26 Direct sequence memorized monitoring

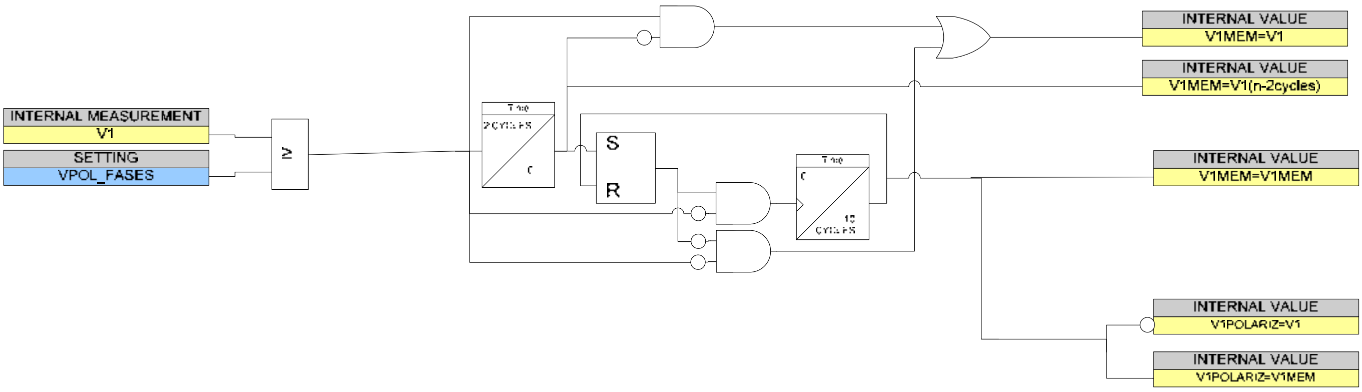
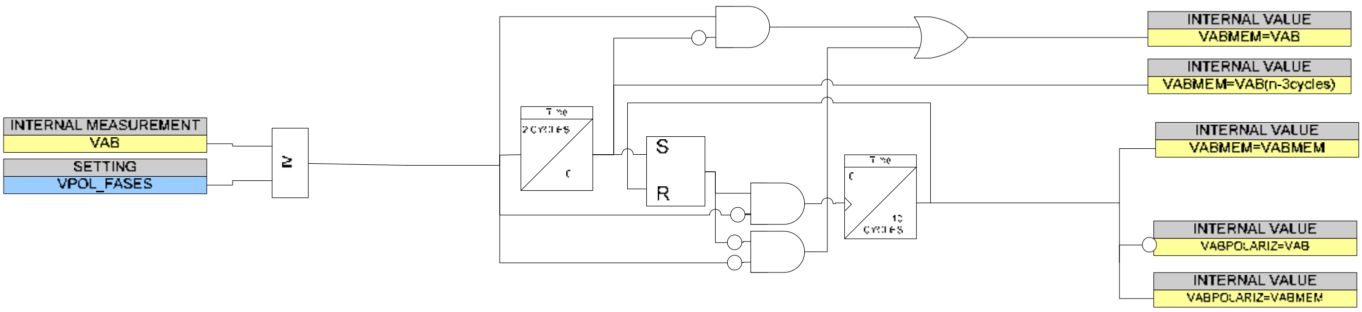


Figure 27 Memorized quadrature monitoring



3.2.2.4 Neutral directional

Affects neutral units, allowing or blocking the trip in accordance with the configuration.

The operation can be selected from among: angular, cosine, sine and watt-metric. Various options can be selected from within the angular criterion.

This unit's settings are in the PROT/GPDIR node. In accordance with the selected mode, they affect:

General

- Ground directional method. Indicates the directional criterion used.
  - "Angular". Analyzes each phase independently.
  - "I·cosϕ"

- “I·senϕ”
- “Watt-metric”

- Minimum 3I0/Irated (%). Percentage of rated I. Indicates the minimum value of 3 I0 in relation to rated I. “I·cosϕ” and “I·cosϕ” are used in zero sequence mode.
- Ground directional Lock. Selects the signal which, when active, blocks the function. When the directional is blocked, it is issues permission for the trip.
- Ground directional inversion. Selects the signal which, when active, inverts the trip direction.
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generate. If set to “YES”, the function’s specific mask is contemplated.

Angular and Zero Sequence

- Polarization type. Selected the polarization type from the options:
  - V. By voltage.
  - IPOL. By current
  - IPOL → V. By current and, in the event of uncertainty, by voltage.
  - IPOL or V. By current or by voltage.
  - IPOL and V. By current and by voltage.
- Voltage directional criterion. Only applied if voltage polarization has been selected.
  - S0. Zero sequence.
  - S2. Inverse sequence.
  - S2 & S0. Inverse and zero sequence.
  - S2 OR S0. Inverse or zero sequence.
  - S2 →S0. Inverse sequence and, in the event of uncertainty, zero sequence.
  - S0 →S2. Zero sequence and, in the event of uncertainty, inverse sequence.
- Torque angle (º). Indicates the directional angle.
- Direct Zone amplitude. Indicates the angle covered by the trip zone.
- Minimum V polarization. Indicates the minimum voltage for polarization; the direction cannot be reliably determined below this value.
- Trip permission with low Vpol. Indicates the functioning of the directional when the polarization voltage is below the threshold. If set to YES, it enables an overcurrent trip if the memorized polarization voltage is lower than the minimum polarization voltage; if set to NO, the overcurrent trip is not allowed under those conditions.
- Minimum Ipol/Irated (%). Indicates the minimum current for polarization; the direction cannot be reliably determined below this value.
- Minimum 3I0/I1 (%). Percentage of I1 Indicates the minimum value of I0 in relation to I1.

Watt-metric, I·cosϕ, I·senϕ

- Minimum power (Icos, Isin, Watt): Power value P=Vn·In·cos(φ-φc),, in which φ=Angle between Vn and In. If the power negative and higher than this value, a forward fault is registered. If it is positive and higher than this value, a reverse fault is registered.
- Icos<->Isen method switch. If a signal is assigned to this input, it indicates the directional type employed (independent of the setting) I·cosϕ if the input is 0 (deactivated) and I·senϕ if the input is 1 (activated). If no signal has been assigned, the criterion selected for the setting is employed.

Table 9 Neutral directional settings

Data	Setting	Minimum	Maximum	Step	Remarks	Type
DirTyp	Ground Directional method				"Angular criterion" "Icos φ" "Isen φ" "Watt-metric"	enum
ChrAng	Torque angle(º)	0	360	1		float32
Amp	DIrect. Zone amplitude	90	170	1		float32
BlkValV	V minimum V polarization	1	200	0,1		float32
BlkValIn	Minimum 3I0/Irated (%)	1	100	1	Value % of I1	float32
LogInInvDir	Ground directional Inversion					Int32
LogInBlDir	Ground directional Lock					Int32
LogInChSC	Icos<->Isen method switch					Int32
PolTyp	Polarization method (V,Ipol)				V IPOL IPOL → V IPOL or V IPOL and V	enum
PolQty	Voltage directional criterion				S0 S2 S2 & S0 S2 OR S0 S2 →S0 S0 →S2	enum
BlkValI1	Minimum 3I0/I1 (%)	1	100	1	Value % of In	float32
EnaOpn	Trip permission with low Vpol				YES/NO	Boolean
BlkValIpol	Minimum Ipol/Irated (%)	1	100	1	Value % of I1	float32
BlkValW	Minimum power (Icos, Isin, Watt)	0	100	0,01		float32
MaskEna	Enable Events record				NO (0) / YES (1)	Boolean

The neutral units have settings, commands and outputs:

- PROT/GPDIR1 node
- Settings and logical inputs. There are 6 settings tables. See Table 9for details.
- Commands:
  - "DOrdBlk": Function block and unblocking.
  - "DOrdInvDir". Inverts the directional's trip direction
- Outputs: Table 10 shows the function's output data.
  - 67N Forward. The detected direction indicates forward.
  - 67N Reverse. The detected direction indicates reverse.
  - Polarization Failure In. Indicates that the direction has not been detected due to a polarization failure.
  - Ground directional inhibition. Indicates that the directional is inhibited.
  - Ground direction inversion. Indicates that the direction is opposite to the setting.

Table 10. Neutral directional outputs

Signal	Data	Attribute
67N Forward	Fw67G	neut
67N Reverse	Rv67G	neut
Polarization Failure In	FailIn	neut
Ground Directional Inhibition	BlkDir	neut
Ground Direction Inversion	InvDir	neut

3.2.2.4.1 Combinations with angle criteria

The various combinations according to the polarization type are:

I→V

If Ineutro is less than (IN<IMIN_IN_S0 or IN<IMIN_I1_S0xI1/100), a “Neutral I polarization signal” is issued and no other actions are taken. (IN=Ineutro).

If the I unit does not determine the polarization fault direction, the voltage signal combination is displayed.

If the result is “Without VPOL”, the “Trip permission without neutral VPOL” setting is inspected.

If there is a fuse failure, only current directional is taken into account.

I and V

If Ineutro is less than (IN<IMIN_IN_S0 or IN<IMIN_I1_S0xI1/100), a “Neutral I polarization signal” is issued and no other actions are taken.

If the I unit does not determine the direction, the voltage signal combination is displayed. If it agrees with the result, a forward or reverse indication is made. If V lacks sufficient polarization, the result is decided in accordance with the "Trip permission without neutral Vpol" setting.

If the I or V unit does not determine the direction, a "polarization fault” message is indicated and a decision is taken in accordance with the “trip permission without Vpol” setting.

This combination is applicable to autotrans when there is a malfunction of Ipol.

If there is a fuse failure, only current directional is taken into account.

I or V

If Ineutro is less than (IN<IMIN_IN_S0 or IN<IMIN_I1_S0xI1/100), a “Neutral I polarization signal” is issued and no other actions are taken.

If the I and V units indicate a polarization failure, “polarization fault” message is indicated and a decision is taken in accordance with the “trip permission without Vpol” setting.

If any unit indicates forward or reverse, the corresponding signal is activated.

If there is a fuse failure, only current directional is taken into account.

Furthermore, we can choose from among the following options:

S0→S2

If Ineutro is less than (IN<IMIN_IN_S0 or IN<IMIN_I1_S0xI1/100), a “Neutral I polarization signal” is activated.

To the contrary, the s0 conditions are displayed.

If the S0 unit does not determine the direction, a “neutral V polarization failure” signal is activated and S2 is displayed.

If the conditions for determining the direction are still not given, a “inverse sequence polarization failure” signal is activated and the “trip permission without Vpol” setting is consulted in order to decide whether trip permission is to be given or not.

<u>Example of specific situations:</u>

One unit set in reverse and one set forward. s0 indicates reverse and s2 forward. Only reverse would be signalled (due to s0).

V0	V2	Result
F	F or R or Without Vpol	F
R	F or R or Without Vpol	R
Without Vpol	F	F
Without Vpol	R	R
Without Vpol	Without Vpol	Without Vpol

S0 & S2

If Ineutro is less than (IN<IMIN_IN_S0 or IN<IMIN_I1_S0xI1/100), a "Neutral I polarization signal" is activated.

To the contrary, the S2 and S0 unit's are analyzed.

If the two match, the decision is signalled.

If either of the units (S0 or S2) does not determine the direction, a "inverse sequence polarization fault" or "Neutral V polarization fault" signal is activated and the signalling is decided upon in accordance with the "trip permission without Vpol" setting.

Specific situations:

One unit set in reverse and one set forward. S0 indicates reverse and S2 forward. No output is given.

V0	V2	Result
F	F	F
F	R	Nothing
R	R	R
R	F	Nothing
F	Without Vpol	Without Vpol
R	Without Vpol	Without Vpol
Without Vpol	F	Without Vpol
Without Vpol	R	Without Vpol
Without Vpol	Without Vpol	Without Vpol

S0 OR S2

If Ineutro is less than (IN<IMIN_IN_S0 or IN<IMIN_I1_S0xI1/100), a "Neutral I polarization signal" is activated.

To the contrary, the V2 conditions are displayed.

If the V2 unit does not determine the direction, an "inverse sequence polarization failure" signal is activated.

If the conditions for determining the direction are still not given in S0, a "Neutral V polarization failure" signal is activated and the "trip permission without Vpol" setting is consulted in order to decide whether trip permission is to be given or not.

V0	V2	Result
F	F	F
F	R	F & R
R	R	R
R	F	F & R
F	Without Vpol	F
R	Without Vpol	R
Without Vpol	F	F
Without Vpol	R	R
Without Vpol	Without Vpol	Without Vpol

3.2.2.4.2 S0 polarization

The direction is determined by comparing the neutral current (3·I0) with the neutral voltage as polarization, (-3·V0). The angle determines the range in which the fault is considered as a forward fault and as a reverse fault.

$$S0pol = -VN$$

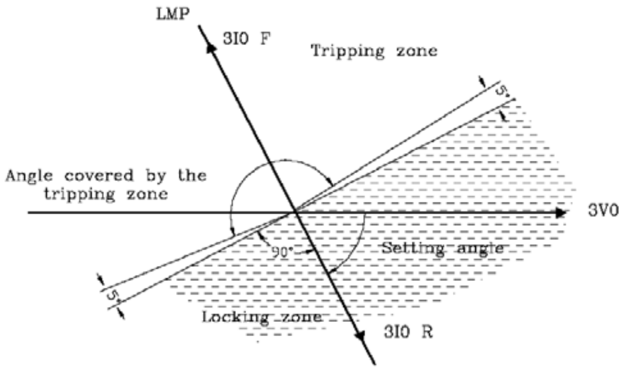
$$S0op = IN \cdot e^{j \cdot MTA\_S0 \cdot \frac{\pi}{180}}$$

The VN=3·V0 voltage can be calculated using the phase to earth voltages of the phases or it can be measured by a transformer, in accordance with the "V0 measurement type" setting in the PROT/PVGE1 node. If the "voltage type" setting is set to "phase to phase", the zero sequence voltage calculated will always be zero and this unit cannot be used.

The 3I0 measurement can also be calculated using the sum of the phase currents in those models in which a transformer is not assigned to this measurement.

The function trips if the Iang(S0op)-arg(S0pol)I is less than amplitude angle between 2.

Figure 28 Zero sequence directional



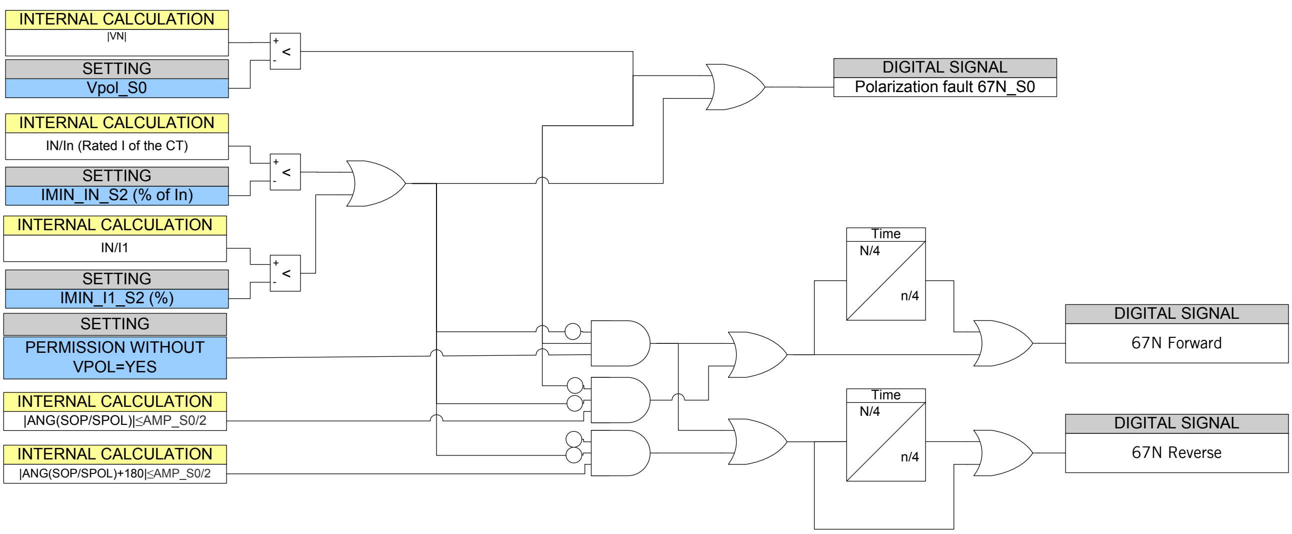
There is a 5º zone between the non-trip zone and the trip zone in which the current directional status is maintained.

Trip permission with low Vpol.

The directional block is used when the S0pol polarization voltage is below a minimum V polarization threshold (VPOL_S0 setting) or the operating current is below another current threshold (Ineutro<IMIN_IN_S0 or Ineutro<IMIN_I1_S0xI1/100). "Neutral polarization fault" is signalled.

If the trip permission without V polarization is set to YES, the trip is permitted (if VN<Vpol_S0). If set to NO, it is blocked. That is, the trip is allowed only the absence of Vn.

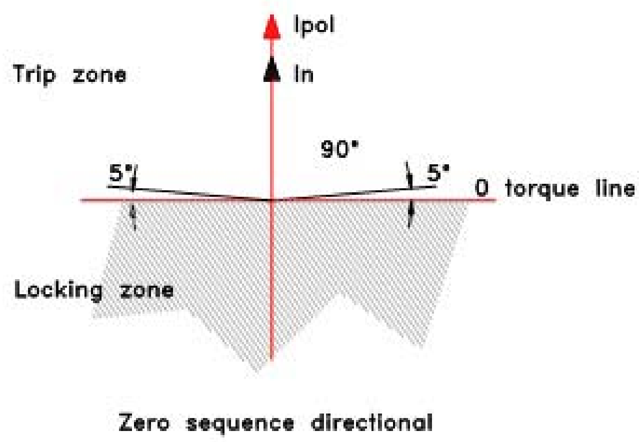
Figure 29 Zero sequence directional scheme



3.2.2.4.3 I polarization

The direction is determined by comparing the grounding current (Ipol) with the neutral current. To be able to verify the direction, Ipol> IMIN_IPOL_S0 must be met.

Figure 30 Directional with current polarization



There is a 5º zone between the non-trip zone and the trip zone in which the current directional status is maintained, both for voltage and for current polarization.

Permission due to polarization fault

If the polarization current (IN< IN<IMIN_IN_S0 or IN<IMIN_I1_S0xI1/100), a “Neutral I polarization fault” is signalled.

If the polarization current (Ipol) falls below a threshold (Ipol<IMIN_IPOL_S0), a “IPOL polarization fault” is indicated. However, the “Vpol fault trip permission” is not consulted and, therefore, no trip permission is issued.

3.2.2.4.4 Watt-metric directional

This is for lines with Petersen coil compensation.

In order to allow the directional unit to pick up, the following must be met:

- Exceed a minimum VN threshold.
- For forward faults, the angle between the current and the displaced voltage, the maximum torque angle must be between 95 and 265.

  95<Ang(I0)-angle(V0)+Torque angle<265

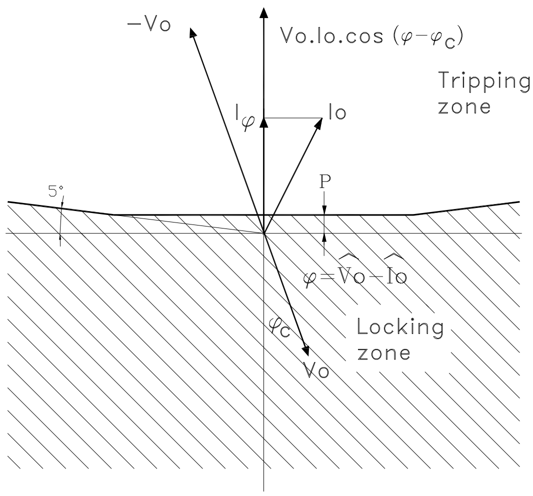
- For reverse faults, the angle between the current and the displaced voltage, the maximum torque angle must be between 275 and 85.

  275<Ang(I0)-angle(V0)+Torque angle<85

- The power P=Vn·In·cos(φ-φc) must exceed the minimum P threshold by the absolute value. If the sign of P is negative, the fault is forward. If positive, the fault is reverse. The equation to be implemented for calculating P is as follows:

$$P = (\mathrm{Re}(V)\cdot\cos(\phi) + \mathrm{Im}(V)\cdot\sin(\phi))\cdot\mathrm{Re}(I) + (\mathrm{Im}(V)\cdot\cos(\phi) - \mathrm{Re}(V)\cdot\sin(\phi))\cdot\mathrm{Im}(I)$$

Figure 31 Directional with watt-metric polarization



3.2.2.4.5 I*cos(φ) / I*sen(φ) directional

An input can be programmed (“67N Isen(phi) r Icos(phi)”) such that when activated the operating mode of I*cos(φ) changes to I*sen(φ). If programmed, this input cancels the setting: if deactivated, it runs the I*cos(φ) algorithm. If activated, the I*sen(φ) algorithm is run, independently of the setting. It does not affect either the angular of the watt-metric directional.

I*cos(φ) directional

In order to allow the directional unit to pick up, the following must be met:

- Exceed a minimum VN threshold.
- The minimum current I minimum=In·cos(?-?c) must exceed the minimum threshold by the absolute value. If the sign is negative, the fault is forward. If positive, the fault is reverse.
- For forward faults, the angle between the current and the displaced voltage, the maximum torque angle must be between 95 and 265.

  95<Ang(I0)-angle(V0)+Torque angle<265

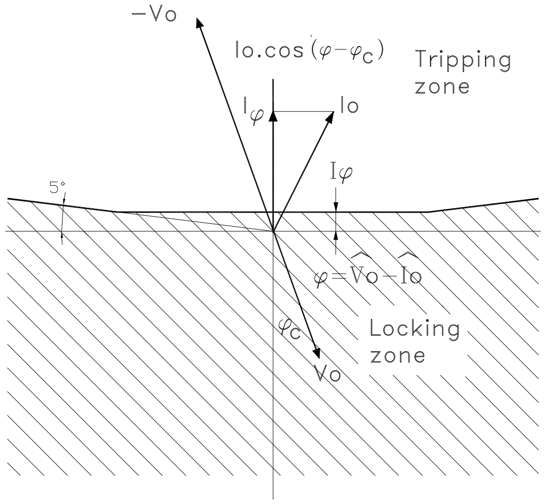
- For reverse faults, the angle between the current and the displaced voltage, the maximum torque angle must be between 275 and 85.

  275<Ang(I0)-angle(V0)+Torque angle<85

- The trip zone will depend on the angle between the zero sequence voltage and the zero sequence current. If we are in the trip zone, the directional will issue trip permission when the value of cos(φ-φc) exceeds the setting (in a negative value).

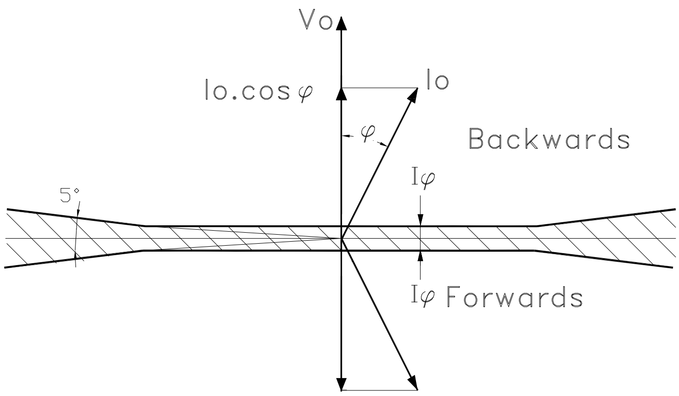
$$\mathrm{I}\cdot\cos(v - i - \phi) = \frac{\left[(\mathrm{Re}(V)\cdot\cos(\phi) + \mathrm{Im}(V)\cdot\sin(\phi))\cdot\mathrm{Re}(I) + (\mathrm{Im}(V)\cdot\cos(\phi) - \mathrm{Re}(V)\cdot\sin(\phi))\cdot\mathrm{Im}(I)\right]}{|V|}$$

Figure 32 Directional with cosine polarization



As the neutral units allow trip permission to be issued with forward and with reverse faults, in reality the characteristics will be as follows.

Figure 33 Forward/Reverse with cosine polarization



67N I*sen(φ) directional

In order to allow the directional unit to pick up, the following must be met:

- Exceed a minimum VN threshold.
- The current I minimum=In·sen(φ-φc) must exceed the minimum threshold by the absolute value. If the sign is negative, the fault is forward. If positive, the fault is reverse.
- For forward faults, the angle between the current and the displaced voltage, the maximum torque angle must be between 185 and 355.

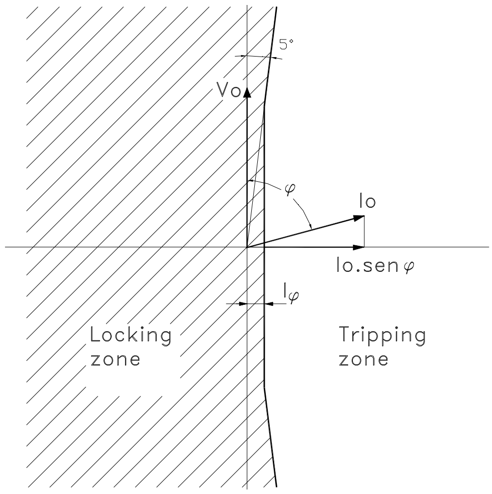
  185<Ang(I0)-angle(V0)+Torque angle<355

- For reverse faults, the angle between the current and the displaced voltage, the maximum torque angle must be between 5 and 175.

  5<Ang(I0)-angle(V0)+Torque angle<175

$$I \cdot \sin(v - i - \phi) = \frac{(\mathrm{Im}(V)\cdot\cos(\phi) - \mathrm{Re}(V)\cdot\sin(\phi))\cdot\mathrm{Re}(I) - (\mathrm{Re}(V)\cdot\cos(\phi) + \mathrm{Im}(V)\cdot\sin(\phi))\cdot\mathrm{Im}(I)}{|V|}$$

Figure 34 Directional with sine polarization



3.2.2.5 Sensitive neutral directional

Affects sensitive neutral units, allowing or blocking the trip in accordance with the configuration.

The operation can be selected from among: angular, cosine, sine and watt-metric. Various options can be selected from within the angular criterion.

This unit's settings are in the PROT/SGPDIR node. In accordance with the selected mode, they affect:

General

- Sen. Ground directional method. Indicates the directional criterion used.
  - Angular". Analyzes each phase independently.
  - "I·cosϕ"
  - "I·senϕ"
  - "Watt-metric"
- Blocking Input. Selects the signal which, when active, blocks the function. When the directional is blocked, it issues permission for the trip.
- 67NS Directional Inversion. Selects the signal which, when active, inverts the trip direction.
- Enable Events record. Allows the generation of protection events associated to the function. If set to "NO", the function's protection events are not generate. If set to "YES", the function's specific mask is contemplated.

Angular

- Torque angle (°). Indicates the directional angle.
- Directional Zone amplitude (°). Indicates the angle covered by the trip zone.
- Trip permission with low Vpol. Indicates the functioning of the directional when the polarization voltage is below the threshold. If set to YES, it enables an overcurrent trip if the memorized polarization voltage is lower than the minimum polarization voltage; if set to NO, the overcurrent trip is not allowed under those conditions. The minimum voltage polarization threshold is the same as in the neutral unit.
- Minimum Isn/Irated (%). Indicates the minimum current for polarization; the direction cannot be reliably determined below this value.

Watt-metric, I·cosϕ, I·senϕ

- Minimum power (Icos, Isin, Watt): Power value P=Vn·In·cos(φ-φc),, in which φ==Angle between Vn and In. If the power negative and higher than this value, a forward fault is registered. If it is positive and higher than this value, a reverse fault is registered.

- Switch method Icos Isen. If a signal is assigned to this input, it indicates the directional type employed (independent of the setting) I·cosϕ if the input is 0 (deactivated) and I·senϕ if the input is 1 (activated). If no signal has been assigned, the criterion selected for the setting is employed.

Table 11 Sensitive neutral directional settings

Data	Setting	Minimum	Maximum	Step	Remarks	Type
DirTyp	Sen. Ground directional method				"Angular criterion" "Icos φ" "Isen φ" "Watt-metric"	enum
ChrAng	Torque Angle (º)	0	360	1		float32
Amp	Directional Zone amplitude (º)	90	170	1		float32
LogInInvDir	67NS Directional Inversion					Int32
LogInBlDir	Blocking Input					Int32
LogInChSC	Switch method Icos Isen					Int32
BlkValA	Minimum Isn/Irated (%)	1	100	1	Value % of In	float32
EnaOpn	Trip permission with low Vpol				NO (0) / YES (1)	Boolean
BlkValW	Minimum power (Icos, Isin, Watt)	0	100	0,01		float32
MaskEna	Enable Events record				NO (0) / YES (1)	Boolean

The sensitive neutral unit has settings, commands and outputs:

- PROT/SGPDIR1 node
- Settings and logical inputs. There are 6 settings tables. See table 6 for settings. See Table 11 for details.
- Commands:
  - "DOrdBlk": Function block and unblocking.
  - "DOrdInvDir". Inverts the directional's trip direction
- Outputs: Table 12 shows the function's output data.
  - 67NS Forward. The detected direction indicates forward.
  - 67NS Reverse. The detected direction indicates reverse.
  - Polarization Failure Ins. Indicates that the direction has not been detected due to a polarization failure.
  - Ins directional inhibition. Indicates that the directional is inhibited.
  - Ins direction inversion. Indicates that the direction is opposite to the setting.

Table 12 Sensitive neutral directional outputs

Signal	Data	Attribute
67NS Forward	Fw67SG	sneut
67NS Reverse	Rv67SG	sneut
Polarization Failure Ins	FailISG	sneut
Ins Directional Inhibition	BlkDir	general
Ins Direction Inversion	InvDir	general

3.2.2.5.1 Angular polarization

Employs the neutral's SO polarization, with the difference that it employs the settings pertaining to the torque angle, zone amplitude, minimum current and trip permission without Vpol.

3.2.2.5.2 Watt-metric directional

This is for lines with Petersen coil compensation.

In order to allow the directional unit to pick up, the following must be met:

- Exceed a minimum VN threshold.
- For forward faults, the angle between the current and the displaced voltage, the maximum torque angle must be between 95 and 265.

  95<Ang(I0)-angle(V0)+Torque angle<265

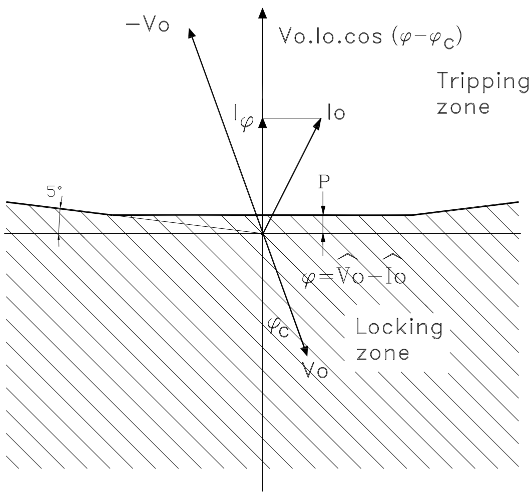
- For reverse faults, the angle between the current and the displaced voltage, the maximum torque angle must be between 275 and 85.

  275<Ang(I0)-angle(V0)+Torque angle<85

- The power P=Vn·Ins·cos(φ-φc) must exceed the minimum P threshold by the absolute value. If the sign of P is negative, the fault is forward. If positive, the fault is reverse. The equation to be implemented for calculating P is as follows:

$$P = \left(\mathrm{Re}(V)\cdot\cos(\phi) + \mathrm{Im}(V)\cdot\sin(\phi)\right)\cdot\mathrm{Re}(I) + \left(\mathrm{Im}(V)\cdot\cos(\phi) - \mathrm{Re}(V)\cdot\sin(\phi)\right)\cdot\mathrm{Im}(I)$$

Figure 35 Directional with watt-metric polarization



3.2.2.5.3 I*cos(φ) / I*sen(φ) directional

An input can be programmed ("67NS Isen(phi) or Icos(phi)") such that when activated the operating mode of I*cos(φ) changes to I*sen(φ). If programmed, this input cancels the setting: if deactivated, it runs the I*cos(φ) algorithm. If activated, the I*sen(φ) algorithm is run, independently of the setting. It does not affect either the angular of the watt-metric directional.

I*cos(φ) directional

In order to allow the directional unit to pick up, the following must be met:

- Exceed a minimum VN threshold.
- The minimum current I minimum=Ins·cos(φ-φc) must exceed the minimum threshold by the absolute value. If the sign is negative, the fault is forward. If positive, the fault is reverse.
- For forward faults, the angle between the current and the displaced voltage, the maximum torque angle must be between 95 and 265.

  95<Ang(I0)-angle(V0)+Torque angle<265

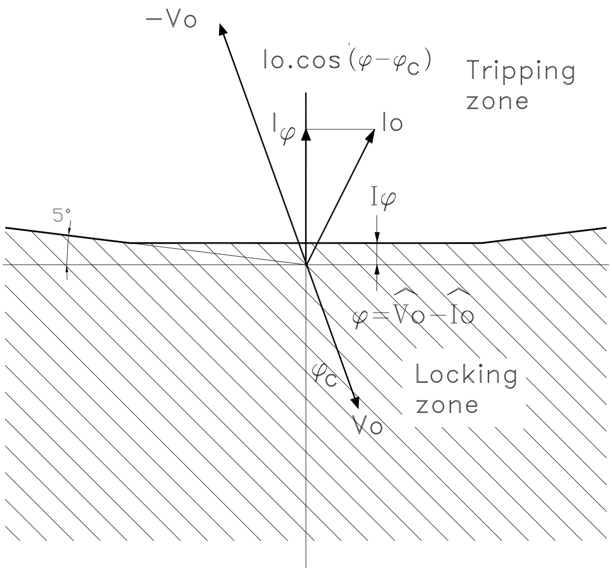
- For reverse faults, the angle between the current and the displaced voltage, the maximum torque angle must be between 275 and 85.

  275<Ang(I0)-angle(V0)+Torque angle<85

- The trip zone will depend on the angle between the zero sequence voltage and the zero sequence current. If we are in the trip zone, the directional will issue trip permission when the value of Io·cos(φ-φc) exceeds the setting (in a negative value).

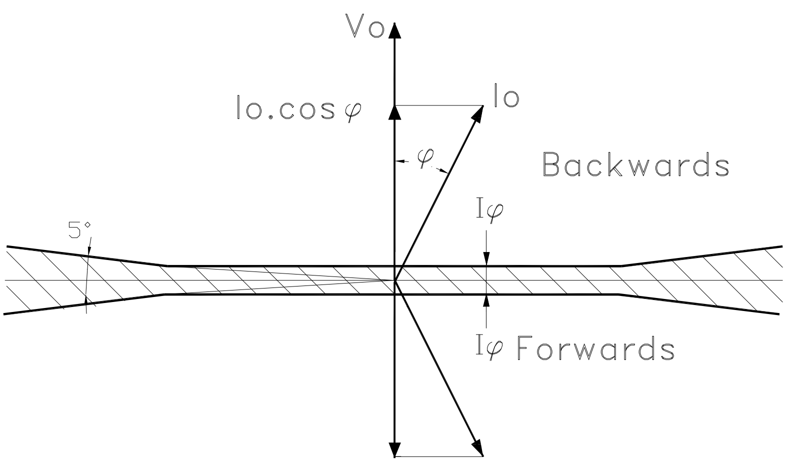
$$I\cdot\cos(v-i-\phi) = \frac{\left[\left(\mathrm{Re}(V)\cdot\cos(\phi)+\mathrm{Im}(V)\cdot\sin(\phi)\right)\cdot\mathrm{Re}(I)+\left(\mathrm{Im}(V)\cdot\cos(\phi)-\mathrm{Re}(V)\cdot\sin(\phi)\right)\cdot\mathrm{Im}(I)\right]}{|V|}$$

Figure 36 Directional with cosine polarization



As sensitive neutral units allow trip permission to be issued with forward and with reverse faults, in reality the characteristics will be as follows.

Figure 37 Forward/Reverse with cosine polarization



67N I*sen(φ) directional

In order to allow the directional unit to pick up, the following must be met:

- Exceed a minimum VN threshold.
- The current I minimum=Ins·sen(φ-φc) must exceed the minimum threshold by the absolute value. If the sign is negative, the fault is forward. If positive, the fault is reverse.
- For forward faults, the angle between the current and the displaced voltage, the maximum torque angle must be between 185 and 355.

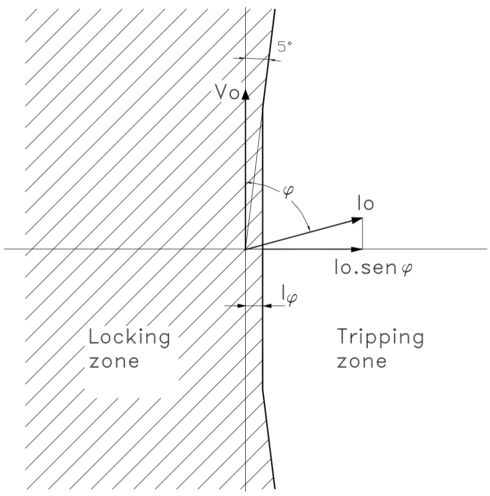
  185<Ang(I0)-angle(V0)+Torque angle<355

- For reverse faults, the angle between the current and the displaced voltage, the maximum torque angle must be between 5 and 175.

  5<Ang(I0)-angle(V0)+Torque angle<175

$$I\cdot\sin(v-i-\phi) = \frac{(\mathrm{Im}(V)\cdot\cos(\phi) - \mathrm{Re}(V)\cdot\sin(\phi))\cdot\mathrm{Re}(I) - (\mathrm{Re}(V)\cdot\cos(\phi) + \mathrm{Im}(V)\cdot\sin(\phi))\cdot\mathrm{Im}(I)}{|V|}$$

Figure 38 Directional with sine polarization



3.2.3 Phase overcurrent

3.2.3.1 Instantaneous

There are 3 independent units for each of the phases.

Each of the three units has independent settings, commands and outputs.

- Nodes:
  - Unit 1: PROT/PIOC1
  - Unit 2: PROT/PIOC2
  - Unit 3: PROT/PIOC3
- Settings and logical inputs. There are 6 settings tables. See Table 4
- Commands:
  - “DOrdBlk”: Function block and unblocking. Only acts when the function is enabled.

- Outputs: Table 13 shows the function's output data.
  - IOC1 Start phase X. Indicates that the unit's phase has picked up. It is independent for each phase.
  - IOC1 Trip phase X. Indicates that the unit's phase has tripped. It is independent for each phase.
  - IOC1 Phase Status. Indicates the function's status. It is active when enabled and not blocked. This is general for all three phases.
  - IOC1 phase Start. Indicates that the unit has picked up
  - IOC1 phase Trip. Indicates that the unit has tripped.

Table 13 Instantaneous phase function outputs

Signal	Data	Atribute
IOC1 Start phase A	Str	phsA
IOC1 Start phase B	Str	phsB
IOC1 Start phase C	Str	phsC
IOC1 Trip phase A	Op	phsA
IOC1 Trip phase B	Op	phsB
IOC1 Trip phase C	Op	phsC
IOC1 Phase Status	StEna	stVal
IOC1 Phase Start	Str	general
IOC1 Phase Trip	Op	general

3.2.3.2 Timed

There are 3 independent units for each of the phases.

Each of the three units has independent settings, commands and outputs.

- Nodes:
  - Unit 1: PROT/PTOC1
  - Unit 2: PROT/PTOC2
  - Unit 3: PROT/PTOC3
- Settings and logical inputs. There are 6 settings tables. See Table 3
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 14 shows the function's output data.
  - TOC1 Start phase X. Indicates that the unit's phase has picked up. It is independent for each phase.
  - TOC1 Trip phase X. Indicates that the unit's phase has tripped. It is independent for each phase.
  - TOC 1 Phase Status. Indicates the function's status. It is active when enabled and not blocked. This is general for all three phases.
  - TIOC1 phase Start. Indicates that the unit has picked up
  - TOC1 phase Trip. Indicates that the unit has tripped.

Table 14 Timed phase function outputs

Signal	Data	Atribute
TOC1 Start phase A	Str	phsA
TOC1 Start phase B	Str	phsB
TOC1 Start phase C	Str	phsC
TOC1 Trip phase A	Op	phsA
TOC1 Trip phase B	Op	phsB
TOC1 Trip phase C	Op	phsC
TOC1 Phase Status	StEna	stVal
TOC1 Phase Start	Str	general
TOC1 Phase Trip	Op	general

3.2.4 Neutral overcurrent

Employs the neutral transformer input as a measurement.

3.2.4.1 Instantaneous

There are 3 independent units.

Each of the three units has independent settings, commands and outputs.

- Nodes:
  - Unit 1: PROT/GPIOC1
  - Unit 2: PROT/GPIOC2
  - Unit 3: PROT/GPIOC3
- Settings and logical inputs. There are 6 settings tables. See Table 4.
- Commands:
  - “DOrdBlk”: Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 15 shows the function’s output data.IOC1 Ground Status. Indicates the function’s status. It is active when enabled and not blocked.
  -
  - GIOC1 Start. Indicates that the unit has picked up.
  - GIOC1 Trip. Indicates that the unit has tripped.
  - IOC1 Ground Status. Indicates the function’s status. It is active when enabled and not blocked.

Table 15 Neutral instantaneous function outputs

Signal	Data	Attribute
GIOC1 Start	Str	neut
GIOC1 Trip	Op	neut
IOC1 Ground Status	StEna	stVal

3.2.4.2 Timed

There are 3 independent units for each of the phases.

Each of the three units has independent settings, commands and outputs.

- Nodes:
  - Unit 1: PROT/GPTOC1
  - Unit 2: PROT/GPTOC2
  - Unit 3: PROT/GPTOC3
- Settings and logical inputs. There are 6 settings tables. See Table 3.
- Commands:
  - “DOrdBlk”: Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 16 shows the function’s output data.
  - GTOC1 Start. Indicates that the unit has picked up.
  - GTOC1 Trip. Indicates that the unit has tripped.
  - TOC1 Ground Status. Indicates the function’s status. It is active when enabled and not blocked.

Table 16 Timed neutral function outputs

Signal	Data	Attribute
GTOC1 Start	Str	neut
GTOC1 Trip	Op	neut
TOC1 Ground Status	StEna	stVal

3.2.5 Sensitive neutral overcurrent

Not available on all models (see model functions).

Employs the sensitive neutral transformer input as a measurement.

The setting range changes in relation to that shown in the overcurrent units:

- Pick up from 0.001A to 10A.
- Additional time from 0ms to 1800000ms (30 minutes).

3.2.5.1 Instantaneous

There are 3 independent units.

Each of the three units has independent settings, commands and outputs.

- Nodes:
  - Unit 1: PROT/SGPIOC1
  - Unit 2: PROT/SGPIOC2
  - Unit 3: PROT/SGPIOC3
- Settings and logical inputs. There are 6 settings tables. See Table 4, except for the pick up and additional time ranges.
- Commands:
  - “DOrdBlk”: Function block and unblocking. Only acts when the function is enabled.

- Outputs: Table 17 shows the function's output data.
  - SGIOC1 Start. Indicates that the unit has picked up.
  - SGIOC1 Trip. Indicates that the unit has tripped.
  - IOC1 Sensitive Ground Status. Indicates the function's status. It is active when enabled and not blocked.

Table 17 Sensitive neutral instantaneous function outputs

Signal	Data	Attribute
SGIOC1 Start	Str	general
SGIOC1 Trip	Op	general
IOC1 Sensitive Ground Status	StEna	stVal

3.2.5.2 Timed

There are 3 independent units for each of the phases.

Each of the three units has independent settings, commands and outputs.

- Nodes:
  - Unit 1: PROT/SGPTOC1
  - Unit 2: PROT/SGPTOC2
  - Unit 3: PROT/SGPTOC3
- Settings and logical inputs. There are 6 settings tables. See Table 3, except for the pick up and additional time ranges.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 18 shows the function's output data.
  - SGTOC1 Start. Indicates that the unit has picked up.
  - SGTOC1 Trip. Indicates that the unit has tripped.
  - TOC1 Sensitive Ground Status. Indicates the function's status. It is active when enabled and not blocked.

Table 18 Sensitive neutral timed function outputs

Signal	Data	Attribute
SGTOC1 Start	Str	general
SGTOC1 Trip	Op	general
TOC1 Sensitive Ground Status	StEna	stVal

3.2.6 Grounding overcurrent

Not available on all models (see model functions).

Employs the polarization current transformer input as a measurement.

This unit is not directional.

3.2.6.1 Instantaneous

There are 3 independent units.

Each of the three units has independent settings, commands and outputs.

- Nodes:
  - Unit 1: PROT/ESPIOC1
  - Unit 2: PROT/ESPIOC2
  - Unit 3: PROT/ESPIOC3
- Settings and logical inputs. There are 6 settings tables. See Table 4.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 19 shows the function's output data.
  - ESIOC1 Start. Indicates that the unit has picked up.
  - ESIOC1 Trip. Indicates that the unit has tripped.
  - IOC1 Earthing System Status. Indicates the function's status. It is active when enabled and not blocked.

Table 19 Instantaneous grounding function outputs

Signal	Data	Attribute
ESIOC1 Start	Str	general
ESIOC1 Trip	Op	general
IOC1 Earthing System Status	StEna	stVal

3.2.6.2 Timed

There are 3 independent units for each of the phases.

Each of the three units has independent settings, commands and outputs.

- Nodes:
  - Unit 1: PROT/ESPTOC1
  - Unit 2: PROT/ESPTOC2
  - Unit 3: PROT/ESPTOC3
- Settings and logical inputs. There are 6 settings tables. See Table 3.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 20 shows the function's output data.
  - ESTOC1 Start. Indicates that the unit has picked up.
  - ESTOC1 Trip. Indicates that the unit has tripped.
  - TOC1 Earthing System Status. Indicates the function's status. It is active when enabled and not blocked.

Table 20 Timed grounding function outputs

Signal	Data	Attribute
ESTOC1 Start	Str	general
ESTOC1 Trip	Op	general
TOC1 Earthing System Status	StEna	stVal

3.2.7 Unbalance overcurrent

Employs 3 times the inverse sequence as a measurement:

3·I2=(Ia+a2·Ib+a·Ic)   In which=1|120º

The calculation of the sequence takes into phase succession order setting (ABC/ACB).

The inverse sequence directional is employed by this unit.

The measurement type setting is not used, as the fundamental is always used.

3.2.7.1 Instantaneous

There are 3 independent units.

Each of the three units has independent settings, commands and outputs.

- Nodes:
  - Unit 1: PROT/UNPIOC1
  - Unit 2: PROT/UNPIOC2
  - Unit 3: PROT/UNPIOC3
- Settings and logical inputs. There are 6 settings tables. It employs the settings in Table 4, with the exception of the measurement type.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 21 shows the function's output data.
  - UNIOC1 Start. Indicates that the unit has picked up.
  - UNIOC1 Trip. Indicates that the unit has tripped.
  - IOC1 Unbalanced Status. Indicates the function's status. It is active when enabled and not blocked.

Table 21 Instantaneous unbalance function outputs

Signal	Data	Attribute
UNIOC1 Start	Str	general
UNIOC1 Trip	Op	general
IOC1 Unbalanced Status	StEna	stVal

3.2.7.2 Timed

There are 3 independent units for each of the phases.

Each of the three units has independent settings, commands and outputs.

- Nodes:
  - Unit 1: PROT/UNPTOC1
  - Unit 2: PROT/UNPTOC2
  - Unit 3: PROT/UNPTOC3
- Settings and logical inputs. There are 6 settings tables. Employs the settings in Table 3, with the exception of the measurement type.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.

- Outputs: Table 22 shows the function's output data.
  - UNTOC1 Start. Indicates that the unit has picked up.
  - UNTOC1 Trip. Indicates that the unit has tripped.
  - TOC1 Unbalanced Status. Indicates the function's status. It is active when enabled and not blocked.

Table 22 Timed unbalance function outputs

Signal	Data	Attribute
UNTOC1 Start	Str	general
UNTOC1 Trip	Op	general
TOC1 Unbalanced Status	StEna	stVal

3.2.8 2nd harmonic restraint

Permits the instantaneous and timed phase, neutral, sensitive neutral and unbalance overcurrent units to be blocked (51, 50, 51N, 50N, 51NS, 50NS and 67Q).

Restraint by phase or for all the phases is available for the 50/51 units. The units to be blocked are selected by settings.

To activate the restraint, the following must be met simultaneously:

- The fundamental current must exceed the minimum inrush value.
- The relationship between the 2nd harmonic value and the fundamental must exceed a set threshold.
- The 2nd harmonic current must exceed 1% of In (50mA with In=5A and 10ma with In=1A).

To deactivate the restraint, the following must be met:

- The current must be less than 95% of the minimum current threshold, or
- The current must be below 95% of the restraint percentage threshold

The restraint is calculated independently for each phase, neutral and sensitive neutral.

The phase units' restraint can act per phase (the restraint in any one phase only blocks the phase in question) or it can be general (the restraint in any one phase blocks all the phases).

For the unbalance unit restraint, it is sufficient that the conditions are given in a phase or in the neutral.

The units' restraint settings are:

- Enabled. Indicates whether the function is enabled or not. The options available are:
  - YES. It is enabled
  - NO. It is disabled
  - Close only. Is enabled for a second after closing.
- I2° / Ifund Threshold (%). Indicates the percentage of the 2nd harmonic in relation to the fundamental above which the restraint is produced.
- Minimum operating current (A). Minimum value of the fundamental current in order for the restraint to be produced. No restraint is indicated below this value, even when the % I2/If is above the setting.
- Restraint. Enables the units on which the restraint is to act to be indicated. There are separate settings for each unit. In general, the setting is YES/NO, except in those phases that can be:
  - NO. Restraint is not permitted
  - Phase. The restraint in one phase only blocks the phase in question.
  - General. The restraint in one phase blocks all the phases.
- Harm. Restraint unit Blocking. Selects the signal which, when active, blocks the function.

- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generate. If set to “YES”, the function’s specific mask is contemplated.

There are independent settings, commands and outputs in each restraint unit.

Phases

- PROT/PHAR1 node
- Settings and logical inputs. There are 6 settings tables. For details see Table 24. There is restraint setting for each timed and instantaneous phase overcurrent unit (No/Yes/General) and unbalance (No/Yes)
- Commands:
  - “DOrdBlk”: Function block and unblocking. Only acts when the function is enabled.
- Outputs:
  - Second harmonic restraint Ix. Indicates that the restraint has been activated in this phase. It is independent for each phase.
  - Second harmonic restraint ph. Indicates that the restraint has been activated in one of the phases.
  - Harmonic Ph restraint Status. Indicates the function’s status. It is active when enabled and not blocked. This is general for all three phases.

Table 23 Phase restraint outputs

Signal	Data	Attribute
Second harmonic restraint Ia	Op	phsA
Second harmonic restraint Ib	Op	phsB
Second harmonic restraint Ic	Op	phsC
Second harmonic restraint ph	Op	general
Harmonic Ph restraint Status	StEna	stVal

Table 24 Phase 2nd harmonic restraint settings

Data	Setting	Min.	Max	Step	Remarks	Type
PHAREna	Enabled				NO (0) / YES (1) Only in closure (2)	Boolean
StrVal	I2° / Ifund. Treshold (%)	10	100	1	1	float32
BlkValA	Minimum operating current (A)	0,1	150,0	0,01		float32
Restr51U1	Restraint 51 unit 1				NO (0) PHASE (1) GENERAL (2)	enum
Restr51U2	Restraint 51 unit 2				NO/PHASE/GENERAL	enum
Restr51U3	Restraint 51 unit 3				NO/PHASE/GENERAL	enum
Restr50U1	Restraint 50 unit 1				NO/PHASE/GENERAL	enum
Restr50U2	Restraint 50 unit 2				NO/PHASE/GENERAL	enum
Restr50U3	Restraint 50 unit 3				NO/PHASE/GENERAL	enum
Restr67QT1	Restraint 67QT unit 1				NO/YES	Boolean
Restr67QT2	Restraint 67QT unit 2				NO/YES	Boolean
Restr67QT3	Restraint 67QT unit 3				NO/YES	Boolean
Restr67QI1	Restraint 67QI unit 1				NO/YES	Boolean
Restr67QI2	Restraint 67QI unit 2				NO/YES	Boolean
Restr67QI3	Restraint 67QI unit 3				NO/YES	Boolean
LogInBlk	Harm.Restraint unit Blocking					Int32
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

Neutral

- PROT/GPHAR1 node
- Settings and logical inputs. There are 6 settings tables. For details see Table 26. There is restraint setting for each timed and instantaneous neutral overcurrent unit (No/Yes).

- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 25 shows the function's output data.
  - Second harmonic restraint In. Indicates that the neutral restraint has been activated.
  - Harmonic In restraint Status. Indicates the function's status. It is active when enabled and not blocked.

Table 25 Neutral restraint outputs

Signal	Data	Attribute
Second harmonic restraint In	Op	neut
Harmonic In restraint Status	StEna	stVal

Table 26 Neutral 2nd harmonic restraint settings

Data	Setting	Min.	Max	Step	Remarks	Type
PHAREna	Enabled				NO (0) / YES (1) Only in closure (2)	Boolean
StrVal	I2° / Ifund. Threshold (%)	10	100	1	1	float32
BlkValA	Minimum operating current (A)	0,1	150,0	0,01		float32
Restr51N1	Restraint 51 unit 1				NO/YES	Boolean
Restr51N2	Restraint 51 unit 2				NO/YES	Boolean
Restr51N3	Restraint 51 unit 3				NO/YES	Boolean
Restr50N1	Restraint 50 unit 1				NO/YES	Boolean
Restr50N2	Restraint 50 unit 2				NO/YES	Boolean
Restr50N3	Restraint 50 unit 3				NO/YES	Boolean
LogInBlk	Harm.Restraint unit Blocking					Int32
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

Sensitive neutral

Only in models equipped with the sensitive neutral option.

- PROT/SGPHAR1 node
- Settings and logical inputs. There are 6 settings tables. For details see Table 28. There is a restraint setting for each timed and instantaneous sensitive neutral overcurrent unit (No/Yes).
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 27 shows the function's output data.
  - Second harmonic restraint Ins. Indicates that the sensitive neutral restraint has been activated.
  - Harmonic Ins restraint Status. Indicates the function's status. It is active when enabled and not blocked.

Table 27 Sensitive neutral restraint outputs

Signal	Data	Attribute
Second harmonic restraint Ins	Op	general
Harmonic Ins restraint Status	StEna	stVal

Table 28 Sensitive neutral 2nd harmonic restraint settings

Data	Setting	Min.	Max	Step	Remarks	Type
PHAREna	Enabled				NO (0) YES (1) Only in closure (2)	Boolean
StrVal	I2° / Ifund. Treshold (%)	10	100	1	1	float32
BlkValA	Minimum operating current (A)	0,1	150,0	0,01		float32
Restr51NS1	Restraint 51NS Unit 1				NO/YES	Boolean
Restr51NS2	Restraint 51NS unit 2				NO/YES	Boolean
Restr51NS3	Restraint 51NS unit 3				NO/YES	Boolean
Restr50NS1	Restraint 50NS unit 1				NO/YES	Boolean
Restr50NS2	Restraint 50NS unit 2				NO/YES	Boolean
Restr50NS3	Restraint 50NS unit 3				NO/YES	Boolean
LogInBlk	Harm. Restraint unit Blocking					Int32
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

3.2.9 Isolated neutral

The "Directional zero-sequence relay" function incorporated into the protection carries out a directional protection against earth faults in isolated neutral systems (function 67 NA).

Figure 39 shows the characteristic curve of this function. It can work as directional or not directional (Figure 40):

- When functioning in directional mode, the relay will trip when the point defined by the measured VN and IN values falls within the characteristic zone's trip region, with IG registering a lag angle in the 90º (MTA_67NA/2 interval in relation to VG.°
- When functioning as "non-directional", the only trip condition is that of falling within the characteristic area, irrespective of the angle.

The first trip is timed according to the corresponding parameter's setting. The successive trips that occur during the time programmed as "switching time" as of the first trip are instantaneous; the first trip as of this that time is timed once again.

Zero sequence current (IG). It is measured in the transformer configured as sensitive neutral. It comes from the connection in parallel of the secondaries of 3 phase current transformers or from a toroid transformer handling the 3 phases.

Zero sequence voltage (VG). The PROT/PVGE node's VO measurement type setting indicates the VG measurement employed:

- Calculated: It is calculated internally as the vector sum of the three voltage phases.
- Measurement. It is measured in the transformer configured as Vn. It comes from the open delta connection of the 3 voltage transformers.

The current measurement range is 1mA to 10A and the voltage range is 0.5V to 200V.

Figure 39 Characteristic isolated neutral curve

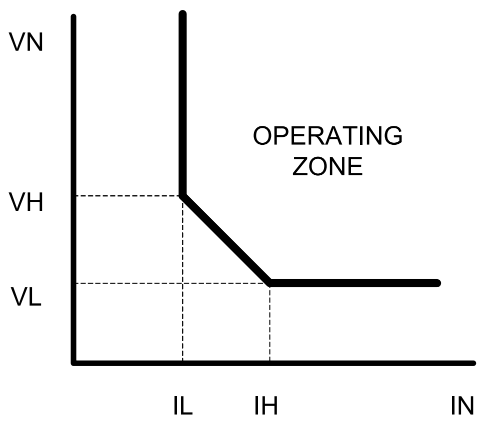
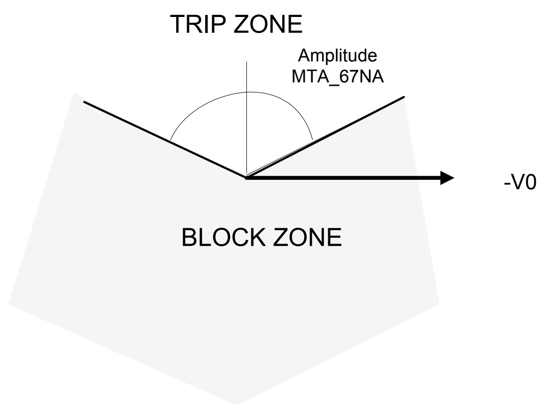


Figure 40 Isolated neutral directional



The settings used in these functions are:

- Enabled. Indicates whether the function is enabled or not.
- Torque control. Indicates whether the function is directional or not.
- Low current. Indicates the IL point of the characteristic curve.
- High current. Indicates the IH point of the characteristic curve. IH >= IL must be met.
- Low voltage. Indicates the VL point of the characteristic curve.
- High voltage. Indicates the VH point of the characteristic curve. VH >= VL must be met.
- First time delay (ms). Time during which the conditions must be met in order for the first trip to take place.
- Switch to Instantaneous (ms). The time following the first trip during which the trips are instantaneous.
- Directional zone amplitude (°). Indicates the amplitude of the directional trip region.
- Blocking Input. Selects the signal which, when active, blocks the function.
- Time delay cancellation Input. Selects the signal which, when active, generates the instantaneous trips regardless of the setting time.
- General trip. Indicates if this unit produces general trip or not. For additional details, see section corresponding to the recloser (5.2.1).
- TripP:RL,RR,RL,R:1,2,3,4,MC. Indicates the trip and block permission in accordance with the recloser status: standby, blocked, safety time after reclosing, after closing. It is configured bit by bit; for additional details, see section corresponding to the recloser (5.2.2).
- Reclose perm.(R1,R2,R3,R4). Indicates whether each trip type can be reclosed or not, in accordance with the recloser's closing cycle (5.2.3).
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generate. If set to “YES”, the function’s specific mask is contemplated.

Table 29 Isolated neutral settings

Data	Setting	Minimum	Maximum	Step	Remarks	Type
PIOCEna	Enabled				NO/YES	Boolean
DirMod	Torque control				NO/YES	enum
LoValA	Low current (A)	5mA 1mA	10 A 1 A	0,001	(10 A range). (1 A range).	float32
HiValA	High current (A)	5mA 1mA	10 A 1 A	0,001	(10 A range). (1 A range).	float32
LoValV	Low voltage (V)	0,5	60,0	0,1		float32
HiValV	High voltage (V)	0,5	60,0	0,1		float32
OpDlTmms	First trip time delay (ms)	0	600000	10		Int32
InstTmms	Switch to Instantaneous (ms)	0	10000	10		Int32
DirVal	Directional zone amplitude (°)	60	170	1°		Int32
LogInBlk	Blocking Input					uint 32
LogInCaTm	Time delay Cancellation Input					uint 32
GenTrip	General trip				NO (0) / YES (1)	Boolean
TripPerm	TripP:RL,RR,RL,R:1,2,3,4,MC	0	255	1	Bit meaning	ING
ReclPerm	Reclose perm.(R1,R2,R3,R4)	0	15		Bit meaning	ING
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

There are independent settings, commands and outputs.

- PROT/IGPIOC node
- Settings and logical inputs. There are 6 settings tables. For details, see Table 29.
- Commands:
  - “DOrdBlk”: Function block and unblocking. Only acts when the function is enabled.

- Outputs: Table 30 shows the function's output data.
  - Isolated Ground Start. Indicates that the unit has picked up.
  - Isolated Ground Trip. Indicates that the unit has tripped.
  - Isolated Ground Status. Indicates the function's status. It is active when enabled and not blocked.

Table 30 Isolated neutral function outputs

Signal	Data	Attribute
Isolated Ground Start	Str	general
Isolated Ground Trip	Op	general
Isolated Ground Status	StEna	stVal

3.2.10 Compensated neutral

Figure 41 shows the characteristic curve of this function. It can work as directional or not directional (Figure 42):

- When functioning in directional mode, the relay will trip when the point defined by the measured VN and IN values falls within the characteristic zone's trip region, with IN displaced at an angle in the MTA_67NC/2 interval in relation to -VN.º
- When functioning as "non-directional", the only trip condition is that of falling within the characteristic area, irrespective of the angle.

The first trip is timed according to the corresponding parameter's setting. The successive trips that occur during the time programmed as "switching time" as of the first trip are instantaneous; the first trip as of this that time is timed once again.

Zero sequence current (IG). It is measured in the transformer configured as sensitive neutral. It comes from the connection in parallel of the secondaries of 3 phase current transformers or from a toroid transformer handling the 3 phases.

Zero sequence voltage (VG). The PROT/PVGE node's VO measurement type setting indicates the VG measurement employed:

- Calculated: It is calculated internally as the vector sum of the three voltage phases.
- Measurement. It is measured in the transformer configured as Vn. It comes from the open delta connection of the 3 voltage transformers.

The current measurement range is 1mA to 10A and the voltage range is 0.5v to 200v.

Figure 41 Characteristic compensated neutral curve

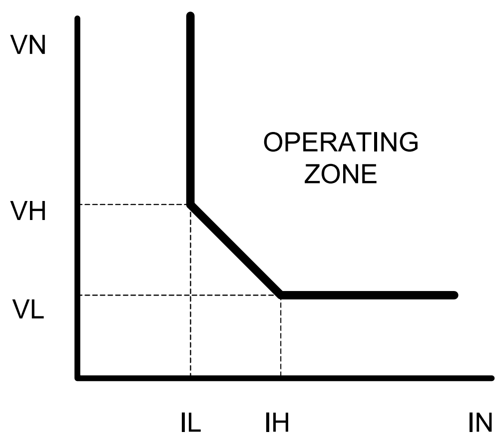
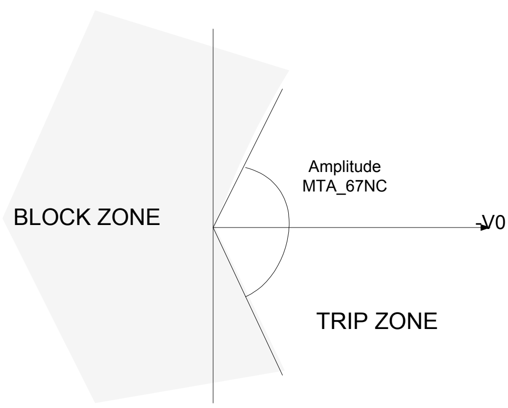


Figure 42 Compensated neutral directional



The settings used in these functions are:

- Enabled. Indicates whether the function is enabled or not.
- Torque control. Indicates whether the function is directional or not.
- Low current (A). Indicates the IL point of the characteristic curve.
- High current (A). Indicates the IH point of the characteristic curve. IH >= IL must be met.
- Low voltage (V). Indicates the VL point of the characteristic curve.
- High voltage (V). Indicates the VH point of the characteristic curve. VH >= VL must be met.
- First trip time delay (ms). Time during which the conditions must be met in order for the first trip to take place.
- Switch to instantaneous (ms). The time following the first trip during which the trips are instantaneous.
- Directional zone amplitude (°). Indicates the amplitude of the directional trip region.
- Blocking Input. Selects the signal which, when active, blocks the function.
- Time delay cancellation Input. Selects the signal which, when active, generates the instantaneous trips regardless of the setting time.
- General trip. Indicates if this unit produces general trip or not. For additional details, see section corresponding to the recloser (5.2.1).
- TripP:RL,RR,RL,R:1,2,3,4,MC. Indicates the trip and block permission in accordance with the recloser status: standby, blocked, safety time after reclosing, after closing. It is configured bit by bit; for additional details, see section corresponding to the recloser (5.2.2).
- Reclose perm.(R1,R2,R3,R4). Indicates whether each trip type can be reclosed or not, in accordance with the recloser's closing cycle (5.2.3).
- Enable Events record. Allows the generation of protection events associated to the function. If set to "NO", the function's protection events are not generate. If set to "YES", the function's specific mask is contemplated.

Table 31 Compensated neutral settings

Data	Setting	Minimum	Maximum	Step	Remarks	Type
PIOCEna	Enabled				NO/YES	Boolean
DirMod	Torque control				NO/YES	enum
LoValA	Low current (A)	5mA 1mA	10 A 1 A	0,001	(10 A range). (1 A range).	float32
HiValA	High current (A)	5mA 1mA	10 A 1 A	0,001	(10 A range). (1 A range).	float32
LoValV	Low voltage (V)	0,5	60,0	0,1		float32
HiValV	High voltage (V)	0,5	60,0	0,1		float32
OpDlTmms	First trip time delay (ms) (ms)	0	600000	10		Int32
InstTmms	Switch to instantaneous (ms)	0	10000	10		Int32
DirVal	Directional zone amplitude (°)	60	170	1°		Int32
LogInBlk	Blocking Input					uint 32
LogInCaTm	Time delay cancelation Input					uint 32
GenTrip	General trip				NO (0) / YES (1)	Boolean
TripPerm	TripP:RL,RR,RL,R:1,2,3,4,MC	0	255	1	Bit meaning	ING
ReclPerm	Reclose perm.(R1,R2,R3,R4)	0	15		Bit meaning	ING
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

There are independent settings, commands and outputs.

- PROT/CGPIOC node
- Settings and logical inputs. See Table 31.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.

- Outputs: Table 32 shows the function's output data.
  - Compensated Ground Start. Indicates that the unit has picked up.
  - Compensated Ground Trip. Indicates that the unit has tripped.
  - Compensated neutral Status. Indicates the function's status. It is active when enabled and not blocked.

Table 32 Compensated neutral function outputs

Signal	Data	Attribute
Compensated Ground Start	Str	general
Compensated Ground Trip	Op	general
Compensated neutral Status	StEna	stVal

3.2.11 Voltage control (51V/50V)

The phase overcurrent functions can be controlled by voltage in such a way that the pick up current decreases if the control voltage is inferior to the rated current. To do so, the "Voltage control enabled" setting must be set to "YES"; if set to NO, the settings programmed in the phase units are effective, as the voltage control is disabled. This setting is common for instantaneous and timed.

It functions independently for timed and instantaneous and the action, the unit on which it is to act and the value of the new settings of the phase overcurrent units can be selected.

Settings are used to determine which unit from among the three 51 and/or the three 50 units it is to act.

The Cold load pickup and special Function functions take precedence over them.

It affects the settings of the instantaneous and timed units (pick up, curve type, time index and additional time), but does not affect the enabled of the units, which does not vary with the voltage control.

Timed function

When enabled, it affects the selected phase timed unit.

It has two functioning modes: boost and settings change.

This function is subordinated to the phase timed function, in the sense that it makes the phase timed operate with other settings. However, if the phase timed function is disabled, function 51V has no effect.

(51V)-Boost by voltage (MODE 1).

It only affects the selected unit's pick up threshold settings, with the rest of the settings remaining unchanged.

Each phase's pick up current is controlled by a phase to phase voltage: IA by VAB, IB by VBC and IC by VCA.

- When the control voltage is 10% of the programmed value, the controlled pick up current is the 10% of the programmed value.
- When the control voltage is 90% of the programmed value, the controlled pick up current is the 90% of the programmed value.
- Between both values, the variation of the pick up current in relation to the control voltage is lineal.
- For control voltage values higher than the 90% of the rated value, the pick up current is the programmed value.

(51V)-Settings change (MODE 2).

When one of the phase to phase voltages is lower than the control voltage (programmed value), function 51's effective settings switch from those programmed in "phase timed" to those programmed as “control by voltage”. In order to recover the “phase timed” settings, the 3 phase to phase voltages must be greater than the control voltage.

Instantaneous function

(50V)-Settings change (MODE 2).

When enabled, it affects the selected phase instantaneous unit.

This function is subordinated to the phase instantaneous functions, in the sense that it makes the phase timed operate with other settings. However, if the phase instantaneous functions are disabled, the 50V function has no effect.

When one of the phase to phase voltages is lower than the control voltage (programmed value), function 50's effective settings switch from those programmed in "phase instantaneous" to those programmed as "control by voltage".

The settings used in these functions are:

- Voltage control type: Affect the instantaneous and the timed units. If set to NO, the function is disabled. If set to YES, it is enabled and the individual timed and instantaneous settings are consulted.
- Timed unit:
  - Enabled. Indicates the timed unit's functioning mode.
    - NO. The timed unit is disabled.
    - Boost. Functions in boost by voltage mode.
    - Settings change. Functions in settings change mode.
  - 51 unit to control. Indicates the unit affected.
  - 51V Start value (A). In the change settings mode, its replace the value of the selected timed units.
  - 51V Operating Curve Type. In the change settings mode, its replace the value of the selected timed units.
  - 51V Time dial. In the change settings mode, its replace the value of the selected timed units.
  - 51V Operate delay time. In the change settings mode, its replace the value of the selected timed units.
- Instantaneous unit:
  - Enabled. Indicates the timed unit's functioning mode.
    - NO. The timed unit is disabled.
    - Settings change. Functions in settings change mode.
  - 50 unit to control. Indicates the unit affected.
  - 50V Start value (A). Replaces the value of the selected instantaneous units.
  - 50V Operate delay time. Replaces the value of the selected instantaneous units.
- Enable Events record. Allows the generation of protection events associated to the function. If set to "NO", the function's protection events are not generated. If set to "YES", the function's specific mask is contemplated.

Table 33 Control by voltage settings

Data	Setting	Min	Max	Step	Remarks	Type
PVOCEna	Voltage control type				YES/NO	Boolean
	Timed					
PVOCTmpEna	Enabled				NO (0) Boost (1) Change settings (2)	Boolean
TmpBlkValV	51V Voltage Control (V)	10	200	0,1		float32
PTOCUn	51 unit to control					enum
TmpStrVal	51V Start Value (A)	0,1	150,0	0,01		float32
TmpAVCrv	51V Operating Curve Type				ANSI-EI Extreme. Inverse (1) ANSI-MI Very inverse (2) ANSI-I Normal inverse(3) ANSI-MODI Moderately inverse (4) IEC-I Normal inverse (9) IEC-MI Very inverse (10) IEC-EI Extreme. Inverse (12) IEC-IC Short inverse (13) IEC-IL Long inverse (14) IEC-MIEs Very inverse special (50)	enum

					User curves 1 (33) User curves 2 (34) User curves 3 (35) User curves 4 (36) Definite time (49)	
TmMult	51V Time dial	0,05	30,0	0,01		float32
TmpOpTmms	51V Operate delay time	0	600000	10		Int32
	Instantaneous					
PVOCInstEna	Enabled				NO (0) Change settings (1)	Boolean
InstBlkValV	50V Voltage Control (V)	10	200	0,1		float32
PIOCUn	50 unit to control					enum
InstStrVal	50V Start Value (A)	0,1	150,0	0,01		float32
InstOpTmms	50V Operate Delay time	0	600000	10		Int32
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

There are independent settings and outputs.

- PROT/PVOC1 node
- Settings and logical inputs. There are 6 settings tables. See Table 33.
- Outputs: The function’s output data are shown in Table 34.
  - 50 V Activation. Indicates that the instantaneous units' control by voltage is activated.
  - 51 V Activation. Indicates that the timed units' control by voltage is activated.
  - Voltage Supervision Status. Indicates the function’s status. It is active when enabled and not blocked. This is general for instantaneous and timed.

Table 34 Control by voltage function outputs

Signal	Data	Attribute
50 V Activation	Op1	general
51 V Activation	Op2	general
Voltage Supervision Status	StEna	stVal

3.2.12 High current lockout

Instantaneous non-directional phase and neutral overcurrent functions that are only enabled as of a certain number of trips.

There are independent settings for phase and neutral.

They differ from standard overcurrent functions by virtue of the two following characteristics:

- If a trip is produced, Definitive Trip is activated
- The number of trips (0 to 3) is programmable within the Current Cycle sequence as of which the function is active. If set to 0, the standby recloser is also active (supervising). If set to 1, the recloser is blocked for any reclosure equal to or greater than 1. When set to 0, the first reclosure is also blocked.

The settings used in these functions are:

- Enabled. Indicates whether the function is enabled or not.
- Start value (A). Set in secondary amps. It indicates the current value as of which the function is activated.
- Operate delay time (ms). Indicates the time during which the conditions for the tripping of the function must be met.
- Trip number. It indicates number of trips as of which the function is activated.
- Blocking Input. Selects the signal which, when active, blocks the function.

- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

Table 35 Phase (PHCL) and neutral (GPHCL) HCL function settings

Data	Setting	Minimum	Maximum	Step	Remarks	Type
PHCLEna	Enabled				NO/YES	Boolean
StrVal	Start value (A)	0,02	150,0	0,01		float32
OpDlTmms	Operate delay time (ms)	0	7200000	10		Int32
TrNum	Trip number	0	3	1		enum
LogInBlk	Blocking Input					uint 32
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

There are independent settings, commands and outputs.

Phases

- Node PROT/PHCL
- Settings and logical inputs. There are 6 settings tables. See Table 35.
- Commands:
  - “DOrdBlk”: Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 36 shows the function’s output data
  - HCL X Start. Indicates that the unit has picked up. It is independent for each phase.
  - HCL X Trip. Indicates that the unit has tripped. It is independent for each phase.
  - General activation. Indicates that one of the unit's phases has tripped.
  - Enabled. Indicates the function’s status. It is active when enabled and not blocked. This is general for all three phases.

Table 36 Phase HCL function outputs (PHCL)

Signal	Data	Attribute
HCL Ia Start	Str	phsA
HCL Ib Start	Str	phsB
HCL Ic Start	Str	phsC
HCL Ia Trip	Op	phsA
HCL Ib Trip	Op	phsB
HCL Ic Trip	Op	phsC
HCL Phase Status	StEna	stVal

Neutral

- PROT/GPHCL nodes
- Settings and logical inputs. There are 6 settings tables. See Table 35.
- Commands:
  - “DOrdBlk”: Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 37 shows the function’s output data.
  - HCL In Start. Indicates that the unit has picked up.
  - HCL In Trip. Indicates that the unit has tripped.
  - HCL Ground Status. Indicates the function’s status. It is active when enabled and not blocked.

Table 37 Neutral HCL function outputs (GPHCL)

Signal	Data	Attribute
HCL In Start	Str	neut
HCL In Trip	Op	neut
HCL Ground Status	StEna	stVal

3.2.13 Cold load pickup

Also called cold load pick up. This function is aimed at avoiding untimely trips when the load returning to a line that has been without supply for a certain period exceeds the value set for the protection without a fault having occurred, due to the expiry of the "off "period of all the oven-, heater-, cooler-, etc. type loads and the simultaneous reconnection of all such elements. Such situations produce a heavy inrush current in the line which, nevertheless, can be supported for a certain period. The effect can be produced not only upon the manual closure of a breaker that has been open for a period, but also with a permanently closed breaker, due to the opening of a breaker up-current.

This function detects such conditions and changes the active table during a programmable time.

The function is activated when the "open pole detector" function detects the three poles as open. In such circumstances, it begins to meter the programmed time to determine that the load is "cold" (this period can be 0, meaning that the opening of a circuit breaker would lead to a cold load situation). If the closure of the breaker is not detected following this period ("3 open poles" signal activated), the protection's normal values are replaced by those in table 6. When the closure of one of the poles is detected ("3 poles open" signal denied), the metering of a programmable time (Action time) begins, during which the settings remain the same as those that were operative prior to the detection of the cold load.

The "open pole detector" function allows the manner in which opening of the breaker is checked (contact + current, contact + current + voltage) to be configured.

The cold load activation time must be greater than the reclosure time. The "cold load" function is deactivated while the unit is on "ongoing cycle", that is to say, while the closure control is assumed by the Reclosure function.

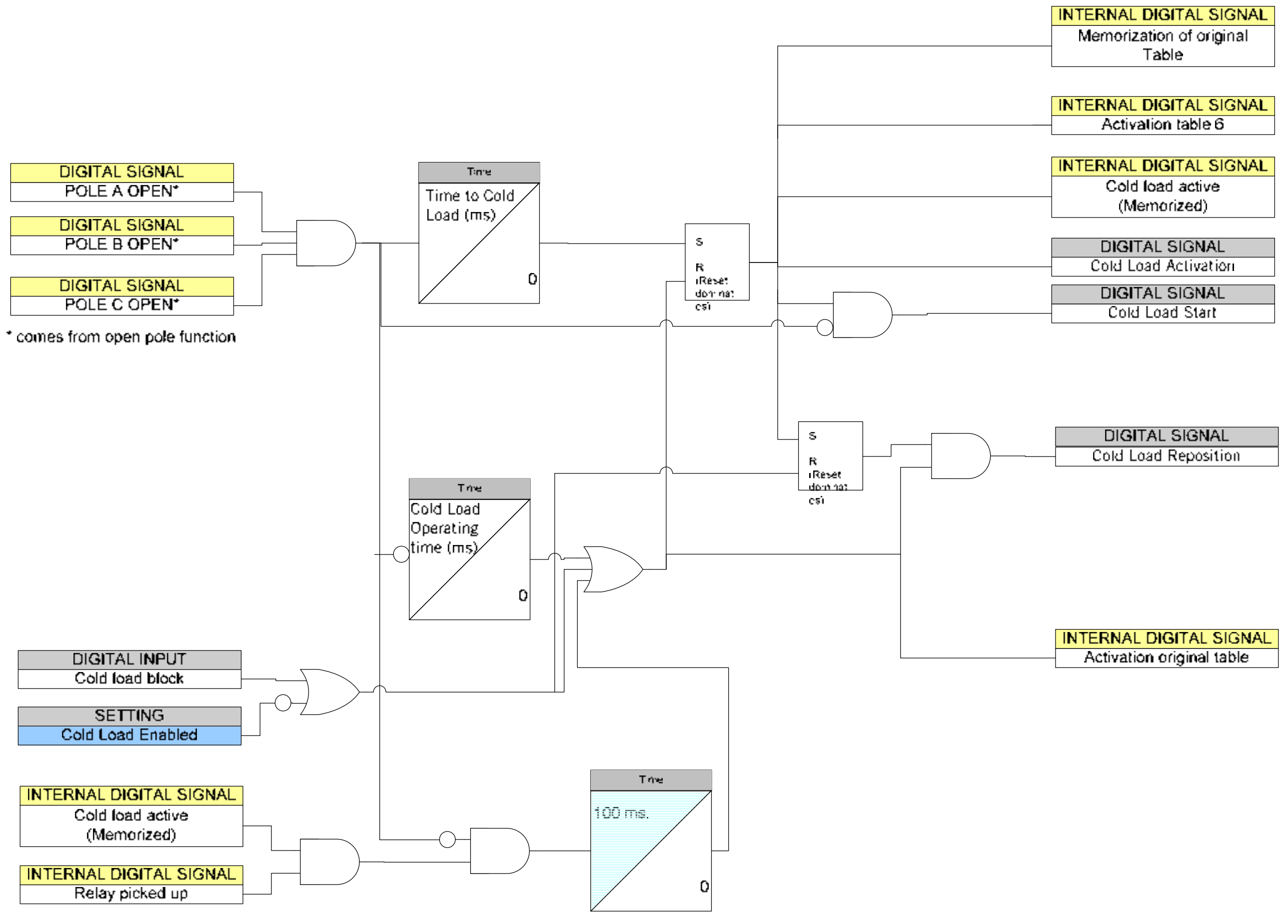
In Figure 44 and in Figure 45 two examples of the cold load unit are shown.

Figure 43 shows the operating scheme of the cold load unit.

If the unit is shut down while the cold load unit is active, the breaker status is checked on reboot during 100ms:

- If it is broken, table 6 is maintained until the breaker closes
- If it is closed, the last table to be active prior to the cold load is used.

Figure 43 Cold load connection scheme



The cold load unit's specific settings are a unique table:

- ❑ Enabled. Indicates whether the function is enabled or not.
- ❑ Time to Cold Load (ms). Cold load activation time.
- ❑ Cold Load Operating time (ms). The action time of the cold load settings in the overcurrent units following the closure of the breaker.
- ❑ Blocking Input. Selects the signal which, when active, blocks the function.
- ❑ Cold Load activation input. Selects the signal which, when active, generates the activation of the cold load, when enabled.
- ❑ Enable Events record. Allows the generation of protection events associated to the function. If set to "NO", the function's protection events are not generated. If set to "YES", the function's specific mask is contemplated.

Table 38 General cold load settings

Data	Setting	Min	Max	Step	Remarks	Type
PCLOEna	Enabled				YES/NO	Boolean
OpDlTmms	Time to Cold Load (ms)	0	10000000	10		Int32
OpTmms	Cold Load Operating time (ms)	100	3600000	10		Int32
LogInBlk	Blocking input					uint 32
LogInAc	Cold Load Activation Input					uint 32
MaskEna	Enable Events Record				NO (0) / YES (1)	enum

There are independent settings, commands and outputs.

- PROT/PCLO node
- Settings and logical inputs. There is a settings table. For details see Table 38.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 39 shows the function's output data.
  - Cold Load Start. Indicates that cold load conditions have been met and that the cold load time is being counted.
  - Cold Load Activation. Indicates that the unit is active (the cold load time has elapsed).
  - Cold Load Reposition. Indicates that the unit is deactivated. The breaker is closed and the action time has elapsed.
  - Cold Load Status. Indicates the function's status. It is active when enabled and not blocked.

Table 39 Cold load function outputs

Signal	Data	Attribute
Cold Load Start	Str	general
Cold Load Activation	Op	general
Cold Load Reposition	OpEx	general
Cold Load Status	StEna	stVal

Figure 44 Example with opening and closure of breaker

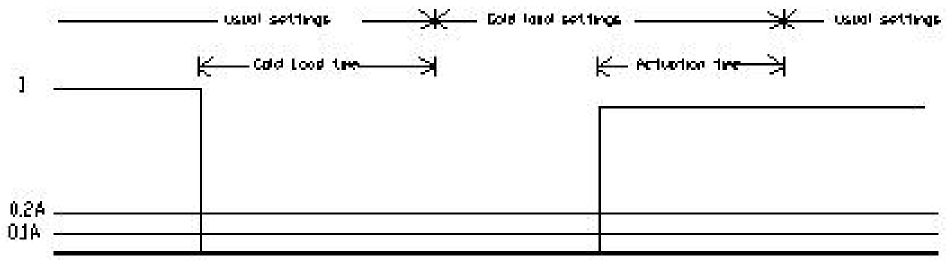
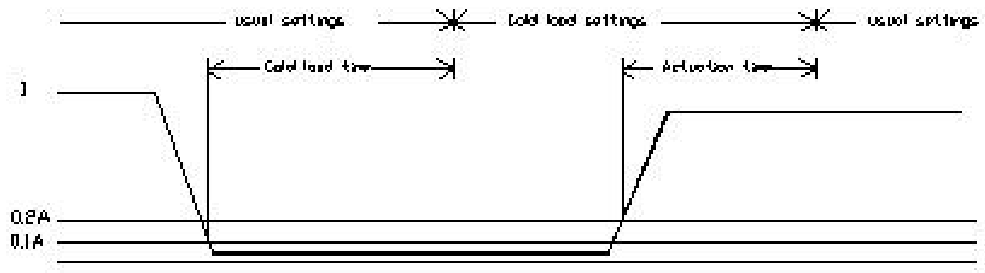


Figure 45 Example with very low load



3.2.14 Broken conductor

This is a definite time protection unit. The pick-up value to be set is, expressed as a decimal, the ratio in modules between the inverse sequence and direct sequence current.

I2/I1=(Ia+a2·Ib+a·Ic)/ (Ia+a·Ib+a2·Ic)   In which=1|120º

The relay trips once the programmed time has elapsed from the moment the pickup setting value is exceeded. For this unit to operate, the direct sequence current must be greater than the setting and at least 3% of In, and both the direct and the inverse sequences must be at least 3% of In.

Furthermore, the following must be met:

- There is no current in one phase with the breaker. (If there is no current in the three phases, this condition is not met)
- The inverse sequence (I2) exceeds 10% of the current’s direct sequence (I1)
- The neutral current (3I0) is less than 5% of the current’s direct sequence (I1)

Figure 46 shows the logic scheme of the function.

The settings used in these functions are:

- Enabled. Indicates whether the function is enabled or not.
- Operation type. To be selected between:
  - “ALWAYS”. If enabled, it operates in independently of the breaker status
  - “YES WITH 52”. In order to act, 52 must be closed.
- Start value (%). I2/I1 ratio based on the operative function.
- Operate delay time (ms). Indicates the time during which the conditions for the tripping of the function must be met.
- Minimum phase current (%In). Minimum phase current value.
- Maximum threshold I0/I1. Maximum I0/I1 value necessary to act.
- Blocking Input. Selects the signal which, when active, blocks the function.
- General trip. Indicates if this unit produces general trip or not. For additional details, see section corresponding to the recloser (5.2.1).
- TripP:RL,RR,RL,R:1,2,3,4,MC. Indicates the trip and block permission in accordance with the recloser status: standby, blocked, safety time after reclosing, after closing. It is configured bit by bit; for additional details, see section corresponding to the recloser (5.2).
- Reclose perm.(R1,R2,R3,R4). Indicates whether each trip type can be reclosed or not, in accordance with the recloser's closing cycle (5.2.3).
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

Table 40 Broken conductor settings

Data	Setting	Min.	Max	Step	Remarks	Type
OPPTOCEna	Enabled				NO (0) YES (1)	enum
Optype	Operation type				ALWAYS (1) YES WITH 52 (2)	enum
StrVal	Start value (%)	5	100	0,1		float32
OpDlTmms	Operate delay time (ms)	0	600000	10		Int32
BlkIph	Minimum phase current (%In)	5	200	0,1		float32
BLkI0I1	Maximum threshold I0/I1	0	20	0,1		float32
LogInBlk	Blocking input					uint 32
GenTrip	General trip				NO (0) / YES (1)	Boolean
TripPerm	TripP:RL,RR,RL,R:1,2,3,4,MC	0	255	1	Bit meaning	ING
ReclPerm	Reclose perm.(R1,R2,R3,R4)	0	15		Bit meaning	ING
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

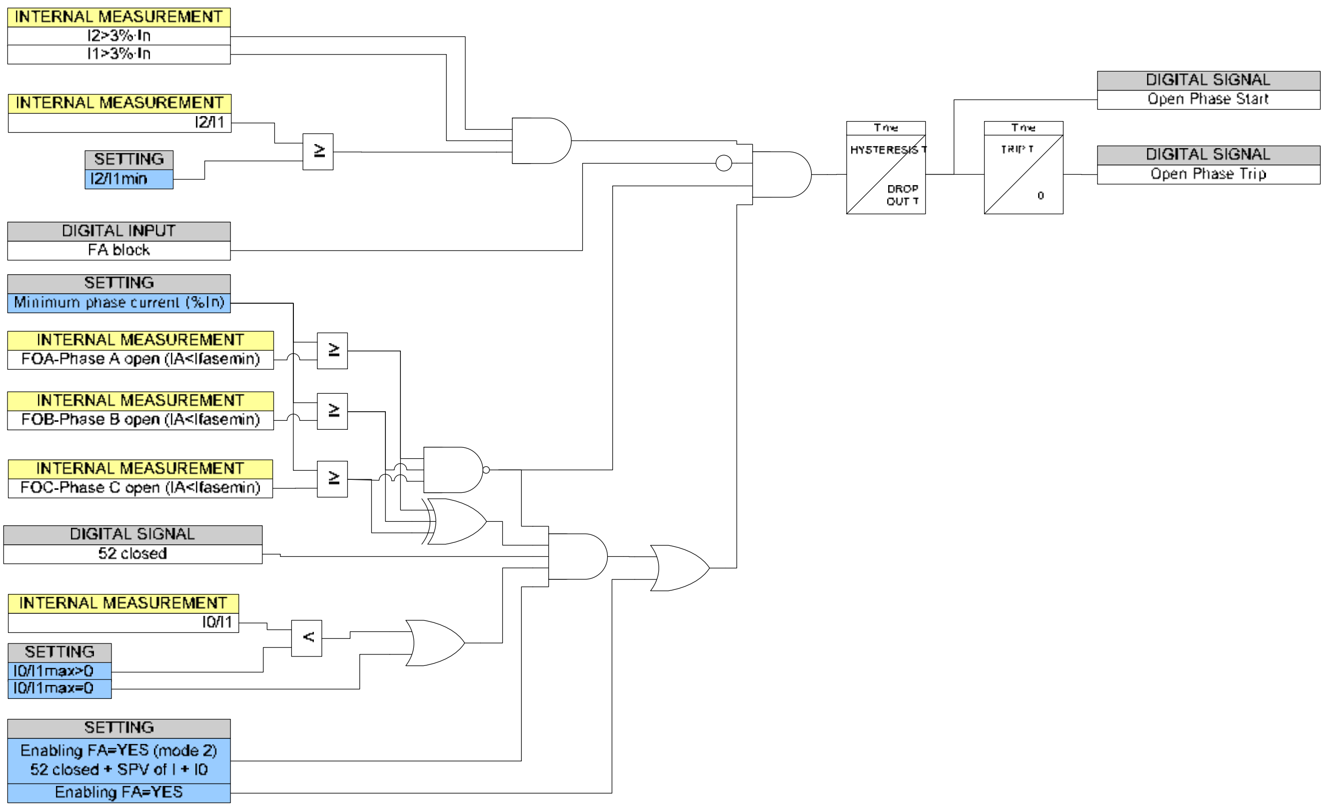
There are independent settings, commands and outputs.

- PROT/OPPTOC node
- Settings and logical inputs. There are 6 settings tables. For details, see Table 40.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 41 shows the function's output data.
  - Open Phase Start. Indicates that the unit has picked up.
  - Open Phase Trip. Indicates that the unit has tripped.
  - Open Phase Status. Indicates the function's status. It is active when enabled and not blocked.

Table 41 Broken conductor function outputs

Signal	Data	Attribute
Open Phase Start	Str	general
Open Phase Trip	Op	general
Open Phase Status	StEna	stVal

Figure 46 Broken conductor logic



3.2.15 Thermal image

There are independent units for phase and neutral.

This function calculates a thermal capacity in accordance with the protected unit's recent and current load conditions. The thermal capacity is displayed as a % of the trip value. If the function is enabled, a warning signal is activated when the programmed value is reached. When 100% is reached, the thermal image trip signal is activated. Once tripped as a result, it does not drop-out while the calculated thermal capacity remains above the reset threshold setting and the rest of the locking conditions are fulfilled. The calculated thermal capacity can be reset by logic input or by command.

The time which elapses before the trip is determined by the following curves, which establish the time in accordance with the ratio between the current and the programmed rated current, and the programmed heating constant. According to the following formula (starting from thermal capacity 0):

$$t = \tau 1 \cdot \ln \frac{\left(\frac{I}{I_0}\right)^2}{\left(\frac{I}{I_0}\right)^2 - 1}$$

In which t: trip time

ζ1 : heating constant

I: measured current

I0: programmed rated current

Once it has tripped, there is another programmable time constant for the cooling.

The heating curve is calculated using the following formula:

$$T = (T_f - T_i) \cdot \left(1 - e^{\frac{-t}{\tau 1}}\right) + T_i$$

In which: Tf = final thermal capacity

Ti = initial thermal capacity

t = time

ζ1 = heating time constant

For Ti = 0 the formula is reduced to

$$T = T_f \cdot \left(1 - e^{\frac{-t}{\tau 1}}\right)$$

As

$$T_f = \left(\frac{I}{I_0}\right)^2$$

The heating curve is

$$T = \left(\frac{I}{I_0}\right)^2 \cdot \left(1 - e^{\frac{-t}{\tau 1}}\right)$$

The cooling curve is calculated using the following formula:

$$T = (T_f - T_i) \cdot \left(1 - e^{\frac{-t}{\tau 2}}\right) + T_i$$

In which: Tf = final thermal capacity

Ti = initial thermal capacity

t = time

ζ2 = cooling time constant

Starting from Ti = 1 (100 in %), which is the thermal capacity at which the trip is produced, the formula employed to obtain a thermal capacity of Tf = 0 (i.e., current I = 0) is as follows

$$T = e^{\frac{-t}{\tau 2}}$$

The current measurements employed in the units are:

- Phases

  $Ieq^2=Imax^2+k\cdot I2^2$

  Where

  Imax is the maximum current of the three phases.

  I2 is the inverse sequence.

- Neutral. The transformer grounding current is employed. If this transformer does not exist, the neutral current is employed.

The settings of each of these units are:

- Enabled. Indicates whether the function is enabled or not.
- Heating constant (s). Heating curve in minutes.
- Cooling constant (s). Cooling curve in minutes.
- Alarm threshold (%). Value at which a thermal image warning is issued
- Reset threshold (%). Thermal image reset value.
- Start current (A). Rated current for the calculation of the thermal image.
- Blocking Input. Selects the signal which, when active, blocks the function.
- Init input. Resets the thermal image value.
- General trip. Indicates if this unit produces general trip or not. For additional details, see section corresponding to the recloser (5.2.1).
- TripP:RL,RR,RL,R:1,2,3,4,MC. Indicates the trip and block permission in accordance with the recloser status: standby, blocked, safety time after reclosing, after closing. It is configured bit by bit; for additional details, see section corresponding to the recloser (5.2.2).
- Calculus store. Allows the value calculated for the thermal image to be stored in the non-volatile memory. If set to “Yes”, the stored value will be the initial thermal image value employed when the unit is booted; if set to “NO”, the initial thermal image value is zero.
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generate. If set to “YES”, the function’s specific mask is contemplated.

Table 42 Thermal image settings

Data	Setting	Min	Max	Step	Remarks	Type
PTTREna	Enabled				YES (0) NO (1)	Boolean
ConsTms1	Heating constant (s)	30	18000	5		Int32
ConsTms2	Cooling constant (s)	30	18000	5		Int32
AlmThm	Alarm threshold (%)	50	100	1		float32
RepVal	Reset threshold (%)	50	95	1		float32
ARTG	Start current (A)	0,1	150,0	0,01		float32
LogInBlk	Blocking input					uint 32
LogInIn	Init input					uint 32
GenTrip	General trip				NO (0) / YES (1)	Boolean
TripPerm	TripP:RL,RR,RL,R:1,2,3,4,MC	0	255	1	Bit meaning	ING
ValStore	Calculus Store				NO (0) / YES (1)	Boolean
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

There are independent settings, commands and outputs.

- Nodes:
  - Phases: PROT/PTTR
  - Neutral: PROT/GPTTR
- Settings and logical inputs. There are 6 settings tables. For details, see Table 42.

- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
  - "DOrdIn": Resetting to zero of thermal image value.
- Outputs: Table 43 shows the function's output data.
  - Thermal Image X Start. Indicates that the unit has picked up. Where X is phase or ground.
  - Thermal Image X Trip. Indicates that the unit has tripped. Where X is phase or ground.
  - Thermal Image X Status. Indicates the function's status. It is active when enabled and not blocked. Where X is phase or ground.

Table 43 Phase Thermal image function outputs

Signal	Data	Attribute
Thermal Image Phase Start	Str	general
Thermal Image Phase Trip	Op	general
Thermal Image Phase Status	StEna	stVal

3.2.15.1 Calculation Example

Figure 47 shows the trip times according to different heating constants.

Figure 47 Trip times

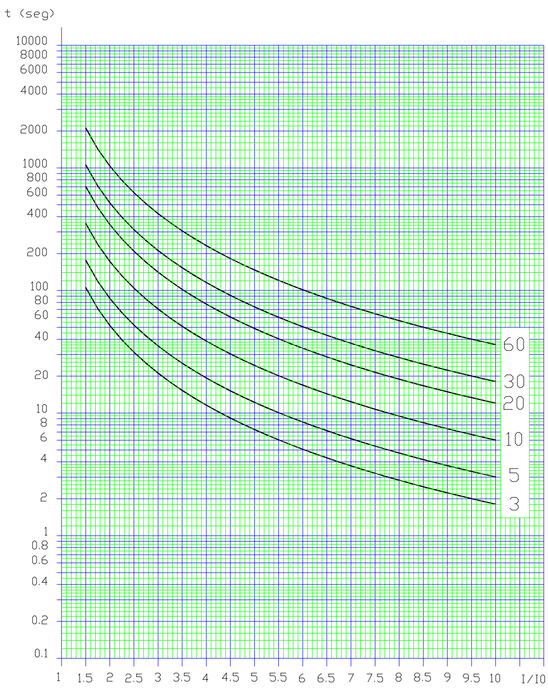


Figure 48 shows an example of heating curves with a 3 minute time constant for I/I0 = 1 and for I/I0 = 2

Figure 48 Heating curve example

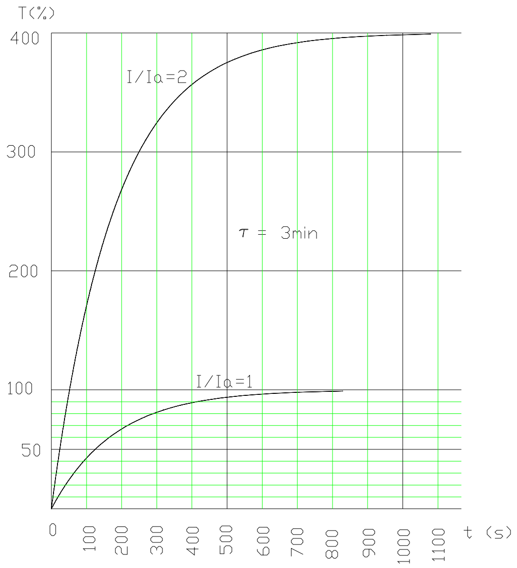
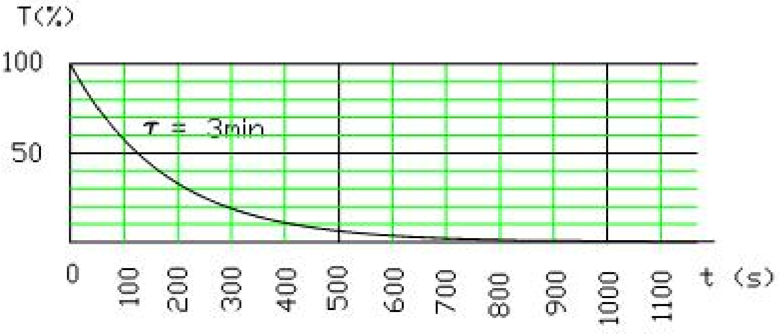


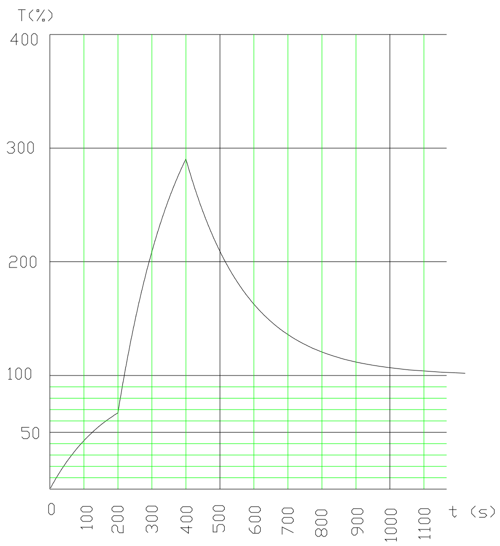
Figure 49 shows an example of a cooling curve with 3-minute constant.

Figure 49 Cooling curve example

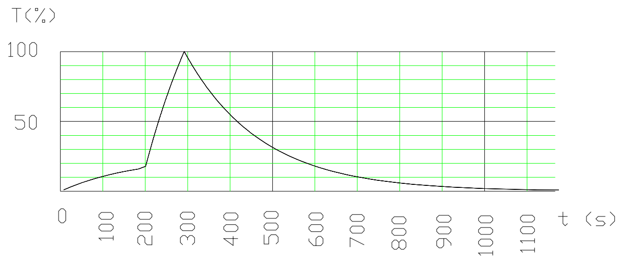


Examples: Combined examples of cooling and heating

Supposing that it is heated with I/I0 =1 for 200sec, I/I0 =2 for the next 200 sec (without tripping) and, as of that point, it returns indefinitely to I/I0 = 1 (both with 3 minute time constants):



2. Supposing that it is heated with I/I0 =0.5 for 200sec, I/I0 =1.5 until reaching 100%, at which point the trip is produced, as of that point, it cools with I/I0 = 0 (both with 3 minute time constants):



3.2.16 Undercurrent

There are two independent undercurrent units.

They employ the phases' fundamental measurements. The unit picks up when the current falls below the setting and drops out when the current rises above 105% of the setting.

The pick up is generated for each phase, regardless of the operation type setting. However, the unit's trip takes the operation type into account.

The settings of each of these units are:

- Enabled. Indicates whether the function is enabled or not.
- Operation type. To be selected between:
  - "AND". The unit trips when all the phases meet the undercurrent conditions
  - "OR". The unit trips when at least one of the phases meets the undercurrent conditions
- Start value (A). Set in secondary amps. It indicates the current value as of which the function is activated.
- Operate delay time (ms). Indicates the time during which the conditions for the tripping of the function must be met.
- Blocking Input. Selects the signal which, when active, blocks the function.
- General trip. Indicates if this unit produces general trip or not. For additional details, see section corresponding to the recloser (5.2.1).
- TripP:RL,RR,RL,R:1,2,3,4,MC. Indicates the trip and block permission in accordance with the recloser status: standby, blocked, safety time after reclosing, after closing. It is configured bit by bit; for additional details, see section corresponding to the recloser (5.2.2).
- Enable Events record. Allows the generation of protection events associated to the function. If set to "NO", the function's protection events are not generate. If set to "YES", the function's specific mask is contemplated.

Table 44 Undercurrent settings

Data	Setting	Minimum	Maximum	Step	Remarks	Type
PTUCEna	Enabled				NO (0) YES (1)	enum
Optype	Operation type				AND (A, B and C) (1) OR (A, B or C) (2)	enum
StrVal	Start value (A)	0,02	10	0,01		float32
OpDlTmms	Operate delay time (ms)	0	600000	10		Int32
LogInBlk	Blocking input					uint 32
GenTrip	General trip				NO (0) / YES (1)	Boolean
TripPerm	TripP:RL,RR,RL,R:1,2,3,4,MC	0	255	1	Bit meaning	ING
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

There are independent settings, commands and outputs in each unit.

- Nodes:
  - Unit 1: PROT/PTUC1
  - Unit 2: PROT/PTUC2
- Settings and logical inputs. There are 6 settings tables. For details, see Table 44.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 45 shows the function's output data.
  - TUC1 phase X Start. Indicates that the unit's phase has picked up. It is independent for each phase and does not consider the operation type setting.
  - TUC1 phase Start. Pick up of at least one phase. Indicates that at least one of the unit's phases has picked up. It does not take into account the operation type setting.
  - TUC1 Start. Taking into account the operation type setting, it indicates that the unit has picked up.
  - TUC1 Trip. Taking into account the operation type setting, it indicates that the unit has tripped.
  - Undercurrent Unit 1 Status . Indicates the function's status. It is active when enabled and not blocked. This is general for all three phases.

Table 45 Phase undercurrent function outputs

Signal	Data	Atribute
TUC1 phase A Start	Str	phsA
TUC1 phase B Start	Str	phsB
TUC1 phase C Start	Str	phsC
TUC1 Start	StrUC	general
TUC1 Trip	OpUC	general
Undercurrent Unit 1 Status	StEna	stVal
TUC1 phase Start	Str	general

3.3 VOLTAGE UNITS

3.3.1 General description

When enabled and unblocked, the overvoltage units act when the setting value is exceed during the programmed time. In order to reset, the voltage must fall below the pick up value return percentage. For example, if the pick up threshold is 50V and the reset percentage is 10%, the unit must register voltage above 50V in order to pick up and voltage below 45V in order to reset (50-0.1 50).

When enabled and unblocked, the undervoltage units act when the voltage is inferior to the setting value during the programmed time. In order to reset, the voltage must exceed the pick up value return percentage. For example, if the pick up threshold is 50V and the reset percentage is 10%, the unit must register voltage below 50V in order to pick up and voltage above 55V in order to reset (50+0.1 50).

The voltage units are not directional.

The voltage unit's general settings are available in the PROT/PVGE1 node (return percentages and VO measurement type):

- Phase overvoltage return percentage (%). Indicates the pickup setting percentage below which the voltage must fall in order that the instantaneous and timed phased units reset.
- Phase undervoltage return percentage (%). Indicates the pickup setting percentage above which the voltage must rise in order that the instantaneous and timed phased units reset.

- V2 overvoltage return percentage (%). Indicates the pickup setting percentage below which the voltage must fall in order that the instantaneous and timed V2 units reset.
- V0 overvoltage return percentage (%). Indicates the pickup setting percentage below which the voltage must fall in order that the instantaneous and timed V0 units reset.
- V0 measurement type. Indicates the measurement employed for the V0 overvoltage:
  - Calculated: The 3 V0 measurement is employed, i.e., the vector sum of the 3 ground to earth phases.
  - 3V0=Va+Vb+Vc
  - Trafo: The measurement from the transformer configured as Vn is employed.

Table 46 General voltage settings

Data	Setting	Minimum	Maximum	Step	Remarks	Type
RepValOVp	Phase overvoltage return percentage (%).	50	99	1		float32
RepValUVp	Phase undervoltage return percentage (%).	101	110	1		float32
RepValOV2	V2 overvoltage return percentage (%).	50	99	1		float32
RepValOV0	V0 overvoltage return percentage (%).	50	99	1		float32
SelV0	V0 measurement type				Calculated (0)/Trafo (1)	enum

3.3.1.1 Instantaneous characteristics

When enabled and unblocked, the unit acts when the setting value is exceed during the programmed time.

The settings used in these functions are:

- Enabled. Indicates whether the function is enabled or not.
- Operation type. Consult in each unit.
- Start value (V). Indicates the voltage value (in secondary volts) at which the function is activated.
- Operate delay time (ms). Indicates the time during which the conditions for the tripping of the function must be met.
- Blocking Input. Selects the signal which, when active, blocks the function.
- General trip. Indicates if this unit produces general trip or not. For additional details, see section corresponding to the recloser (5.2.1).
- TripP:RL,RR,RL,R:1,2,3,4,MC. Indicates whether there is trip permission for the different recloser statuses: standby, blocked, safety time following couplings, following closure. For additional details, see section corresponding to the recloser (5.2.2).
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

Table 47 Instantaneous voltage unit settings

Data	Setting	Minimum	Maximum	Step	Remarks	Type
PIOVEna	Enabled				NO (0) YES (1)	enum
Optype	Operation type				Standard (0) Vphase-ground FUND(1) Vphase-ground FUND(2) Vphase-ground RMS (3) Vphase-phase RMS (4)	enum
StrVal	Start value (V)	0,5	200	0,01		float32
OpDlTmms	Operate delay time (ms)	0	600000	10		Int32
LogInBlk	Blocking input					uint 32
GenTrip	General trip				NO (0) YES (1)	Boolean
TripPerm	TripP:RL,RR,RL,R:1,2,3,4,MC	0	255	1	Bit meaning (1)	ING
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

In which:

Bit meaning (1)	Bit	Value
Reclosure block	0	YES/NO
Trip permission 79 standby	1	YES/NO
Trip permission 79 blocked	2	YES/NO
Permission for trip in safety time following reclosure 1	3	YES/NO
Permission for trip in safety time following reclosure 2	4	YES/NO
Permission for trip in safety time following reclosure 3	5	YES/NO
Permission for trip in safety time following reclosure 4	6	YES/NO
Permission for trip in safety time following manual closure	7	YES/NO

3.3.1.2 Timed characteristics

The different curve options are shown in the curve appendix.

The timed unit can be configured with a minimum of response time, that is, a limit that prevents any unit from tripping below a minimum time when the trip time corresponding to the curve in use is met. This avoids timed trips which are quicker than the instantaneous trips. It is configured with additional time setting, so that if it set to zero, there is no such limit.

The settings used in these functions are:

- Enabled. Indicates whether the function is enabled or not.
- Start value (V). Set in secondary volts. Indicates the voltage value at which the function is activated.
- Operation type. Consult in each unit.
- Operating Curve Type Indicates the type of curve selected from the options:
  - ANSI-EI Extreme. Inverse (1)
  - ANSI-MI Very inverse (2)
  - ANSI-I Normal inverse(3)
  - ANSI-MODI Moderately inverse (4)
  - IEC-I Normal inverse (9)
  - IEC-MI Very inverse (10)
  - IEC-EI Extreme. Inverse (12)
  - IEC-IC Short inverse (13)
  - IEC-IL Long inverse (14)
  - IEC-MIEs Very inverse special (50)
  - User curves 1 (33)
  - User curves 2 (34)
  - User curves 3 (35)
  - User curves 4 (36)
  - Definite time (49)
- Time dial. Indicates the time curve within the selected characteristic.
- Operate/minimum time (ms). It has a different functionality depending on the type of curve selected:

  When the selected curve is a definite time, it indicates the time during which the conditions for the tripping of the function must be met.

  In the rest of the curve, it indicates the minimum response time. i.e., in order for a trip to be produced, the time employed will be greater between this setting and the time associated to the curve.

- Blocking Input. Selects the signal which, when active, blocks the function.
- General trip. Indicates if this unit produces general trip or not. For additional details, see section corresponding to the recloser (5.2.1).
- Trip permission. Indicates the trip and block permission in accordance with the recloser status: standby, blocked, safety time after reclosing, after closing. It is configured bit by bit; for additional details, see section corresponding to the recloser (5.2.2).
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

Table 48 Timed voltage unit settings

Data	Setting	Min	Max	Step	Remarks	Type
PTVEna	Enabled				NO (0) YES (1)	enum
Optype	Operation type				Standard (0) Vphase-ground FUND (1) Vphase-ground FUND (2) Vphase-ground RMS (3) Vphase-phase RMS (4)	enum
StrVal	Start value (V)	0,5	200	0,01		float32
TmVCrv	Operating curve type				ANSI-EI Extreme. Inverse (1) ANSI-MI Very inverse (2) ANSI-I Normal inverse(3) ANSI-MODI Moderately inverse (4) IEC-I Normal inverse (9) IEC-MI Very inverse (10) IEC-EI Extreme. Inverse (12) IEC-IC Short inverse (13) IEC-IL Long inverse (14) IEC-MIEs Very inverse special (50) User curves 1 (33) User curves 2 (34) User curves 3 (35) User curves 4 (36) Definite time (49)	enum
TmMult	Time dial	0,05	30,0	0,01		float32
OpDlTmms	Operate/minimum time (ms)	0	600000	10		Int32
LogInBlk	Blocking input					uint 32
GenTrip	General trip				NO (0) SI (1)	Boolean
TripPerm	TripP:RL,RR,RL,R:1,2,3,4,MC	0	255	1	Bit meaning (1)	ING
MaskEna	Enable Events record				NO (0) / YES (1)	Boolean

In which:

Bit meaning (1)	Bit	Value
Reclosure block	0	YES/NO
Trip permission 79 standby	1	YES/NO
Trip permission 79 blocked	2	YES/NO
Permission for trip in safety time following reclosure 1	3	YES/NO
Permission for trip in safety time following reclosure 2	4	YES/NO
Permission for trip in safety time following reclosure 3	5	YES/NO
Permission for trip in safety time following reclosure 4	6	YES/NO
Permission for trip in safety time following manual closure	7	YES/NO

3.3.2 Phase overvoltage

Acts on the phase voltage transformers. If the unit is configured with ground to phase voltages, the protection is wired with ground to phase measurements (Va, Vb and Vc), while if it is configured with phase to phase voltages, the protection is wired with phase to phase measurements (Vab, Vbc and Vca).

The return percentage can be configured by the user in the PROT/PVGE1 node.

3.3.2.1 Instantaneous

There are 2 independent units for each of the phases.

The operation type setting allows for a selection to be made from among the following:

- "Standard". Acts with the phase-ground voltage and fundamental
- "Vphase-ground FUND". Acts with the phase-ground voltage and fundamental value without harmonics
- "Vphase-phase FUND". Acts with the phase-phase voltage and fundamental value without harmonics
- "Vphase-ground RMS". Acts with the phase-ground voltage and rms value with harmonics
- "Vphase-phase RMS". . Acts with the phase-phase voltage and rms value with harmonics

If the PROT/TVTR voltage phase setting indicates that at least one of the phase-phase voltage options, the operation type can only be selected as VFAs-phase Fund or Vphase-phase RMS. If any other type is selected, the unit will correct itself internally.

The return percentage is user-configurable (PVGE1).

Each of the three units has independent settings, commands and outputs.

- Nodes:
  - Unit 1: PROT/PIOV1
  - Unit 2: PROT/PIOV2
- Settings and logical inputs. There are 6 settings tables. For details, see Table 47.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 49 shows the function's output data
  - IOV1 Start phase X. Indicates that the unit's phase has picked up. It is independent for each phase.
  - IOV1 Trip phase X. Indicates that the unit's phase has tripped. It is independent for each phase.
  - IOV1 Phase Status. Indicates the function's status. It is active when enabled and not blocked. This is general for all three phases.
  - IOV1 phase Start. Indicates that the unit has picked up
  - IOV1 phase Trip. Indicates that the unit has tripped.

Table 49 Instantaneous phase overvoltage function outputs

Signal	Data	Atribute
IOV1 Start phase A	Str	phsA
IOV1 Start phase B	Str	phsB
IOV1 Start phase C	Str	phsC
IOV1 Trip phase A	Op	phsA
IOV1 Trip phase B	Op	phsB
IOV1 Trip phase C	Op	phsC
IOV1 Phase Status	StEna	stVal
IOV1 Phase Start	Str	general
IOV1 Phase Trip	Op	general

3.3.2.2 Timed

There is a single timed unit, which is independent for each of the phases.

The operation type setting allows for a selection to be made from among the following:

- "Standard". Acts with the phase-ground voltage and fundamental
- "Vphase-ground FUND". Acts with the phase-ground voltage and fundamental value without harmonics
- "Vphase-phase FUND". Acts with the phase-phase voltage and fundamental value without harmonics
- "Vfphase-ground RMS". Acts with the phase-ground voltage and rms value with harmonics
- "Vphase-phase RMS". Acts with the phase-phase voltage and rms value with harmonics

If the PROT/TVTR voltage phase setting indicates that at least one of the phase-phase voltage options, the operation type can only be selected as VFAs-phase Fund or Vphase-phase RMS. If any other type is selected, the unit will correct itself internally.

There are settings, commands and outputs.

- Nodes: PROT/PTOV1
- Settings and logical inputs. There are 6 settings tables. For details see Table 48.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 50 shows the function's output data
  - TOV Start phase X. Indicates that the unit's phase has picked up. It is independent for each phase.
  - TOV Trip phase X. Indicates that the unit's phase has tripped. It is independent for each phase.
  - TOV Phase Status. Indicates the function's status. It is active when enabled and not blocked. This is general for all three phases.
  - TOV1 phase Start. Indicates that the unit has picked up
  - TOV1 phase Trip. Indicates that the unit has tripped.

Table 50 Timed phase overvoltage function outputs

Signal	Data	Atribute
TOV Start phase A	Str	phsA
TOV Start phase B	Str	phsB
TOV Start phase C	Str	phsC
TOV Trip phase A	Op	phsA
TOV Trip phase B	Op	phsB
TOV Trip phase C	Op	phsC
TOV Phase Status	StEna	stVal
TOV Phase Start	Str	general
TOV Phase Trip	Op	general

3.3.3 Zero sequence overvoltage

There is a timed and an instantaneous unit.

The following can be configured in the PROT/PVGE1 node:

- The measurement employed between Vn transformer measurement or the vector sum of the three voltage phases (3 V0).
- The return percentage is user-configurable (PVGE1).

The operation type setting is not used, as the fundamental frequency measurement is always used.

3.3.3.1 Instantaneous

There is one unit.

It has independent settings, commands and outputs.

- PROT/GPIOV1 node
- Settings and logical inputs. There are 6 settings tables. For details see Table 46 and Table 47.
- Commands:
  - “DOrdBlk”: Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 51 shows the function’s output data
  - GIOV1 Start. Indicates that the unit has picked up.
  - GIOV1 Trip. Indicates that the unit has tripped.
  - IOV V0 Status. Indicates the function’s status. It is active when enabled and not blocked.

Table 51 Instantaneous zero sequence overvoltage function outputs

Signal	Data	Atribute
GIOV1 Start	Str	neut
GIOV1 Trip	Op	neut
IOV V0 Status	StEna	stVal

3.3.3.2 Timed

There is one timed unit.

There are settings, commands and outputs.

- Nodes: PROT/GPTOV1
- Settings and logical inputs. There are 6 settings tables. For details see Table 47 and Table 45.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 52 shows the function's output data.
  - GTOV1 Start. Indicates that the unit has picked up.
  - GTOV1 Trip. Indicates that the unit has tripped.
  - TOV V0 Status. Indicates the function's status. It is active when enabled and not blocked.

Table 52 Timed zero sequence overvoltage function outputs

Signal	Data	Atribute
GTOV1 Start	Str	neut
GTOV1 Trip	Op	neut
TOV V0 Status	StEna	stVal

3.3.4 Inverse sequence overvoltage

There is a timed and an instantaneous unit.

Employs 3 times the inverse sequence as a measurement:

3·V2=(Va+a2·Vb+a·Vc)   In which=1|120º

The calculation of the sequence takes into phase succession order setting (ABC/ACB).

The return percentage can be configured by the user in the PROT/PVGE1 node.

The operation type setting is not used, as the fundamental frequency measurement is always used.

3.3.4.1 Instantaneous

There is one unit.

It has independent settings, commands and outputs.

- PROT/UNPIOV1 node
- Settings and logical inputs. There are 6 settings tables. For details see Table 46 and Table 47.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 53 shows the function's output data.
  - UNIOV1 Start. Indicates that the unit has picked up.
  - UNIOV1 Trip. Indicates that the unit has tripped.
  - IOV V2 Status. Indicates the function's status. It is active when enabled and not blocked.

Table 53 Instantaneous V2 overvoltage function outputs

Signal	Data	Atribute
UNIOV1 Start	Str	general
UNIOV1 Trip	Op	general
IOV V2 Status	StEna	stVal

3.3.4.2 Timed

There is one timed unit.

There are settings, commands and outputs.

- Nodes: PROT/UNPTOV1
- Settings and logical inputs. There are 6 settings tables. For details see Table 48 and Table 46.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 54 shows the function's output data.
  - UNTOV1 Start. Indicates that the unit has picked up.
  - UNTOV1 Trip. Indicates that the unit has tripped.
  - TOV V2 Status. Indicates the function's status. It is active when enabled and not blocked.

Table 54 Timed V2 overvoltage function outputs

Signal	Data	Atribute
UNTOV1 Start	Str	general
UNTOV1 Trip	Op	general
TOV V2 Status	StEna	stVal

3.3.5 Phase undervoltage

Acts on the phase voltage transformers. If the unit is configured with ground to phase voltages, the protection is wired with ground to phase measurements (Va, Vb and Vc), while if it is configured with phase to phase voltages, the protection is wired with phase to phase measurements (Vab, Vbc and Vca).

The return percentage can be configured by the user in the PROT/PVGE1 node.

3.3.5.1 Instantaneous

There are 2 independent units for each of the phases.

The operation type setting allows for a selection to be made from among the following:

- "Standard". Acts with the phase-ground voltage and fundamental
- "Vphase-ground FUND". Acts with the phase-ground voltage and fundamental value without harmonics
- "Vphase-phase FUND". Acts with the phase-phase voltage and fundamental value without harmonics
- "Vphase-ground RMS". Acts with the phase-ground voltage and rms value with harmonics
- "Vphase-phase RMS". . Acts with the phase-phase voltage and rms value with harmonics

The return percentage is user-configurable (PVGE1).

Each of the three units has independent settings, commands and outputs.

- Nodes:
  - Unit 1: PROT/PIUV1
  - Unit 2: PROT/PIUV2
- Settings and logical inputs. There are 6 settings tables. For details see Table 47 and Table 46.
- Commands:
  - “DOrdBlk”: Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 55 shows the function’s output data.
  - IUV1 Start phase X. Indicates that the unit's phase has picked up. It is independent for each phase.
  - IUV1 Trip phase X. Indicates that the unit's phase has tripped. It is independent for each phase.
  - IUV1 Phase Status. Indicates the function’s status. It is active when enabled and not blocked. This is general for all three phases.
  - IUV1 phase Start. Indicates that the unit has picked up
  - IUV1 phase Trip. Indicates that the unit has tripped.

Table 55 Instantaneous phase undervoltage function outputs

Signal	Data	Atribute
IUV1 Start phase A	Str	phsA
IUV1 Start phase B	Str	phsB
IUV1 Start phase C	Str	phsC
IUV1 Trip phase A	Op	phsA
IUV1 Trip phase B	Op	phsB
IUV1 Trip phase C	Op	phsC
IUV1 Phase Status	StEna	stVal
IUV1 Phase Start	Str	general
IUV1 Phase Trip	Op	general

3.3.5.2 Timed

There is a single timed unit, which is independent for each of the phases.

The operation type setting allows for a selection to be made from among the following:

- “Standard”. Acts with the phase-ground voltage and fundamental
- “Vphase-ground FUND”. Acts with the phase-ground voltage and fundamental value without harmonics
- “Vphase-phase FUND”. Acts with the phase-phase voltage and fundamental value without harmonics
- “Vphase-ground RMS”. Acts with the phase-ground voltage and rms value with harmonics
- “Vphase-phase RMS”. . Acts with the phase-phase voltage and rms value with harmonics

There are settings, commands and outputs.

- Nodes: PROT/PTUV1
- Settings and logical inputs. There are 6 settings tables. For details see Table 47 and Table 45.
- Commands:
  - “DOrdBlk”: Function block and unblocking. Only acts when the function is enabled.

- Outputs: Table 56 shows the function's output data
  - TUV1 Start phase X. Indicates that the unit's phase has picked up. It is independent for each phase.
  - TUV1 Trip phase X. Indicates that the unit's phase has tripped. It is independent for each phase.
  - TUV Phase Status. Indicates the function's status. It is active when enabled and not blocked. This is general for all three phases.
  - TUV1 phase Start. Indicates that the unit has picked up
  - TUV1 phase Trip. Indicates that the unit has tripped.

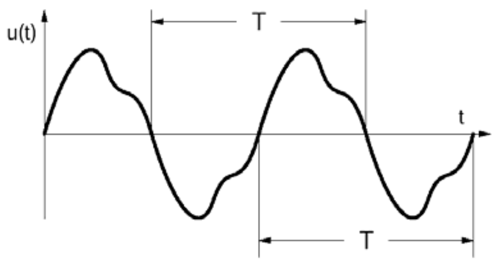
Table 56 Timed phase undervoltage function outputs

Signal	Data	Atribute
TUV1 Start phase A	Str	phsA
TUV1 Start phase B	Str	phsB
TUV1 Start phase C	Str	phsC
TUV1 Trip phase A	Op	phsA
TUV1 Trip phase B	Op	phsB
TUV1 Trip phase C	Op	phsC
TUV Phase Status	StEna	stVal
TUV1 Phase Start	Str	general
TUV1 Phase Trip	Op	general

3.4 FREQUENCY UNITS

The frequency is measured each cycle and refreshed each half cycle, as shown in Figure 50.

Figure 50 Frequency Calculation



The algorithm is executed in the event of the phase B voltage registering zero.

Both the positive and negative registers are measured, although the frequency measurement is carried out for complete cycles.

The frequency is calculated if the phase B voltage measurement is superior to 5V.

3.4.1 Frequency

This function is composed of 8 steps, which are programmable as maximum or minimum frequencies. The frequency is measured on the phase B voltage.

The function's node, PROT/PTGF1, has independent settings for each step and common settings for all.

The common settings for all steps are as follows:

- Minimum allowed voltage (V). Indicates the minimum phase B voltage value below which the frequency protection does no act, the unit is not permitted to pick up.
- Number of cycles (Start). Indicates the number of cycles during which the frequency conditions necessary for the unit to pick up must be met.
- Number of cycles (Reset). Indicates the number of cycles during which the drop conditions necessary for the unit to reset must be met in the event of the unit's not having tripped.
- Overfrequency reset time (ms). Once tripped by overfrequency, this is the time during which the reset conditions must be met in order to clear the trip from the unit. It is applied to all the steps configured as overfrequency.
- Underfrequency reset time (ms). Once tripped by underfrequency, this is the time during which the reset conditions must be met in order to clear the trip from the unit. It is applied to all the steps configured as underfrequency.
- General trip. Indicates if this unit produces general trip or not. For additional details, see section corresponding to the recloser (5.2.1).
- Trip permission. Indicates the trip and block permission in accordance with the recloser status: standby, blocked, safety time after reclosing, after closing. It is configured bit by bit; for additional details, see section corresponding to the recloser (5.2.2).
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

The independent settings for each of the 8 steps are:

- Enabled. Indicates whether the step is enabled or not.
- Start value (HZ). Indicates the frequency value at which the function is activated.
- Operate delay time (ms). Indicates the time during which the conditions for the tripping of the function must be met.
- Function type. Indicates whether its acts on overfrequency or underfrequency.
- Blocking Input. Selects the signal which, when active, blocks the step.

The form in which it acts varies in accordance with type of step selected.

Minimum frequency. Each step picks up when the frequency falls below the set value during a number of cycles equal or higher than the “No. of pickup cycles” setting. Once it picks up, the programmed time must elapse in order for a trip to be produced. If the unit has tripped, it drops out if the frequency is correct during the underfrequency reset time. If it has picked up but has not tripped, it drops out if the frequency is correct during reset cycles.

Maximum frequency. Each step picks up when the frequency exceeds the set value during a number of cycles equal or higher than the “No. of pickup cycles” setting. Once it picks up, the programmed time must elapse in order for a trip to be produced. If the unit has tripped, it drops out if the frequency is correct during the overfrequency reset time. If it has picked up but has not tripped, it drops out if the frequency is correct during reset cycles.

There are settings, commands and outputs.

- Nodes: PROT/PTGF1
- Settings and logical inputs. There are 6 settings tables. For details see Table 57.
- Commands:
  - “DOrdBlk”: Function block and unblocking. It only acts on the enabled steps. If acts on the 8 steps
  - “DOrdFminB”. Blocking and unblocking of the steps configured as minimum frequency. It only acts on the enabled steps.
  - “DOrdFmaxB”. Blocking and unblocking of the steps configured as maximum frequency. It only acts on the enabled steps.
  - “DOrdFL1Bl”. Blocking and unblocking of step 1. It only acts if the step is enabled
  - “DOrdFL2Bl”,… “DOrdFL8Bl”. As above, but acts on steps 2 to 8.

Outputs: Table 58 shows the function's output data. They are independent for each step

- Level X Frequency Start. Indicates that the step has picked up. It is independent for each step.
- Level X Frequency Trip. Indicates that the step has tripped. It is independent for each step.
- Level X Frequency Status. Indicates the step's status. Active when enabled and not blocked. Independent for each step.

Table 57 General frequency protection settings

Data	Parameter	Min	Max	Step	Remarks	Type
BlkValV	Minimum allowed voltage (V)	40	200	1		float32
StrNumCyc	Number of cycles (Start)	3	15	1		Int32
RepNumCyc	Number of cycles (Reset)	0	10	1		Int32
OFRsDlTmms	Overfrequency reset time (ms)	0	600000	10		Int32
UFRsDlTmms	Underfrequency reset time (ms)	0	600000	10		Int32
PTGFEna1	Step 1 enabled				YES/NO	Boolean
StrVal1	Step 1 Start value (Hz)	45	65	0,01		float32
OpDlTmms1	Step 1 Operate delay time(ms)	0	600000	10		Int32
StTyp1	Step 1 Function type				Maximum/Minimum	enum
LogInBlk1	Step 1 Blocking input					uint 32
PTGFEna2	Step 2 enabled				YES/NO	Boolean
StrVal2	Step 2 Start value (Hz)	45	65	0,01		float32
OpDlTmms2	Step 2 Operate delay time(ms)	0	600000	10		Int32
StTyp2	Step 2 Function type				Maximum/Minimum	enum
LogInBlk2	Step 2 Blocking input					uint 32
PTGFEna3	Step 3 enabled				YES/NO	Boolean
StrVal3	Step 3 Start value (Hz)	45	65	0,01		float32
OpDlTmms3	Step 3 Operate delay time(ms)	0	600000	10		Int32
StTyp3	Step 3 Function type				Maximum/Minimum	enum
LogInBlk3	Step 3 Blocking input					uint 32
PTGFEna4	Step 4 enabled				YES/NO	Boolean
StrVal4	Step 4 Start value (Hz)	45	65	0,01		float32
OpDlTmms4	Step 4 Operate delay time(ms)	0	600000	10		Int32
StTyp4	Step 4 Function type				Maximum/Minimum	enum
LogInBlk4	Step 4 Blocking input					uint 32
PTGFEna5	Step 5 enabled				YES/NO	Boolean
StrVal5	Step 5 Start value (Hz)	45	65	0,01		float32
OpDlTmms5	Step 5 Operate delay time(ms)	0	600000	10		Int32
StTyp5	Step 5 Function type				Maximum/Minimum	enum
LogInBlk5	Step 5 Blocking input					uint 32
PTGFEna6	Step 6 enabled				YES/NO	Boolean
StrVal6	Step 6 Start value (Hz)	45	65	0,01		float32
OpDlTmms6	Step 6 Operate delay time(ms)	0	600000	10		Int32
StTyp6	Step 6 Function type				Maximum/Minimum	enum
LogInBlk6	Step 6 Blocking input					uint 32
PTGFEna7	Step 7 enabled				YES/NO	Boolean
StrVal7	Step 7 Start value (Hz)	45	65	0,01		float32
OpDlTmms7	Step 7 Operate delay time(ms)	0	600000	10		Int32
StTyp7	Step 7 Function type				Maximum/Minimum	enum
LogInBlk7	Step 7 Blocking input					uint 32
PTGFEna8	Step 8 enabled				YES/NO	Boolean
StrVal8	Step 8 Start value (Hz)	45	65	0,01		float32
OpDlTmms8	Step 8 Operate delay time(ms)	0	600000	10		Int32
StTyp8	Step 8 Function type				Maximum/Minimum	enum
LogInBlk8	Step 8 Blocking input					uint 32
GenTrip	General trip				NO/YES	Boolean
TripPerm	TripP:RL,RR,RL,R:1,2,3,4,MC	0	255	1	Bit meaning	ING
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

Table 58 Frequency function outputs

Signal	Data	Attribute
Level 1 Frequency Start	Str1	general
Level 1 Frequency Trip	Op1	general
Level 1 Frequency Status	StEna1	stVal
Same for the rest of the steps		
Level 8 Frequency Start	Str8	general
Level 8 Frequency Trip	OP8	general
Level 8 Frequency Status	StEna8	stVal

3.4.2 Frequency rate of change

This unit has 8 steps. In each step, a relay is activated if the frequency variation per time unit is higher than the set value. The variation can represent a reduction and/or an increase in the frequency, depending on the operation type setting.

The function's node, PROT/PFRC1, has independent settings for each step and common settings for all.

The common settings for all steps are as follows:

- Enabled. Indicates whether the unit is enabled or not.
- Operation type. Indicates the whether the frequency variation is a reduction (Negative), and increase (Positive) or both (Negative and positive).
- Minimum current level (A). Indicates the minimum current value below which it does no act, the unit is not permitted to pick up.
- Number of cycles (Start). Indicates the number of cycles during which the conditions necessary for the unit to pick up must be met.
- Number of cycles (Reset). Indicates the number of cycles during which the drop conditions necessary for the unit to reset must be met in the event of the unit's not having tripped.
- Reset delay time (ms). Once tripped, this is the time during which the reset conditions must be met in order to clear the trip from the unit.
- Blocking Input. Selects the signal which, when active, blocks the unit.
- General trip. Indicates if this unit produces general trip or not. For additional details, see section corresponding to the recloser (5.2.1).
- TripP:RL,RR,RL,R:1,2,3,4,MC. Indicates the trip and block permission in accordance with the recloser status: standby, blocked, safety time after reclosing, after closing. It is configured bit by bit; for additional details, see section corresponding to the recloser (5.2.2).
- Enable Events record. Allows the generation of protection events associated to the function. If set to "NO", the function's protection events are not generated. If set to "YES", the function's specific mask is contemplated.
- Minimum allowed voltage (V). The setting as employed in the frequency protection (PTGF1). Indicates the minimum phase B voltage value.

The independent settings for each of the 8 steps are:

- Supervision f max. Indicates the maximum frequency above with the frequency rate of change is not measured.
- f start value(Hz/seg). Indicates the frequency variation value at which the function is activated.
- Operate delay time (ms). Indicates the time during which the conditions for the tripping of the function must be met.
- Trip lock. Selects the signal which, when active, locks the activation of the function; so, once activated, the signal is kept until the lock signal and the rate of change signal are deactivated.

Table 59 Frequency rate of change settings

Data	Parameter	Min.	Max	Step	Remarks	Type
PFRCEna	Enabled				YES/NO	Boolean
Optype	Operation type				Negative(0) Positive (1) Negative and Positive (2)	uint 32
BlkValA	Minimum current level (A)	0	100,0	0,1		float32
StrNumCyc	Number of cycles (Start)	3	15	1		Int32
RepNumCyc	Frequency rate of change drop off cycles	0	10	1		Int32
RsDITmms	Overfrequency rate of change drop off time	0	600000	10		Int32
BlkValHz1	Step 1: Supervision f max	40	70	0,01		float32
StrVal1	Step 1: f start value (Hz/seg)	0,20	10	0,05		float32
OpDITmms1	Step 1:Operate delay time (ms)	0	2000	10		Int32
LogInTrLck1	Step 1: Trip Lock					uint 32
BlkValHz2	Step 2: Supervision f max	40	70	0,01		float32
StrVal2	Step 2: f start value (Hz/seg)	0,20	10	0,05		float32
OpDITmms2	Step 2: Operate delay time (ms)	0	2000	10		Int32
LogInTrLck2	Step 2:Trip Lock					uint 32
	Same for the rest of the steps					
BlkValHz8	Step 8: Supervision f max	40	70	0,01		float32
StrVal8	Step 8: f start value (Hz/seg)	0,20	10	0,05		float32
OpDITmms8	Step 8: Operate delay time (ms)	0	2000	10		Int32
LogInTrLck8	Step 8: Trip Lock					uint 32
GenTrip	General trip				NO (0) / YES (1)	Boolean
TripPerm	TripP:RL,RR,RL,R:1,2,3,4,MC	0	255	1	Bit meaning	ING
LogInBlk	Blocking input					uint 32
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

There are settings, commands and outputs.

- Nodes: PROT/PFRC1
- Settings and logical inputs. There are 6 settings tables. For details see Table 59.
- Commands:
  - "DOrdBlk": Function block and unblocking. It only acts on the enabled steps. If acts on the 8 steps
- Outputs: Table 60 shows the function's output data. They are independent for each step
  - Rate of change enabled. It is active when enabled and not blocked. Common for all steps.
  - Step X pick up. Indicates that the step has picked up. It is independent for each step.
  - Step X activation. Indicates that the step has tripped. It is independent for each step.

Table 60 Frequency rate of change function outputs

Signal	Data	Attribute
Rate of change enabled	StEna	stVal
Step 1 pick up	Str1	general
Step 1 activation	Op1	general
Same for the rest of the steps		
Step 8 pick up	Str8	general
Step 8 activation	OP8	general

General operation.

The function is only effective for frequencies inferior to a threshold called “maximum monitoring frequency”, currents superior to the threshold called “minimum current” and voltages superior to the minimum monitoring threshold:

- Minimum monitoring current. The maximum phase current is compared to this setting. If the minimum current circulating in all the phases is inferior to the setting, the frequency rate of change unit is not allowed to pick up. When a current superior to the set threshold appears in at least one of the phases, the relay waits for 10 cycles before running the frequency rate of change function.
- Minimum monitoring voltage. If the phase B voltage is inferior to the setting, the frequency rate of change unit is not allowed to pick up. When the voltage exceeds the set threshold, the relay waits for 10 cycles before running the frequency rate of change function.

The frequency is measured each cycle and reloaded every half cycle, as shown in Figure 50.

The algorithm stores the periods of the signal’s last 5 cycles and calculates the frequency rate of change by comparing the current cycle’s frequency measurement with the measurement taken from 5 cycles previously, taking into account the time lapse between both (Figure 51).

df/dt =(f1-f5)/(T1+T2+T3+T4)

In which:

f5 =frequency measurement taken 4 cycles previously

f4 =frequency measurement taken 3 cycles previously	T4 period of the 4th cycle starting from the end
f3 =frequency measurement taken 2 cycles previously	T3 period of the 3rd cycle starting from the end
f2 =frequency measurement taken 1 cycle previously	T2 period of the 2nd cycle starting from the end
f1 =Last frequency measurement	T1 period of the last cycle

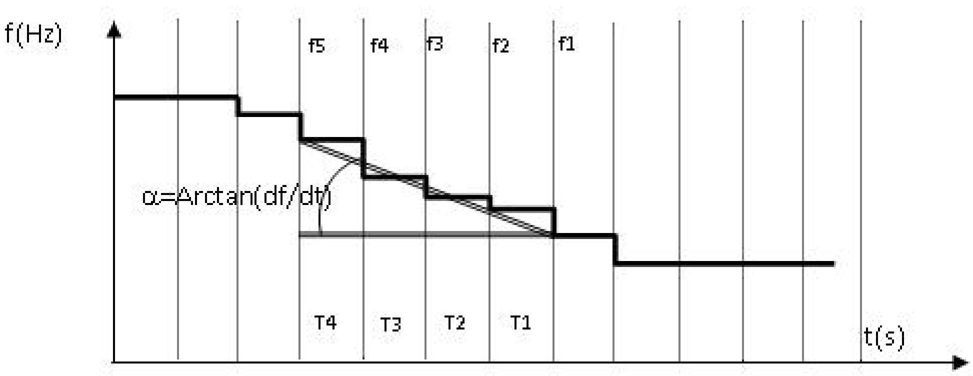
This calculation is repeated, taking into account the measurements separated by two cycles in order to ensure that the frequency has fallen during the entire period, i.e., to ensure that an incorrect measurement does not lead to a trip. Two checks are carried out:

- the measurement of the current cycle against that of the cycle minus two cycles

  df/dt2=(fn-fn-4)/(tn-tn-4)
- the measurement of the cycle minus two cycles against that of the cycle minus four cycles

  df/dt3=(fn-4-fn-8)/(tn-4-tn-8)

Figure 51 Frequency rate of change calculation



For the unit to pick up, the frequency rate of change must be exceeded by an absolute value during the set number of cycles minus four cycles. That is, if the setting is 5 cycles, the frequency rate of change value must be contemplated once in order for it to pick up. If the setting is four cycles or less, the pick up is produced the first time the measurement is registered above the threshold (by an absolute value).

The pick up is only produced if the frequency rate of change/voltage rate of change value meets the criterion selected in the operation type setting:

- Negative. The frequency rate of change/voltage rate is negative, i.e., when the current frequency is inferior to that measured 5 cycles previously.
- Positive. The frequency rate of change/voltage rate is positive, i.e., when the current frequency is greater than that measured 5 cycles previously.
- Negative and Positive. Acts on frequency rate of change/voltage rate in both directions.

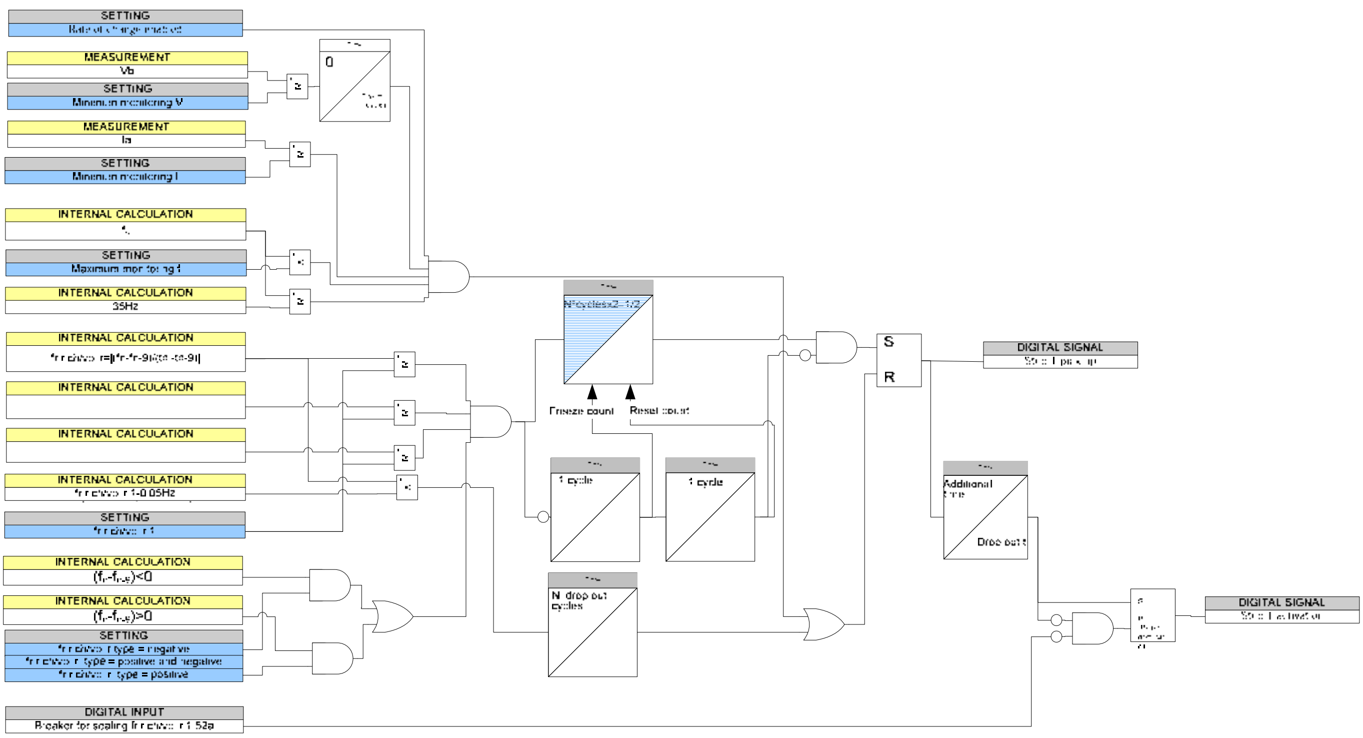
During the pickup process, one measurement is allowed to be out of the pickup range without restarting the process. For example, if 3 cycles (set to 7 cycles) are required to cause a pickup, the threshold need only be exceeded 3 times from a total of 4 consecutive measurements.

In order for a trip to occur once the unit has picked up, the frequency rate of change measurement must remain between the set frequency rate of change/voltage rate of change value and a reset value to the frequency rate of change/voltage rate of change minus 0.05Hz/s during the set time.

In order for the unit to reset once it has picked up, the frequency rate of change/voltage rate of change measurement must be detected as being 0.05Hz/s below the set value during the number of cycles programmes as reset cycles.

In order for the unit to reset once it has tripped, the frequency rate of change/voltage rate of change measurement must be detected as being 0.05Hz/s below the set value during the reset time. Any sealing signals that have been configured must register a value of zero in order for the trip to be deactivated.

Figure 52 Frequency rate of change trip diagram



3.5 POWER UNITS

3.5.1 General

Using the voltage and current measurements, the real and reactive powers and the power factor are calculated. The values obtained are employed for the power protection functions.

The trip thresholds are programmed as a percentage of the rated apparent power, S = 3 * V * I, in which:

- Vn: rated ground to phase voltage (phase-ground) of the PROT/TVTR node.
- In: The rated phase current of the PROT/TCIN node.

The units' reset threshold is configured in the PROT/PDOP1 node, ranging from 0.1% to 5%:

- Real P reset threshold (%). Indicates the reset threshold for the real power units.
- Reactive P reset threshold (%). Indicates the reset threshold for the reactive power units.
- Apparent P reset threshold (%). Indicates the reset threshold for the apparent power units.

Table 61 Power units reset settings

Data	Setting	Minimum	Maximum	Step	Remarks	Type
RepValP	Real P drop off threshold (%)	0.1	5	0,1		float32
RepValQ	Reactive P drop off threshold (%)	0.1	5	0,1		float32
RepValS	Apparent P drop off threshold (%)	0.1	5	0,1		float32

The power units' settings are similar to each other. Each unit has independent settings:

- Enabled. Indicates whether the function is enabled or not.
- Start value (%). Indicates the percentage in relation to the rated power necessary for the unit to pick up.
- Operate delay time (ms). Indicates the time during which the conditions for the tripping of the function must be met.
- Blocking Input. Selects the signal which, when active, blocks the step.
- General trip. Indicates if this unit produces general trip or not. For additional details, see section corresponding to the recloser (5.2.1).
- TripP:RL,RR,RL,R:1,2,3,4,MC. Indicates the trip and block permission in accordance with the recloser status: standby, blocked, safety time after reclosing, after closing. It is configured bit by bit; for additional details, see section corresponding to the recloser (5.2.2).
- Enable Events record. Allows the generation of protection events associated to the function. If set to "NO", the function's protection events are not generated. If set to "YES", the function's specific mask is contemplated.

Table 62 Power unit settings

Data	Setting	Minimum	Maximum	Step	Remarks	Type
PDUPEna (minimum) PDOPEna(maximum)	Enabled				YES/NO	Boolean Boolean
PcStrVal	Start value (%)	1,0	200,0	0,1		float32
OpDlTmms	Operate delay time (ms)	0	60000	10		Int32
GenTrip	General trip				NO (0) / YES (1)	Boolean
TripPerm	TripP:RL,RR,RL,R:1,2,3,4,MC	0	255	1	Bit meaning	ING
LogInBlk	Blocking input					uint 32
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

The settings, commands and outputs available are similar in all the units, with the exception of the node:

- Node: Indicated in each specific unit.
- Settings and logical inputs. There are 6 settings tables. For details see Table 61 and Table 62.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts if the unit is enabled.
- Outputs: Table 63 shows the function's output data.
  - Status. It is active when enabled and not blocked.
  - Start. Indicates that the unit has picked up.
  - Trip. Indicates that the unit has tripped.

Table 63 Power function outputs

Signal	Data	Attribute
Status	StEna	stVal
Start	Str	general
Trip	Op	general

3.5.2 Minimum real power

This unit's node is PROT/PDUP1.

Provides protection against excessive decreases in the generated power. It compares the real power with the minimum power given by the setting. In the event of the generated power being inferior to the power established in the setting during the programmed time, the protection trips the corresponding relay. Any reverse power will be considered as below the minimum power threshold and will thus activate the function.

In order to reset, the power must exceed the pick up threshold plus the reset percentage. For example, if the reset percentage is set at 2%, the unit will reset if the power exceeds the 102% of the pick up threshold.

The settings, commands and outputs available are indicated in section 3.5.1.

3.5.3 Maximum real power

There are two independent units, whose nodes are PROT/PDOP1 and PROT/PDOP2.

It provides protection against excessive increases in the power generated. It compares the real power with the maximum power given by the setting. In the event of the generated power being superior to the power established in the setting during the programmed time, the protection trips the corresponding relay.

In order to reset, the power must be inferior to the pick up threshold less the reset percentage. For example, if the reset percentage is set at 2%, the unit will reset if the power is inferior to 98% of the pick up threshold.

The settings, commands and outputs available are indicated in section 3.5.1.

3.5.4 Real power inversion

There are two independent units, whose nodes are PROT/PDOP3 and PROT/PDOP4.

The protection is activated when the real power flow is inverted (motorization of generators).

In order to act, the real power must be negative; in the event of the real power exceeding the set value during the programmed time, the protection trips the corresponding relay.

In order to reset, the power must be inferior to the pick up threshold less the reset percentage.

For example, if the threshold is set at 100W, the unit will pick up as of a measured power of -100w. If the reset percentage is set at 2%, the unit will reset when the power is below -98W (98% of set value).

The settings, commands and outputs available are indicated in section 3.5.1.

3.5.5 Reactive power inversion

There are two independent units, whose nodes are PROT/PDOP5 and PROT/PDOP6.

The protection is activated when the reactive power flow is inverted (field loss in generators).

In order to act, the reactive power must be negative; in the event of the real power exceeding the set value during the programmed time, the protection trips the corresponding relay.

In order to reset, the power must be inferior to the pick up threshold less the reset percentage.

For example, if the threshold is set at 100W, the unit will pick up as of a measured power of -100w. If the reset percentage is set at 2%, the unit will reset when the power is below -98W (98% of set value).

The settings, commands and outputs available are indicated in section 3.5.1.

3.5.6 Minimum apparent power

This unit's node is PROT/PDUP2.

It provides protection against excessive decreases in the power generated. It compares the apparent power with the minimum power given by the setting. In the event of the generated power being inferior to the power established in the setting during the programmed time, the protection trips the corresponding relay.

In order to reset, the power must exceed the pick up threshold plus the reset percentage. For example, if the reset percentage is set at 2%, the unit will reset if the power exceeds the 102% of the pick up threshold.

The settings, commands and outputs available are indicated in section 3.5.1.

3.5.7 Maximum apparent power

There are two independent units, whose nodes are PROT/PDOP7 and PROT/PDOP8.

It provides protection against excessive increases in the power generated. It compares the apparent power with the maximum power given by the setting. In the event of the generated power being superior to the power established in the setting during the programmed time, the protection trips the corresponding relay.

In order to reset, the power must be inferior to the pick up threshold less the reset percentage. For example, if the reset percentage is set at 2%, the unit will reset if the power is inferior to 98% of the pick up threshold.

The settings, commands and outputs available are indicated in section 3.5.1.

3.6 PHASE SHIFT

This function produces a trip when a angle variation superior to the set value is detected within a 2 consecutive periods.

This function compares the angle of each phase with the angle present during the previous cycle and a quarter. If it detects that the variation of the angle is greater than the setting value, and provided that blocking input is deactivated and the current measured is greater than the setting value, the function will trip.

If the "Trip Type" setting is set as three-phase, the three measurement phases detect the angle lag difference simultaneously and the presence of sufficient voltage. To the contrary, the trip will not take place. However, if it is set as single phase, the trip occurs even when only one of the phases detects the angle variation.

The angle variation is measured each half cycle in accordance with the zero passages of the voltage channels.

To ensure that the angle variation is not due to a frequency variation, the following measurement within the period must exceed the setting, but not the n+2. Each n may be a positive or negative slop, as both are considered zero passages (see Figure 53). The frequency measurement is calculated over 10 cycles.

Taveragen-1=Tn-19+Tn-17+Tn-15+Tn-13+Tn-11+Tn-9+Tn-7+Tn-5+Tn-3+Tn-1

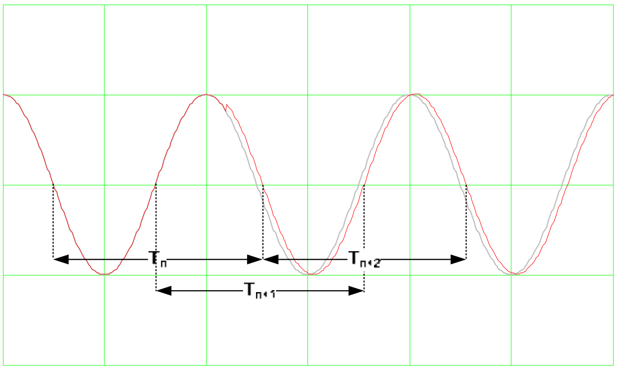
faverage-1=1/ Taveragen-1

The trip is issued after 1.5 cycles, as the following conditions must be met first:

- ITn- Taveragen-1 I·360·faveragen-1>Threshold Δθ (1)
- ITn+1- Taveragen-1 I·360·faveragen-1>Threshold Δθ (2)
- ITn+2- Taveragen-1I·360·faveragen-1<(Threshold Δθ-2º) (3)
- Vn+2>Vminimum (4)

If only (1) is met, the average frequency measurement is taken again following another 11 cycles, as a minimum of 10 cycles are required in order to obtain a valid value. This applies if the voltage drops.

Figure 53 Calculation of signal periods



The unit's settings are:

- Enabled. Indicates whether the function is enabled or not.
- Angle difference (º). Indicates the limit of the angle variation necessary for the consideration of a phase shift.
- Minimum voltage threshold (V). Minimum voltage value for the activation of the function.
- Trip type. Indicates if the variation must be detected in all the phases (three-phase) in order to be activated, or only in one.
- Minimum trip time (ms). Indicates the time during which the phase shift signal will remain active.
- Blocking Input. Selects the signal which, when active, blocks the function.
- General trip. Indicates if this unit produces general trip or not. For additional details, see section corresponding to the recloser (5.2.1).
- TripP:RL,RR,RL,R:1,2,3,4,MC. Indicates the trip and block permission in accordance with the recloser status: standby, blocked, safety time after reclosing, after closing. It is configured bit by bit; for additional details, see section corresponding to the recloser (5.2.2).
- Enable Events record. Allows the generation of protection events associated to the function. If set to "NO", the function's protection events are not generated. If set to "YES", the function's specific mask is contemplated.

Table 64 Phase shift settings

Data	Setting	Minimum	Maximum	Step	Remarks	Type
PPAMEna	Enabled of the function				NO (0) / YES (1)	Boolean
Ang	Angle difference (º)	2	22	1		float32
BlkValV	Minimum voltage threshold (V)	12	200	1		float32
Typ	Trip type				Single phase / Three phase	enum
TrTmms	Minimum trip time (ms)	10	1000	1		Int32
LogInBlk	Blocking input					uint 32
GenTrip	General trip				NO (0) / YES (1)	Boolean
TripPerm	TripP:RL,RR,RL,R:1,2,3,4,MC	0	255	1	Bit meaning	ING
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

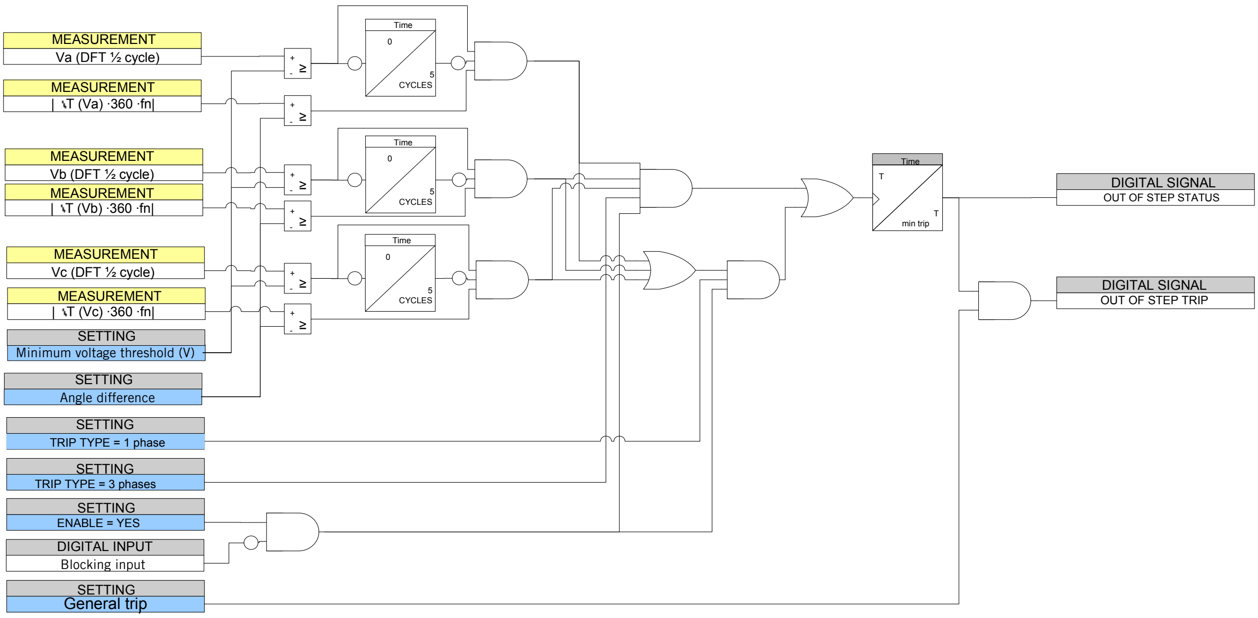
It has independent settings, commands and outputs:

- PROT/PPAM1 node
- Settings and logical inputs. There are 6 settings tables. See Table 64.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 65 shows the function's output data.
  - Out of Step Status. It is active when enabled and not blocked.
  - Out of Step Trip. Indicates that the unit has tripped.

Table 65 Phase shift function outputs

Signal	Data	Attribute
Out of Step Status	StEna	stVal
Out of Step Trip	Op	general

Figure 54 Phase shift scheme



3.7 FIELD LOSS

Field loss protection (generator excitation) with the following selectable characteristics:

- 2 MHO trip zones with independent settings
- 1 directional unit common to both zones
- 1 undervoltage unit common to both zones. The enabled can be carried out independently for each zone.

Figure 55 shows a field loss graph in which the different settings that determine the mho zones are indicated:

- Zone Offset, in this case positive for zone 1 and negative for zone 2.
- Zone diameter. Delimits the zone
- Directional angle. Permits the blocking of the unit in a specific direction.

This unit employs the direct sequence impedance, which is calculated using the direct sequence current and voltage. The calculations relative to impedances are based on the condition that the direct sequence current is equal to or greater than a minimum value, set at 0.01 In.

The unit acts differently depending on whether it is in undervoltage conditions or not. The following conditions must be met in order for undervoltage to be considered:

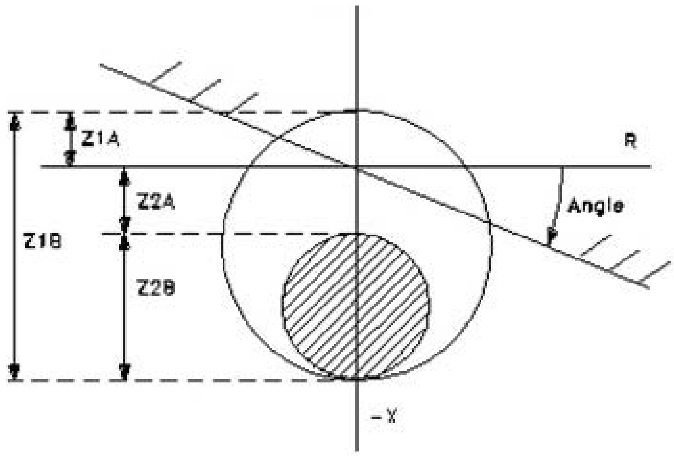
- The measurement in any of the voltage phases is below the undervoltage pickup value,
- The undervoltage monitoring setting of the zone in question is disabled.

When a generator enters one of these MHO zones, a timer is activated. One the time has elapsed, the timer activates the corresponding outputs:

- If the zone is not under these undervoltage conditions, the zone alarm timer is activated.
- If the zone is not under these undervoltage conditions, the zone trip timer is activated.

The trip timer must be set to a value lower than that of the alarm, as faults must be cleared quickly when the undervoltage conditions occur, given the limited possibilities of the generator recovering and the consequent risk of instability in the electrical system.

Figure 55 Field loss



The unit's settings are:

- Enabled. Indicates whether the function is enabled or not.
- Minimum voltage. Indicates the minimum voltage threshold for the undervoltage condition.
- Directional torque angle (°). Indicates the limits for blocking the unit in a specific direction.
- mho zone settings. They are duplicated for each of the two zones available:
  - Offset Z1A (Ohm). Indicates the offset of the mho zone's upper section.
  - Diameter Z1B (Ohm). Indicates the mho zone diameter.
  - Undervoltage checking zone. Indicates whether to undervoltage monitoring is enabled.
  - Alarm delay time zone (s). Additional time in which to issue a zone 1 alarm.
  - Trip delay time zone (s). Additional time in which to issue a zone 1 trip.
- Blocking Input. Selects the signal which, when active, blocks the function.
- General trip. Indicates if this unit produces general trip or not. For additional details, see section corresponding to the recloser (5.2.1).
- TripP:RL,RR,RL,R:1,2,3,4,MC. Indicates the trip and block permission in accordance with the recloser status: standby, blocked, safety time after reclosing, after closing. It is configured bit by bit; for additional details, see section corresponding to the recloser (5.2.2).
- Enable Events record. Allows the generation of protection events associated to the function. If set to "NO", the function's protection events are not generated. If set to "YES", the function's specific mask is contemplated.

It has independent settings, commands and outputs:

- PROT/PLOF1 node
- Settings and logical inputs. There are 6 settings tables. For details see Figure 66.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Figure 67 shows the function's output data.
  - Loss of Field Status. It is active when enabled and not blocked.
  - MHO X Undervoltage. Indicates that the undervoltage conditions have been met. For each of the two mho zones.
  - MHO X Alarm. Located within the mho zone, but without the undervoltage conditions being met. For each of the two mho zones.
  - MHO X Trip. Located within the mho zone, with the undervoltage conditions being met. For each of the two mho zones.

Table 66 Field loss settings

Data	Parameter	Min.	Max	Step	Remarks	Type
PLOFEna	Enabled				YES/NO	
BlkValV	Minimum voltage	10,0	65,0	0,1		float32
Ang	Directional torque angle (°)	0	180	1	Clockwise	float32
Ofs1	Offset Z1A (ohm)	-20,0	20,0	0,1		float32
PoRch1	Diameter Z1B (Ohm)	0,0	120,0	0,1		float32
VSpv1	Undervoltage checking zone 1				YES/NO	Int32
AlTmms1	Alarm delay time zone 1 (s)	0	10000	100		Int32
TrTmms1	Trip delay time zone 1 (s)	0	10000	10		Int32
Ofs2	Offset Z2A (Ohm)	-20,0	20,0	0,1		float32
PoRch2	Diameter Z2B (Ohm)	0,0	120,0	0,1		float32
VSpv2	Undervoltage checking zone 2				YES/NO	Int32
AlTmms2	Alarm delay time zone 2 (s)	0	10000	100		Int32
TrTmms2	Trip delay time zone 2 (s)	0	10000	10		Int32
LogInBlk	Blocking input					uint 32
GenTrip	General trip				NO (0) / YES (1)	Boolean
TripPerm	TripP:RL,RR,RL,R:1,2,3,4,MC	0	255	1	Bit meaning	ING
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

Table 67 Field loss function outputs

Signal	Data	Attribute
Loss of Field Status	StEna	stVal
MHO 1 UnderVoltage	OpVMHO1	general
MHO 1 Alarm	StrMHO1	general
MHO 1 Trip	OpMHO1	general
MHO 2 UnderVoltage	OpVMHO2	general
MHO 2 Alarm	StrMHO2	general
MHO 2 Trip	OpMHO2	general

3.8 RESTRICTED EARTH

Employed to detect internal grounding faults within a zone (hence "restricted"). It is usually used in resistance grounded Yn-D transformers in which the current level in the event of a failure is insufficient to activate the phase differential unit. It can also be used in all ground connections.

The function calculates the zero sequence differential current using the transformer's neutral and grounding currents. The magnitude and angle are analyzed to determine the direction.

The following conditions must be met in order for a trip to be produced:

- The sensitivity (A) setting and slope (%) are exceeded.
- It directional indicates that the fault is internal
- There is a minimum current in the grounding.

The unit operates as follows:

Sensitivity: The unit picks up if the difference between the grounding current and the neutral current (algebraic sum), following the application of their respective transformation ratios, exceeds the programmed threshold. The neutral current can be obtained by the sum of phase current or the transformer's neutral measurement (see node PROT/TCIN):

- If IN is obtained from the sum of the phase currents:

$$IN = Ia + Ib + Ic$$

$$Idif\_S0 = \left| \frac{RTF}{RTG} \cdot (Ia + Ib + Ic) - I_G \right|$$

$$Idif\_S0 \geq Ajuste$$

RTF = Transformation ratio of the phase TIs
RTG = Transformation ratio of the grounding TI

- If IN is obtained from neutral current measurement transformer:

$$Idif\_S0 = \left| \frac{RTN}{RTG} \cdot IN - I_G \right|$$

$$Idif\_S0 \geq Ajuste$$

RTN = Transformation ratio of the neutral TI
RTG = Transformation ratio of the grounding TI

Slope: The calculated zero sequence differential current must also exceed a percentage of the maximum phase current (from the winding in question).

$$\frac{Idif\_S0 * RTG}{Ibias * RT(F,G,N)} * 100 \geq Pendiente$$

In Ibias, the transformation ration of the value taken as Ibias when selecting the maximum is taken into account.

in which the calculation of the Ibias is

$$Ibias_n = \max\{Ia, Ib, Ic, I_G, IN, \alpha\}$$
$$\alpha = Ibias_{n-1} \cdot 0.998$$

The Ibias is selected by taking into account the primary values in order to be able to select a maximum from among all the currents.

Directional: It must indicate that the fault is internal: The grounding and the neutral currents (the sum of the two windings following the application of their transformation ratios) must be opposed. The minimum grounding current level must always be exceeded (polarization IG or I). If this current does not exceed 50% of the set sensitivity, the unit is blocked. In the event of the neutral current (IN) being below 5% of In, the directional is not taken into account, as it is assumed that the failure is internal and there is no current circulating towards the fault.

For the fault to be considered internal, the compared current must be more than 120%.

Minimum current: The minimum grounding current level must always be exceeded (polarization IG or I). If this current does not exceed 50% of the set sensitivity, the unit is blocked. In the event of the neutral current (IN) being below 5% of Inominal, the directional is not taken into account, as it is assumed that the failure is internal and there is no current circulating towards the fault.

Signals: The restricted earth trip signals are issued if the directional indicates and internal fault and the difference between both magnitudes is greater than the threshold and the slope.

The unit's settings are:

- Enabled. Indicates whether the function is enabled or not.
- Operation type.Sensitivity (A). Indicates the unit's sensitivity threshold.
- Slope (%). Indicates the function's status.
- Operate delay time (ms). Indicates the time during which the conditions for the tripping of the function must be met.
- Blocking Input. Selects the signal which, when active, blocks the function.
- General trip. Indicates if this unit produces general trip or not. For additional details, see section corresponding to the recloser (5.2.1).
- TripP:RL,RR,RL,R:1,2,3,4,MC. Indicates the trip and block permission in accordance with the recloser status: standby, blocked, safety time after reclosing, after closing. It is configured bit by bit; for additional details, see section corresponding to the recloser (5.2.2).
- Enable Events record. Allows the generation of protection events associated to the function. If set to "NO", the function's protection events are not generated. If set to "YES", the function's specific mask is contemplated.

Table 68 Restricted earth settings

Data	Parameter	Min.	Max	Step	Remarks	Type
PREAEna	Enabled				NO (0) YES (1)	enum
StrVal	Sensitivity (A)	0,05	20	0,01		float
SlpVal	Slope (%)	0%	100%	1%		float
OpDlTmms	Operate delay time (ms)	0	600000	10		Int32
LogInBlk	Blocking input					uint 32
GenTrip	General trip				NO (0) / YES (1)	Boolean
TripPerm	TripP:RL,RR,RL,R:1,2,3,4,MC	0	255	1	Bit meaning	ING
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

It has independent settings, commands and outputs:

- PROT/PREA1 node
- Settings and logical inputs. There are 6 settings tables. For details see Table 68.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 69 shows the function's output data.
  - Restricted Ground Status. It is active when enabled and not blocked.
  - Restricted Ground Start. Indicates that the unit has picked up.
  - Restricted Ground Trip. Indicates that the unit has tripped.

Table 69 Restricted earth function outputs

Signal	Data	Attribute
Restricted Ground Status	StEna	stVal
Restricted Ground Start	Str	general
Restricted Ground Trip	Op	general

3.9 LOAD ZONE

This unit determines an operational zone and generates a signal when the unit is within the zone.

This unit only acts when the breaker is closed (the three phases must be closed).

Figure 56 shows the unit's scheme, in which it is possible to see that the activation is produced when the following are met simultaneously:

- The direct sequence impedance is between impedance margins (see Figure 56).
- The direct current sequence exceeds the threshold (setting).
- At least one of the following conditions must be met:
  - The zero sequence must be greater than 5% of the rated current and 10% of the highest phase current.
  - The inverse sequence must be greater than 5% of the rated current and 10% of the direct sequence.
- The breaker's three poles must be closed (open pole detector function).

Although it does not directly inhibit any unit, this signal can be used to inhibit the protection functions when it is assigned to the function's blocking input.

The unit's settings are:

- Enabled. Indicates whether the function is enabled or not.
- Operation type
- Minimum I1 thershold (A). Indicates the minimum current direct sequence value necessary to activate the unit.
- Z Forward (Ohm). Indicates the forward load zone impedance module.
- Positive angle forward (º). Indicates the forward load zone positive angle limit.
- Negative angle forward (º). Indicates the forward load zone negative angle limit.
- Z Reverse (Ohm). Indicates the reverse load zone impedance module.
- Positive angle reverse (º). Indicates the reverse load zone positive angle limit.
- Negative angle reverse (º). Indicates the reverse load zone negative angle limit.
- Blocking Input. Selects the signal which, when active, blocks the function.
- Enable Events record. Allows the generation of protection events associated to the function. If set to "NO", the function's protection events are not generated. If set to "YES", the function's specific mask is contemplated.

Table 70 Load zone settings

Data	Setting	Min.	Max	Step	Remarks	Type
LoEnEna	Enabled				NO (0) YES (1)	Boolean
Optype	Operation type				ALWAYS (1) CLOSED POLES (2)	uint32
BlkValI1	Minimum I1 thershold (A)	0,05	25	0,01		float32
FwRisLod	Z forward (Ohm)	0,01	500	0,01		float32
FwAngLod	Positive angle forward (º)	0	90	1		float32
FwNAngLod	Negative angle forward (º)	270	359	1		float32
RvRisLod	Z reverse (Ohm)	0,01	500	0,01		float32
RvAngLod	Positive angle reverse (º)	90	180	1		float32
RvNAngLod	Negative angle reverse (º)	180	270	1		float32
LogInBlk	Blocking inout					uint 32
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

It has independent settings, commands and outputs:

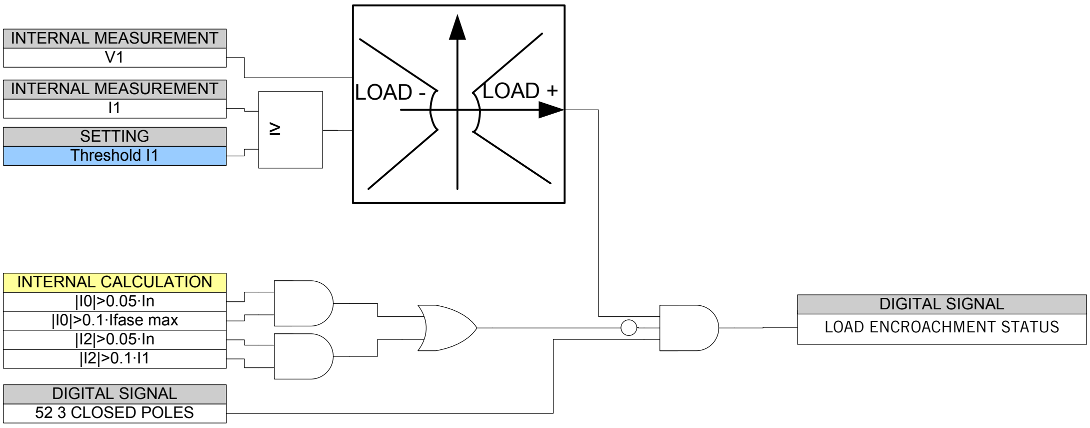
- PROT/PLEC1 node
- Settings and logical inputs. There are 6 settings tables. For details see Table 70.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 71 shows the function's output data.
  - Load Area. Indicates that the unit is active.

- Load Encroachment Status. Indicates the function's status. It is active when enabled and not blocked.

Table 71 Load zone function outputs

Signal	Data	Attribute
Load Area	Op	general
Load Encroachment Status	StEna	stVal

Figure 56 Load zone scheme



3.10 FUSE FAILURE

The measurement obtained from the half-cycle DFT is used to obtain results before the protection units are activated.

The fuse failure conditions are as follows:

- The three breakers are closed. (Open pole detector)
- I1 direct sequence current greater than 5% of rated current.
- The increase in I1 direct sequence and the IN neutral current in relation to the current measured 1 cycle previously must be less than 0.1 A for 5 A rated current and 0.02 A for rated current 1.
- Overcurrent units (phase, ground, sensitive ground, earth system and unbalance) haven´t picked up.
- The angle difference between currents I1 and I0 and those of 1 cycle previous are less than 5º.
- The V1 direct sequence voltage memorized 1 cycle previously must exceed VFF and drop below 95% of VFF,

$$V_{FF} := V_N \cdot 80\% \quad (V)$$

with VN as the rated ground to phase voltage (PROT/TVTR node).

If the function detects all the above conditions, or if the "fuse failure" input is activated, a fuse failure pick up signal is produced and used to block the units in question (configurable).

These conditions must be met during a programmable time in order for the fuse failure trip to be activated. Once tripped, the fuse fault is maintained until the V1 voltage rises above VFF.

If any of the overcurrent functions (phase, ground, sensitive ground, earth system and unbalance) have picked up or if during the timeout the relay picks up at least one of these units, the fuse fault output is not activated as the situation is considered a fault, not a fuse failure.

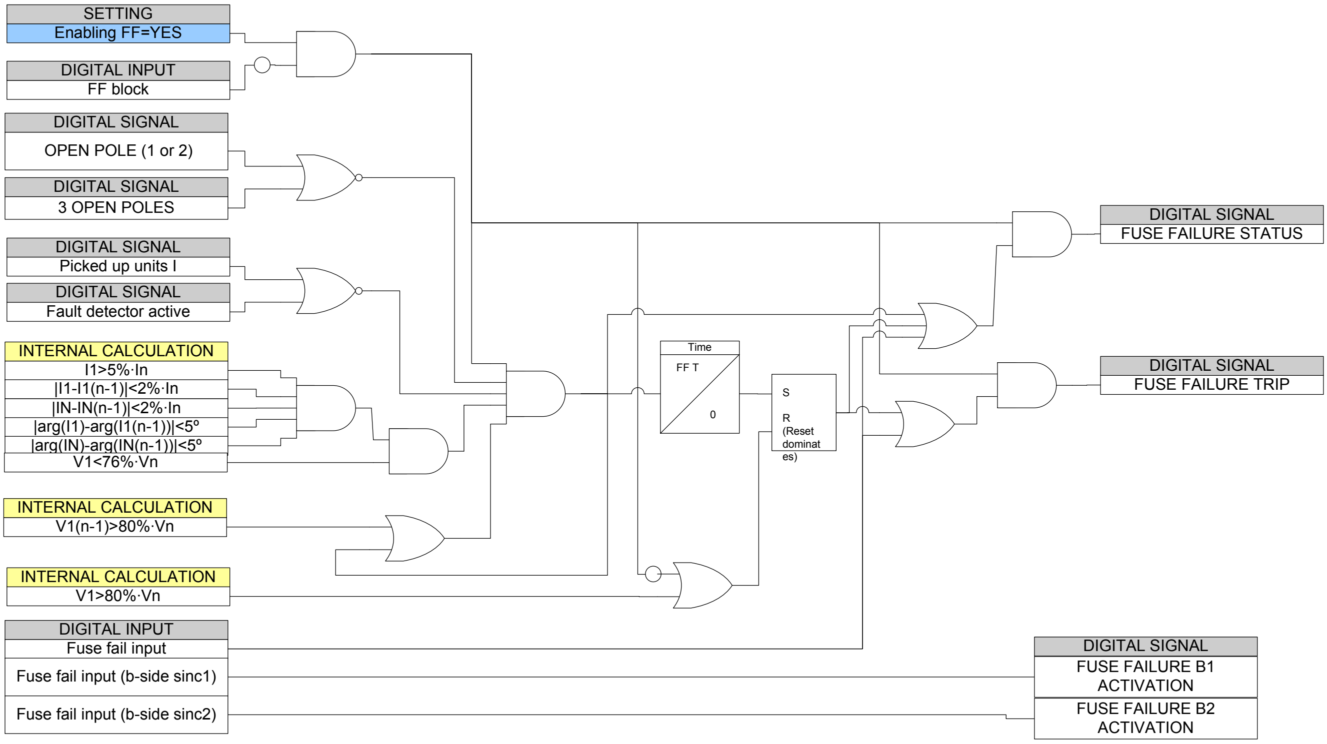
The fuse failure pick up and trip are also activated when the digital “Fuse Failure” input is activated independently of the programmed time. The fuse failure is only deactivated when the input is deactivated.

If the "B side fuse failure” input is activated, the synchrocheck unit is deactivated.

The fuse failure pick up can be used as a blocking signal for other functions by means of each function’s logic signals.

The overcurrent units have settings that configure their functioning in the event of a fuse failure, allowing the enabled of the function, the inhibition of directional, etc.

Figure 57 Fuse failure scheme



The settings used in these functions are:

- Enabled. Indicates whether the function is enabled or not.
- Operate delay time (ms). Indicates the time during which the conditions must be met in order for the trip to take place.
- Blocking Input. Selects the signal which, when active, blocks the function.
- Fuse fail input. Selects the signal which, when active, indicates a fuse failure.
- Fuse Fail input (B-side sinc1). It selects the signal which, when activated, indicates a fuse failure on breaker 1’s side B synchronism.
- Fuse Fail input (B-side sinc2). It selects the signal which, when activated, indicates a fuse failure on breaker 2’s side B synchronism.
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

Table 72 Fuse failure settings

Data	Setting	Minimum	Maximum	Step	Remarks	Type
RFUFEna	Enabled				YES/NO	Boolean
OpDlTmms	Operate delay time (ms)	0	10000	10		Int32
LogInBlk	Blocking input					uint 32
LogInFF	Fuse fail input					uint 32
LogInFFB1	Fuse Fail input (B-side sinc1)					uint 32
LogIn FFB2	Fuse Fail input (B-side sinc2)					uint 32
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

It has independent settings, commands and outputs:

- PROT/RFUF1 node
- Settings and logical inputs. There are 6 settings tables. For details see Table 72.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 73 shows the function's output data.
  - Fuse Failure Start. Indicates that the fuse failure has picked up.
  - Fuse Failure Trip. Indicates that the fuse failure has tripped, that is, the additional time has elapsed with the unit picked up.
  - Fuse Failure B1 Activation. Indicates that fuse failure is activated on breaker 1's synchronism B side.
  - Fuse Failure B2 Activation. Indicates that fuse failure is activated on breaker 2's synchronism B side.
  - Fuse Failure Status. Indicates the function's status. It is active when enabled and not blocked.

Table 73 Fuse failure function outputs

Signal	Data	Attribute
Fuse Failure Start	Str	general
Fuse Failure Trip	Op	general
Fuse Failure B1 Activation	FFB1	general
Fuse Failure B2 Activation	FFB2	general
Fuse Failure Status	StEna	stVal

3.11 SWITCH ONTO FAULT

This unit provides an instantaneous three-phase trip when a fault occurs upon the generation of a breaker closure command (manual, by input or by recloser).

The function is enabled during a programmable time (TSOTF) in the following situations:

- If the "SOTF timed start type" is set to standard:
  - upon the closure of the 3-poles without reclosure commnad, or
  - following the manual closure command
- If the "SOTF timed start type" is set to programmable:
  - upon the activation of the "Switch onto fault timed start"

Depending on the "Operation type" setting, the action of the switch onto fault is produced when:

- Programmed as "V&I": The phase voltage is below a threshold and the phase current is above a threshold for 10ms.
- Programmed as "programmable pick up I": The Programmable SOTF Pick up input is activated.

The function’s settings are:

- Enabled. Indicates whether the function is enabled or not.
- Operation type. Indicates the unit’s operation type.
  - V&I. The V and I measurements are checked in order to determine the switch onto fault.
  - Programmable. The action is produced with the logical pick up input.
- Operation start type. Indicated the unit verification start type:
  - Standard. The unit picks up with the closure command and the breaker status.
  - Programmable. The unit picks up with the logical “Timed start” input.
- Normalized voltage reset. Indicates if resetting due to voltage above the threshold is enabled or not.
- Phase Current threshold (A). Indicates the current value for indicating a switch onto fault.
- Activation time (s). Indicates the time during which the unit is enabled once the start conditions have been met.
- Blocking Input. Selects the signal which, when active, blocks the function.
- Timed Init Input. Selects the signal which, when active, indicates the start of the enabled of the unit. It only functions if the start type is set to “programmable”.
- Start input. Selects the signal which, when active, indicates the activation of the switch onto fault. It only functions if the operation type is set to “programmable”.
- General trip. Indicates if this unit produces general trip or not. For additional details, see section corresponding to the recloser (5.2.1).
- TripP:RL,RR,RL,R:1,2,3,4,MC. Indicates the trip and block permission in accordance with the recloser status: standby, blocked, safety time after reclosing, after closing. It is configured bit by bit; for additional details, see section corresponding to the recloser (5.2.2).
- Reclose perm.(R1,R2,R3,R4). Indicates whether each trip type can be reclosed or not, in accordance with the recloser's closing cycle (5.2.3).
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

The voltage threshold set in the open pole detector is employed.

Table 74 Switch onto fault settings

Data	Setting	Minimum	Maximum	Step	Remarks	Type
PSOFEna	Enabled				NO (0) YES (1)	Boolean
Optype	Operation type				V&I (2) Programmable (4)	uint32
TimInTyp	Operation start type				Standard (0) Programmable (1)	
TimAutEna	Operation delay start input				YES/NO	
VNorRst	Normalized voltage reset				YES/NO	
IThr	Phase current threshold(A)	0,01	200,0	0,01		float32
OpTmms	Activation time (s)	100	1000	10		Int32
LogInBlk	Blocking input					uint 32
LogInTmIn	Timed Init Input					uint 32
LogInSt	Start input					uint 32
GenTrip	General trip				NO (0) / YES (1)	Boolean
TripPerm	TripP:RL,RR,RL,R:1,2,3,4,MC	0	255	1	Bit meaning	ING
ReclPerm	Reclose perm.(R1,R2,R3,R4)	0	15		Bit meaning	ING
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

It has independent settings, commands and outputs:

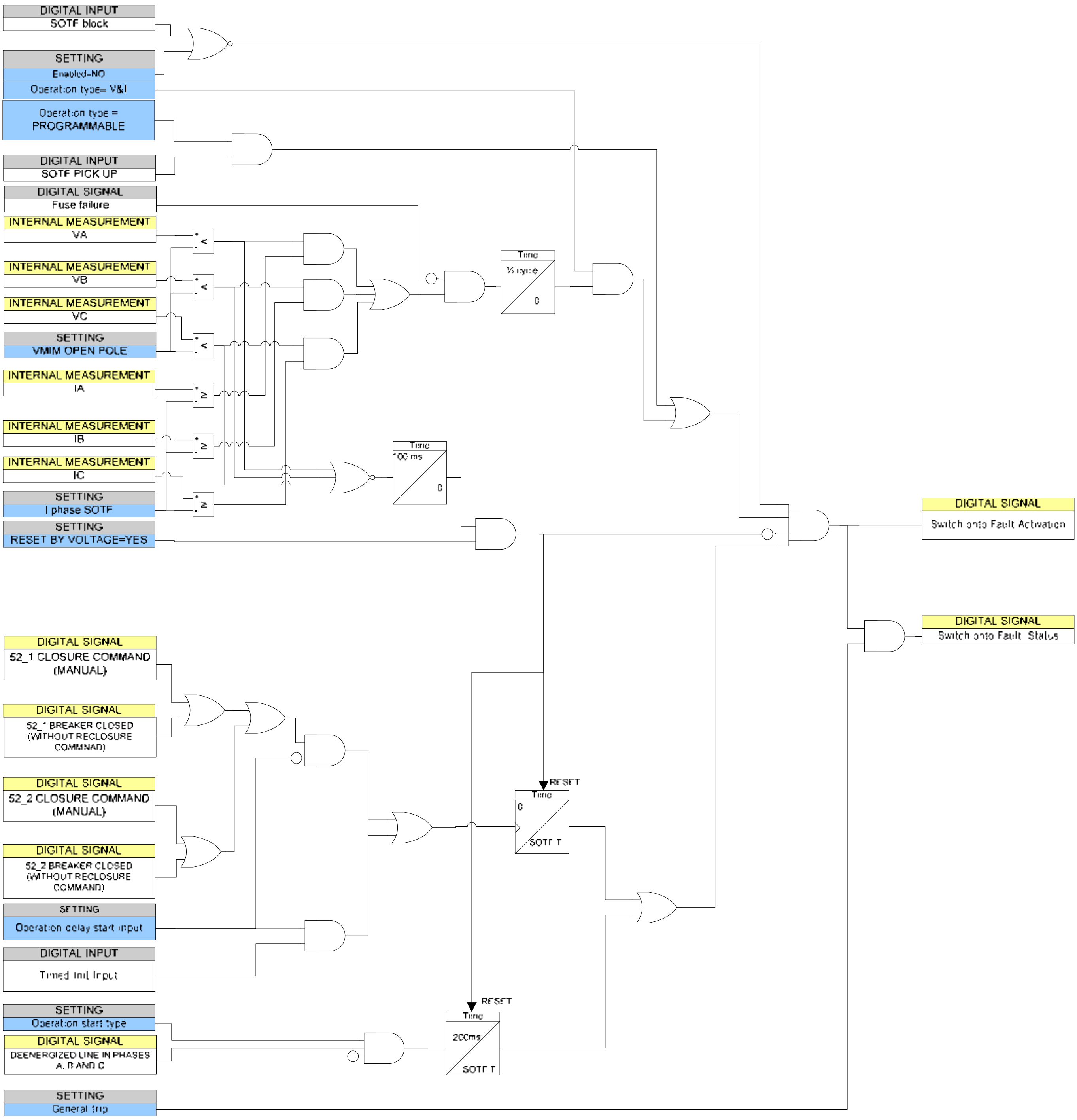
- PROT/PSOF1 node
- Settings and logical inputs. There are 6 settings tables. For details see Table 74.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 75 shows the function's output data.
  - Switch onto Fault Activation. Indicates that the switch onto fault has been activated.
  - Switch onto Fault Status. Indicates the function's status. It is active when enabled and not blocked.

Table 75 Switch onto fault function outputs

Signal	Data	Attribute
Switch onto Fault Activation	Op	general
Switch onto Fault Status	StEna	stVal

Figure 58 shows the complete switch onto fault unit scheme.

Figure 58 Switch onto fault scheme



3.12 BREAKER FAILURE

When enabled, the basic functioning is as follows (see Figure 59):

- If the unit issues a trip signal or an external protection action signal is received via a logical input, a timer picks up;
- If, following a period programmed as “definite retrip time”, the current of at least one of the phases exceeds the programmed "phase reset current", or if the neutral exceeds the "neutral reset current", the retrip signal is activated.
- If, following a period programmed as “definite trip time”, the current of at least one of the phases exceeds the programmed "phase reset current", or if the neutral exceeds the "neutral reset current", the trip signal is activated.
- The signals are only deactivated when the phase and neutral currents fall below their drop off values.

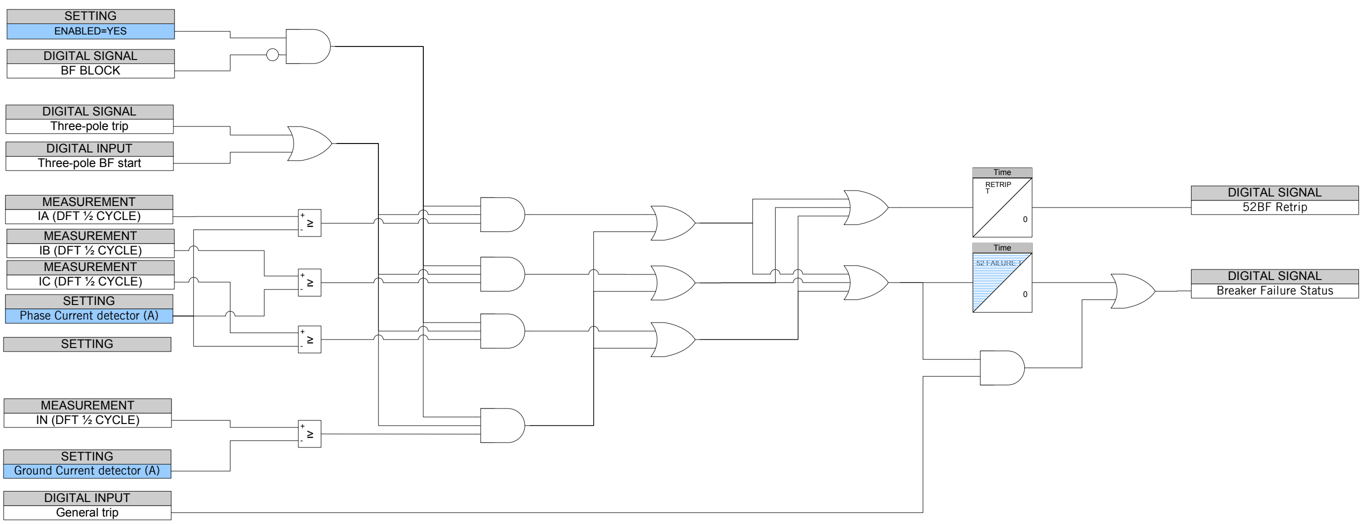
This unit does not contemplate the breaker status digital input, but rather the current values.

This unit does not contemplate the breaker status digital input, but rather the current values. The measurement obtained from the half-cycle DFT of the full-cycle DFT is employed (the lesser of the two).

Each of the phases and the neutral are analyzed separately.

The external protection signal is memorized internally, that is to say, it may be a pulse.

Figure 59 Basic breaker failure scheme



The unit’s settings are:

- Enabled. Indicates whether the function is enabled or not.
- Phase Current detector (A). Indicates the current value below which the phase is considered as open.
- Ground Current detector (A). Indicates the current value below which the neutral is considered as open.
- Retrip time delay (ms). Indicates the waiting time for the activation of the retrip signal if the current does not drop below the reset level.
- Trip time delay (ms). Indicates the waiting time for the activation of the trip signal if the current does not drop below the reset level.
- Blocking Input. Selects the signal which, when active, blocks the function.
- 3 pole breaker failure start. Selects the signal which, when active, indicates the start of the breaker failure timed.
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

Table 76 Breaker failure settings

Data	Parameter	Min.	Max	Step	Remarks	Type
RBRFEna	Enabled				NO/YES	Boolean
DetValAPhs	Phase Current detector (A)	0,02	150	0,01		float32
DetValAGnd	Ground Current detector (A)	0,02	150	0,01		float32
RFailTmms	Retrip time delay (ms)	0	60000	0,5	0.5 ms step	float
FailTmms	Trip time delay (ms)	0	60000	0,5	0.5 ms step	float
LogInBlk	Blocking input					Int32
LogInBFIn	3 pole breaker failure start					Int32
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

It has independent settings, commands and outputs:

- PROT/RBRF1 node
- Setting and logical inputs. There are 6 settings tables. For details see Table 76.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts when the function is enabled.
- Outputs: Table 77 shows the function's output data.
  - 52BF Trip . Indicates that a trip has been produced as a result of a phase or neutral breaker failure.
  - 52BF Retrip . Indicates that a retrip has been produced as a result of a phase or neutral breaker failure.
  - Breaker Failure Status. Indicates the function's status. It is active when enabled and not blocked.

Table 77 Breaker failure function outputs

Signal	Data	Attribute
52BF Trip	Tr	general
52BF Retrip	ReTr	general
Breaker Failure Status	StEna	stVal

3.13 TRIP LOGICS

3.13.1 Teleprotection schemes

The high voltage line protection requires protection systems specially fast, selective and reliable, in order not to expose the electrical system stability to danger. Teleprotection systems associated to the protection units installed in each extreme of the line have to be used in order to fulfil these requirements. The protection has a teleprotection system in order to protect the whole line with high speed protections.

They are based upon the use of teleprotection signals between both end terminals of the line. The effect upon the output relays' operation is determined according to the signals given by the protection along with the signals given by the other terminal.

- TPT: Teleprotection signal sent by a terminal.
- TPR: Received teleprotection signal.
- SGR: Guard channel loss received signal (Schemes to unlocking).

3.13.1.1 Escheme types

The schemes respond to two basic types:

- Blocking schemes: The signal received indicates that the fault is outside the zone to be protected. An overreach zone can trip of, following a waiting time, the blocking signal has not been received.
- Permission schemes: The signal received allows an instantaneous trip in the overreach zone. The additional ECO, weak infeed and inverse directional blocking schemes can be used.

When selecting a determined scheme, the following features must be considered: in case of an internal fault in the protected line and failure in the communication channel, in the permissive schemes, the protection does not trip, while in the locking schemes the trip is ensured. However, in locking schemes, in case of external fault and a communication channel loss, the protection can trip.

If the communication system is an integral part of the energy transfer line, as the case of the carrier wave, the use of locking signal schemes will be preferred, since the internal faults could disturb or weaken the carrier signal. That is why it is also preferable the use of locking schemes in weak infeed configurations, due to is higher reliability vs. permissive schemes.

Finally, permissive schemes are faster than locking ones, since these last schemes imply times for clearing faults slightly higher due to the security waiting time for the reception of the possible locking signal.

It is possible to select between several schemes:

- Step trip
- Permissive overreaching
- Permissive underreaching
- Directional comparison blocking
- Directional comparison unblocking

Additionally, the following can be selected together with the schemes:

- Transferred direct tripping
- ECHO
- Weak infeed
- Inverse directional lock

The signals that activate the dispatch of the teleprotection between the different overcurrent units can be configured for all the schemes. A “Configurable configuration schemes” setting is to be included which, together with logical input to which the pick ups of the units in question are taken, allows the signals carried to the schemes.

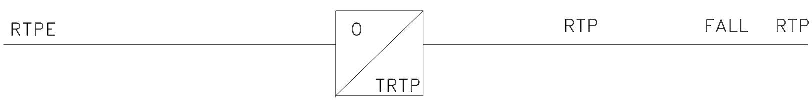
The applicable units can be configured to indicate:

- Reverse faults.
- Teleprotection trip following the reception of the teleprotection signal and providing the unit has picked up.

The following signals are employed in the schemes:

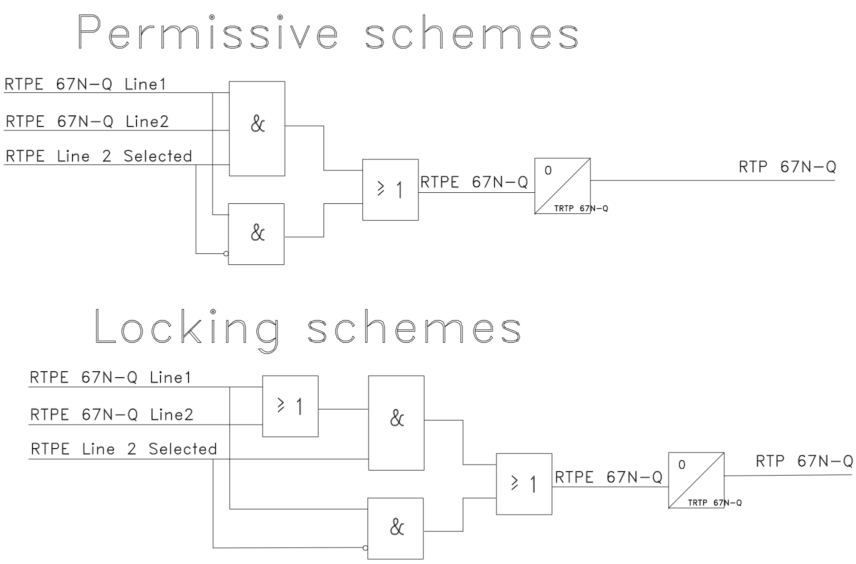
- ETP for the teleprotection signal sent from a terminal. In any case, the ETP signal sent by a terminal remains active for at least the programmed time, even if the cause for its activation disappears.
- RTPE and RTP. These signals are differentiated: RTPE is the teleprotection input received by a terminal, while the activation of the RTP follows the RTPE input, although it maintains the memorized input during the TRTP to deactivate itself. If TRTP is set to zero, RTP matches the RTPE input. RTP is employed in the teleprotection schemes.

Figure 60 Reception of teleprotection



- 67NQ_RV_MEM. Reverse direction change blocking signal. See the section corresponding to the inverse direction blocking.

Figure 61 Reception of teleprotection in double lines



The settings for selecting the protection schemes are:

- Scheme Type: Selects the scheme type.. Allows for selection from among:
  - Step trip (0)
  - Permissive overreaching (1)
  - Permissive underreaching (2)
  - Direct. comparison blocking (3)
  - Direct. comparison unblock. (4)
- TPRx Drop off time (ms): The time during which the teleprotection input is memorized (RTP).
- Lock delay time (ms): Locking signal timeout.
- GSL Minimum time (ms).Minimum security signal loss time to permit trips.
- GSL Maximum time (ms). Maximum time during which the trip permission for loss of security signal is enabled.
- GSL Drop off time (ms): Reset time following the recovery of the security channel.

- ECHO enabled: Enables the ECHO function.
- ECHO pulse time (ms): The time during which the conditions for the activation of the ECHO signal must be met.
- ECHO Blocking time (ms): The time following the deactivation of the scheme signal during which it remains active.
- ECHO delay time (ms): The duration of the ECHO output signal pulse.
- Current Reversal Blocking: Enables the memorization of the inverse direction.
- Current rev. pick up t.(ms): Inverse direction memorization time.
- Weak Infeed Enabled: Enables the weak infeed function.
- Weak Infeed Threshold (V). Voltage threshold for the consideration of weak infeed.
- TPRx _67NQ line 1. Selects the signal which, when active, indicates the line 1 teleprotection reception.
- TPRx _67NQ line 2. Selects the signal which, when active, indicates the line 2 teleprotection reception.
- GSLRx_67NQ line 1. It selects the active signal, indicating the reception of the line 1 security signal loss signal.
- GSLRx_67NQ line 2. It selects the active signal, indicating the reception of the line 2 security signal loss signal.
- TP Trip Block. Selects the signal which, when active, locks the teleprotection trip.
- ETP Comms Channel Stop. Selects the signal which, when active, indicates the reception of the STOP signal.
- Start value 67NQ. Selects the signal which, when active, indicates the start of the 67Q units for the teleprotection schemes.
- 67NQ Enable Units. Selects the signal which, when active, indicates the activation of the 67Q start signal employed by the permissive units.
- 67NQ Block Units. Selects the signal which, when active, indicates the activation of the 67Q start signal employed by the locking units.
- General trip. Indicates if this unit produces a general trip or not. For additional details, see section corresponding to the recloser (**5.2.3**).
- Trip perm. by recloser. Indicates the trip and lock permission in accordance with the recloser status: standby, locked, safety time after reclosing, after closing. It is configured bit by bit; for additional details, see section corresponding to the recloser (5.2).
- Reclose perm.(R1,R2,R3,R4). Indicates whether each trip type can be reclosed or not, in accordance with the recloser's closing cycle (**5.2.5**).
- Enable Events Record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

Table 78 Teleprotection scheme settings

Data	Setting	Min.	Max.	Step	Remarks	Type
SchTyp	Scheme type				Step trip (0) Permissive overreaching (1) Permissive underreaching (2) Direct. comparison blocking (3) Direct. comparison unblock. (4)	enum
RsRTPTmms	Drop off time (ms)	0	1000	10		Int32
BlkTms	Lock delay time (ms)	0	1000	10		Int32
LoGMinTmms	GSL Minimum time (ms)	0	150	10		Int32
LoGMaxTmms	GSL Maximum time (ms)	0	200	10		Int32
LoGRepTmms	GSL Drop off time (ms)	0	200	10		Int32
EcEna	ECHO enabled				YES/NO	enum
EcTmms	ECHO pulse time (ms)	0	1000 0	10		Int32
EcBlkTmms	ECHO Blocking time (ms)	0	1000	10		Int32
EcActTmms	ECHO delay time (ms)	0	200	10		Int32
RvAEna	Current Reversal Blocking				YES/NO	enum
RvATmms	Current rev pick up t.(ms)	0	1000 0	10		Int32
WeiEna	Weak Infeed Enabled				YES/NO	enum
WeiVal	Weak Infeed Threshold (V)	0,1	200	0,1		float
LogInRTP1	TPRx _67NQ line 1					Int32
LogInRTP2	TPRx _67NQ line 2					Int32
LogInPSG1	GSLRx_67NQ line 1					Int32
LogInPSG2	GSLRx_67NQ line 2					Int32
LogInBl	TP Trip Block					Int32
LogInStop	TPTx Block					Int32
LogInSt	Start value 67NQ					Int32
LogInAIU	67NQ Enable Units					Int32
LogInBIU	67NQ Block Units					Int32
GenTrip	General trip				NO (0) / YES (1)	Boolea n
TripPerm	Trip perm. by recloser	0	255	1	Bit meaning	ING
ReclPerm	Reclose perm.(R1,R2,R3,R4)	0	15		Bit meaning	ING
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolea n

It has independent settings, commands and outputs:

- PROT/OCPTPS1 node
- Setting and logical inputs. There are 6 settings tables. (Table 78)
- There are no associated commands.
- Outputs: Table 79 shows the function's output data.
  - TPRx 67NQ L1. Indicates that the line 1 teleprotection signal has been received.
  - TPRx 67NQ L2. Indicates that the line 2 teleprotection signal has been received.
  - SGR 67NQ L1. Indicates that the line 1 security signal loss signal has been received.
  - SGR 67NQ L2. Indicates that the line 2 security signal loss signal has been received.
  - 85_L1_END_perm_SGL_67NQ. Indicates that the termination of the line 1 security signal loss permission has been activated.
  - 85_L2_END_perm_SGL_67NQ. Indicates that the termination of the line 2 security signal loss permission has been activated.
  - TPTx 67NQ. Indicates that the dispatch of the teleprotection signal has been activated.
  - ECHO 67NQ. Indicates that the dispatch of the ECHO signal has been activated.
  - STOP 67NQ. Indicates that the STOP signal has been dispatched.
  - 27WI 67NQ Phase X. Indicates that the weak infeed conditions have been met during the configured time. There are independent signals for each phase and a general signal for certain phases.

- Weak Infeed Phase. Indicates that the weak infeed conditions have been met in at least one phase.
- Teleprotection Trip 67NQ. Indicates that a teleprotection trip has been produced.
- Permissive Unit Activation. Indicates that the permissive units have been activated.
- Block Inverted Current. Indicates that current inversion lock has been activated.
- Memory Inverted Current. Indicates that current inversion lock memorization has been activated.

Table 79 Teleprotection scheme outputs

Signal	Data	Attribute
TPRx 67NQ L1	TPL1Rx	general
TPRx 67NQ L2	TPL2Rx	general
SGR 67NQ L1	GSL1Rx	general
SGR 67NQ L2	GSL2Rx	general
85_L1_END_perm_SGL_67NQ	GSL1End	general
85_L2_END_perm_SGL_67NQ	GSL2End	general
TPTx 67NQ	TPTx	general
ECHO 67NQ	ECOTx	general
STOP 67NQ	STOPTx	general
27WI 67NQ Phase A	WeakInF	phsA
27WI 67NQ Phase B	WeakInF	phsB
27WI 67NQ Phase C	WeakInF	phsC
Weak Infeed Phase	StrWeakInF	general
Teleprotection Trip 67NQ	OpTP	general
Permissive Unit Activation	OpPerUnit	general
Block Inverted Current	BlkInvDir	general
Memory Inverted Current	MemBlkInvDir	general

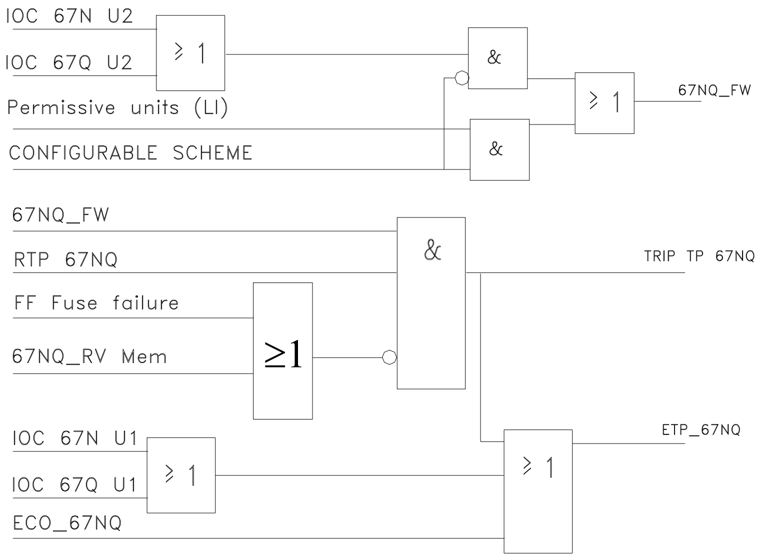
3.13.1.2 Permissive underreach

The teleprotection signal (ETP) is dispatched upon the activation of the overcurrent unit 1.

It produces an instantaneous teleprotection trip upon the reception of the teleprotection signal (RTP), together with the pick up of overcurrent unit 2, providing that the reverse memorization of unit 3 is not activated (67NQ_RV_MEM). The 67NQ_RV_MEM signal can be deleted from the logic by disabling the “Inverse direction lock” function. In this case, 67NQ_RV_MEM would be set permanently to 0.

The “Teleprotection trip lock” input locks the "Teleprotection trip" output signal and the dispatch of the ETP.

Figure 62 Underreach logic diagram



3.13.1.3 Permissive overreach

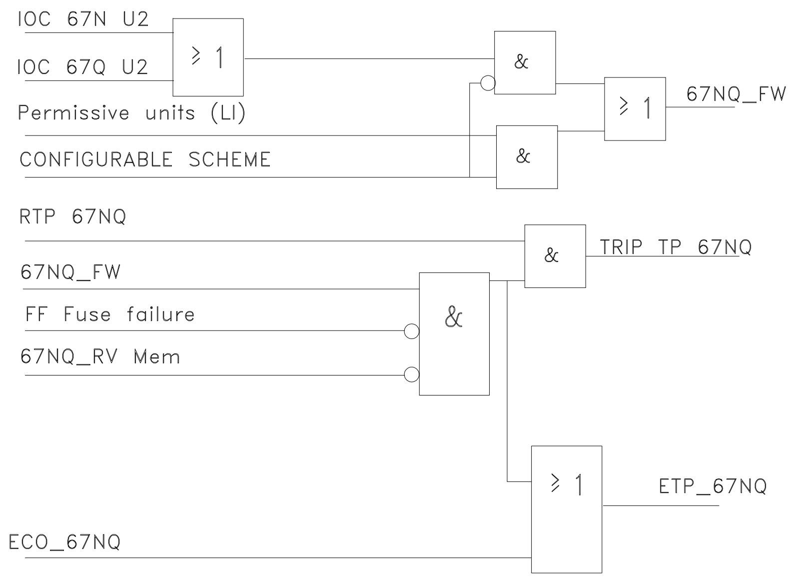
It produces an instantaneous teleprotection trip upon the reception of the teleprotection signal (RTP), together with the pick up of overcurrent unit 2, providing that the memorized reverse zone is not activated (67NQ_RV_MEM). The 67NQ_RV_MEM signal can be deleted from the logic by disabling the "Inverse direction lock" function. In this case, 67NQ_RV_MEM would be set permanently to 0.

The teleprotection signal is dispatched upon the activation of the 2 overcurrent units, without detection of a reverse fault (67NQ_RV_MEM).

If the "Configurable teleprotection scheme" setting is set to YES, a logical "85L permissive units" signal is used.

The "Teleprotection trip lock" input locks the "Teleprotection trip" output signal and the dispatch of the ETP.

Figure 63 Overreach logic diagram



3.13.1.4 Directional unlock

Boosted teleprotection trip with the activation of the overcurrent unit 2 if the unlock signal (RTP) is received or if the channel loss signal (RPSG) is received during the security signal loss time (TPSG). As of the activation of the security channel loss signal, a TmximoPSG window is opened. During this period, a trip may be produced if the RPSG signal remains active during the set time (TPSG) without the reception of RTP.

Following the elapse of the TmáximoPSG time, security channel loss signal will cease to have an effect on the teleprotection trip. It is therefore imperative that TPSG time be programmed with a value inferior to the TmáximoPSG in order that the loss of the security signal activates the trip.

Once the security signal has been recovered, TrepPSG must elapse before restarting the previous logic in the event of the security channel being lost once more.

The ETP output is the same as in the permissive overreach scheme (POTT).

The 67NQ_RV_MEM signal can be deleted from the logic by disabling the “Inverse direction lock” function. In this case, 67NQ_RV_MEM would be set permanently to 0.

The “Teleprotection trip lock” input locks the "Teleprotection trip" output signal and the dispatch of the ETP.

Figure 64 Treatment of line 1 security signals

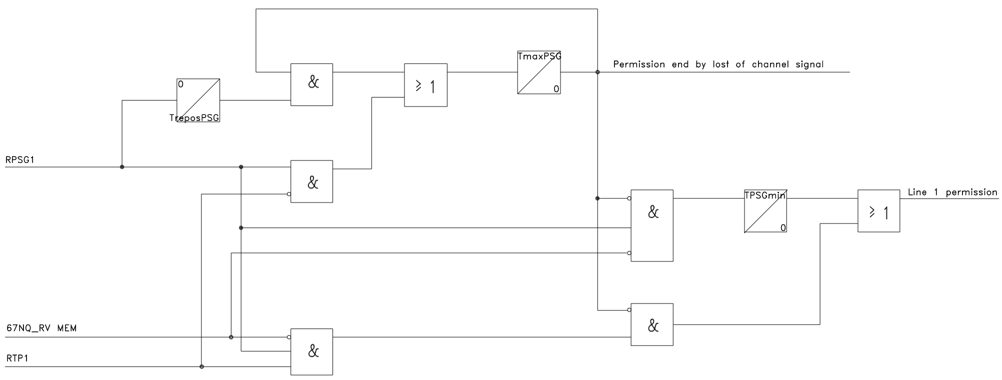


Figure 65 Treatment of line 2 security signals

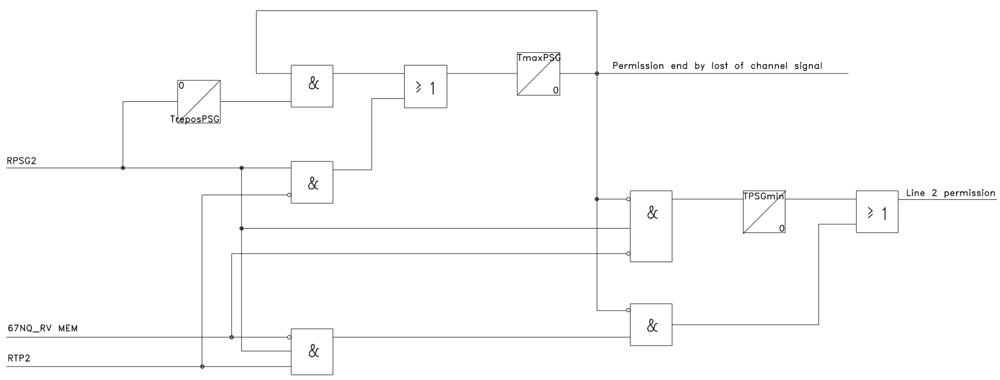
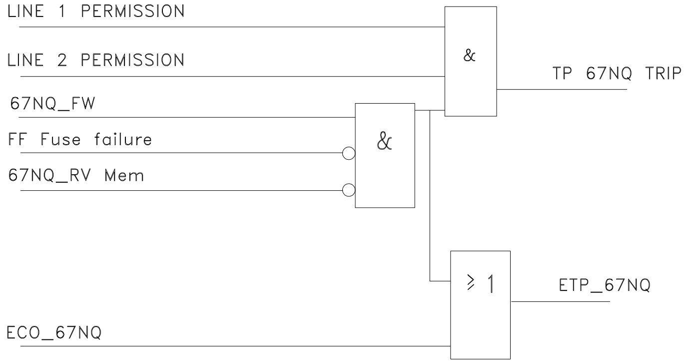


Figure 66 ETP signals and trip



3.13.1.5 Directional lock

An instantaneous teleprotection trip with the activation of the overcurrent unit 2 if the RTP signal is not received following the elapse of the lock time (TBLQ) and no fault is detected in zone 4 (67NQ_RV_MEM).

The ETP locking signal is sent if a reverse fault is detected (67NQ_RV_MEM).

A channel interruption signal (STOP) is activated is a forward fault is detected (overcurrent units 1 and 2) without the detection of a fault in the overcurrent unit 3 (67NQ_RV_MEM).

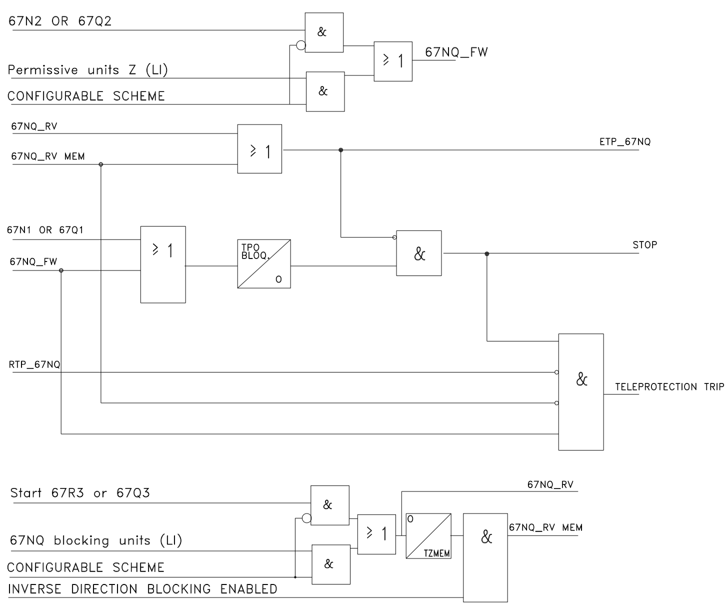
The sending of the ETP stops when the internal STOP signal is activated or when the “ETP communication channel interruption” input is activated.

The “Teleprotection trip lock” input locks the "Teleprotection trip" output signal.

In order to add functions to the overreach or locking units, the “Configurable teleprotection scheme” setting must be set to YES and a logic containing the pick up of the units in question transferred to the “Permissive units” logic signal.

A typical application contemplates the use of phase and neutral overcurrent units to send a faster locking signal, thus enabled a reduction or even the elimination of an additional timeout for the units responsible for producing the trip. In this case, the ETP+Pick up logic is obtained from a relay (50,50 N).

Figure 67 Directional lock scheme



3.13.1.6 ECHO

Employed in conjunction with the permissive schemes (overreach, and direction lock) and acts on the teleprotection signal (ETP).

The boosted teleprotection trip corresponds to the selected scheme.

The ECHO signal only provides a programmable pulse. The ECHO function sends the teleprotection signal (ETP) under any of the following conditions:

- Those corresponding to the selected scheme.
- If RTP is received and no forward or reverse faults are detected:
  - during a minimum programmable time (“minimum RTP time” setting for ECHO), or
  - the breaker is open (in this situation, it does not wait for the programmed time to elapse).

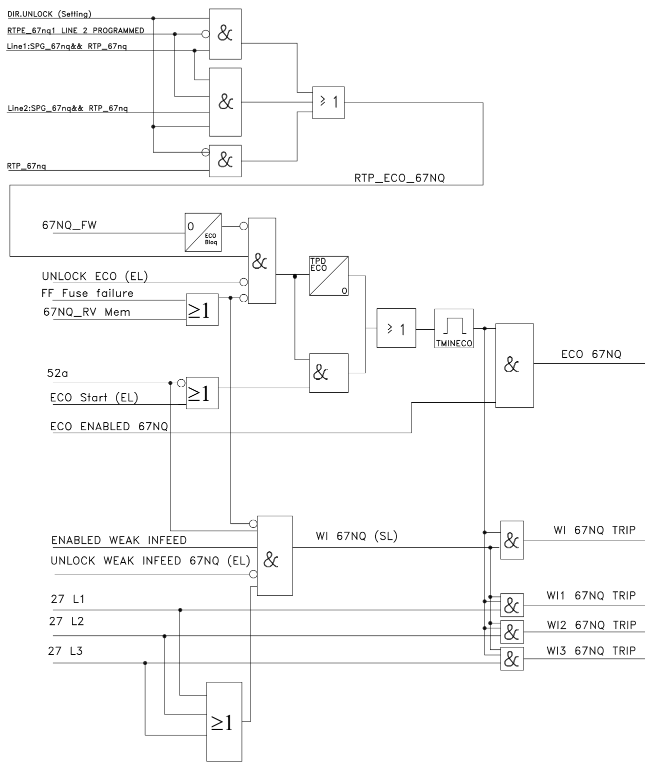
3.13.1.7 Weak infeed 27WI

A complement to the ECHO, in which in the event of the of the ECHO conditions being met, with the breaker closed and undervoltage in at least one of the phases, a trip is produced in the phases in question.

The undervoltage unit associated to the Weak Infeed function has its own settings and is not dependent on the undervoltage units.

The thresholds are 0.1V to 200V.

Figure 68 ECHO and weak infeed



If an unlocking scheme is used, the RTP_Z signal is replaced by .RTP_Z & PSG.

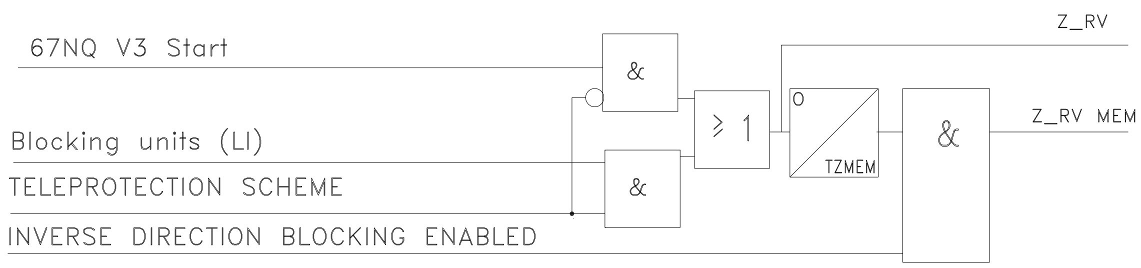
3.13.1.8 Inverse directional lock

Employed in the double circuit lines to avoid the immediate tripping of a protection that has detected a reverse fault (and the carrier signal that sends the opposite protection) when the power flow direction changes (due to the breaking of the parallel line's breaker).

It delay's the teleprotection trip for a number of cycles in order to allow the remote terminal time to clear the permission signal (ETP) following a change in the flow direction due to the breaking of the breaker. The overcurrent unit 2 signal is used with a memorization time (Z_RV_67NQ_RV_MEM), which enables the 67NQ_RV_MEM signal to be employed in the rest of the schemes to be obtained, as shown in Figure 69.

If the "Configurable teleprotection scheme" setting is set to YES, a logical "85L locking units" signal is used.

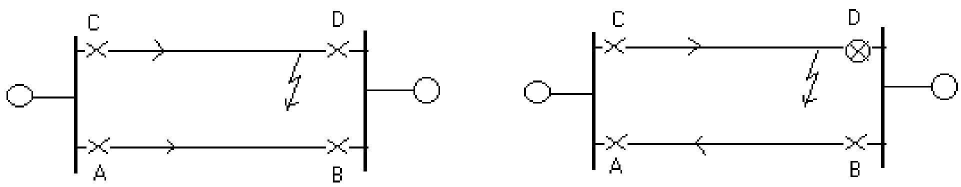
Figure 69 Inverse directional lock



The Figure 70 shows a flow scheme following a fault and the breaking of the breaker. If this scheme is not used, the following effect may be produced:

- Terminal D detects the fault in zone 1, terminal C in zone 1 or 2, depending on the length, terminal B detects it as reverse and terminal A as in zone 2. In this situation, terminal D breaks the breaker and sends the ETP signal to C. In the same way, A sends ETP to B.
- Upon the breaking of the breaker and the changing of the flow direction, A detects the fault as reverse, while B detects it in zone 2 or 3, and as such may trip before A has cleared the RTP signal.

Figure 70 Flow change due to tripping of breaker



3.13.1.9 Transferred trip

This additional teleprotection scheme causes a three-pole trip upon the reception of the teleprotection signal, independently of the status of the protection functions.

This scheme has an enabling setting. In order to operate correctly, it must be enabled. Further, a logical input must be programmed as a direct trip, otherwise is will effectively be disabled

The reception signals associated to the direct trip are:

- Direct trip Pole A, B or C: Indicates an external single-pole trip.
- Direct trip pole ABC: Indicates an external single-pole trip.

These transferred trips cause the start of the reclosing cycle when the teleprotection closure is permitted, i.e., they are considered the same as the rest of the teleprotection trips.

Any digital signal can be used as an output signal for signalling a direct trip to the other extreme, either via the programming of the digital outputs or via the programmable logics.

The settings for the configuration of the direct trip are:

- Enabled: Enables the direct trip function.
- Direct trip - Pole A. Selects the signal which, when active, indicates the reception of the Pole A direct trip.
- Direct trip - Pole B. Selects the signal which, when active, indicates the reception of the Pole B direct trip.
- Direct trip - Pole C. Selects the signal which, when active, indicates the reception of the Pole C direct trip.
- Direct trip - 3 Poles ABC. Selects the signal which, when active, indicates the reception of the pole ABC direct trip.
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

Table 80 Direct trip settings

Data	Setting	Min.	Max.	Step	Remarks	Type
DTEna	Enabled				YES/NO	enum
LogInDTA	Direct trip - Pole A					Int32
LogInDTB	Direct trip - Pole B					Int32
LogInDTC	Direct trip - Pole C					Int32
LogInDT	Direct trip - 3 Poles ABC					Int32
MaskEna	Enable Events Record				NO (0) / YES (1)	Boolean

It has independent settings, commands and outputs:

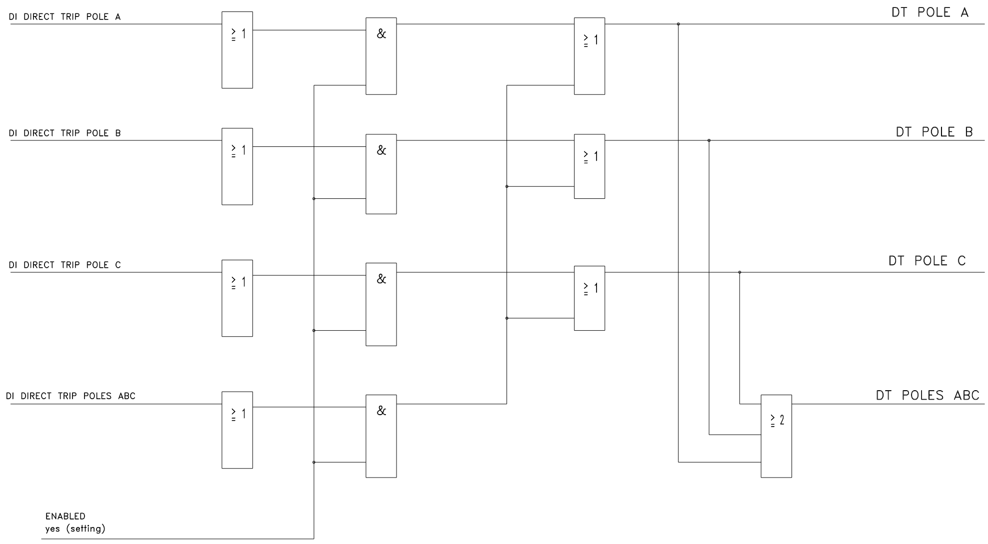
- PROT/PTDS1 node
- Settings and logical inputs. There are 6 settings tables. For details see Table 80.
- There are no associated commands.
- Outputs: Table 81 shows the function’s output data.
  - Reception of pole A direct trip. Indicates that reception of the pole A direct trip.
  - Reception of pole B direct trip. Indicates that reception of the pole B direct trip.
  - Reception of pole C direct trip. Indicates that reception of the pole C direct trip.
  - Reception of the pole ABC direct trip. Indicates that the reception of the pole ABC direct trip signal.

Table 81 Teleprotection scheme outputs

Signal	Data	Attribute
Reception of the pole A direct trip	DTTRx	phsA
Reception of the pole B direct trip	DTTRx	phsB
Reception of the pole C direct trip	DTTRx	phsC
Reception of the pole ABC direct trip	DTTRx	general

Figure 71 Direct trip scheme

o



3.13.2 Trip logics

Each protection unit has a mask that allows it to produce a general trip:

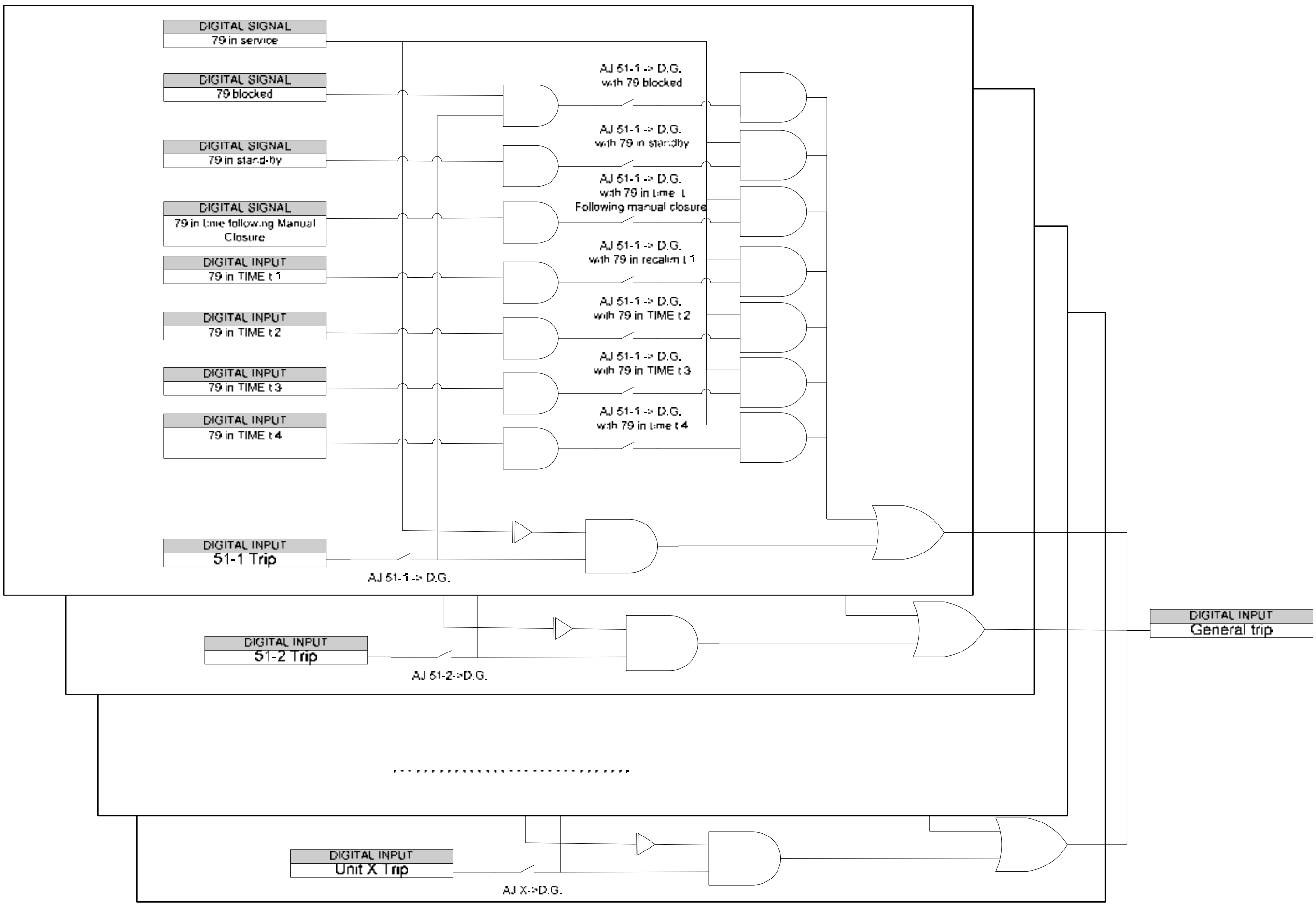
- If a unit trips during a specific recloser status (blocked, in security t, etc.) and the corresponding mask is set to YES, the trip is sent to the general trip output.
- If the mask is set to NO, the trip is produced but the "direct trip" signal is not received. In this way, the recloser is independent of any trips used for signalling.
- If the recloser is out of service, all the units programmed to produce a general trip will issue a trip.

In the event of a specific trip failing to activate the “general trip”, the fault report is not generated.

If a trip is produced at the same time as another trip which activates the general trip, all the trips are reflected in the fault report: those which go to GT and those which do not.

The picks ups are effected in the same way as with each unit's trips. Each of the relay’s pick ups generates a signal. This signal passes through the trip mask filter and is included in an OR in order to generate a "General pick up" signal.

Figure 72 General trip scheme



3.14 CT MONITORING

If the event of neutral current in the 4th transformer, a fault may be detected in at least one of the relay input channels (adaptation transformer + internal circuitry). The absolute value of three times the zero sequence current (calculated using the phase currents) is compared with the current measured at the transformer, taking the phase (RTF) and neutral (RTN) transformation ratios into account. None of the phases must exceed 1.5 times the rated current.

The unit activates a “CT monitoring alarm” signal" when the following conditions are met.

- The measurements are outside the range: $$0,8 < \frac{|I_a + I_b + I_c| \cdot RTF}{|I_N| \cdot RTN} < 1,3$$
- The measurement ratios meet: $$\frac{\left||I_a + I_b + I_c| \cdot RTF - |I_N| \cdot RTN\right|}{RTF} > 0,2$$
- lIa+Ib+Ic-INl/3>>10%·max(lIal, lIbl, lIcl)+5%·Irated
- The measurement of 3 current phases is less than 1.5 times the rated current.

The settings for the configuration of the current transformer monitoring are shown in Table 82.

- Enabled: Enables the CT monitoring function.
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

Table 82 CT monitoring settings

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
CTSpvEna	Enabled				NO (0) / YES (1)	enum
MaskEna	Enable Events record				NO (0) / YES (1)	Boolean

It has independent settings, commands and outputs:

- PROT/CCTS1 node
- Settings. There are 6 settings tables.
- There are no logical inputs or commands
- Outputs: Table 83 shows the function’s output data.
  - Enabled. It is active when enabled and not blocked.
  - CT monitoring. Indicates that the CT monitoring conditions have been met.

Table 83 CT monitoring outputs

Signal	Data	Attribute
Enabled	StEna	stVal
CT monitoring	CTSpv	general

4. BREAKER

4.1 BREAKER LOGICS

4.1.1 Breaker status

The breaker unit uses the PROT/XCBR logical node. The settings used for each breaker are:

- Enabled: Enables the breaker status function.
- Breaker type. Indicates the type of breaker employed:
  - 1 pole/4 status (1). Only one input is used for the status of the three poles.
  - 3 pole/4 status (2). An independent input is used for the status of each of the three poles.
- Pole status failure time (ms). Indicates the (ms) during which the difference between the type a and type b inputs must be detected in the 52 status in order for the failure to be registered. Although the setting is unique, it affects the three poles.
- Logical 52a Status general input. If the breaker type is "1-pole / 4 statuses", it indicates the breaker status.
- Logical 52a Status phase A input. If the breaker type is "3-pole / 4 statuses", it indicates the phase A breaker status.
- Logical 52a Status phase B input. The same as phase A, but for B.
- Logical 52a Status phase C input. The same as phase A, but for C.
- Logical 52b Status general input. If the breaker type is "1-pole / 4 statuses", it indicates the breaker status.
- Logical 52b Status phase A input. If the breaker type is "3-pole / 4 statuses", it indicates the phase A breaker status.
- Logical 52b Status phase B input. The same as phase A, but for B.
- Logical 52b Status phase C input. The same as phase A, but for C.
- Breaker open command input. When active, it blocks the manual breaker breaking commands. The trip breaks are not blocked.
- Close command input. When active, it blocks the breaker closure breaking commands.
- Trip sealed. Allows the breaking commands to be enabled. When it is enabled, the break command is maintained after the cause of the break has disappeared and until the breaker is detected as open.
- Close sealed. Allows the closure commands to be enabled. When it is enabled, the closure command is maintained after the cause of the closure has disappeared and until the breaker is detected as closed.
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

Table 84 Breaker status settings

Data	Setting	Min.	Max.	Step	Remarks	Type
BrNum	Enabled				NO/YES	enum
BrTyp	Breaker type				1 pole/4 status 3 pole/4 status	enum
FaBrTmms	Pole status failure time (ms)	0	10000	10		Int32
LogIn52a1	52a input					Int32
LogIn52a1A	52a-Pole A					Int32
LogIn52a1B	52a-Pole B					Int32
LogIn52a1C	52a-Pole C					Int32
LogIn52b1	52b input					Int32
LogIn52b1A	52b-Pole A					Int32
LogIn52b1B	52b-Pole B					Int32
LogIn52b1C	52b-Pole C					Int32
LogInOpBl	52 break block					Int32
LogInClBl	52 closure block					Int32
LogIn52Op	Breaker open command input					Int32
LogIn52Cl	Close command input command					Int32
TrLck	Trip sealed				NO/YES	Boolean
ClLck	Close sealed				NO/YES	Boolean
MaskEna	Enable Events Record				NO/YES	Boolean

Breaker status via digital input

The status of the general breaker and by pole is determined with the status of digital inputs and breaker type setting. Used to determine the status of the breaker without uncertainty and employed in functions that require the breaker's status to be known, such as the breaking and closure sealing logic, the recloser, etc.

The 52b status inputs take precedence over the 52a status inputs, i.e., if 52b status inputs have been configured, the breaker status is determined by means of these inputs, independently of the status of the 52a inputs.

Depending on the breaker type setting, the functioning is:

- 1 pole/4 statuses. The general 52b Status input is used for the breaker status. If it is not configured, the general 52b Status input is used. The phase breaker status matches the general.
- 3 pole/4 statuses. The independent phases' 52b Status inputs are used for the breaker status. If they are not configured, the general 52b Status inputs are used. The general breaker status is generated from the phases, taking into account the following:
  - Closed general status, if all the phases are closed.
  - Open general status, if at least one of the phases is open.

Table 85 shows this function's outputs.

- General 52 Status (Digital input). Indicates the breaker's general status, in accordance with the status of the digital inputs.
- Phase X 52 Status (Digital input). Indicates the status of each of the breaker's phases, in accordance with the status of the digital inputs.

Breaking monitoring status

The status of each pole (open, closed) is determined in accordance with a combination of N/O and N/C inputs. If inconsistencies are detected between the N/O and the N/C input after the failure time (pole status failure time), a failure is signalled and no other action is taken (relative to the discrepancy) until the anomaly is corrected. The functioning of this unit is shown in Figure 73.

It has independent settings, commands and outputs:

- PROT/XCBR1 node
- Settings and logical inputs. There are 6 settings tables. For details see Table 84.
- There are no associated commands.
- Outputs: Table 85 shows the function's output data.
  - 52_1 Open. Indicates that the 52 is open. There are independent general and phase signals.

- 52_1 closed. Indicates that the 52 is closed. There are independent general and phase signals.
- 52_1 Undetermined. Indicates that the 52 is undetermined. There are independent general and phase signals.
- 52_1 failure. Indicates that the 52 has a failure. There are independent general and phase signals.

Figure 73 Breaker status.

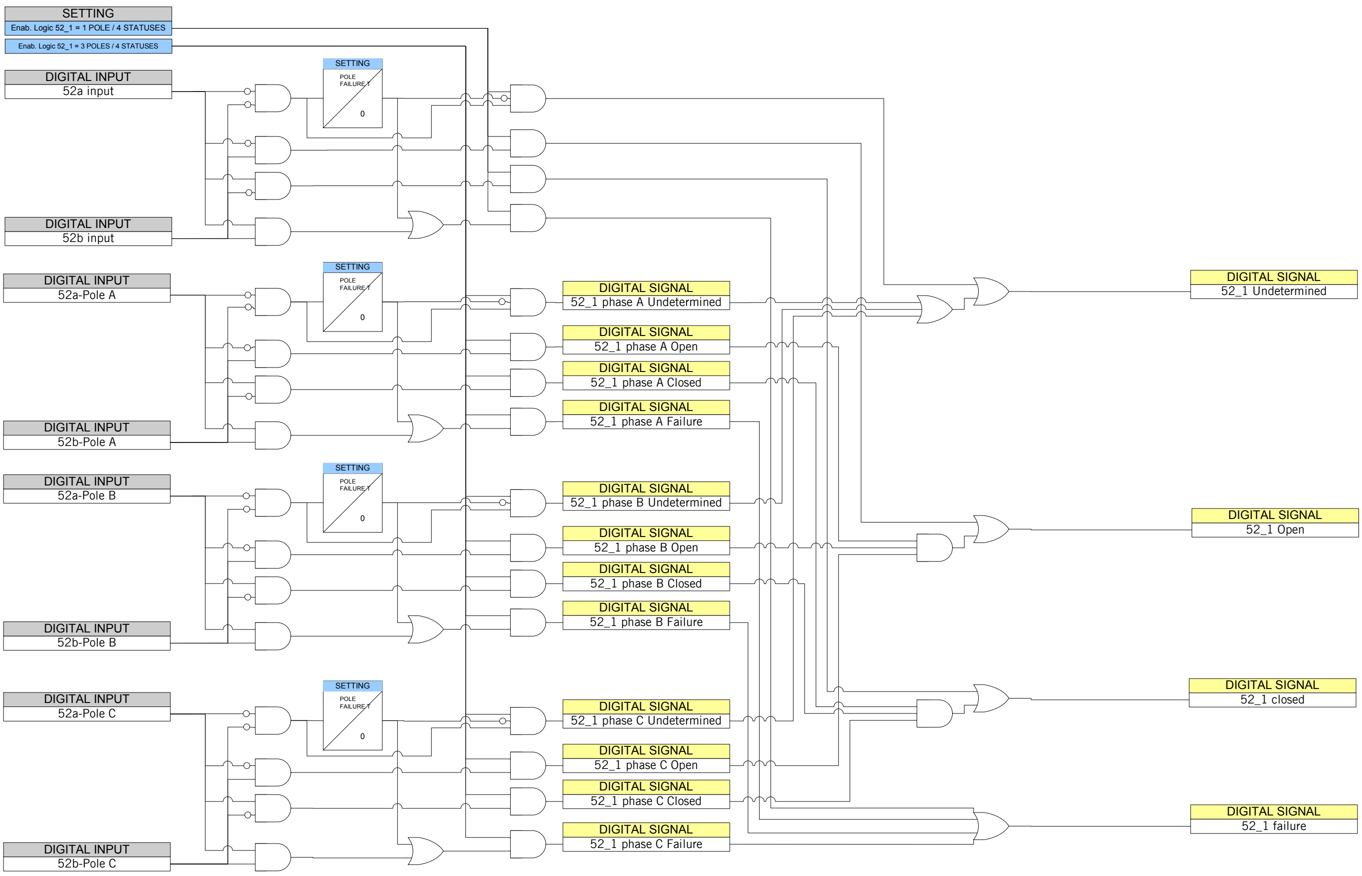


Table 85 Breaker status outputs

Signal	Data	Attribute
52_1 Open	OpenBr	general
52_1 closed	CloseBr	general
52_1 Undetermined	UndetBr	general
52_1 failure	FailureBr	general
52_1 phase A Open	OpenBr	phsA
52_1 phase A Closed	CloseBr	phsA
52_1 phase A Undetermined	UndetBr	phsA
52_1 phase A Failure	FailureBr	phsA
52_1 phase B Open	OpenBr	phsB
52_1 phase B Closed	CloseBr	phsB
52_1 phase B Undetermined	UndetBr	phsB
52_1 phase B Failure	FailureBr	phsB
52_1 phase C Open	OpenBr	phsC
52_1 phase C Closed	CloseBr	phsC
52_1 phase C Undetermined	UndetBr	phsC
52_1 phase C Failure	FailureBr	phsC

4.1.2 Breaker failure and operating logic

The opening and closure failure time settings determine the time lapse between the issue of the corresponding command and the reception of the breaker's activity signal, on the understanding that the breaker has acted correctly. To the contrary, the break failure and closure failure signals are generated and failure and general indications are issued.

This unit's settings are grouped in the PROT/RBFS logical node:

- Enabled: Enables the breaker monitoring.
- Definite breaking time (ms) Indicates the maximum time (ms) during which the breaker can be detected as broken following the break command.
- Definite closure time (ms). Indicates the maximum time (ms) during which the breaker can be closed as broken following the closure command.
- Enable Events record. Allows the generation of protection events associated to the function. If set to "NO", the function's protection events are not generated. If set to "YES", the function's specific mask is contemplated.

Table 86 Breaker status monitoring settings

Data	Setting	Min.	Max.	Step	Remarks	Type
BRFEna	Enabled				NO/YES	enum
OpTmms	Open failure time (ms)	20	100000	1		Int32
ClTmms	Close failure time (ms)	20	100000	1		Int32
MaskEna	Enable Events Record				YES/NO	Boolean

Table 87 shows the operating logic's output Data, which are available in the PROT/XCBR node.

- 52_1 Closed (Simple Log.). Indicates the breaker's general status, in accordance with the status of the digital inputs.
- 52_1 X Closed (Simple Log.). Indicates the status of each of the breaker's phases, in accordance with the status of the digital inputs. "X" can be A, B, C.
- Close Command - Breaker 1. Indicates that a closure command has been generated.
- Open Command - Breaker 1. Indicates that a break command has been generated.
- Ph. X Open Command - Br.1. Indicates that a break command for the breaker's pole X has been generated. "X" can be A, B, C.
- Close Failure - Br.1. Indicates that a failure has occurred in one of the breaker's poles due to the maximum closure time having been exceeded.
- Ph. X Close Failure- Br.1. Indicates that a closure failure has occurred in the breaker's pole X due to the maximum closure time having been exceeded. "X" can be A, B, C.
- Open Failure - Br.1. Indicates that an opening failure has occurred in one of the breaker's poles due to the maximum closure time having been exceeded.
- Ph. X Open Failure- Br.1. Indicates that an opening failure has occurred in the breaker's pole X due to the maximum closure time having been exceeded. "X" can be A, B, C.

Table 87 Breaker monitoring outputs

Signal	Data	Attribute
52_1 Closed (Simple Log.)	BrDISt	general
52_1 A Closed (Simple Log.)	BrDISt	phsA
52_1 B Closed (Simple Log.)	BrDISt	phsB
52_1 C Closed (Simple Log.)	BrDISt	phsC
Close Command - Breaker 1	CloseOrdBr	general
Open Command - Breaker 1	OpenOrdBr	general
Ph. A Open Command - Br.1	OpenOrdBr	phsA
Ph. B Open Command - Br.1	OpenOrdBr	phsB
Ph. C Open Command - Br.1	OpenOrdBr	phsC
Close Failure - Br.1	ClsFailBr	general
Ph. A Close Failure- Br.1	ClsFailBr	phsA
Ph. B Close Failure- Br.1	ClsFailBr	phsB
Ph. C Close Failure- Br.1	ClsFailBr	phsC
Open Failure - Br.1	OpenFailBr	general
Ph. A Open Failure- Br.1	OpenFailBr	phsA
Ph. B Open Failure- Br.1	OpenFailBr	phsB
Ph. C Open Failure- Br.1	OpenFailBr	phsC

4.1.3 Locking logic

The trip and close commands can be locked with the breaker status, depending on the configuration of the trip sealing and closure sealing settings. Figure 74 and Figure 75 show the sealed trip and closure schemes.

Figure 74 Trip logic scheme

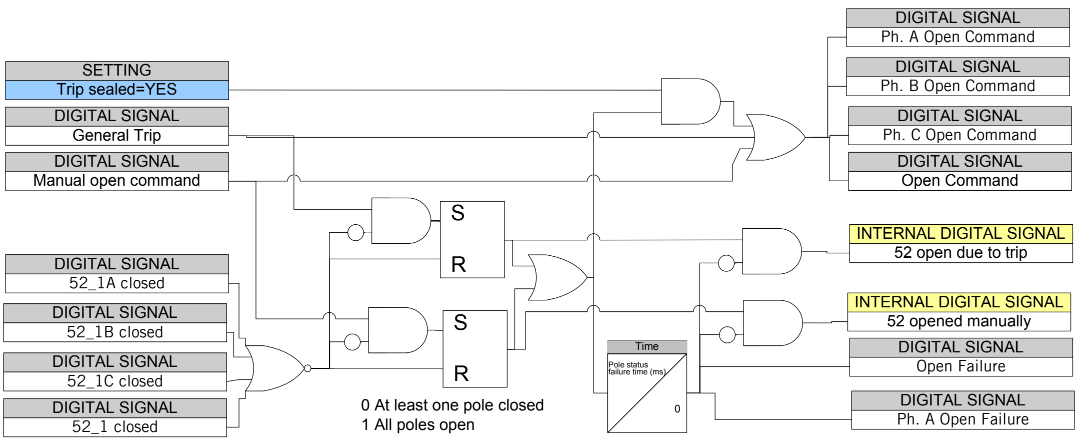
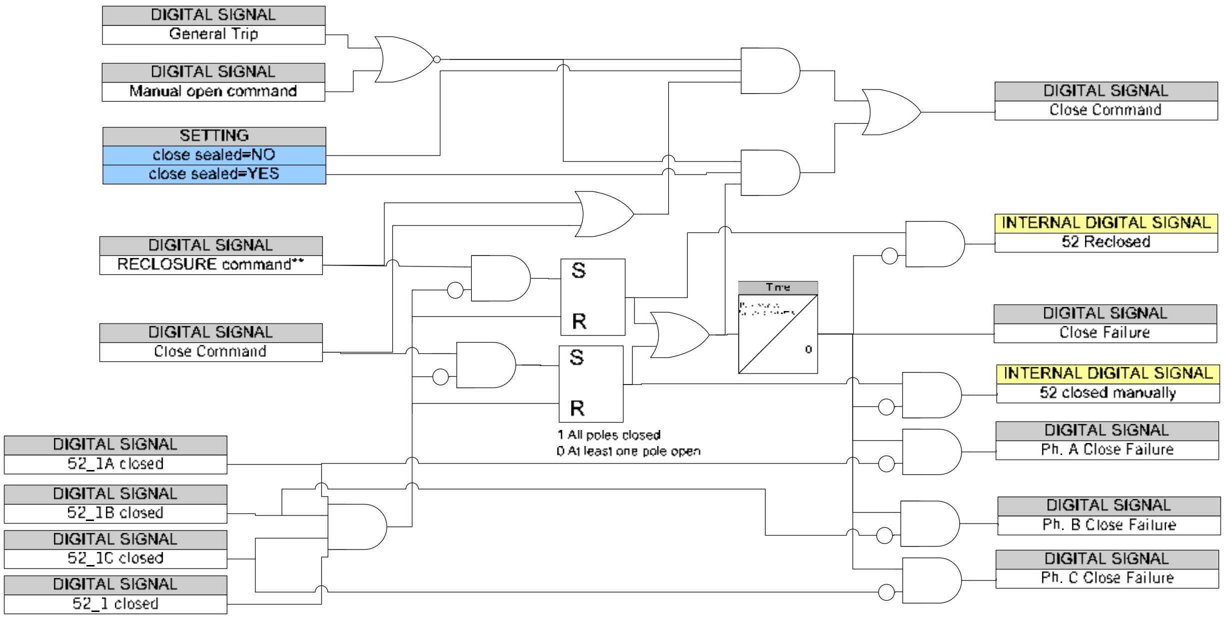


Figure 75 Closure logic scheme



4.1.4 Open pole detector

It determines the open pole or poles using the digital inputs and each current's current and/or voltage measurement.

In order for a pole to be considered open, a combination of the following conditions must be (depending on the operation type setting):

A phase's breakers indicate that the phase is open (in the case of 1 ½ breaker, two are employed)

- The current is below the threshold set in the open pole due to current detection logic.
- The current and the voltage are below the threshold (according to the setting). In this case, if there is a fuse failure the open pole due to voltage signal is not activated.

To determine the breaker's status by digital input, the 52b (normally closed) of each phase is employed, when configured. If the 52b is not configured, the 52a is used (normally open).

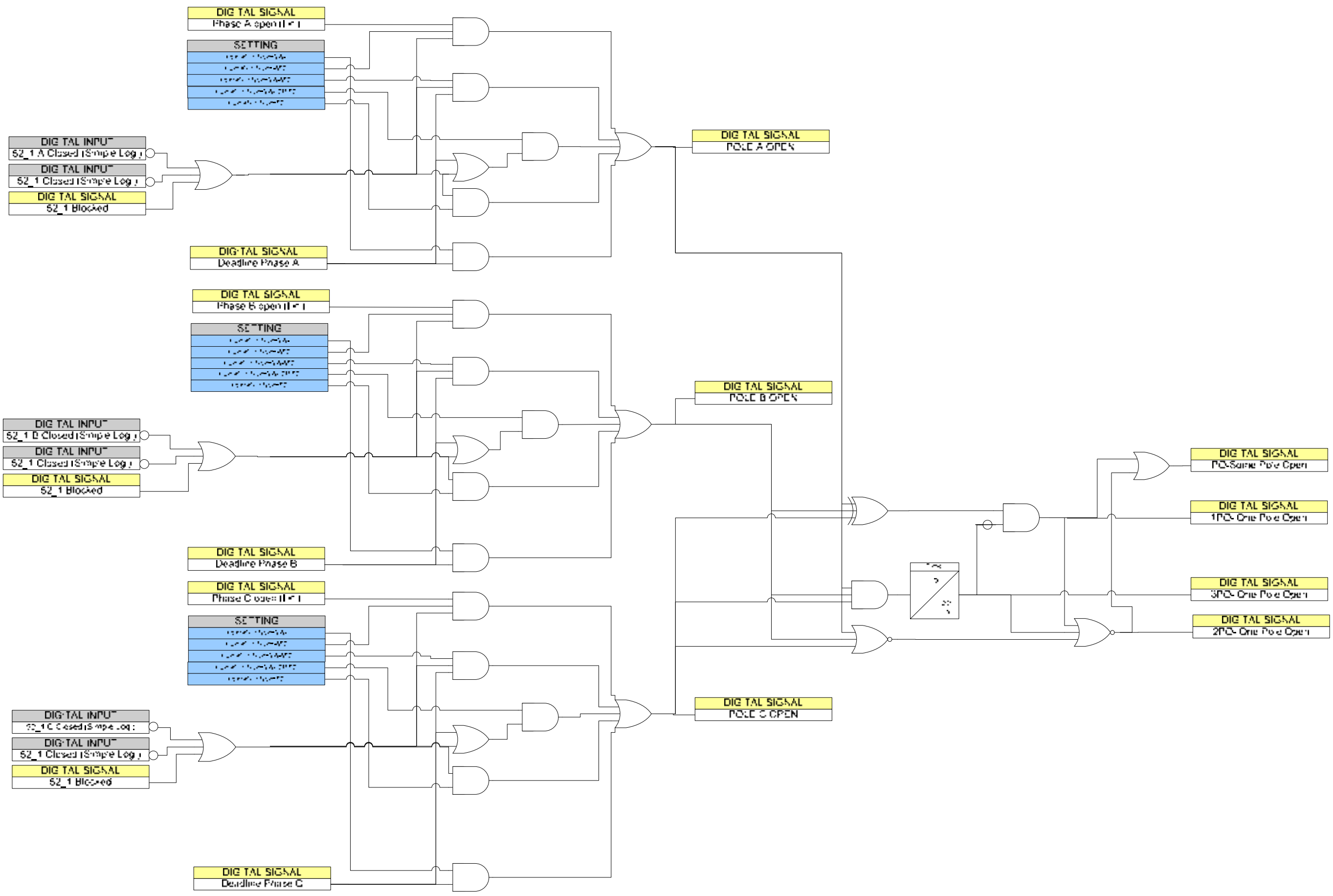
If a single pole break is detected, the following functions can be blocked, if they are selected by settings:

- Neutral overcurrent, sensitive neutral and unbalance
- Overvoltage V0 and V2

There is a delay of one cycle before the reset of the 3PO output (three open poles). Therefore, there is also a one-cycle delay in the change from 3PO to 1PO (1 open pole).

There is a delay of one cycle before the reset of the 1PO output (when the breaker closes.

Figure 76 Open pole detector scheme



The settings for the configuration of the open pole detector are shown in Table 88 Open pole detector settings

Enabled: Enables the open pole detector function.

- Operation type. Indicates the manner in which the open pole is detected:
- V&I. The voltage and current conditions must be met.
- I&52. The current and 52 status input conditions must be met.
- V&I&52. The voltage and current and 52 status input conditions must be met.
- V&I or 52. The voltage and current or the 52 status input conditions must be met.

- Voltage threshold. Indicates the voltage value below which the phase is considered as broken.
- Current threshold. Indicates the current value below which the phase is considered as open.
- Unbalance units block. Indicates whether the unbalance, neutral and sensitive neutral units are to be blocked upon the detection of an open pole.
- Blocking Input. Selects the signal which, when active, blocks the open pole detector function.
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

Table 88 Open pole detector settings

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
OPDEna	Enabled				NO (0) YES (1)	enum
Optype	Operation type				V&I (1) I&52 (2) V&I&52 (3) V&I or 52 (4)	enum
OpValV	Voltage threshold (V)	10,0	165,0	0,1		floating
OpValI	Current threshold (I)	0,01	0,5	0,01		floating
UnbUnBl	Unit unbalance lock				YES/NO	Boolean
LogInBlk	Open pole block					Int32
MaskEna	Enable Events record				NO (0) / YES (1)	Boolean

It has independent settings, commands and outputs:

- PROT/POPD1 node
- Settings and logical inputs. There are 6 settings tables. See Table 88.
- Commands:
  - "DOrdBlk": Function block and unblocking. Only acts if the unit is enabled.
- Outputs: Table 89 shows the function's output data.
  - Open Pole Status. It is active when enabled and not blocked.
  - Pole A Open. Indicates that the open pole conditions have been met in phase A.
  - Pole B Open. Indicates that the open pole conditions have been met in phase B.
  - Pole C Open. Indicates that the open pole conditions have been met in phase C.
  - 1PO- One Pole Open. Indicates that there is only one pole open (A, B or C).
  - 2PO- Two Pole Open. Indicates that there are two poles open.
  - 3PO- Three Pole Open. Indicates that there are three poles open.
  - PO-Some Pole Open. Indicates that at least one pole is open, but not all three.
  - Phase A open. Indicates that the phase A current is below the threshold.
  - Phase B open. Indicates that the phase B current is below the threshold.
  - Phase C open. Indicates that the phase C current is below the threshold.
  - Deadline Phase A. Indicates that pole A is de-energized.
  - Deadline Phase B. Indicates that pole B is de-energized.
  - Deadline Phase C. Indicates that pole C is de-energized.
  - Deadline Phase ABC. Indicates that the three poles are de-energized.

Table 89 Open pole detector outputs

Signal	Data	Attribute
Open Pole Status	StEna	stVal
Pole A Open	OpenPole	phsA
Pole B Open	OpenPole	phsB
Pole C Open	OpenPole	phsC
1PO- One Pole Open	OneOpenPole	general
2PO- Two Pole Open	TwoOpenPole	general
3PO- Three Pole Open	ThreeOpenPole	general
PO-Some Pole Open	OpenPole	general
Phase A Open (I <)	OpenPhs	phsA
Phase B Open (I <)	OpenPhs	phsB
Phase C Open (I <)	OpenPhs	phsC
Deadline Phase A	DeadLine	phsA
Deadline Phase B	DeadLine	phsB
Deadline Phase C	DeadLine	phsC
Deadline Phase ABC	DeadLine	general

4.1.4.1 Open pole due to current

This is used to detect the breaker status with the current measurement. Using the half- and full-cycle DFT measurements (the lower of the two), it is determined whether the current is below a minimum noise threshold in at least one of the phases (see Figure 77)

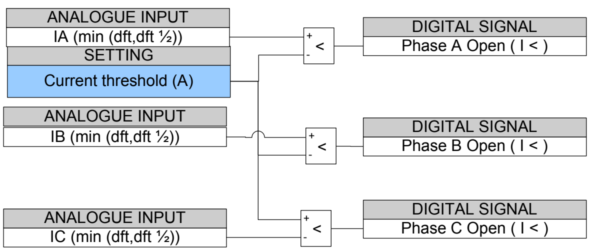
If the open pile detection is activated in at least one of the phases, the phases overcurrent instantaneous units are reset.

The current threshold is indicated in the open pole detector (PROT/POPD).

The output signals are in the PROT/POPD node (see Table 89):

- Phase A open. Indicates that the phase A current is below the threshold.
- Phase B open. Indicates that the phase B current is below the threshold.
- Phase C open. Indicates that the phase C current is below the threshold.

Figure 77 Open pole due to current scheme



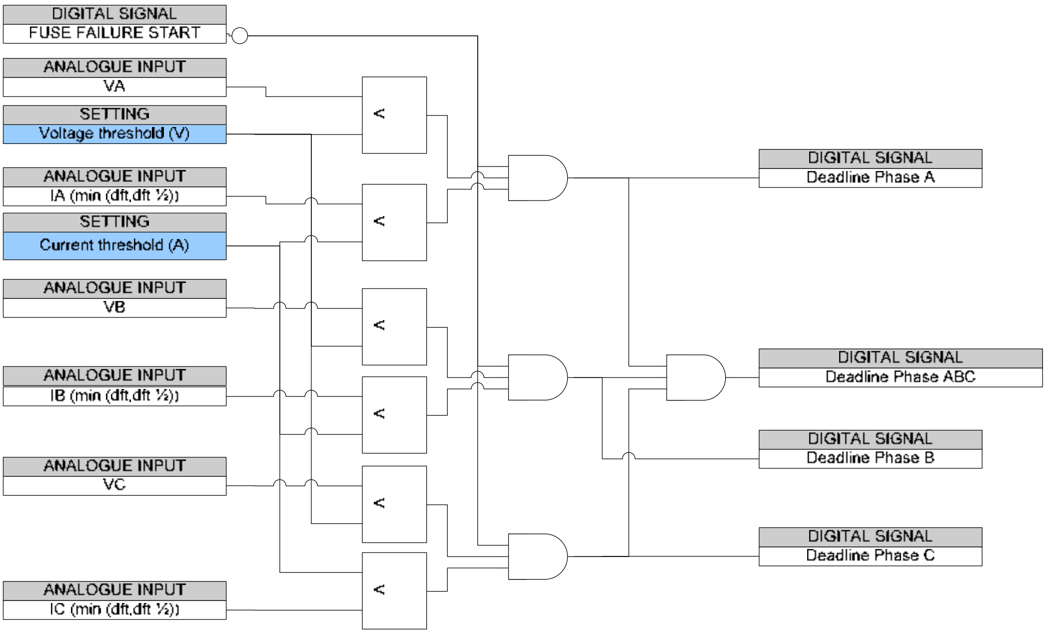
4.1.4.2 Dead or de-energized line

It detects a line's disconnected phases. If a phase's voltage and current levels simultaneously drop below the voltage and current thresholds, this phase is considered dead. In such cases, the following signal is generated for each phase: "Dead line phase x", in which x is A, B or C. Figure 78 shows a diagram of the dead line. The voltage and current thresholds are as indicated in the open pole detector (PROT/POPD).

The output signals are in the PROT/POPD node (see Table 89):

- Line A dead. Indicates that pole A is de-energized.
- Line B dead. Indicates that pole B is de-energized.
- Line C dead. Indicates that pole C is de-energized.
- Lines ABC dead. Indicates that the three poles are de-energized.

Figure 78 Dead line scheme



4.1.5 Pole discordance

If any of the poles are detected as having a status different to that of the other poles during a configurable period of time, the pole discordance signal is generated. A differentiation is made between single open pole discordance and two open pole discordance. A trip can be generated or the action can be limited to signalling. It allows a selection to be made from between two modes of operation (see Figure 79 and Figure 80).

Figure 79 Mode 1 pole discordance

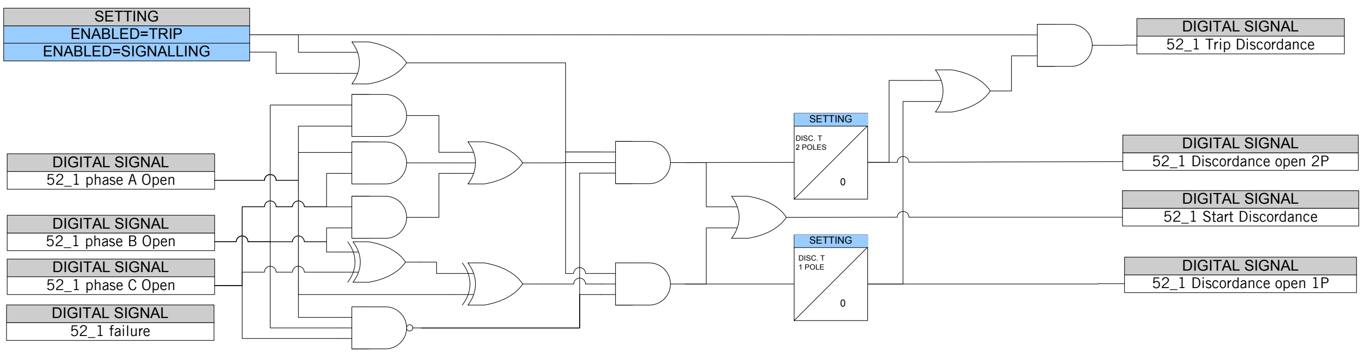
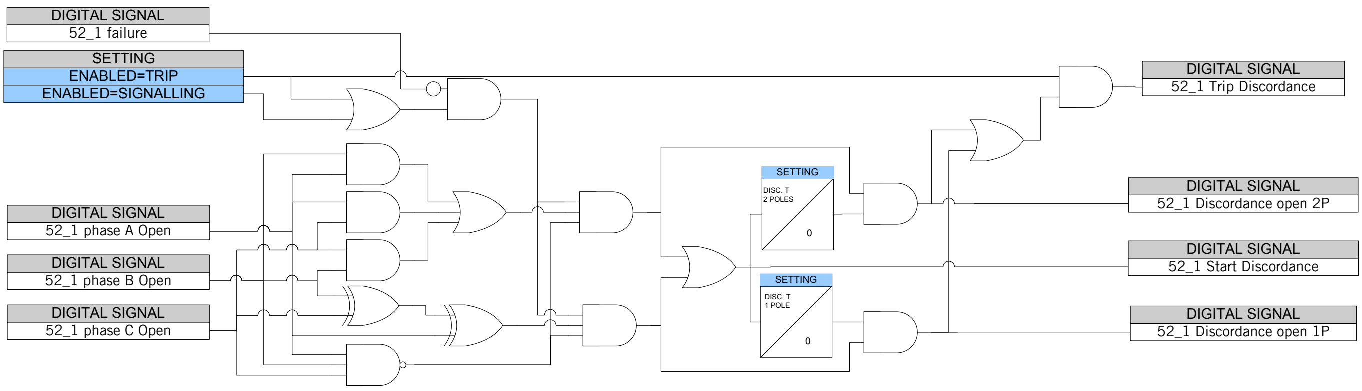


Figure 80 Mode 2 pole discordance



The settings for the configuration of this unit are shown in Table 90.

- Enabled: Enables the open pole detector function.
- Operation type. Indicates the unit’s operation type.
  - Mode 1 signalling
  - Mode 1 signalling and trip
  - Mode 2 signalling
  - Mode 2 signalling and trip
- Time 1 open pole (ms). Time for the discordance activation with 1 open pole.
- Time 2 open pole (ms). Time for the discordance activation with 2 open poles.
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

Table 90 Pole discordance settings

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
PDEna	Enabled				NO (0) / YES (1)	enum
Optype	Operation type				Mode 1 signalling Mode 1 signal and trip Mode 2 signalling Mode 2 signal and trip	enum
PTmms1	1 poles open delay time (ms)	100	60000	10		Int32
PTmms2	2 poles open delay time (ms)	100	60000	10		Int32
MaskEna	Unit unbalance lock				YES/NO	Boolean

It has independent settings, commands and outputs:

- PROT/RPLD1 node
- Settings and logical inputs. There are 6 settings tables.
- Commands:
  - “DOrdBlk”: Function block and unblocking. Only acts if the unit is enabled.
- Outputs: Figure 95 shows the function’s output data.
  - Pole Discordance Status. It is active when enabled and not blocked.
  - 52_1 Start Discordance. Indicates that the function has started.
  - 52_1 Trip Discordance. Indicates that the function has tripped.
  - 52_1 Discordance open 1P. Indicates that there is discordance with only one open pole.
  - 52_1 Discordance open 2P. Indicates that there is discordance with two open poles.

Table 91 Pole discordance outputs

Signal	Data	Attribute
Pole Discordance Status	StEna	stVal
52_1 Start Discordance	StrPDBr1	general
52_1 Trip Discordance	OpPDBr1	general
52_1 Discordance open 1P	OneOpenBr1	general
52_1 Discordance open 2P	TwoOpenBr1	general

4.2 OPERATING MONITORING

Monitors the breaker's operations after the trip and closure commands. In addition to signals, the counters generated by these functions are shown in the statistical data.

The settings for the configuration of this unit are shown in Table 92:

- ki2 type: Indicates the type of calculation in question, between kI2*t, kI2 and kI.
- ki2 time (ms). Indicates the timeout following the trip for the measurement of the ki1 calculation current.
- ki2 sum alarm value. Indicates the ki2 summation threshold which, when exceeded, generates a "ki2 exceeded" signal.
- Ki2 sum initial value. Indicates the initial value of the ki2 summation when a reset command is received.
- Exc.nº trips T. Wind (min). Time window in minutes for the excessive number of trips counter.
- Excessive number of trips. Maximum number of trips permitted in the set time window.
- Max. mechanical opening time (ms). Indicates the maximum time as of the opening command until the detection of the open pole by the digital input status.
- Max. mechanical closure time (ms). Indicates the maximum time as of the closure command until the detection of the closed pole by the digital input status.
- Max. electrical opening time (ms). Indicates the maximum time as of the opening command until the detection of the absence of current in the phase.
- Max. electrical closure time (ms). Indicates the maximum time as of the closure command until the detection of the presence of current in the phase.
- Max. inactivity time (days). Indicates the maximum number of days without breaker activity.
- Max. opening dispersion time. (ms). Indicates the maximum dispersion time between two poles upon opening.
- Max. dispersion closure t. (ms). Indicates the maximum dispersion time between two poles upon closing.
- Enable Events record. Allows the generation of protection events associated to the function. If set to "NO", the function's protection events are not generated. If set to "YES", the function's specific mask is contemplated.

Table 92 Operation monitoring settings

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
KIType	ki2 type	0	2	1	Ki2 (0) / KI (1) / KI2t (2)	enum
KITmms	ki2 time (ms)	0	100	10		Int32
KIAlarm	ki2 sum alarm value	0	100000	1		Int32
KIInit	Ki2 sum initial setting	0	100000	1		Int32
ExTrTmm	Exc.nº trips T. Wind. (min)	1	60	1		Int32
ExTrNum	Excessive number of trips	0	500	1		Int32
OpMeTmms	Max. mechanical opening time (ms)	0	5000	1		Int32
ClMeTmms	Max. mechanical closure time (ms)	0	5000	1		Int32
OpElTmms	Max. electrical opening time (ms)	0	5000	1		Int32
ClElTmms	Max. electrical closure time (ms)	0	5000	1		Int32
NoOpDays	Max. inactivity time (days)	0	10000	1		Int32
OpDisTmms	Max. opening dispersion time. (ms)	0	1000	1		Int32
ClDisTmms	Max. dispersion closure t. (ms)	0	1000	1		Int32
MaskEna	Protection event recording enabled	0	1	1	NO (0) / YES (1)	Boolean

There are independent settings and outputs:

- PROT/CBOU1 node
- Settings. There are 6 settings tables. See Table 92.
- Outputs: Table 93 shows the function's output data. The meaning of each signal is detailed in the function explanation.

Table 93 Breaker monitoring signals

Signal	Dato	Atributo
Phase A Ki2 exceeded	KI2	phsA
Phase B Ki2 exceeded	KI2	phsB
Phase C Ki2 exceeded	KI2	phsC
Ki2 exceeded	KI2	general
Ph.A mechanical time exceeded	MechTmExc	phsA
Ph.B mechanical time exceeded	MechTmExc	phsB
Ph.C mechanical time exceeded	MechTmExc	phsC
Ph.A electric time exceeded	ElecTmExc	phsA
Ph.B electric time exceeded	ElecTmExc	phsB
Ph.C electric time exceeded	ElecTmExc	phsC
Phase A inactivity exceeded	NoOpTmExc	phsA
Phase B inactivity exceeded	NoOpTmExc	phsB
Phase C inactivity exceeded	NoOpTmExc	phsC
AB dispersion time exceeded	DispTmExc	phsAB
BC dispersion time exceeded	DispTmExc	phsBC
CA dispersion time exceeded	DispTmExc	phsCA
Pole A trip number exceeded	PolTrExc	phsA
Pole B trip number exceeded	PolTrExc	phsB
Pole C trip number exceeded	PolTrExc	phsC
Trip number exceeded	PolTrExc	general

kI2 sum

After a trip, the ∑kI2 counter increases in accordance the selected setting. The value of each phase's current is calculated in primary (VT ratio), as kA primary. There are a total of 3 counters (one for each phase).

If it exceeds the set threshold (the treatment is pole to pole), a "Phase X Ki2 exceeded" signal is generated. While in this situation, the corresponding signal is sent to control. The signals are:

- Phase X Ki2 exceeded. Independent for each phase
- Ki2 exceeded. One for all the phases.

In order to calculate the pole wear, the type of calculation wanted can be programmed from among kI2*t, kI2 and kI.

- If Ki2 is chosen, the kA2 are calculated with I as the current measured after exceeding the set timeout following the trip.
- If kI is chosen, only the sum of the currents in kA is calculated, with I as the current measured after exceeding the set timeout following the trip.
- If Ki2 *t is chosen, the Ki2 //100 value is accumulated every 10ms, with I as the current measured after exceeding the set timeout following the trip. The accumulation terminates when I<0.05 A.

Excessive number of trips

It counts the trips produced in the time, generating a signal when the number of trips is higher than the programmed number during the programmed time and changes to a definite trip. The time period is reset upon a manual closure. The counter may be reset to the initial value at any moment by means of a command. The signals are:

- Pole X trip number exceeded. Independent for each phase
- Trip number exceeded. One for all the phases.

Break counter.

There are independent break and trip counters for each phase:

- The trip commands generation by the protection are considered trips.
- A breaker's changes from closed to broken (including manual and trip breaks) are considered breaks.

There are 6 counters: 3 trip counters and 3 break counters. There is a reset command for each counter.

Closure counters.

There are independent closure counters for each phase. A breaker's changes from broken to closed are considered closures.

There is a reset command for each counter.

Operating time for electric breaking and closure by pole:

They count the time elapsed from the command sent to the breaker unto its electric operation, measured with the current:

- Trip time: The time elapsed from the break command until the detection of the absence of power.
- Closure time: The time elapsed from the closure command until the detection of the presence of power.

The open pole detector current threshold is used.

These times are compared with the threshold settings. Events are generated by per pole when the thresholds are exceeded “Ph.X electric time exceeded”:

- If the time elapsed from the break command exceeds the setting “Max. T. electrical Opening (ms)”
- If the time elapsed from the closure command exceeds the setting “Max. T. electrical closure (ms)”

Mechanical breaking and closure operating time per pole:

They count the time elapsed from the command sent to the breaker unto its mechanical operation, detected in the digital inputs status:

- Trip time: Indicates the time elapsed as of the opening command until the detection of the open pole by the digital input status.
- Closure time: Indicates the time elapsed as of the closure command until the detection of the closed pole by the digital input status.

These times are compared with the threshold settings. Events are generated by per pole when the thresholds are exceeded “Ph.X mechanical time exceeded”:

- If the time elapsed from the break command exceeds the setting “Max. T. mechanical Opening (ms)”
- If the time elapsed from the closure command exceeds the setting “Max. T. mechanical closure (ms)”

Breaking and closure dispersion time for each pole pair:

They count the difference between the opening and closure times for every two poles. There are opening/closure counters for pole pairs AB, BC and CA. The breaker status is determined by means of the digital input status.

These times are compared with the threshold settings. Events are generated by per pole when the thresholds are exceeded “XY dispersion time exceeded”:

- During the break, a comparison is made with the "Max. opening dispersion time (ms)"
- During the closure, a comparison is made with the "Max. closure dispersion time (ms)"

Days of breaker inactivity without status change:

The days elapsed, since the last opening or closure of the breaker, are counted for each pole. Complete fractions of 24 hours since the last action are considered. Partial periods of 24 hours are not accumulated, i.e., if 2 days and 20 hours have passed since the last action, the counter will indicate 2 days. If at this point the time count is reset to zero, the 20 hours would be lost.

These counters are compared with the “Max. inactivity time (days)” setting and an event is generated per pole in the event of it being exceeded " Phase X inactivity exceeded ".

Last interrupted current:

The current value upon the trip is indicated per pole.

Maximum interrupted current:

The maximum current value measured at the moment of the trip is indicated per pole. The three poles can be reset to zero using the reset command.

Overcurrent levels:

Indicates time in seconds during which each phase's current is within each of the following ranges (with In as the set rated current):

- Seconds with the current between 2 and 5 times In
- Seconds with the current between 5 and 12.5 times In
- Seconds with the current between 12.5 and 20 times In
- Seconds with the current greater than 20 In

There are 12 counters (4 for each phase).

4.3 MONITORING OF TRIP AND CLOSE CIRCUITS

Monitors the circuits by pole, detecting any discontinuity with the breaker open and closed. It requires the assignment of the monitoring inputs (the breaker circuit with open and closed breaker, the closure circuit with open and closed breaker). It is activated 20 seconds after the detection of the fault and remains active while the fault persists.

Up to six trip circuits and three closure circuits can be monitored, using the number of digital inputs required.

The “closure circuit fault” or “trip circuit fault” signals are activated 20 seconds after the fault is detected, in the event of the fault persisting upon the conclusion of this period.

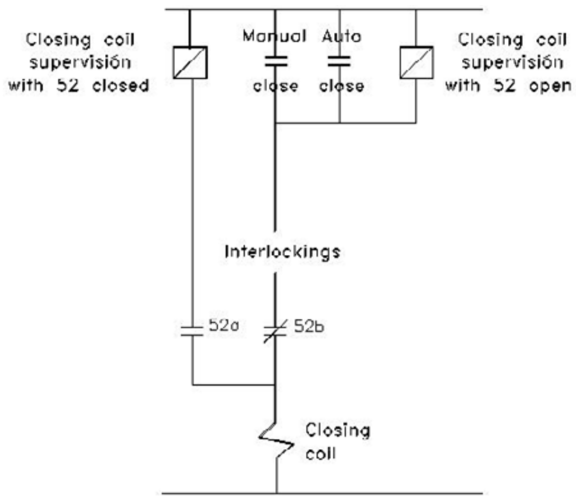
Figure 81 shows an example of the wiring for the monitoring of the closure circuit. The wiring for the trip circuit is similar.

When the breaker is closed, the contact “52” contact is also closed. If there is continuity in the circuit, the input programmed as “Coil monitoring with 52 closed” is detected as closed. If there is no continuity, it is detected as open (circuit failure).

When the breaker is open, the contact “52 b” contact is also closed. If there is continuity in the circuit, the input programmed as “Coil monitoring with 52 open” is detected as closed. If there is no continuity, it is detected as open (circuit failure).

The “closure circuit fault” or “trip circuit fault” signals are activated 20 seconds after the fault is detected, in the event of the fault persisting upon the conclusion of this period.

Figure 81 Closure circuit monitoring



The settings for the configuration of this unit are shown in Table 94:

- Trip circuit enabled: Enables the monitoring of the trip circuits.
- Closure circuit enabled: Enables the monitoring of the closure circuits.
- Closure circuit monitoring with 52 open pole X. Indicates the signal used to monitor the closure circuit with the breaker open.
- Closure circuit monitoring with 52 closed pole X. Indicates the signal used to monitor the closure circuit with the breaker closed.
- Trip circuit monitoring with 52 open pole X. Indicates the signal used to monitor the trip circuit with the breaker open.
- Trip circuit monitoring with 52 closed pole X. Indicates the signal used to monitor the trip circuit with the breaker closed.
- Enable Events record. Allows the generation of protection events associated to the function. If set to "NO", the function's protection events are not generated. If set to "YES", the function's specific mask is contemplated.

Table 94 Coil monitoring settings

Data	Setting	Min.	Max.	Step	Remarks	Type
TCEna	Trip circuit enabled					Boolean
CCEna	Closure circuit enabled					Boolean
LogInCCOA1	Closure circuit monitoring with 52 open pole A					Int32
LogInCCOB1	Closure circuit monitoring with 52 open pole B					Int32
LogInCCOC1	Closure circuit monitoring with 52 open pole C					Int32
LogInCCOA2	Closure circuit monitoring with 52 open pole A					Int32
LogInCCOB2	Closure circuit monitoring with 52 open pole B					Int32
LogInCCOC2	Closure circuit monitoring with 52 open pole C					Int32
LogInCCCA1	Closure circuit monitoring with 52 closed pole A					Int32
LogInCCCB1	Closure circuit monitoring with 52 closed pole B					Int32
LogInCCCC1	Closure circuit monitoring with 52 closed pole C					Int32
LogInCCCA2	Closure circuit monitoring with 52 closed pole A					Int32
LogInCCCB2	Closure circuit monitoring with 52 closed pole B					Int32
LogInCCCC2	Closure circuit monitoring with 52 closed pole C					Int32
LogInTCOA1	Trip circuit monitoring with 52 open pole A					Int32
LogInTCOB1	Trip circuit monitoring with 52 open pole B					Int32
LogInTCOC1	Trip circuit monitoring with 52 open pole C					Int32
LogInTCOA2	Trip circuit monitoring with 52 open pole A					Int32
LogInTCOB2	Trip circuit monitoring with 52 open pole B					Int32
LogInTCOC2	Trip circuit monitoring with 52 open pole C					Int32
LogInTCCA1	Trip circuit monitoring with 52 closed pole A					Int32
LogInTCCB1	Tripe circuit monitoring with 52 closed pole B					Int32
LogInTCCC1	Trip circuit monitoring with 52 closed pole C					Int32
LogInTCCA2	Trip circuit monitoring with 52 closed pole A					Int32
LogInTCCB2	Tripe circuit monitoring with 52 closed pole B					Int32
LogInTCCC2	Trip circuit monitoring with 52 closed pole C					Int32
MaskEna	Enable Events record				NO (0)/YES (1)	Boolean

It has independent settings, commands and outputs:

- PROT/RBCS1 node
- Settings and logical inputs. There are 6 settings tables. See Table 94.
- Outputs: Table 95 shows the function's output data.
  - X trip coil failure. Indicates that there has been failure in the pole X trip coil.
  - X closing coil failure. Indicates that there has been failure in the pole X closure coil.
  - 1 trip circuit failure. Indicates that there has been failure in the trip coil of pole A1, B1 or C1.
  - 2 trip circuit failure. Indicates that there has been failure in the trip coil of pole A2, B2 or C2.
  - 1 closing circuit failure. Indicates that there has been failure in the closure coil of pole A1, B1 or C1.
  - 2 closing circuit failure. Indicates that there has been failure in the closure coil of pole A2, B2 or C2.

Table 95 Coil monitoring outputs

Signal	Data	Attribute
A1 trip coil failure	FailTC1	phsA
B1 trip coil failure	FailTC1	phsB
C1 trip coil failure	FailTC1	phsC
A2 trip coil failure	FailTC2	phsA
B2 trip coil failure	FailTC2	phsB
C2 trip coil failure	FailTC2	phsC
A1 closing coil failure	FailCC1	phsA
B1 closing coil failure	FailCC1	phsB
C1 closing coil failure	FailCC1	phsC
A2 closing coil failure	FailCC2	phsA
B2 closing coil failure	FailCC2	phsB
C2 closing coil failure	FailCC2	phsC
1 trip circuit failure	FailTC1	general
2 trip circuit failure	FailTC2	general
1 closing circuit failure	FailCC1	general
2 closing circuit failure	FailCC2	general

5. AUTOMATISMS

5.1 SYNCHRONISM

The synchronism function or "synchrocheck" waits for the appropriate conditions established in the settings, to determine breaker closure, both manual and automatic.

Two voltage signals from the two sides of the breaker, which we will call side A and side B, are compared.

Side A corresponds to the analogue programmed voltage input. A setting allows for the selection between ground to phase and phase to phase voltages and, when applicable, a compensation factor is applied to equalize the module and the angle of the two voltages compared.

Side B corresponds to the analogue voltage input connected to the synchronism voltage terminals.

These are all selectable by means of settings (see Table 96):

- Enabling of the function.
- Side A phase reference: selectable between A/AB, B/BC, C/AC, corresponding to the measurement of the selected voltage transformer.
- Module compensation: the factor by which the module is multiplied in order to equalize the voltages.
- Angle compensation: the factor to be added to the angle in order to equalize the voltages.

The synchronism function can be disabled by means of a setting ("NO"), or by means of a "fuse failure" or a "breaker closure permission block" digital input.

In order to give closure permission when enabled, the function contemplates the conditions that grant undervoltage permission or synchronism permission.

5.1.1 Undervoltage permission

Permission is granted if there is voltage on one or on both sides of the breaker. In order to verify whether there is no voltage present on one side of the breaker, the voltage measured is checked to see whether it is lower than the programmed value.

- Voltage presence side A: the voltage measured in side A must exceed this value in order to consider that there is voltage on that side of the breaker.
- No Voltage side A: the voltage measured in side A must be inferior this value in order to consider that there is an absence of voltage on that side of the breaker.
- Presence of voltage on the synchronism side B: the voltage measured in side B must exceed this value in order to consider that there is voltage on that side of the breaker.
- Absence of voltage on the synchronism side B: the voltage measured in side B must be inferior this value in order to consider that there is an absence of voltage on that side of the breaker.
- Conditions for granting undervoltage block permission:
  - Without permission: under no circumstances will the function grant undervoltage permission
  - No A and B: there must be an absence of voltage on side A in order for the function to grant undervoltage permission.
  - A and not B: there must be an absence of voltage on side B in order for the function to grant undervoltage permission.
  - No A and No B: there must be an absence of voltage on both sides of the breaker in order for the function to grant undervoltage permission.
  - No A or No B: there must be an absence of voltage on one of the sides of the breaker in order for the function to grant undervoltage permission.
  - A XOR B: there must be voltage presence on one side of the breaker and an absence on the other in order for the function to grant undervoltage permission.

These conditions are set for both manual closing and automatic reclosing.

The detection of the presence or the absence of voltage is always done in all the phases. However, the analysis of the conditions for granting or refusing breaker close permission is only carried out if the function is enabled.

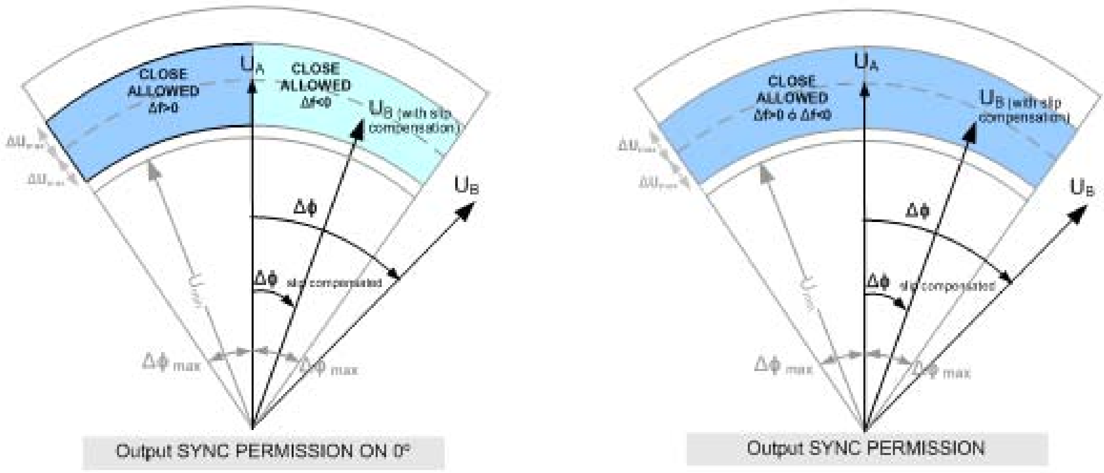
5.1.2 Synchronism permission

Synchronism permission is given when following conditions indicated by the corresponding setting are simultaneously fulfilled during a programmable time. These conditions are based on the comparison of voltage modules, phases and frequency on both sides of the breaker. The analysis is performed whenever there is voltage on both sides of the breaker.

The parameters to be set are listed below:

- Enabling of synchrocheck with reclosure:
  - Not enabled: in this case, permission is always granted. The closure will depend on the compliance with the conditions required by the recloser function.
  - Without compensation: comparisons between angles, arguments and frequencies are taken into account to grant permission if the set conditions are met during the programmed time
  - With compensation: in addition to the module and frequency comparisons, breaker close time is taken into account. See Figure 82.
  - With compensation (closure in 0º): a specific case of enabling with compensation, and also taking into account that closure permission will be granted when the argument difference is 0°. See Figure 82.
- Enabling of synchrocheck with manual closure:
  - Not enabled: in this case, manual closure permission is always granted.
  - Without compensation: comparisons between angles, arguments and frequencies are taken into account to grant permission if the set conditions are met during the programmed time
  - With compensation: in addition to the module and frequency comparisons, breaker closure time is taken into account. See Figure 82.
  - With compensation (closure in 0º): a specific case of enabling with compensation, and also taking into account that closure permission will be granted when the argument difference is 0°. See Figure 82.
- Breaker close time (s): taken into account when calculating the argument difference, and providing that the enabling "with compensation" has been programmed. In this case, the frequency slip is taken into account to compensate for this time.
- Voltage difference (V): the difference between the voltage modules on side A and side B must be less than this value in order for permission to be granted.
- Frequency difference (Hz): the difference between the frequencies on side A and side B must be less than this value in order for permission to be granted.
- Argument difference (º): the difference between the voltage arguments on side A and side B must be less than this value in order for permission to be granted.
- Manual closure condition compliance time (s): the time during which the conditions for the granting of permission for closure must be met.
- Reclosure condition compliance time (s): the time during which the conditions for the granting of permission for reclosure must be met.

Figure 82 Synchronism check with compensation



ϕUB (wi9th compensation) =ϕUB + ωslip·TCB

Δϕ with compensation =ϕUB (with compensation) -ϕUA

In which:

Frequency slip	Δf=fB-fA	(Hz)
Slip speed	ωslip=Δf·360º	(º/s)
Breaker closure time	TCB	(s)

If this argument difference decreases when the enabling is set with compensation and closure in 0º, the condition for granting permission will be:

lΔϕ with compensationl=0

If this difference decreases when the enabling is set with compensation, in order for permission to be granted the difference must be around 0º.

If the argument difference is increasing, the following must be met:

lΔϕ with compensationl<argument difference setting

Synchronism function measurements available in the unit status:

- Module, argument, frequency of the voltage on side A
- Module, argument, frequency of the voltage on side B
- The difference between the module, argument, frequency of the voltage on side A and side B. They are only available when the voltage presence conditions are met on both sides.

Data related to synchronism function:

- Node: PROT/RSYN1
- Settings and logical inputs: There are 6 settings tables. See Table 96.
  - LogInBlSy1: logic input which, when active, blocks the function.
  - LogInBlCl1: logic input which, when active, blocks the breaker close permission.
  - LogInRFF: fuse failure logic input which, when active, blocks the function.
- Commands:
  - DOrdSyBlk1: Function block and unblocking. Only acts when the function is enabled.
  - DOrdPeBlk1: Close permission block and unblock. Only acts when the function is enabled.
- Outputs: Table 97 shows the function's output data.

Table 96 Synchronism settings

Data	Setting	Minimum	Maximum	Step	Remarks	Type
SynEna	Enabled	0	1	1		enum
SiASel	Phase synchronism side A				AA/AB, B/BC, C/CA	enum
CoModVs1	Compensation factor |Vsync1|	0.1	3	0.01		float
CoArgVs1	Compensation argument (Vsync1)	0	330	30		float
PrVSiA	Voltage presence side A	0	200	0.1		float
AbVSiA	Absence of voltage side A	0	200	0.1		float
BrClTmms1	Closure time	0	10000	10		float
SyWReEna1	Enabling of synchronism with reclosure				No, Without compensation, With compensation (0º), With compensation	enum
SyWMaClEna1	Enabling of synchronism with manual closure				No, Without compensation, With compensation (0º), With compensation	enum
SyDifV1	Voltage difference	0	90	0.1		float
SyDifF1	Frequency difference	0.01	2	0.01		float
SyDifA1	Argument difference	0	360	1		float
ReTmms1	Reclosure conditions compliance time	0	10000	10		float
MaClTmms1	Manual closure condition compliance time	0	10000	10		float
PrVSiB1	Voltage presence side B	0	200	0.1		float
AbVSiB1	Absence of voltage side B	0	200	0.1		float
ClCond1	Manual closure conditions					enum
ReCond1	Reclosure condition					enum
LogInBlSy1	Synchronism block input					Int32
LogInBlCl1	Closure permission block input					Int32
LogInRFF	Fuse failure signal input					Int32

Synchrocheck function signals (see Table 97). It is necessary that voltage presence is detected on both sides of the breaker in all of them:

- Positive slip Breaker 1: active if the frequency on the B side is also greater than that on side A by more than 5mHz.
- Negative slip Breaker 1: active if the frequency on the A side is also greater than that on side B by more than 5mHz.
- Underfrequency side B B1: active if the frequency difference of both sides exceeds the setting value and the frequency on side A is greater than that on side B.
- Overfrequency side B B1: active if the frequency difference of both sides exceeds the setting value and the frequency on side B is greater than that on side A.
- Delay without comp. side B 1: with the difference between the arguments exceeds the setting value and is greater on side A than on side B.

- Advance without comp. side B 1: with the difference between the arguments exceeds the setting value and is greater on side B than on side A.
- Delay with comp. side B 1: with the difference between the arguments, calculated by taking into account breaker closure time, exceeds the setting value and is greater on side A than on side B.
- Advance with comp. side B 1: with the difference between the arguments, calculated by taking into account breaker closure time, exceeds the setting value and is greater on side B than on side A.
- Positive Slip Breaker 1: the difference in arguments, calculated by taking into account breaker closure time, is positive and, in absolute value, exceeds the programmed setting.
- Over Module side B B1: the voltage difference is greater than the programmed setting and the voltage in B is greater than in A.
- Under Module side B B1: the voltage difference is greater than the programmed setting and the voltage in A is greater than in B.
- Perm. without comp.. B1: indicates that differences in voltage, argument and frequencies are lower than the corresponding settings.
- Perm. with comp.. B1: when the necessary conditions related to the voltage, argument and frequencies differences are given, taking into account the breaker closure time for calculating the argument difference.

Compliance with the undervoltage conditions gives rise to the generation of the following permissions:

- Perm. Manual Close V B1: Manual closure permission for voltage checks
- Permission Recloser V B1: Reclosure permission for voltage checks

Either due to compliance with the circumstances that give rise to the permission for undervoltage or, alternatively, because the appropriate synchronism conditions are met, the following outputs are activated:

- Perm. Manual Close B1: closure permission for undervoltage or for synchronism. If the function is disabled, manual closure permission will also be signalled.
- Perm. Reclose Br 1: reclosure permission for undervoltage or synchronism, so that the recloser decides on the automatic closure of the breaker.

Table 97 Synchronism function outputs for breaker 1

Signal	Data	Atribute
Positive Slip Breaker 1	PosSlipBr1	stVal
Negative Slip Breaker 1	NegSlipBr1	stVal
Underfrequency side B B1	UFSideBBr1	stVal
Overfrequency side B B1	OFSideBBr1	stVal
Delay without comp. side B 1	DBNSlipBr1	stVal
Adv. without comp.side B B1	ABNSlipBr1	stVal
Delay with comp. side B B1	DBSlipBr1	stVal
Advance with comp. side B 1	ABSlipBr1	stVal
Over Module side B B1	OAbsBBr1	stVal
Under Module side B B1	UAbsBBr1	stVal
Perm. without comp.. B1	PNoSlipBr1	stVal
Perm. with comp.. B1	PSlip0Br1	stVal
Perm. Manual Close B1	PMCBr1	stVal
Perm. Close Recloser Br 1	PRecBr1	stVal
Perm. Manual Close V B1	PMClVChBr1	stVal
Permission Recloser V B1	PRecVChBr1	stVal
Permission with compens. 1	PSlipBr1	stVal
Enable Synchro Breaker 1	EnaBr1	stVal
Voltage presence Va/Vab side A	SAVPres	phsA
Voltage presence Vb/Vbc side A	SAVPres	phsB

Voltage presence Vc/Vca side A	SAVPres	phsC
Voltage presence ABC side A	SAVPres	general
No Voltage Va/Vab side A	SAVAbs	phsA
No Voltage Vb/Vbc side A	SAVAbs	phsB
No Voltage Vc/Vca side A	SAVAbs	phsC
No Voltage ABC side A	SAVAbs	general
Voltage presence side A	SAPres	stVal
No Voltage side A	SAAbs	stVal
Voltage presence side B B1	SBVPresBr1	stVal
No Voltage side B B1	SBVAbsBr1	stVal
Active Sync V Vs1	Vs1	stVal

5.2 RECLOSER

The unit allows up to 4 reclosures to be effected. In order to make the recloser as useful as possible, the number of reclosures allowed is programmable (0 is not permitted).

Differentiated close times for each of the closures.

The recloser is put into service – out of service by means of a setting. Only when enabled by setting can it be put into service-out of service by means of a command via communications or the ES-FS button on the keyboard.

Programmable reclaim time following manual closure and following automatic closure.

The 5 closure counters (total, first, second, third and fourth closures) are stored in non-volatile memory and can be viewed in the console and on the display. These counters can be set to 0 by command or by the keyboard.

The closure cycle can be started either by the unit's own protection trips or by external trips from other protections.

The main recloser statuses are:

- ❑ Supervising status.

This is the normal status, during which the recloser “monitors” for the occurrence of any trips. If any trip occurs, the recloser is activated.

- ❑ Ongoing cycle status.

The status of the recloser while activated, from the first trip up to the closure of the breaker and the elapse of the reclaim time (successful reclosure), or until all the programmed reclosures have been unsuccessfully executed. In the first case, the recloser switches to “supervising” and, in the second, to “definitive trip”.

- ❑ Definitive trip status.

The recloser’s final situation once it has run all the programmed attempts and the breaker remains open due to the existence of a permanent fault. It only leaves this status when the breaker is closed manually.

- ❑ Internal block status.

The status is reached as a result of different causes. The reclosure cycle cannot be started nor can the termination of the cycle be provoked if the cycle is running. It is cancelled by a breaker closure.

Definitions:

- ❑ Reclosable units.

Units which are capable of initiating the reclosure process. By default, they are overcurrent or distance units. The non-reclosable units are those whose trips do not initiate the reclosure cycle (voltage, frequency, power units, etc). There is an input which can be programmed as “Reclosable configurable trip”.

- Trips permitted following reclosure.

Each of the units that are blocked during the reclaim time following each reclosure are programmed by means of "Yes" or "NO".

5.2.1 Settings and signals

The general settings used in the recloser (PROT/RREC node) are (see Table 98):

- Enabled. Indicates whether the function is enabled or not.
- Number of reclosures. Indicates the maximum number allowed before the issued of the definitive trip.
- Faults between phases reclosure timeouts: first, second, third and fourth.

This is the timeout following a phase trip until the recloser issues a closure command in each of the reclosure phases. There are differentiated closure times for each of the closures.

- Earth fault reclosure timeouts: first, second, third and fourth.

This is the timeout following a grounding trip until the recloser issues a closure command in each of the reclosure phases. There are differentiated closure times for each of the closures.

- Reclaim time following manual closure.

The time following the manual closure of the breaker, during which the existence of a protection trip is monitored. In such a case, a definitive trip is triggered instead of a change to supervising status.

- Reclaim time following automatic closure following grounding fault.

This is the time following the automatic closure of the breaker due to a grounding fault, during which the existence of a protection trip is monitored. In such a case, the cycle is continued instead of a change to supervising status.

- Reclaim time following automatic closure following fault between phases.

This is the time following the automatic closure of the breaker due to a fault between phases, during which the existence of a protection trip is monitored. In such a case, the cycle is continued instead of a change to supervising status.

- Incomplete sequence enabled. Indicates whether the incomplete sequence function is enabled or not.
- Incomplete sequence block time. Indicates the maximum time for the completion of the reclosure process.
- Blocking Input by level. Selects the signal which, when active, blocks the recloser.
- Logical block input by pulse. Selects the signal that, when there is a status change from deactivated to activated, blocks the recloser.
- Logical unblock input by pulse. Selects the signal that, when there is a status change from deactivated to activated, unblocks the recloser.
- Logical external synchronism permission logic. Selects the signal which, when active, indicates the existence of permission for synchronism.
- Logical closure time reset input. Selects the signal which, when active, restarts the closure time.
- Logical closure time pause input. Selects the signal which, when active, stops the closure time.
- Logical reclosure reset input. Selects the signal which, when active, initiates the closure process.
- Logical configurable reclosure input.
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

Table 98 General recloser settings

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
RecEna	Recloser in service				YES/NO	enum
RecNum	Number of closures	1	4	1		Int32
Rec1PhTms	Timeout first closure for faults between phases	0,05	600	0,01		float
Rec2PhTms	Timeout second closure for faults between phases	1	600	1		float
Rec3PhTms	Timeout third closure for faults between phases	1	600	1		float
Rec4PhTms	Timeout fourth closure for faults between phases	1	600	1		float
Rec1GTms	Timeout first closure for grounding faults	0,05	600	0,01		float
Rec2GTms	Timeout second closure for grounding faults	1	600	1		float
Rec3GTms	Timeout third closure for grounding faults	1	600	1		float
Rec4GTms	Timeout fourth closure for grounding faults	1	600	1		float
PReSe3Tms	Reclaim time following automatic closure following fault between phases	0	600	1		float
PReSe1Tms	Reclaim time following automatic closure following grounding fault	1	600	1		float
MaClSeTms	Reclaim time after manual closure	1	600	1		float
BlInSecEna	Incomplete sequence block enabled				YES/NO	enum
BlInSecTms	Incomplete sequence block time	1	600	1		float
LogInReLB	Recloser block by level					Int32
LogInRePB	Recloser block by pulse					Int32
LogInRePUb	Recloser unblock by pulse					Int32
LogInExSy	External synchronism permission					Int32
LogInRcTmRst	Reclosure reset time input					Int32
LogInRcTmPau	Reclosure pause time input					Int32
LogInRst	Recloser reset input					Int32
LogInConf	Configurable recloser input					Int32
MaskEna	Enable Events record				NO (0) / YES (1)	Boolean

The general settings used for the supervising for synchronism (PROT/RLSS1 node) are (see Table 99):

- Synchronism type.

Indicates whether the synchronism is internal or external.

- Three-phase closure 1 monitoring.

Indicates whether the first closure is to be monitored with synchronism.

- Monitoring remaining closures.

Indicates whether the closures other than the first are to be monitored with synchronism.

- Synchronism timeout.

This is the maximum time waited before the synchronism grants permission before a three-phase closure. If closure permission is granted before the conclusion of this time, a closure command is issued. On the other hand, if this time elapsed without permission being granted, a definitive trip is triggered.

- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

Table 99 Monitoring by synchronism settings

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
SynTyp	Synchrocheck type				Internal/External	enum
Rec1SyEna	Three-phase closure 1 monitoring				YES/NO	Boolean
RecSyEna	Monitoring of remaining closures				YES/NO	Boolean
SyWaTms	Synchronism timeout (s)	0.05	600	0.01		Int32
MaskEna	Protection event recording enabled				YES/NO	Boolean

The settings used for the monitoring by reference voltage (PROT/RVRS1 node) are (see Table 100):

- Enabled. Indicates whether the function is enabled or not.
- Waiting time (s)

This is the time, following the opening of the breaker, that is waited for the activation of the reference voltage signal to allow the reclosure.

It is used to wait for the activation of an external signal before allowing a reclosure. E.g., to wait for the line voltage to disappear following a trip (e.g., if there were motors or batteries connected) before reconnecting the line.

- Minimum time (s)

This is the minimum time during which the vref signal must be seen to be active in order to consider the existence of reference voltage.

- Logical Vref input. Selects the signal which, when active, indicates the existence of reference voltage (Vref).
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

Table 100 Monitoring by Vref settings

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
VrefEna	Enabled				YES/NO	enum
VrefWaTms	Timeout (s)	0.05	600	0.01		float
VrefMinTms	Minimum time (s)	0.05	600	0.01		float
LogInVref	Vref signal					Int32
MaskEna	Protection event recording enabled				YES/NO	Boolean

The setting used for blocking a closure due to a failure in the breaker’s coils (PROT/RTCS1 node) is (see Table 101):

- Enabled. Indicates whether the function is enabled or not.

Table 101 Closure block settings

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
CIBITCF	Enabled				YES/NO	enum

5.2.1.1 Signals

The recloser’s output signals are in the PROT/RREC1 node and are shown in Table 102 and Table 103.

The general recloser signals are:

- Recloser in service. Indicates whether it is enabled or not.
- Recloser in standby. Indicates that it is in standby or supervising.

- Recloser Locked. Indicates that it is locked.
- Definitive trip. Indicates that it is in the definitive trip.
- Definitive Trip+Ext blocked. Indicates that it is in definitive trip and external block.
- Reclosure command. Automatic breaker closure command.
- 79 in progress. Active from the moment the breaker is opened by a trip until the monitoring or definitive trip status is reached.
- Reclosing 1 in progress. During the closure cycle 1. As of the opening of the breaker by the first trip or until supervising is reached following the reclaim time or trip which leads to it being blocked (by Definitive T.) or a new cycle is produced.
- Reclosing 2 in progress. During the closure cycle 2. As of the opening of the breaker by a trip during the reclaim time following the first reclosure until the closure command is given or the block is produced.
- Reclosing 3 in progress. During the closure cycle 3. As of the opening of the breaker by a trip during the reclaim time following the second reclosure until the closure command is given or the block is produced.
- Reclosing 4 in progress. During the closure cycle 4. As of the opening of the breaker by a trip during the reclaim time following the third reclosure until the closure command is given or the block is produced.
- Safety time. Following the closure of the breaker, the reclaim time is counted until supervising is entered or a new closure cycle is initiated.
- Safety time manual closing. Following the automatic closure of the breaker, the reclaim time is counted until supervising is entered or a new closure cycle is initiated.
- Safety time reclosing. Following the manual closure of the breaker, the reclaim time is counted until supervising is entered or a new closure cycle is initiated.
- Safety time 1 st reclosing. Following the closure of the breaker by the first closure, the reclaim time is counted until supervising is entered, a new closure cycle is initiated or the definitive trip is triggered.
- Safety time 2nd reclosing. Following the closure of the breaker by the second closure, the reclaim time is counted until supervising is entered, a new closure cycle is initiated or the definitive trip is triggered.
- Safety time 3rd reclosing. Following the closure of the breaker by the third closure, the reclaim time is counted until supervising is entered, a new closure cycle is initiated or the definitive trip is triggered.
- Safety time 4th reclosing. Following the closure of the breaker by the fourth closure, the reclaim time is counted under supervising is entered or the definitive trip is triggered.
- Vref presence. Indicates the presence of reference voltage.
- Block without Vref. Indicates the blocking of the recloser due to the absence of reference voltage.
- Recloser paused. Indicates that the recloser is in pause in the closure time counter.
- Reclosing Started. Indicates that the reclosure process has started.
- Reclosing 1 Started. Indicates that the first reclosure process has started.
- Reclosing 2 Started. Indicates that the second reclosure process has started.
- Reclosing 3 Started. Indicates that the third reclosure process has started.
- Reclosing 4 Started. Indicates that the fourth reclosure process has started.
- Successful Reclosing. Indicates that the reclosure process was completed successfully.
- Breaker Reclosing ongoing. Indicates that the breaker is reclosing.

Table 102 General recloser outputs

Signal	Dato	Atributo
Recloser in service	Auto	general
Recloser in standby	RestST	general
79 in progress	RecCyc	general
Successful Reclosing	RecOK	general
Definitive Trip	DefTrip	general
Reclose Command	OpCls	general
Recloser Locked	Blk	general
Reclosing 1 in progress	RecCyc1	general
Reclosing 1 1P in progress	RecCycMon1	general
Reclosing 1 3P in progress	RecCycTr1	general
Reclosing 2 in progress	RecCyc2	general
Reclosing 3 in progress	RecCyc3	general
Reclosing 4 in progress	RecCyc4	general
Safety time	SecTime	general
Safety time manual closing	ManClSecT	general
Safety time reclosing	RecSecT	general
Safety time 1 st reclosing	Rec1SecT	general
Safety time 2nd reclosing	Rec2SecT	general
Safety time 3rd reclosing	Rec3SecT	general
Safety time 4th reclosing	Rec4SecT	general
Recloser paused	Pause	general
Reclosing Started	RecPrIn	general
Reclosing 1 Started	RecPrIn1	general
Reclosing 2 Started	RecPrIn2	general
Reclosing 3 Started	RecPrIn3	general
Reclosing 4 Started	RecPrIn4	general
Definitive Trip+Ext blocked	DefTripBlk	general
Breaker Reclosing ongoing	BrRec	general

The recloser blocking signals are:

- Recloser Internal Lock. Indicates that the recloser is in internal block due to any cause.
- Recloser Definitve Trip Lock. Indicates that the recloser is in internal block due to a definitive trip.
- Recloser Lock 52 opened. Indicates that the recloser is in internal block due to a manual break.
- Recloser Lock Trip Exceeded. Indicates that the recloser is in internal block due to an excessive number of trips.
- Recloser Lock switch on fault. Indicates that the recloser is in internal block due to a switch onto fault, i.e., a trip is produced during the reclaim time following a manual closure.
- Recloser Lock No Syncrocheck. Indicates that the recloser is in internal block due to the ausence of syncrcheck.
- Recloser Lock without Vref. Indicates that the recloser is in internal block due to the ausence of vref.
- Recloser Lock Pole discordance. If the discordance function acts, the reclosure cycle is blocked.
- Recloser Lock Close Failure. Indicates that the recloser is in internal block due to the close failure. Related to the breaker monitoring.
- Recloser Lock opening Failure. Indicates that the recloser is in internal block due to the open failure. Related to the breaker monitoring.
- Recloser External Lock. Indicates that the recloser is in external block due to any cause.

- Recloser External Lock Comms. Indicates that the recloser is in external block due to command.
- Recloser External Lock Input. Indicates that the recloser is in external block due to logical input.
- Reclosing Start failure. Indicates that the recloser is blocked due to reclosing start failure.
- Recloser Lock End of cycle. Indicates that the recloser is blocked due to the end of the reclosing cycle.
- Recloser Lock manual closing. Indicates that the recloser is blocked due to manual reclosing.
- Recloser Lock manual opening. Indicates that the recloser is blocked due to manual opening.
- Recloser Trip In Safety time. Indicates that the recloser is blocked due to a trip in safety time.
- Recloser Incomplete sequence. Indicates that the recloser is blocked because the sequence time is exceeded.
- Recloser Lock TC Failure. Indicates that the recloser is blocked due to breaker circuit supervision failure.

Table 103 Recloser block outputs

Signal	Dato	Atributo
Recloser Internal Lock	BlkInt	general
Recloser Definitve Trip Lock	BlkIntDeTr	general
Recloser Lock 52 opened	BlkIntOpBr	general
Recloser Lock Trip Exceeded	BlkInExcTr	general
Recloser Lock switch on fault	BlkIntSOF	general
Recloser Lock tripoloar trip	BlkInt3PTr	general
Recloser Lock No Syncrocheck	BlkINoSync	general
Recloser Lock without Vref	BlkINoVref	general
Recloser Lock Pole discordance	BlkIPoleD	general
Recloser Lock Close Failure	BlkIClFail	general
Recloser Lock opening Failure	BlkIOpFail	general
Recloser External Lock	BlkExt	general
Recloser External Lock Comms	BlkExtComs	general
Recloser External Lock Input	BlkExtDI	general
Reclosing Start failure	BlkIntInFa	general
Reclosing A Start failure	BlkIAInFa	general
Reclosing B Start failure	BlkIBInFa	general
Reclosing C Start failure	BlkICInFa	general
Recloser Lock End of cycle	BlkICyEnd	general
Recloser Lock manual closing	BlkIManCl	general
Recloser Lock manual opening	BlkIManOp	general
Recloser Trip In Safety time	BlkITrMaSe	general
Recloser Incomplete sequence	BlkInSec	general
Recloser Lock TC Failure	BlkClsTrip	general

5.2.1.2 Reclosure counters

There are independent reclosure counters for the first, second, third, fourth reclosures and for the totals.

They are stored in a non-volatile memory and displayed in the statistical data (communications and display).

These counters can be set to 0 by command.

5.2.1.3 Excessive number of trips

Allows the number of trips within the time to be limited.

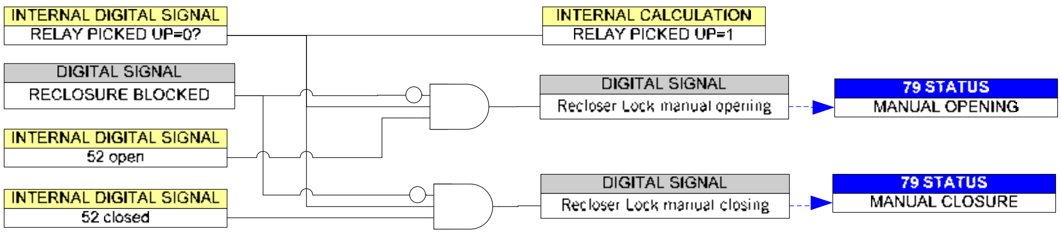
A signal is generated the trip limit is exceeded ("excessive number of trips" setting) within a set time ("excessive number of trips time window" setting).

It sets 79 to "Internal block", signalling "Internal block due to excessive number of trips" and "Definitive trip".

5.2.2 General operation

After a certain period following the introduction of voltage (or after resetting), the recloser enters the Supervising status when the breaker is closed (passing through manual closure) or Manual Opening (manual opening block) if the breaker is open. If it is disabled or there is a block signal, the reclosure cycle is not launched and it remains in the blocked status.

Figure 83 Recloser initialization



It remains in the Manual Opening and Definitive Trip statuses until the breaker is closed manually.

Following the closure:

- If the breaker does not open during the block (or reclaim) time, it enters Supervising.
- If there is a manual opening, it enters Manual Opening Block.
- If there is an opening by a protection, it enters Definitive Trip Block.

If the protection acts but the breaker does not open (or the trip remains active) during the programmed time, it enters internal block due to opening failure and the corresponding signal is activated. It leaves this status following a manual opening, a breaker closure command or a reset.

The Supervising (or reset) status is maintained until:

- There is a manual opening.
- The protection acts and opens the breaker, initiating the cycle when applicable.

The cycle consists of 1 to 4 reclosures.

During each cycle a programmed time is observed and the breaker closes. If the breaker does not trip due to a protection within the reclaim time, the Supervising (reset) status is entered. If it does, the following closure is initiated. If this was the last, the Definitive Trip is initiated.

If, following the action of the protection, the breaker does not open in the preset time or the relay continues to trip, the internal block begins to operate. If, following a closure and while the block time is being counted, there is a manual opening. In this case, it enters Manual Opening Block and exits the cycle.

If, while the reclosure time is being counted, a manual closure is produced, the recloser aborts the reclosure cycle and enters "Manual closure". Following the corresponding reclaim time, it returns to standby.

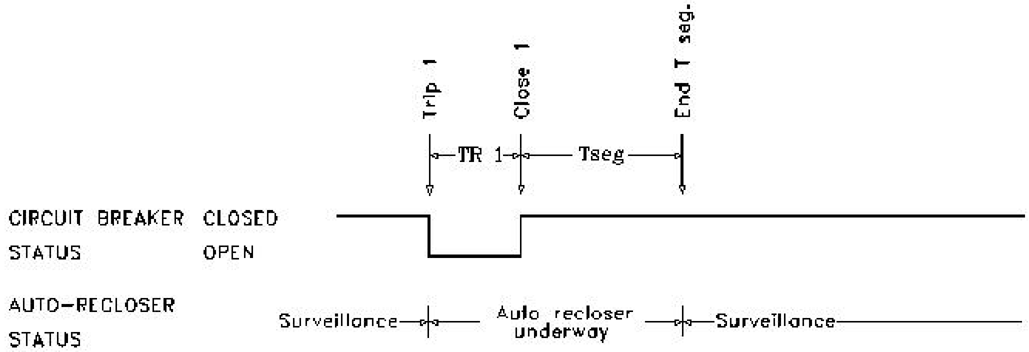
If, once closed, a reset is received, it also enters manual closure.

The action of the external block prevents the cycle from being entered, or the exit from any ongoing cycle. If the breaker opens while the block is in effect, it enters Definitive Trip block.

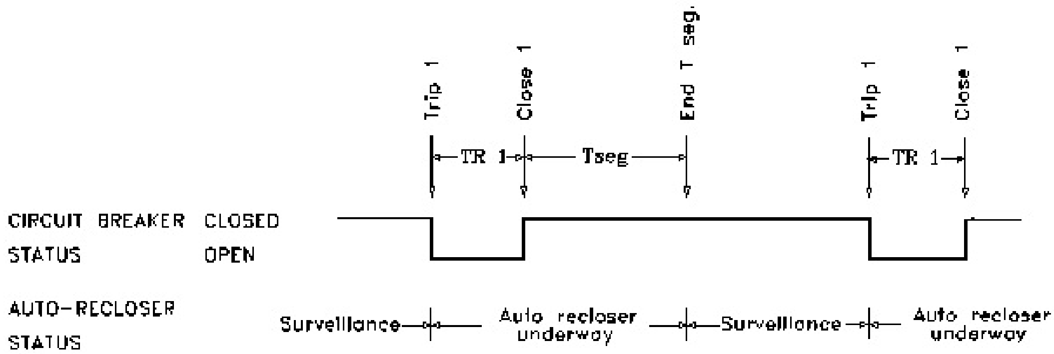
If the synchrocheck function is enabled and the synchrocheck monitoring setting is set to YES, this function must issue closure permission in order for the closure relay to be activated.

The figures below show the sequence of events for a reclosure which has been programmed for three reclosure attempts (TR1, TR2 and TR3, respectively), with a reclaim time of Tsec, for different situations:

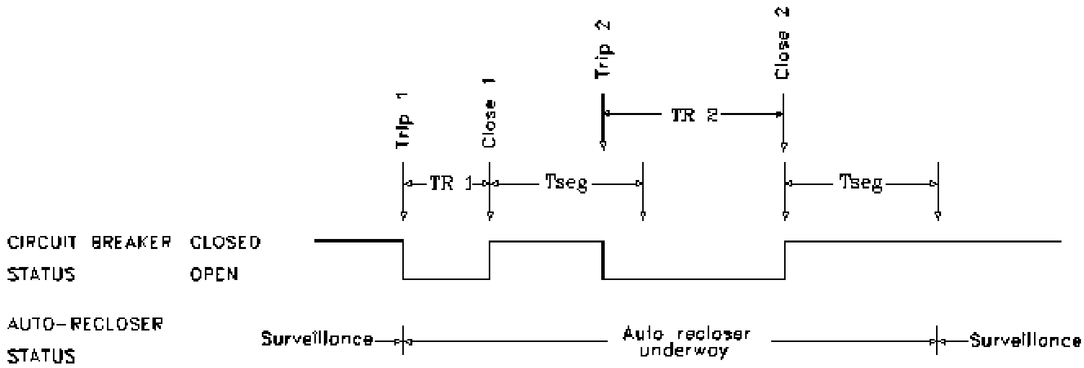
a.- Successful first reclosure.



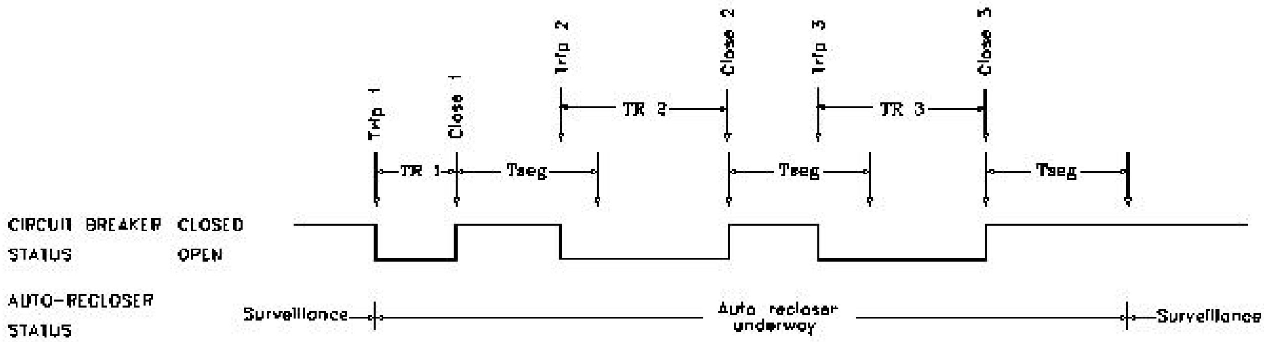
Once the Supervising status has been reached, a new trip causes a new cycle to begin and reclosure 1 is started once more, as shown below:



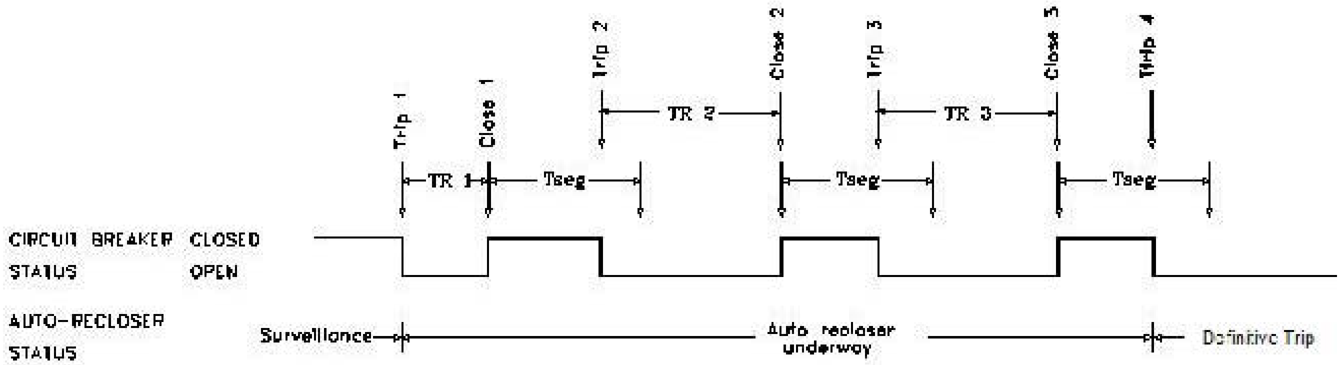
b.- Successful second reclosure.



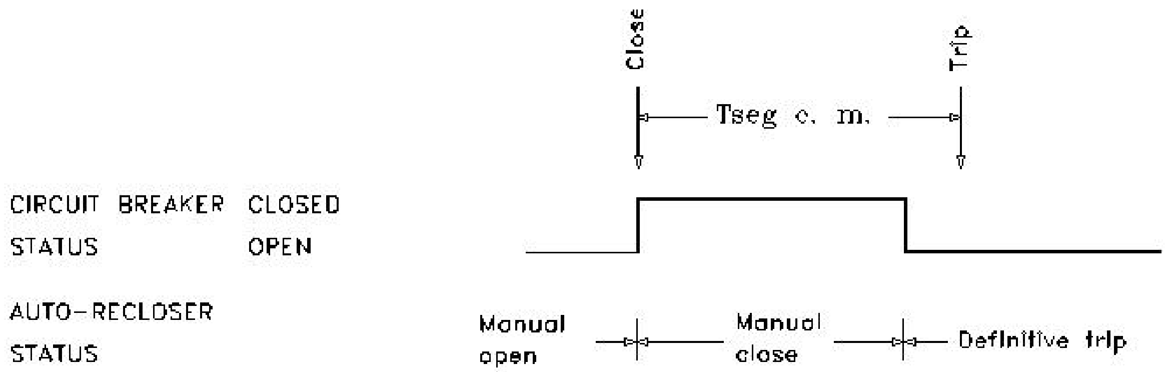
c.- Successful third reclosure.



d.- Changes to definitive trip after exhausting the number of programmed reclosures.



e.- Changes to definitive trip due to a trip during the reclaim time following a manual closure.



5.2.3 General trip masks

It is independent for each of the protection units.

Indicates if this unit produces a general trip or not. The protection functions can be enabled or disabled and can trigger a trip and/or a pick up independently of which units are to open the breaker. The general trip signal is sent to the breaker and is configured by means of this mask.

In order, upon tripping, for a unit to activate the general trip, it must meet (see Figure 84):

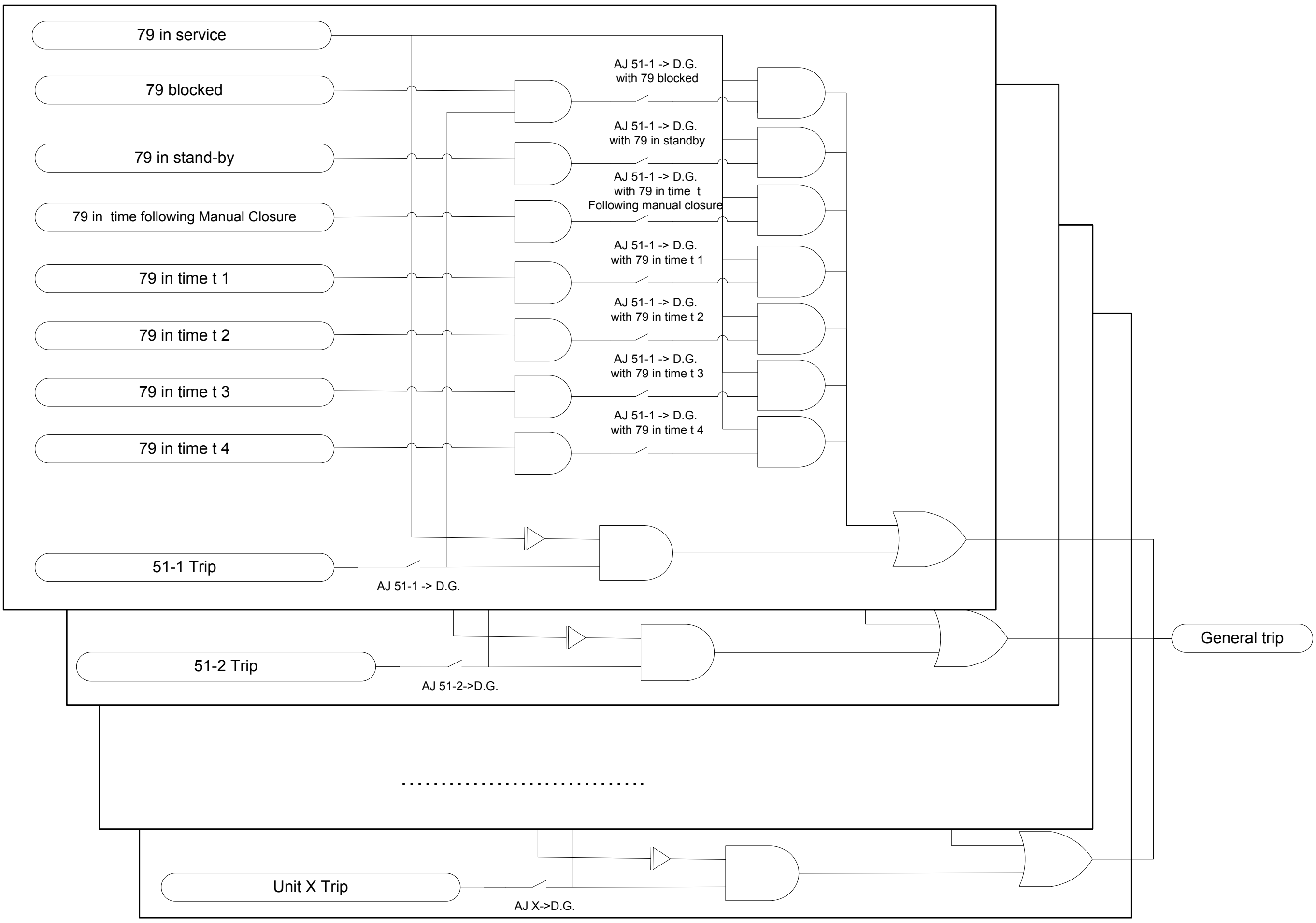
- Be enabled
- Have its general trip mask set to YES
- If the recloser is enabled, the unit must not be blocked by the trip permission mask.

Each protection unit has an independent setting which is used to enable or disable its general trip. Its reference is "GenTrip" and allows the options “YES/NO”.

Table 104 General trip (in each protection node)

Data	Parameter	Min.	Max	Step	Remarks	Type
GenTrip	General trip				YES/NO	

Figure 84 General trip scheme



5.2.4 Trip permission masks

They are independent for each of the protection units and are configured in the protection nodes.

This mask is used to select which trips are associated to the “general trip” (with the recloser in service), depending on the status of the recloser.

Independently of these settings, the protection units pick up and trip, activating their corresponding signals.

The unit that is to produce the trip (activate the general trip signal) can be selected by programming 4 trip masks peer unit and which are active in the following moments:

- Standby (supervising or reset).
- Reclaim time following manual closure
- Reclaim time following reclosure 1, 2, 3, or 4.
- Recloser blocked (external or internal block)

If the recloser is out of service, these masks have no effect, and thus all the units programmed to produce a general trip will issue a trip.

Each protection unit has independent masks. If a unit trips during a specific recloser status (blocked, in security t, etc.) and the corresponding mask is set to YES, the trip is sent to the general trip output. If the mask is set to NO, the trip is produced but the "direct trip" signal is not received.

Each protection unit has an independent setting which is used to enable or disable the unit’s permissions. The reference is “TripPerm”. The setting is configured as a bit field where each bit corresponds to a selection, indicating the integer value:

Bit meaning (1)	Bit	Value
Reclosure block	0	YES/NO
Trip permission 79 standby	1	YES/NO
Trip permission 79 blocked	2	YES/NO
Permission for trip in reclaim time following reclosure 1	3	YES/NO
Permission for trip in reclaim time following reclosure 2	4	YES/NO
Permission for trip in reclaim time following reclosure 3	5	YES/NO
Permission for trip in reclaim time following reclosure 4	6	YES/NO
Permission for trip in reclaim time following manual closure	7	YES/NO

An example of use with trip permissions in standby and following reclosures would be the decimal value 122 (01111010 in binary), broken down into:

Bit	7	6	5	4	3	2	1	0
Value	0	1	1	1	1	0	1	0

The maximum permitted value with all permissions enabled is 255 (11111111 in binary).

Table 105 Trip permission following reclosure (in each protection node)

Data	Parameter	Min.	Max	Step	Remarks	Type
TripPerm	Trip permission	0	8191	1		Int32

5.2.5 Post-trip reclosure permission mask

They are independent for each of the protection units and are configured in the protection nodes.

The enabling of the corresponding R1, R2, R3 and R4 post-trip reclosure permission mask is checked with each trip. If they are not enabled, the reclosure cycle is interrupted.

In the event of simultaneous trips (before the opening of 52), the units with reclosure permission are taken into account in order start the reclosure cycle.

Additionally, the trips which force the recloser to enter a block are also checked.

If consecutive trips are produced in different units, the relay reviews the tripped units’ masks and allows as many reclosures as correspond to the minimum number allowed for the units involved.

That is, if the minimum number of reclosures is set to 3, reclosures 1, 2 and 3 are allowed.

Once the number of permitted cycles has been exceeded, a new trip causes the recloser to enter “Definitive trip block”.

Reclosable trips

These are trips that are capable of initiating the reclosure cycle is programmed accordingly. In general, they are trips corresponding to the overcurrent and distance units, as well as the external trip inputs and the configurable reclosable trip input.

Each trip’s programming options are:

- Reclosure following a trip set to YES

In order to allow reclosure following a specific trip type, the reclosure permission settings must be set to “YES”.

If various units issue a trip order during a fault and at least one of the tripped units has reclosure permission, the reclosure cycle is initiated, unless one of the units is set to produce a 79 block.

- Reclosure following a trip set to NO

If, in the event of simultaneous trips, reclosure is not to be produced by a specific unit but rather the units with permission are to have precedence, i.e., the reclosure cycle is to be initiated.

The logical “configurable reclosable trip” input allows any internal signal to be assigned as the cause of a reclosure. It allows reclosure for any external cause (including the breaker status).

Likewise, there are various unit block inputs (for status and for pulses), thus making it possible to transfer any signal that is to be used to avoid the reclosure to this input.

Non-reclosable trips

If a non-reclosable trip is produced (27, 59, 59N, 81, 81R), the reclosure unit will not launch the reclosure sequence for this cause and, depending on whether the reclosure block mask has been set to YES, it will force the recloser to enter the definitive trip status.

If the trip does not open the breaker (because it has not given rise to the general trip), the recloser will remain in its current status.

Non-reclosable unit’s can be made to produce a reclosure by means of the connection to the trip output corresponding to the “configurable reclosable trip”.

Recloser block due to trip

This is used when a specific unit is not to produce a reclosure following a trip and when this unit is to prevail over those with permissions in the event of simultaneous trips.

If this mask is not used, two units may trip simultaneously and the 79 may reclose due to one of the units being reclosable.

In the event of the non-reclosable unit tripping on its own, the breaker will open and remain in a block status.

In addition to these masks, the relay has logic inputs that allow the recloser to be blocked. Through the logical assignment of internal signals to these inputs, the user can modify the operation of the recloser.

Each protection unit has an independent setting which is used to enable or disable this unit’s reclosure due to trip permissions. The reference is “ReC1Perm”. The setting is configured as a bit field where each bit corresponds to a selection, indicating the integer value:

Bit meaning (2)	Bit	Value
Reclosure permission 1	0	YES/NO
Reclosure permission 2	1	YES/NO
Reclosure permission 3	2	YES/NO
Reclosure permission 4	3	YES/NO

The PacFactory has a drop-down menu showing the possible combinations.

An example of use with reclosure permissions 2 and 4 would be the decimal value 10 (1010 in binary), broken down into:

Bit	3	2	1	0
Value	1	0	1	0

The maximum permitted value with all permissions enabled is 31 (1111 in binary).

Table 106 Reclosure permissions following trip (in each protection node)

Data	Parameter	Min.	Max	Step	Remarks	Type
ReclPerm	Reclosure permission	0	8191	1		Int32

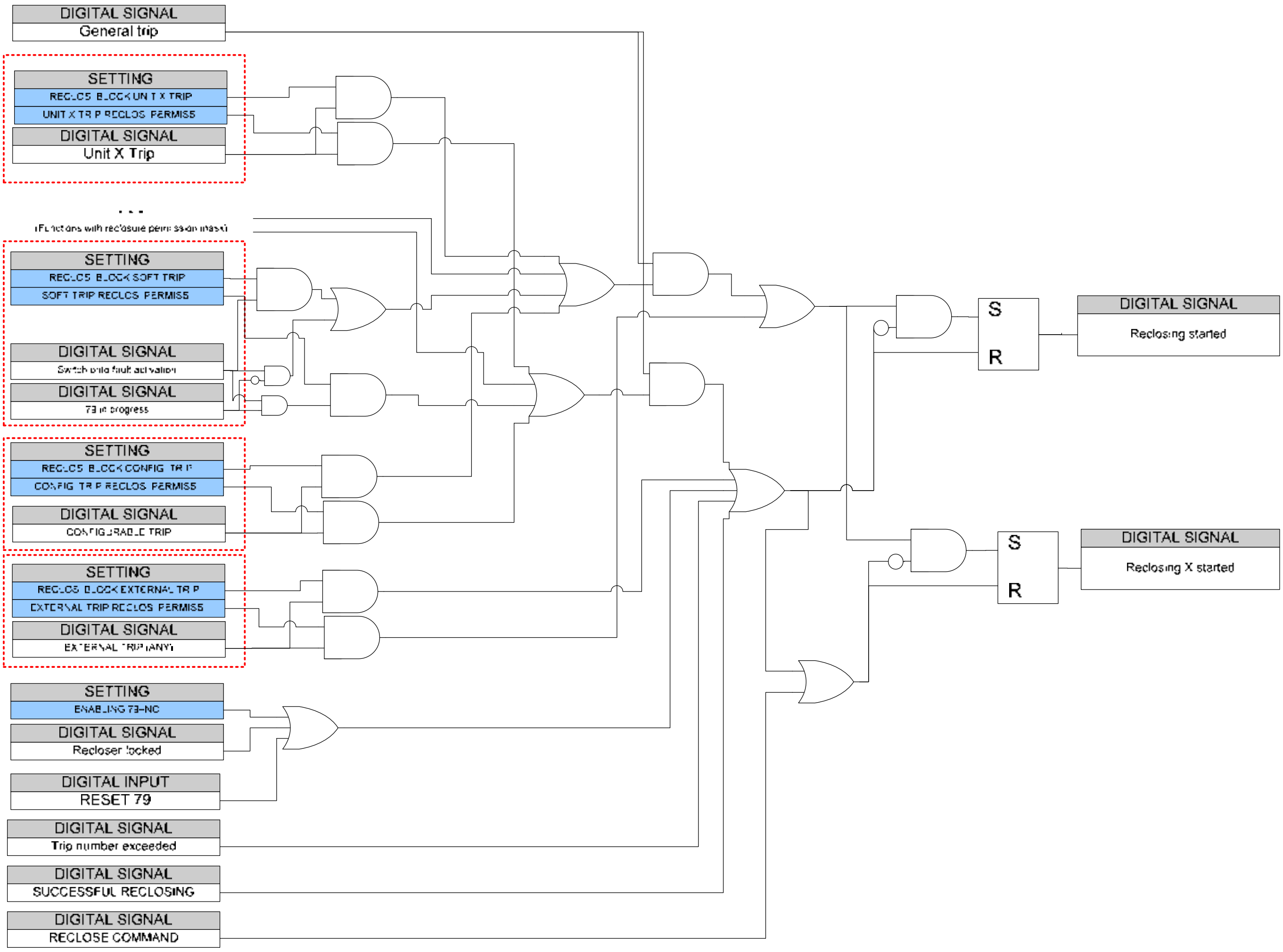
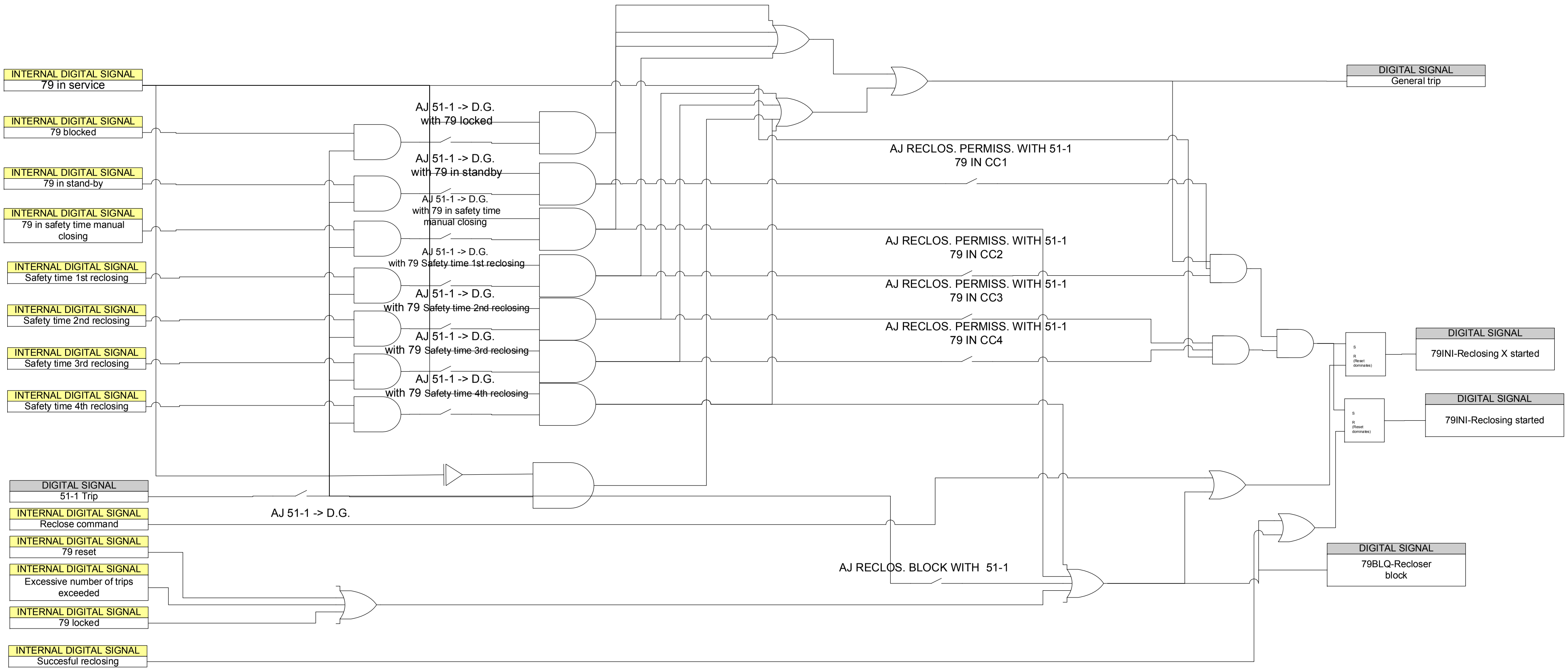


Figure 85 Example of trip and reclosure permission operation



5.2.6 Fault type selection

Depending on which unit has provoked the initiation of the reclosure process, the reclosure time to elapse before the generation of the reclosure signal, as well as the reclaim time following the reclosure, is selected.

Trips by units

Depending on the type of trip produced, there are 2 types of reclosure:

- Reclosure following a grounding fault. These involve at least one of the neutral units (neutral, sensitive neutral or grounding units)
- Reclosure following a fault between phases (the rest).

If reclosable trips from several units coincide with the same fault, the reclosure and reclaim times are employed in accordance with the first reclosable trip to take place.

External trips

Includes the following signals:

- DPE - External protection trip: Can be three-phase or not. It is equivalent to an external trip by pole OR.
- DPR-Reclosable programmable trip. An internal signal which is wired for logics and whose activation allows the reclosure cycle to be initiated.

If a “DPE-External trip” or “DPR-programmable trip” input signal is activated, the time to be employed is the time corresponding to faults between phases.

Upon the opening of the breaker and once it has been determined whether the fault is a grounding fault or a fault between phases, a reclosure time that is programmed in accordance with the chosen setting (phases or grounding) is launched.

5.2.7 52 break timeout

Once the relay has tripped (activation of the general trip), the breaker is to open (by contact) and the trip is to disappear within the opening fault time. If the breaker does not open or if the relay remains tripped (general trip activated) upon the conclusion of this time, “opening failure block” is entered.

If during this programmed period of time the breaker opens and the trip drops off, the ongoing cycle is initiated and the “79CC-Ongoing cycle” signal is activated.

This signal will remain active until the cycle terminates upon its completion and a standby or block status is entered.

If the 52 NO and NC inputs are programmed, the 52b (NC) will be taken into consideration to detect the opening. If only the 52a (NO) input is programmed, this signal at zero will be used as an open status.

5.2.8 Number of reclosures available

The total number of reclosures can be selected by settings.

The reclosures which are to be possible following the tripping of a specific unit can also be selected.

The enabling of the corresponding R1, R2, R3 and R4 permission mask is checked with each trip. If they are not enabled, the reclosure cycle is interrupted.

In the event of simultaneous trips (before the opening of 52), the units with reclosure permission are taken into account in order start the reclosure cycle.

Additionally, the trips which force the recloser to enter a block are also checked.

If consecutive trips are produced in different units, the relay reviews the tripped units’ masks and allows as many reclosures as correspond to the minimum number allowed for the units involved. That is, if the minimum number of reclosures is set to 3, reclosures 1, 2 and 3 are allowed.

Once the number of permitted cycles has been exceeded, a new trip causes the recloser to enter “Definitive trip block”.

All the trips (reclosable, non-reclosable and block) are checked up to the moment in which the breaker opens.

Any block trips which appear are sent directly to a blocked recloser.

If there are only reclosable trips, the reclosure cycle is begun with the time of the first reclosable produced by the trip.

Examples of operation.

The total number of reclosure cycles is set to 4.

Example 1:

- Unit 50 trips (with R2 reclosure permission) 79 does not reclose as the reclosure permission is not allowed in CC1 79 would enter “Internal Block-Definitive Trip”

Example 2:

- 52 is closed and reclaim time following manual closure is initiated.
- Unit 51N trips (with R1 and R2 reclosure permission). 79 recloses with “reclosure time for grounding faults 1”.
- With 52 closed, and while “reclosure time for grounding faults 1” is running, unit 50 trips (with R2 and R3 reclosure permission) Reclosure R2 is not performed with the “reclosure time for faults between phases 2".
- There follows a new trip by 50 during the “reclaim time for phases 2”. A reclosure with “reclosure time for faults between phases 3” would take place.
- There follows a new trip by 50 during the “reclaim time for phases 3”. 79 does not reclose as reclosure R4 is not permitted. 79 would enter “Internal Block-Definitive Trip”

Example 3:

- While in standby, a 50 trio with R1 permission is produced and, before 52 opens, another 50N with R2 permission, programmed without blocking, trip is produced.

In this case, the 50 trip would take precedence, provoking the reclosure cycle.

Example 4:

- While in standby, a 50 trio with R1 permission is produced and, before 52 opens, another 50N programmed with blocking trip is produced.

In this case, when the 50N trip is produced and the breaker opens, the reclosure cycle would be interrupted and “Internal Block-Definitive Trip” would be entered.

5.2.9 Reference voltage monitoring

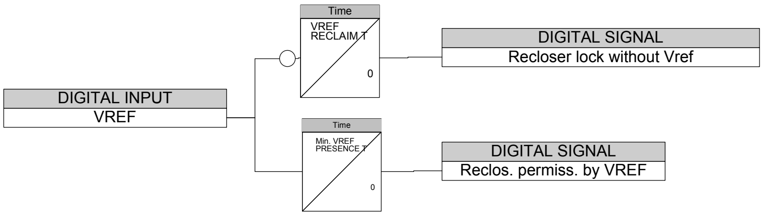
This is used to wait for the activation of an external signal before allowing a reclosure. For example, to wait for the disappearance of the line voltage following a trip (if there were motors or batteries connected to the line) or for a specific network condition (power fluctuations, etc).

This monitoring is equivalent to a pause signal that halts the reclosure cycle during the VREF timeout.

It operates as follows:

- Once the breaker has opened and the trip has dropped out, the reclosure cycle is initiated and the reclosure time is launched.
- In the absence of VREF, “VREF timeout” is launched, during which the VREF signal should be activated to allow the continuation of the reclosure process.
- If the VREF signal does not appear prior to the elapse of this time, the internal 79 block due to absence of VREF” status is entered.
- This status is cancelled by means of a closure or following the activation of the recloser reset input.

Figure 86 Reference voltage monitoring scheme



5.2.10 Re-initiation of reclosure time

The digital “Pause with reclosure reinitiation” input is used to reset the reclosure time counter to zero.

When the “Pause with reclosure reinitiation” input is activated, the recloser time counter (dead time) is reset to zero and the 79 is halted until this input is cleared.

When this input is deactivated, the reclosure time count is restarted.

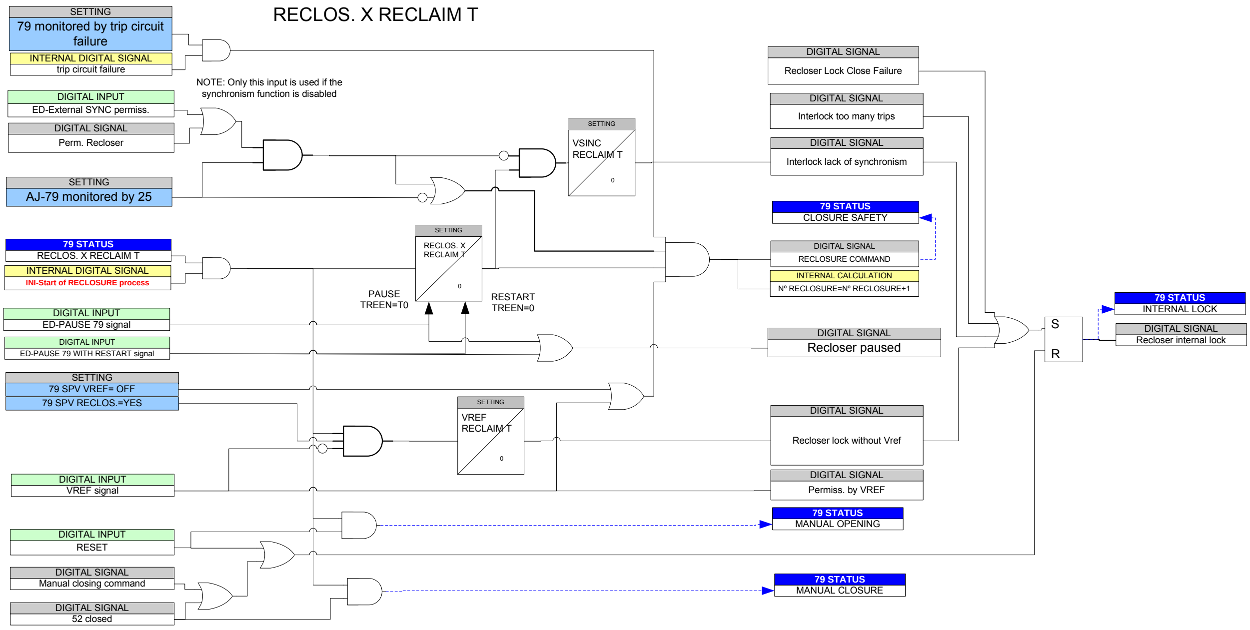
5.2.11 Pausing of reclosure time

The digital “Recloser pause” input is used to pause the reclosure time counter.

When this input is activated, the reclosure time counter (dead time) is halted until this input is cleared.

When this input is deactivated, the reclosure time count continues.

Figure 87 Reclosure time with pause and restart scheme

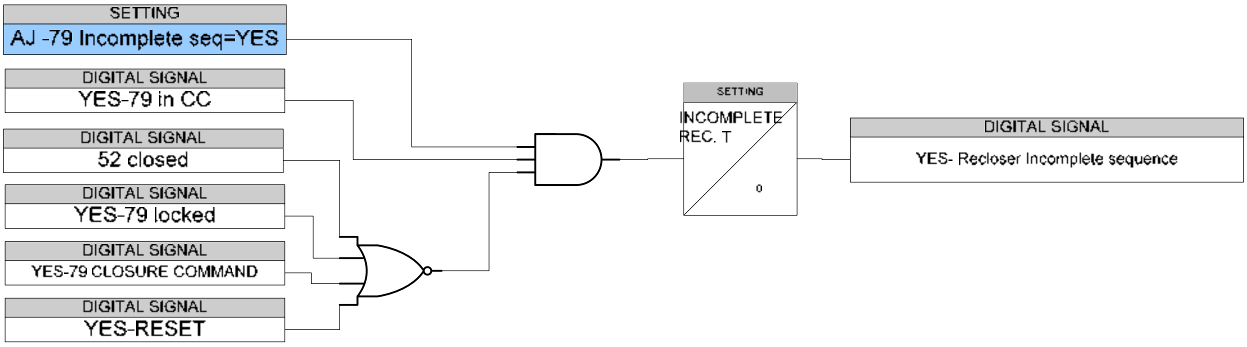


5.2.12 Incomplete sequence block

The two pause inputs can be used to wait for a certain signal, although the cycle can be extended indefinitely. It is thus important to prevent the recloser from remaining permanently in the current cycle.

This timed is used to check that the recloser has exceeded a defined time without issuing a closure command nor becoming blocked or resetting, thus causing the recloser to enter a block by incomplete sequence status.

Figure 88 Block by incomplete sequence scheme



5.2.13 Synchronism monitoring

If a specific reclosure is set to "monitored by synchronism" and once the reclosure time has elapsed, there is a maximum timeout equivalent to the "synchronism timeout" setting in which the "synchronism permission" signal is to activate. Upon the issue of the synchronism permission the reclosure command is activated.

If synchronism permission is not activated, the "Block due to lack of synchronism" status is entered.

The first and the rest of the reclosures can be set to monitoring by synchronism by means of a setting. This allows the first reclosures to be carried out quickly and without the need to check for synchronism, in the case of specific faults, and normal reclosures for the rest.

Settings can be used to establish whether the synchronism is to check the relay's functioning or that or an external input.

There is a setting within the synchronism unit to enable monitoring by synchronism for the recloser and for manual closing. As they are independent settings, by disabling function 25 it is possible to monitor the reclosure with the external synchronism input.

5.2.14 Closure block by trip circuit monitoring

If the closure block by trip circuit monitoring is set to YES, when the reclosure command is activated while the trip circuit monitoring logic's "trip circuit failure" signal, the closure command is not received and "Internal block due to failure in the SPV trip circuit" is signalled.

This status is cancelled by the manual closure of the breaker following the elapse of the reclaim time.

5.2.15 52 closure timeout

Once the relay has issued a reclosure command (Activation of the 79 output-reclosure command), the breaker should close during the closure failure timeout (by contact), If the breaker has not closed upon the conclusion of the timeout, "79 block due to closure failure" s entered and the reclosure command is deactivated.

This status is cancelled by means of a manual closure.

If the 52 NO and NC inputs are programmed, the 52b (NC) will be taken into consideration to detect the closure.

If only the 52b (NC) is programmed, this denied signal will be used.

5.2.16 Recloser statuses

During its operation, the recloser enters through various statuses that are grouped together as stables and transitory.

5.2.16.1 Stable statuses

The "Recloser" function has 5 stable statuses, i.e., statuses in which it can remain indefinitely until something occurs to cancel the status. They are:

- Out of service.
- Supervising, standby or reset.
- Manual opening.
- Internal block. Includes the Definitive trip.
- External block.
- Reclosure successful

5.2.16.1.1 Out of service

It will be placed out of service by settings (Enabled NO).

If it is in service, it can be placed out of service by pressing the R key on the keyboard or by means of a command.

This status is exited when the function is enabled by a setting or command (R key or command). The transitory manual closure setting is entered if the breaker is closed at this time. If the breaker is open, internal block (due to manual opening) is entered.

The functioning is similar when the relay lights and the reclosure setting is set to YES.

5.2.16.1.2 Supervising or standby

This is the normal status, during which the recloser "monitors" for the occurrence of any trips. If any trips occur, the recloser is activated.

This status is entered:

- Whenever the breaker is closed for a period that exceeds the reclaim time (following a manual closure or following a trip).
- If the block signal is cleared when the breaker is closed and in the external block status.

This status is exited:

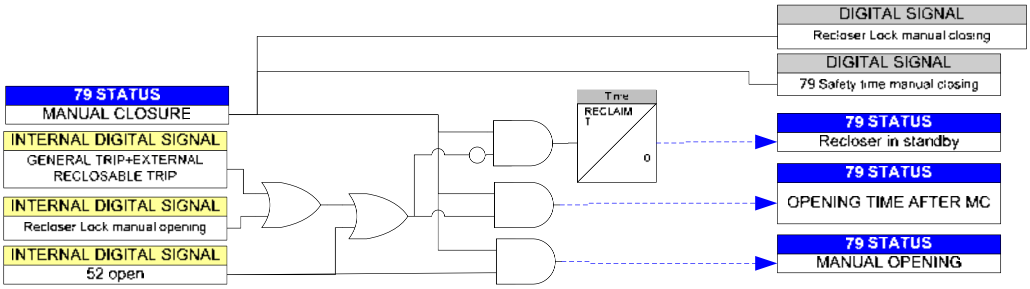
- By the action of the protection and the subsequent opening of the breaker. If reclosure is to follow, the cycle is initiated. If not, Definitive trip is entered.
- Due to the manual opening of the breaker. Manual Opening is entered.

5.2.16.1.3 Manual opening

This status is entered by a manual opening command (by command, contact or other causes, but not by a trip).

This status is cancelled when the 52 is closed manually (by command, contact, etc., by not by reclosure).

Figure 89 Manual opening



5.2.16.1.4 Internal block

There is a general internal block status with different signalling, in accordance with the cause. This status is entered as result of different causes:

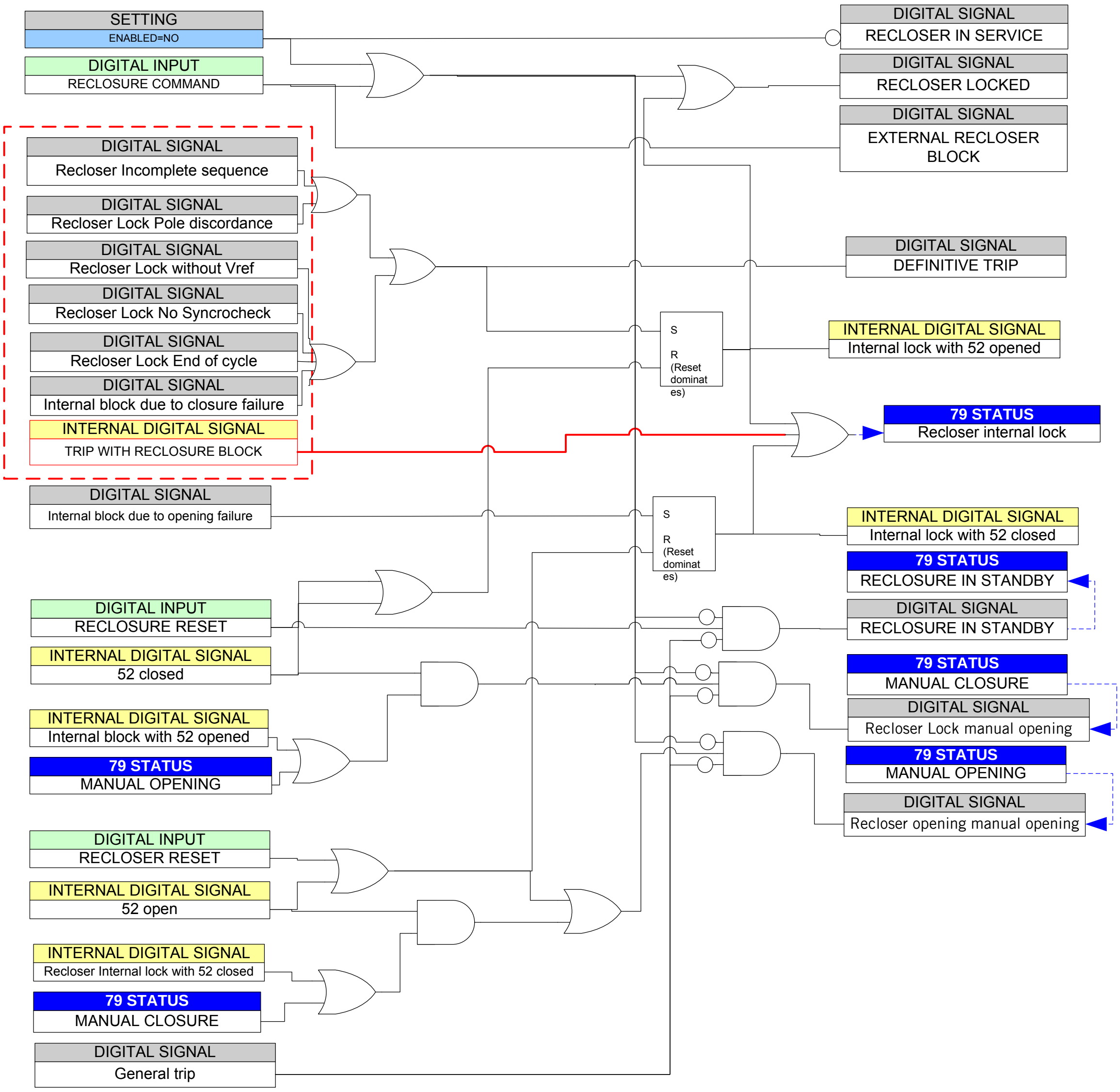
- Opening failure
- Closure failure
- Manual opening
- Three-phase Trip
- Definitive trip
- Incomplete sequence

The reclosure cycle is not started in this status. The cycle is abandoned if it has already been started and Definitive Trip is signalled if the breaker has opened as a result of a protection trip.

This status is cancelled by the closure of the breaker following the elapse of the reclaim time.

In all cases, a generic “internal block” signal is activated, in addition to a specific signal identifying the cause of the block. In those cases where the block status occurs after a trip and the opening of the 52, “definitive trip block” is also indicated.

Figure 90 Block scheme



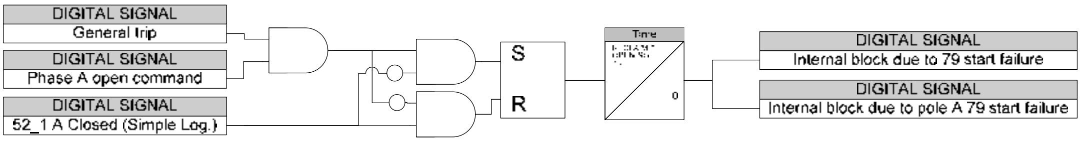
Internal block as a result of an opening fault

This status is entered if, following the elapse of the breaker fault time after a trip, any of the following conditions are met:

- ❑ The trip has not dropped out
- ❑ The breaker remains closed

This status is cancelled when the breaker opens or by the reception of a closure command (if the 52 opens). The opening failure time is the same as that of the opening fault with contact function.

Figure 91 Opening failure block scheme



Internal block as a result of a closure failure

This status is entered of any of the following conditions are met:

- If the breaker remains open following the elapse of the breaker closure failure time after a closure command. “Definitive trip” is also signalled.
- If the trip circuit failure block is enabled. If, when activating the closure command, the command activates the trip and closure circuits’ monitoring logic’s "trip circuit failure” signal, the closure command is not issued and “closure command blocked" is signalled. Following the elapse of the closure failure time, the block by closure failure status is entered.

This status is cancelled by the manual closure of the breaker following the elapse of the reclaim time.

Internal block by open breaker (manual opening)

This status is entered by a manual opening or by means of a breaker command when the 79 is in standby or in a current cycle.

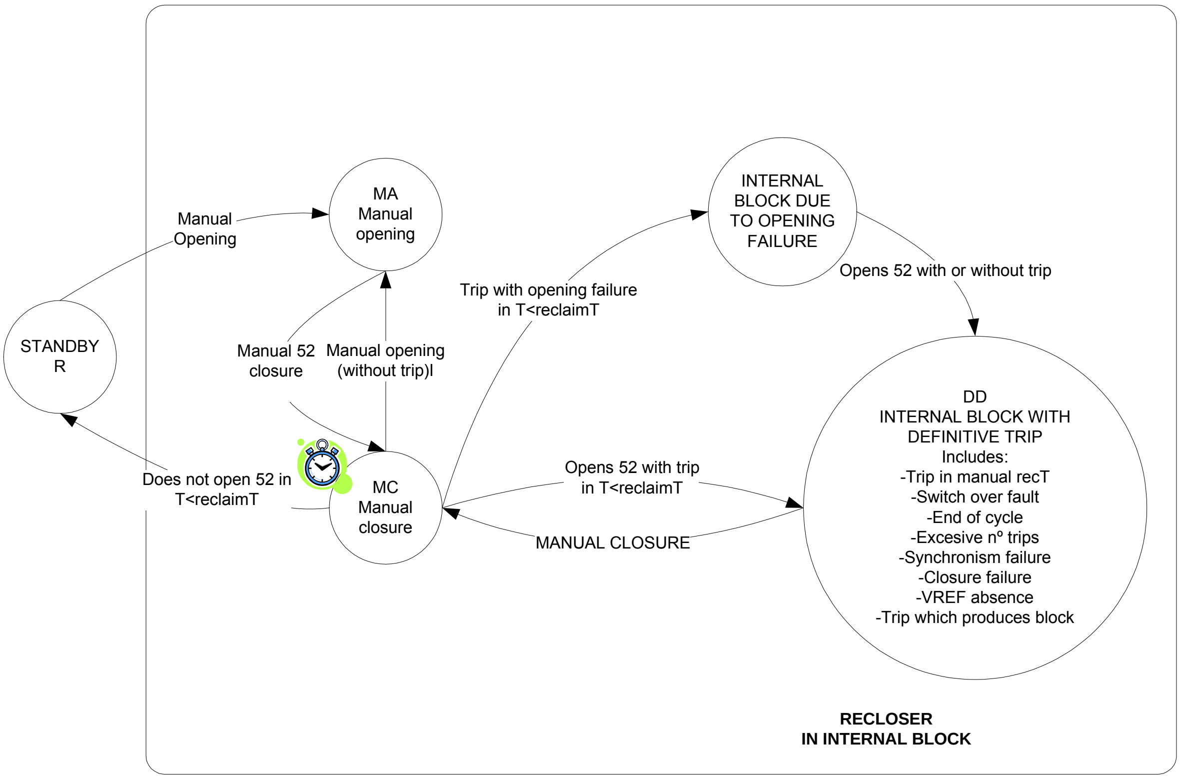
It is cancelled by a manual breaker closure. The transitory Manual Closure status is entered.

Definitive trip

This status is activated following a trip that fails to produce a reclosure due to a 79 block or for having reached the end of the cycle with the fault intact:

- Because a trip is produced within a period that is inferior to the reclaim time following a manual breaker closure.
- Because a trip is produced in a period that is inferior to the reclaim time following the last reclosure.
- Because a protection trip is produced while the block status is active.
- Because an excessive number of trips is produced within a defined time.
- Because the recloser does not issue a closure command due a voltage monitoring failure (synchronism).
- Because the recloser issues a closure command and the recloser does not close in the closure failure time.
- Because the recloser does not issue a closure command due to an interlock (for example, a trip circuit failure) and the recloser does not close in the closure failure time.
- Because the voltage presence conditions are not met during a current cycle.
- If a trip does not produce a reclosure due the programming of a block (with the block taking precedence over other functions with permissions) or the absence of the programming of a reclosure (unless there is another function with reclosure permission trips simultaneously).
- A switch onto fault function trip following a manual closure.
- By incomplete sequence.
- This status is cancelled by one of the following causes.
- Manual breaker closure, following which the transitory MC (Manual Closure) status is activated.
- Reception of recloser’s reset input.

Figure 92 Internal block statuses diagram



Incomplete sequence block.

See the “Incomplete sequence block” section.

5.2.16.1.5 External block

This status is activated by:

- Activation of the recloser’s logical block input.
- Reception of a block command. There are block and unblock commands.

No cycles are started while the block is active and any cycles which had already been started are terminated. “internal 79 block”, “external 79 block by communication” or “external 79 block by input” is signalled. “Definitive trip + Trip & extern.block” is also signalled if the breaker has been opened by a protection trip (general trip) or by an external protection.

5.2.16.1.6 Successful reclosure

Successful reclosure is signalled when, following the issue of a closure command and the closure of the three 52 poles, the reclaim time elapses without a new trip being produced.

The “successful reclosure” signal is activated and remains so until the relay trips once again.

5.2.16.2 Transitory statuses

Those statuses in which the system can not remain for longer than a specific time.

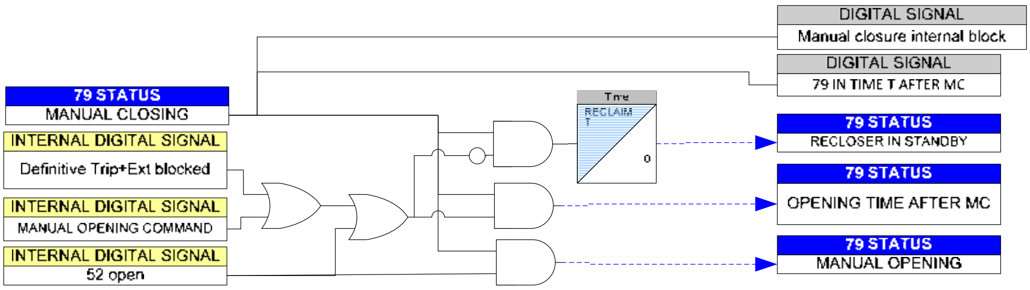
5.2.16.2.1 Manual closure

This status is activated as a result of a manual breaker closure or by means of a command (not be reclosure), independently of whether a cycle is in progress. It maximum duration is equivalent to the reclaim time following manual closure.

This status is cancelled by one of the following causes:

- Due to the manual opening of the breaker. An internal block due to manual opening is activated.
- Due to the action of the protection. An internal block due to definitive trip is activated.
- Following the elapse of the reclaim time. Standby is activated.
- Due to the activation of the external block input or block command. An external block is activated.
- Due to the action of the protection following an opening failure (52 does not open or the unit remains tripped). An internal block due to an opening fault is activated.

Figure 93 Reclaim time following manual closure



5.2.16.2.2 First closure. Phase 1: Timed.

This is reached at the start of the cycle. Its maximum duration is equivalent to the first closure time. If monitoring by synchronism is activated, the synchronism timeout is added, if there is no synchronism upon the termination of the reclosure time count.

At the same time as the closure time count, the monitoring by VREF (during a maximum “VREF timeout” period) and by synchronism.

This is cancelled by:

- Manual breaker closure. “Internal block” is activated and “Temporary block by manual closure” is signalled.
- Following the elapse of the reclosure time. Phase 2 of the closure is entered.
- Activation of the external block input. “External block” is activated.
- Failure to meet the reference voltage (VREF) monitoring conditions. An internal block is activated and Internal block due to absence of VREF and Definitive trip is signalled.
- Failure to meet the synchronism monitoring conditions. An internal block is activated and Internal block due to synchronism fault and Definitive trip is signalled.

Figure 94 Reclosure line scheme

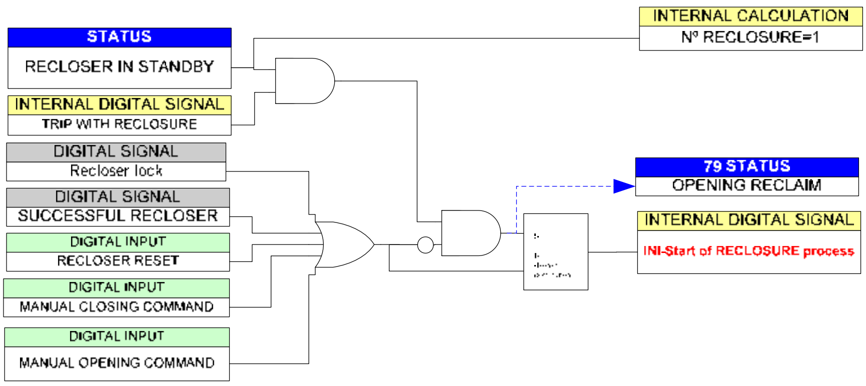


Figure 95 Opening timeout scheme

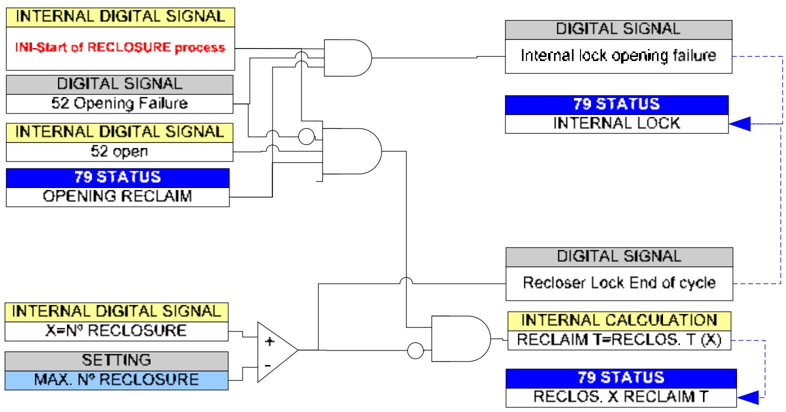
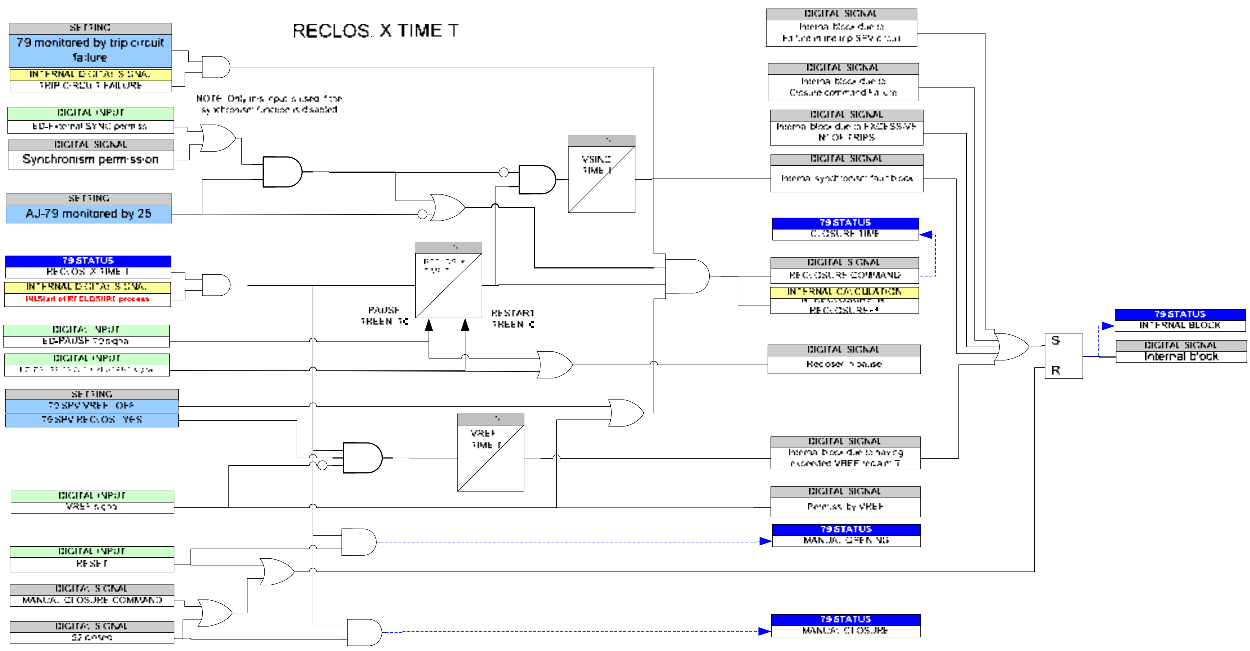


Figure 96 Reclosure timeout scheme



5.2.16.2.3 First closure. Phase 2: closure command.

This is reached once the first closure timed is complied with. It activates the closure command and increments the closures meter.

It is cancelled:

- Because the breaker has closed in the permitted time. Phase 3 entered.

- Because the permitted time has elapsed without the closure of the breaker. An internal block is activated and "Internal block due to closure failure" and "Definitive trip" is signalled. The relay's Breaker failure due to contact signal is also activated.

5.2.16.2.4 First closure. Phase 3: breaker closure.

This is reached following the closure command issued in phase 2 when the breaker has closed. It maximum duration is equivalent to the reclaim time following automatic closure. It deactivates the closure signal.

It is cancelled:

- Due to the manual opening of the breaker. "Internal block" is activated and "Internal block by manual opening" is signalled.
- Due to a protection trip. The second reclosure process is entered, phase 1.
- Because the block time has elapsed without the opening of the breaker. Standby is activated.

A low current permanent fault may cause tripping following the elapse of the safety period. To avoid, in the event of all the reclosures being first reclosures and no definitive trip is produced, the automatic extension of the timeout due the pick up of a unit capable of producing a reclosable general trip in standby ("Trip permission with 79 in standby" set to YES) until reset or a trip is produced.

Figure 97 Closure scheme

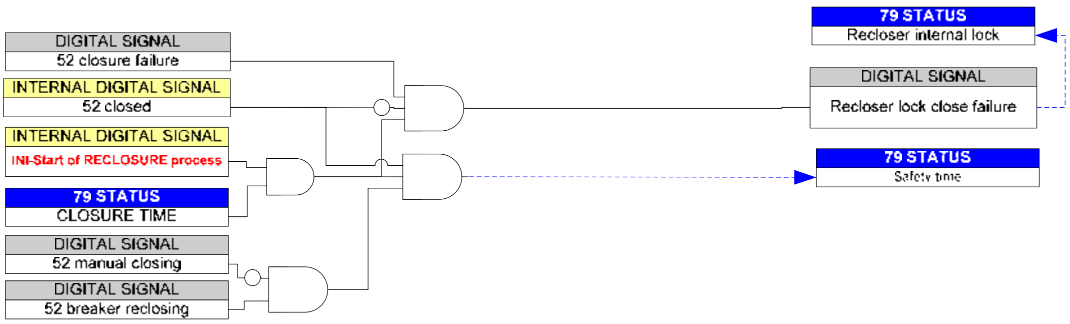
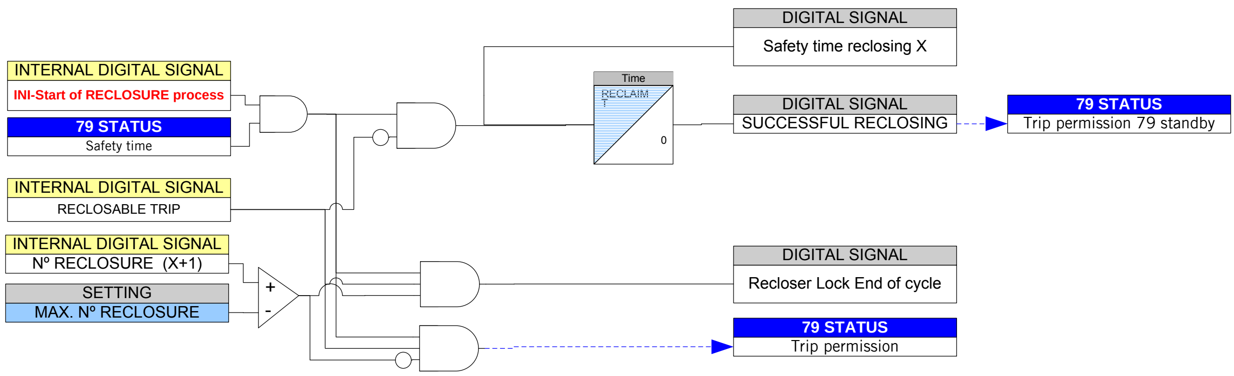


Figure 98 Timeout following closure scheme



5.2.16.2.5 Second closure.

This is reached as a result of protection trip in the timeout following the closure originated by the first closure. Its functioning (phases, activated relays, etc.) is the same as that of the first closure.

5.2.16.2.6 Third closure.

This is reached as a result of protection trip in the timeout following the closure originated by the second closure. Its functioning (phases, activated relays, etc.) is the same as that of the first closure.

5.2.16.2.7 Fourth closure

This is reached as a result of protection trip in the timeout following the closure originated by the third closure. Its functioning (phases, activated relays, etc.) is the same as that of the first closure, with the exception that if a protection trip is produced within the block time the definitive trip status is activated. In this case, the end of the cycle is reached.

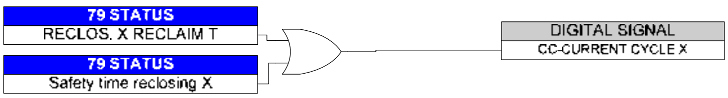
5.2.16.2.8 Ongoing cycle

The status of the recloser while activated, from the first trip and the opening of the breaker up to the closure of the breaker and the elapse of the safety period (successful reclosure), or until all the programmed reclosures have been unsuccessfully executed. In the first case, the recloser switches to “supervising” and, in the second, to “definitive trip”

If, during the operating cycle, a manual order (or command) is given to the circuit breaker, the recloser suspends the cycle and switches "internal block due to manual opening" or "manual closure".

These same applies if a reset signal is received.

Figure 99 Ongoing cycle scheme



5.3 FREQUENCY RECLOSER

The unit, following a minimum frequency trip and in the case of the function having been enabled and not locked, will only attempt one reclosure.

When the trip occurs, the 79f-breaker closure lock signal is activated and the period programmed as the “definite trip timeout” is observed. If the minimum frequency condition is set to “NO” or if the frequency is higher than the minimum programmed value during the programmed “closure time”, a closure command is issued to the breaker. If the minimum voltage condition is set to “YES” and is not met, the definitive trip is activated.

The 79f-breaker closure block will remain active until the reclosure or definitive trip conditions are met.

If the “Enab. maximum reset time” is set to “YES” and the programmed “maximum reset time (s)” elapses without the reclosure conditions having been met, an internal block due to failure to meet conditions (with definitive trip) is activated. If the setting is set to “NO”, the reclosure conditions are waited for indefinitely.

A “reclaim time” is observed following the closure. If a new minimum frequency trip occurs during this period, it moves to internal block with definitive trip.

The frequency recloser’s general operation is shown in Figure 100 to Figure 107.

The settings used in this unit are shown in Table 107:

- Enabled. Indicates whether the function is enabled or not.
- Minimum frequency monitoring. Indicates whether the minimum frequency monitoring is enabled or not.
- Minimum reset time (Hz). Indicates the minimum frequency above which reset permission is given.
- Reset time (s). Indicates the time during which the reset conditions must be met in order for the reset command to be issued.
- Reclaim time after closure. Indicates the timeout following a reset command. No trips must be produced during this time in order for the reclosure to be considered as successful. If a trip is produced, an end of cycle block is activated.
- Enab. maximum reset time. Indicates whether the maximum reset time limit is enabled.
- Maximum reset time (s). Indicates the maximum timeout in which the reset conditions are to be met. To the contrary, a block due to the absence of reset conditions is generated.
- V minimum monitoring enabled. Indicates whether the minimum voltage monitoring is enabled or not.
- Minimum closure voltage. Indicates the minimum voltage above which reset permission is given.
- Synchronism monitoring. Indicates whether the synchronism conditions check is enabled or not.

- Reset function block Logic input, which selects the signal which, when active, blocks the frequency recloser.
- Trip with reset (start). Logic input, which selects the signal which, when active, indicates that a trip with reset has been produced.
- Reset function block. Logic input, which selects the signal which, when active, resets the frequency recloser.
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

Table 107 Frequency recloser settings

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
FRecEna	Enabled				NO (0) / YES (1)	enum
FminEna	Minimum freq. monitoring				NO (0) / YES (1)	enum
FminVal	Minimum reset f (Hz).	40	70	0.1		float
RepTms	Reset time (s)	1	3600	1		Int32
SegTms	Reclaim time after closure	1	600	1		float
ReTmLiEna	Enab. maximum reset time.				NO (0) / YES (1)	enum
MaxReTms	Maximum reset time (s)	0	86400	1		Int32
VRecEna	V minimum monitoring				NO (0) / YES (1)	enum
VrecVal	Minimum closure voltage	0	200	0.1		float
VSynEna	Synchronism monitoring				NO (0) / YES (1)	enum
LogInBlk	Reset function block	-1	99999	1		Int32
LogInTr	Trip with reset (start)	-1	99999	1		Int32
LogInRst	Reset function block	-1	99999	1		Int32
MaskEna	Protection event recording enabled	0	1	1		Boolean

It has independent settings, commands and outputs:

- PROT/FRREC1 node
- Settings. There are 6 settings tables. See Table 107.
- There are no commands
- Outputs: Table 108 shows the function’s output data.
  - Start reclosing F_RREC
  - Current Cycle F_RREC
  - Successful Reclosing F_RREC
  - Reclosing in Safety time F_RREC
  - Finally Interlock Cycle F_RREC
  - Interlock clousure failure F_RREC
  - Interlock opening failure F_RREC
  - Interlock absence reset cond. F_RREC
  - Permission reclosing F_RREC
  - Reclosing Order F_RREC
  - Reclosing Blocked F_RREC
  - Final Trip F_RREC

Table 108 Frequency recloser outputs

Signal	Data	Attribute
Start reclosing F_RREC	RecInit	general
Current Cycle F_RREC	RecCyc	general
Successful Reclosing F_RREC	ClOK	general
Reclosing in Safety time F_RREC	SecTime	general
Finally Interlock Cycle F_RREC	BlkCycEnd	general
Interlock clousure failure F_RREC	BlkClFail	general
Interlock opening failure F_RREC	BlkOpFail	general
Interlock absence reset cond. F_RREC	BlkNoCond	general
Permission reclosing F_RREC	Fperm	general
Reclosing Order F_RREC	FClOrd	general
Reclosing Blocked F_RREC	FRecBlk	general
Final Trip F_RREC	DefTrip	general

Figure 100 Trip with reset scheme

Figure 101 Process start scheme

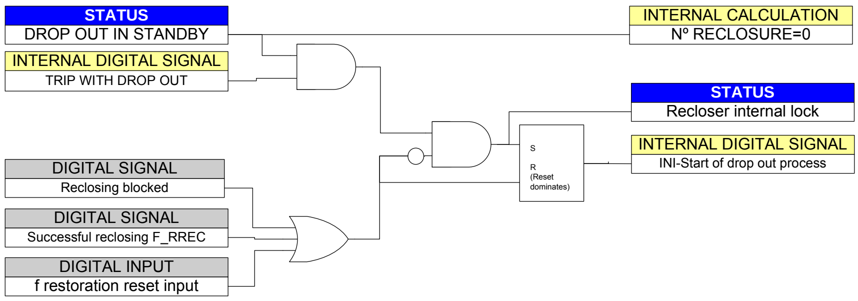


Figure 102 Opening timeout scheme

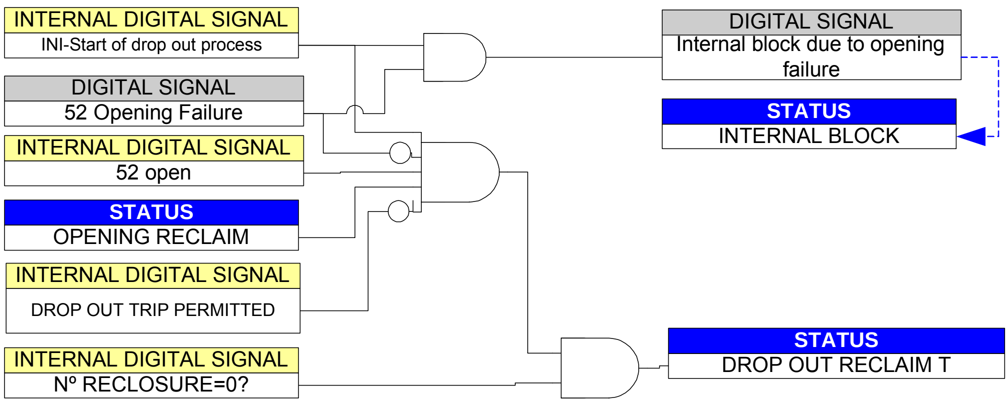


Figure 103 Reset permission scheme

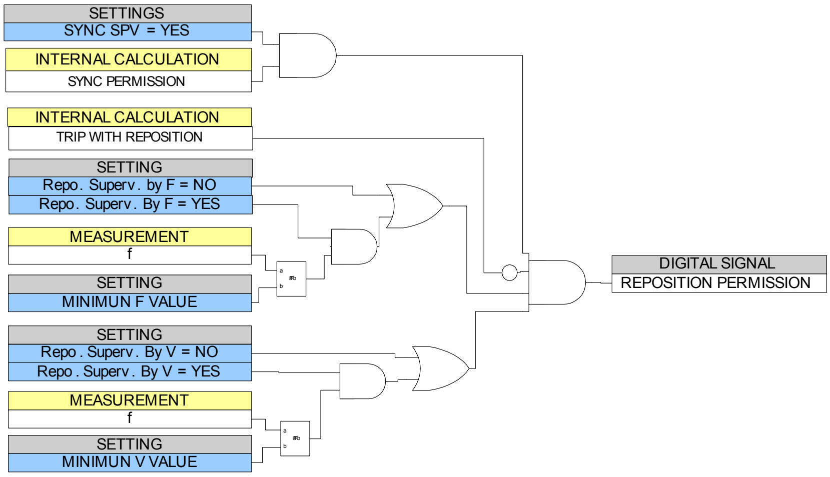


Figure 104 Reset command scheme

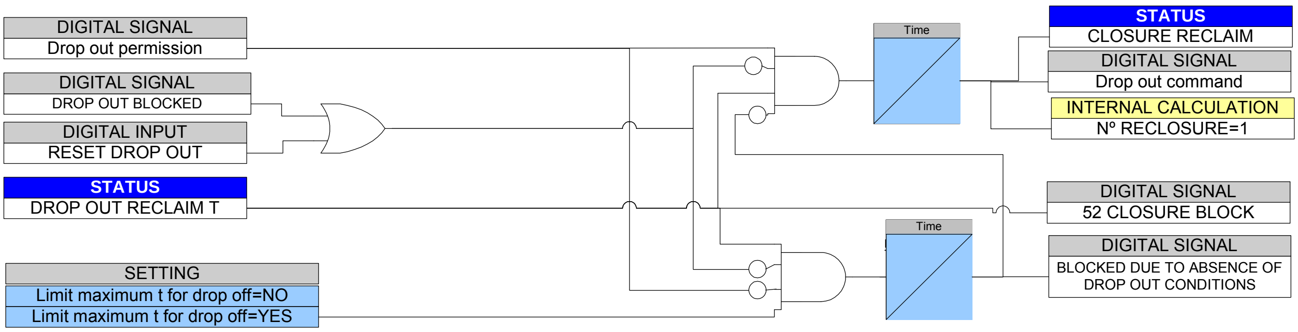


Figure 105 Reset timeout scheme

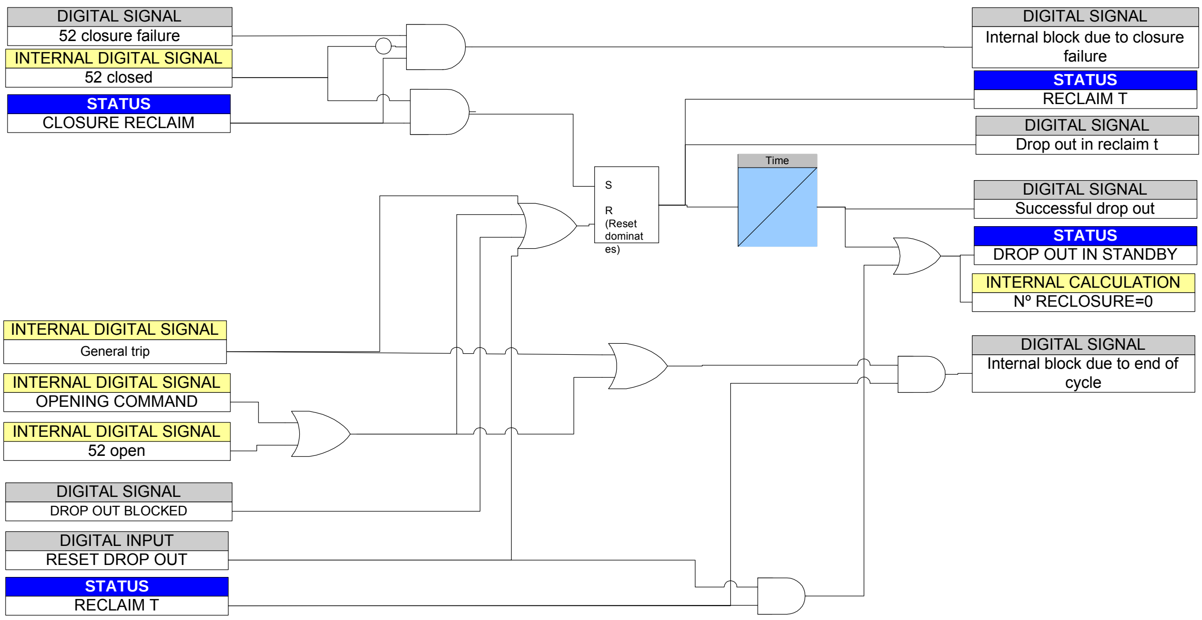


Figure 106 Start scheme

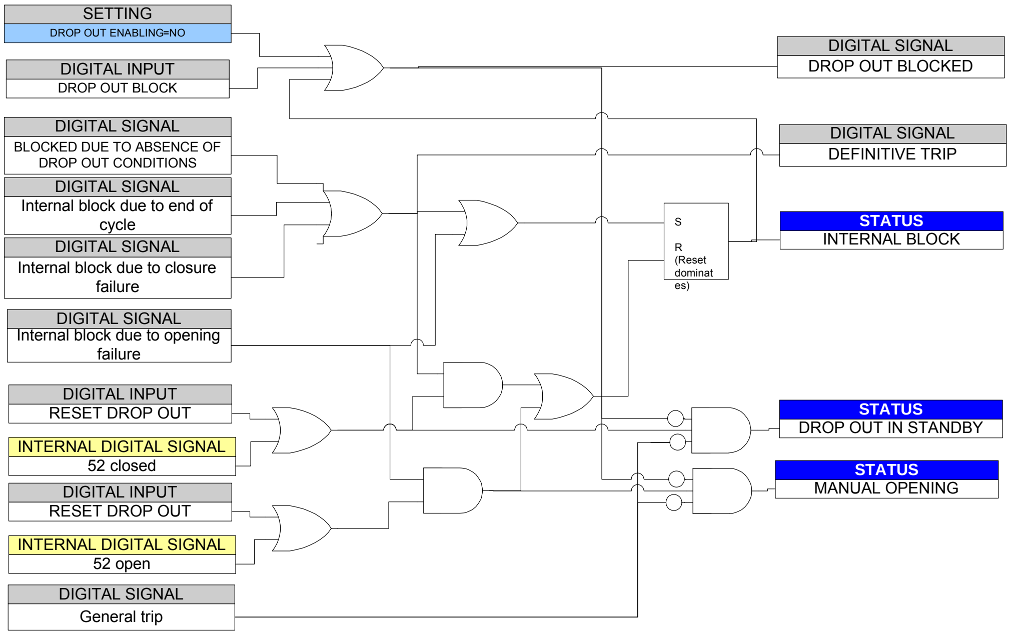
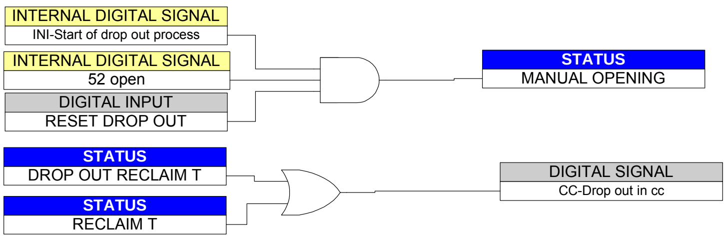


Figure 107 Frequency recloser signals



6. FAULT LOCATOR

The fault locator for single and double lines processes the information collected in relation to each fault and calculates the estimated distance to the point in which the fault has occurred, as well as the fault resistance.

The initial data necessary in order to arrive at the final calculation are:

- Sample by sample values of the voltage and current signals collected in the moment in which the fault is produced.
- The impedance parameters of the line in which the fault has occurred.
- Length of the line.
- The Tts and Tis transformation ratios of the bay that captured the fault.

The result is the distance to the fault in km, together with fault resistance and a locater finalization code.

The node corresponding to the locator is PROT/RFLO.

The settings necessary for the operation of the distance calculation algorithm are as follows (see Table 109):

- Enabled. Indicates whether the locator is enabled or not.
- Line length (km). Indicates the length of the line that is being protected.
- Module Z1 (ohm p.u). The line's direct sequence module by unit of length.
- Angle Z1 (°). The line's direct sequence angle.
- Module Z0 (ohm p.u)1. The line's zero sequence impedance module per unit of length.
- Angle Z0 (°). The line's zero sequence angle.
- Y1 Admittance (1/ ohm p.u)1. Imaginary part of the line's direct sequence admittance.
- Y0 Admittance (1/ ohm p.u)1. Imaginary part of the line's zero sequence admittance.
- Z1R local source (ohm). Local source direct impedance module.
- Z1R local source angle (º). Local source direct impedance angle.
- Z0R local source (ohm). Local source zero impedance module.
- Z0R local source angle (º). Local source zero impedance angle.
- Z1S remote source (ohm). Remote source direct impedance module.
- Z1S remote source angle (º). Remote source direct impedance angle.
- Z1eq Parallel (ohm). Direct impedance module in parallel with line.
- Z1eq Parallel Ang (º) Direct impedance angle in parallel with line (º)
- Phase Sensitivity (A primaries). Minimum variation threshold in the phase current for the detection of the fault.
- Neutral Sensitivity (A primaries). Minimum variation threshold in the neutral current for the detection of the fault.
- Voltage Sensitivity (A primaries). Minimum variation threshold in the voltage for the detection of the fault.
- Maintenance Time (s). Measurement signalling maintenance time (s).
- Permanent measurement signalling. Indicates whether the distance measurement is maintained until the next fault (set to "YES") or only the seconds indicated in the "Maintenance time" setting (set to "NO").
- Line type. Allows the user to select between single line or double line.
- Z0M mutual impedance (ohm p.u)1. Mutual impedance module, by unit of length.
- Z0M mutual impedance Ang (º). Mutual impedance angle.
- Calculation filter enabled. If set to YES and the fault point is detected during the ten cycles following a breaker closure, the neutral current is checked to see whether is exceeds the "Minimum current following closure" setting. If it is, inrush is considered to exist and prefault current values equal to zero are employed in order to avoid the inrush distortion in these measurements. The neutral current is also checked to see whether is exceeds the "Maximum neutral current" setting. If it is set to "NO", neither the inrush nor the neutral current are measured.
- Minimum current following closure (A primaries). Current threshold for the detection of inrush. Only used if the calculation filter setting is enabled.

- Maximum neutral current (A primaries). Threshold indicating the system's maximum neutral current under normal conditions. Only used if the calculation filter setting is enabled.

Ohm p.u indicates ohms per unit of length. For a line length of 100 km and a line impedance of 100 ohm, the setting in ohm p.u is calculated as follows:

Ohm p.u = Line impedance / line length = 100 ohm /100km = 1 ohm p.u,

Table 109 Locator settings

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
LocEna	Enabled					Boolean
LinLenKm	Line length (km/miles).	0.1	5000	0.1		float
Z1Mod	Module Z1 (ohm p.u.)	0.0001	300	0.0001		float
Z1Ang	Angle Z1 (°)	0	359.9	0.1		float
Z0Mod	Module Z0 (ohm p.u.)	0.01	300	0.01		float
Z0Ang	Angle Z0 (°)	0	359.9	0.1		float
Y1	Admittance Y1 (1/ohm p.u.)	0	50000	0.1		float
Y0	Admittance Y0 (1/ohm p.u.)	0	50000	0.1		float
Z1LMod	Local source Z1R (ohm)	0.01	20000	0.01		float
Z1LAng	Z1R local source angle (°)	0	359.9	0.1		float
Z0LMod	Z0R Local source (ohm)	0.0001	300	0.0001		float
Z0LAng	Z0R local source angle (°)	0	359.9	0.1		float
Z1RMod	Z1S Remote source (ohm)	0.01	20000	0.01		float
Z1RAng	Z1S Remote source ang. (°)	0	359.9	0.1		float
Z1mMod	Z1eq Parallel (ohm)	0.01	20000	0.01		float
Z1mAng	Z1 eq Parallel Ang. (°)	0	359.9	0.1		float
PhsASens	Phase I sensitivity (A)	0	5000	0.1		float
NeuSens	Neutral I sensitivity (A)	0	5000	0.1		float
PhsVSens	Voltage sensitivity (V)	0	100000	0.1		float
PlsTms	Maintenance Time (s).	0	7200	1		Int32
PlsFEna	Permanent measurement	0	1	1		Boolean
Linetype	Line type	0	1	1	Single (0) /Double (1)	enum
ZmMod	Z0M Mutual impedance (ohms p.u.)	0.0001	300	0.0001		float
ZmAng	Z0M mutual impedance Ang (°)	0	359.9	0.1		float
FilEna	Calculation filter enabled	0	1	1		Boolean
IminAfCl	Minimum current following closure	0	5000	0.1		float
NMaxVal	Maximum neutral I	0	5000	0.1		float
MaskEna	Protection event recording enabled	0	1	1		Boolean

There are independent settings:

- PROT/RFLO node
- Settings: There are 6 settings tables. For details see Table 103.

6.1 LOCATOR OPERATION

The process that follows the locator's algorithm can be summarized in 5 steps, which are explained below:

- Fault instant detection.
- Pre-fault and post-fault filtering
- Determination of fault type
- Localization algorithm

6.1.1 Fault detection

Once the protection has picked up, the fault detection algorithm starts processing the analogue signals received in search of the exact instant in which a fault has been produced. This search is made by comparing samples from consecutive cycles.

6.1.2 Pre-fault and post-fault filtering

The distance calculation algorithm uses the fundamental components of the voltage and current waves. The filtering extracts the components from the signals stored at pick up.

The collected signals are processed by a digital filter which provides the fundamental voltage and current components. A cosine filter is used for this stage.

6.1.3 Determination of fault type

Before launching the distance calculation algorithm in conjunction with the pre-fault and fault measurements calculated in the previous step, the type of fault produced must be defined.

The locator includes an algorithm that determines which phases have been affected by the fault. The algorithm is based on the well-known Girgis method for distance relays. This procedure, which analyzes the different magnitudes of change between the pre-fault and post-fault situations in the current's fundamental component, has demonstrated enviable precision in its results.

6.1.4 Distance calculation

The distance calculation algorithm has been developed for single (see Figure 108) and double lines.

When a fault is produced in a line corresponding to our relay, the information gathered by the locator, placed at one extreme of the line, is reduced to the voltage and current values.

The equations necessary to fully determine the system are obtained from the situation existing in the instant immediately preceding the fault and in the situation of the fault itself. The application of the principle of superposition in the model generators and an appropriated mathematical development give rise to a system of equations.

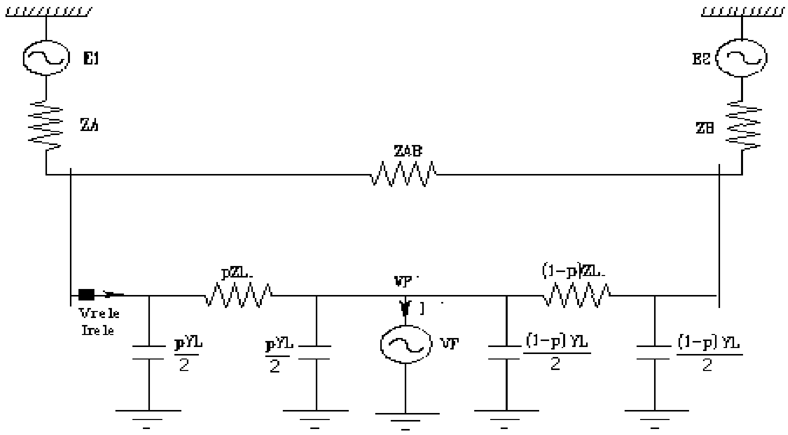
6.1.4.1 Filtered by the maximum neutral current level (cross country faults)

In cross country faults (simultaneous faults in different lines, e.g. AN in the protection line and BN in the adjacent line), the zero sequence current level detected in the system is superior to the maximum zero sequence current level for single phase faults.

In these situations, the protection locates the fault but indicates that the "Maximum neutral I" setting has been exceeded, as in these situations the voltages are distorted by the lack of the adjacent line fault and can cause erroneous calculations in the fault distance.

This mode is only operative if the "Calculation filter enabled" setting is active. In this case, the result of the localization will be displayed in the fault report, although the control measurements will be reported as invalid.

Figure 108 Line topology



6.2 PRESENTATION OF THE RESULTS

The presentation of the results is carried out in several ways:

- By display. In the "Fault reports" submenu
- In the faults report.
- In a control measurement. It remains active during the programmed time or until another fault is produced.

In addition to the distance calculated and the fault resistance, the locator finalization code is provided both in the display and in the fault report. The different texts that can form part of the localization code are shown below:

LOCATED: The fault has been located.

LITTLE PREFAULT/ LITTLE PRE: There are few pre-fault cycles, pre-fault cycles <3 cycles.

LITTLE POSTFAULT/ LITTLE POST: There are few post-fault cycles.

TRUNC: The fault has been processed but truncated when running the localization algorithm and high number of iterations.

IN>I: The neutral current (IN) is greater than the set maximum neutral current.

IN<I: The neutral current (IN) is lower than the set minimum neutral current following closure.

NOT FAULT: The fault instant has not been detected.

OUT OF LINE: The calculated distance is out of the set line length. If the calculated distance is greater than 150% of the line length, the distance value is not shown.

NOT ENABLED: The locator is not enabled

NEGATIVE DISTANCE: The distance calculated is negative. In this case, the distance value is not displayed.

NOT LOCATED: The locator algorithm has not been run.

For example, a locator result indicating the LITTLE PRE/IN>I/OUT OF LINE code should be interpreted as follows:

The location algorithm does not have sufficient pre-fault cycles and therefore considers that the fault sample is in the cycle in which the digital pick was produced. Furthermore, the neutral current in the system has exceeded the current value set in the "Maximum neutral current" setting (this check is only carried out when the "Calculation filter enabled" setting is set to "YES"). By exceeding this value, the distance calculation may be erroneous. Therefore, although it is shown in the fault report it is marked as an invalid control measure. Finally, the distance calculation has returned a value in excess of the value established in the "Line length" setting. If this result is between 100% and 150% of the line length, it will be displayed. If it is greater, the distance will appear as NOT CALCULATED.

7. MONITORING

7.1 EXTERNAL POWER SUPPLY MONITORING

This function checks if the external supply voltage is within the set range. It generates two signals:

- Auxiliary power supply greater than maximum threshold. If the supply voltage exceeds the set maximum threshold.
- Auxiliary power supply lower than minimum threshold. If the supply voltage is below the set minimum threshold.

The settings for configuring the external power supply monitoring (Table 110):

- Enabled: Enables the external power supply monitoring function.
- Minimum threshold. Indicates the minimum power supply voltage threshold, below which an alarm is issued.
- Maximum threshold. Indicates the maximum power supply voltage threshold, above which an alarm is issued.
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

Table 110 External power supply monitoring settings

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
SupSpvEna	Enabled				NO (0) / YES (1)	enum
LoSuppV	Minimum threshold	10	280	1		float
HiSuppV	Maximum threshold	10	280	1		float
MaskEna	Enable Events record				NO (0) / YES (1)	Boolean

It has independent settings, commands and outputs:

- PROT/CESS1 node
- Settings. There are 6 settings tables. For details see Table 110.
- There are no logical inputs or commands
- Outputs: Table 111 shows the function’s output data.
  - Enabled. It is active when enabled and not blocked.
  - Power supply greater than maximum threshold. Indicates that the power supply has exceeded the maximum threshold.
  - Power supply lower than minimum threshold. Indicates that the power supply is below the minimum threshold.

Table 111 Power supply monitoring outputs

Signal	Data	Attribute
Enabled	StEna	stVal
Power supply greater than maximum	OverVcc	general
Power supply lower than minimum	UnderVcc	general

7.2 TEMPERATURE MONITORING

This function checks if the temperature is within the set range. It generates two signals:

- Temperature greater than maximum threshold. If the temperature exceeds the set maximum threshold.
- Temperature lower than minimum threshold. If the temperature is below the set minimum threshold.

The settings for configuring the external power supply monitoring (Table 110):

- Enabled: Enables the temperature monitoring function.
- Minimum temperature (ºC). Indicates the minimum temperature threshold, below which an alarm is issued.
- Maximum temperature (ºC). Indicates the maximum temperature threshold, above which an alarm is issued.
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

Table 112 Temperature monitoring settings

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
TmpSpvEna	Enabled				NO (0) / YES (1)	enum
LoTmpVal	Minimum temperature (ºC)	-40	0	1		float
HiTmpVal	Maximum temperature (ºC)	50	100	1		float
MaskEna	Enable Events record				NO (0) / YES (1)	Boolean

It has independent settings, commands and outputs:

- PROT/CTSU1 node
- Settings. There are 6 settings tables. For details see Table 112.
- There are no logical inputs or commands
- Outputs: Table 113 shows the function’s output data.
  - Enabled. It is active when enabled and not blocked.
  - Temperature greater than maximum threshold. Indicates that the temperature has exceeded the maximum threshold.
  - Temperature lower than minimum threshold. Indicates that the temperature is below the minimum threshold.

Table 113 Temperature monitoring outputs

Signal	Data	Attribute
Enabled	StEna	stVal
Power supply greater than maximum	OverTemp	general
Power supply lower than minimum	UnderTemp	general

7.3 DIS BLOCKING BY LACK OF VAUX

If enabled, it checks that the external power supply exceeds the battery failure threshold, generating an alarm signal when it is below the threshold.

The settings for configuring the battery failure monitoring (Table 114)

- Enabled: Enables the battery failure monitoring function.
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

Table 114 Battery failure monitoring settings

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
SupSpvEna	Enabled				NO (0) / YES (1)	enum
MaskEna	Enable Events record				NO (0) / YES (1)	Boolean

There are independent settings and outputs:

- PROT/CSUS1 node
- Settings. There are 6 settings tables. See Table 114.
- There are no logical inputs or commands
  - Outputs: Table 115 shows the function's output data.
  - Enabled. It is active when enabled and not blocked.
  - Low power supply (DFFA). Indicates that the external power supply is below the minimum threshold.

Table 115 Battery failure monitoring outputs

Signal	Data	Attribute
Enabled	StEna	stVal
Low power supply (DFFA)	DFFA	general

7.4 INTERNAL BATTERY FAILURE MONITORING

The internal battery used for data maintenance is checked to ensure that it does not fall below a security level.

There are independent outputs:

- GEN/LPHD1 node
- It does not use settings.
- There are no logical inputs or commands.
- Outputs: Table 116 shows the function's output data.
  - Internal battery failure. Indicates that the internal battery level is below the minimum threshold.

Table 116 Internal battery failure outputs

Signal	Data	Attribute
Battery failure	BatAlm	general

7.5 UNIT CHECKS

The unit continually checks the various incorporated elements and cards. If an error is detected in any of the elements or cards, an alarm is generated. If the error affects the unit's operation, a critical error is generated, which in addition to the signal acts on :

- Colour front LED. Non-configurable status LED, which indicates the unit's general status. If the LED is green, it indicates that everything is correct, while if it is red it indicates a critical error in the unit.
- CPU Relay. Non-configurable 3-contact relay, which indicates the unit's general status. If the LED is active (common terminal – NO), it indicates that everything is correct, while if it is deactivated (common terminal– NC) it indicates a critical error in the unit. If the unit is switched off, the relay is deactivated.
- The unit's alarm signals are to be found in the LPHD node. The available signals indicate faults in the card check, in the communications between the cards, in the unit's configuration, etc.:

- Critical hardware error. Indicates that a critical error has been produced. In addition to this signal, the cause that produced the signal will be indicated.
- CPU error. Indicates that the check has detected an error in the CPU. It generates critical error signal.
- Analogue error. Indicates an error in transformers card. It generates critical error signal.
- I/O micro error. Indicates an error in the I/O cards' micro.
- Analogue connection error. Indicates that a fault has been produced in the communications between the CPU and the transformers card. It generates critical error signal.
- I/O connection error. Indicates that a fault has been produced in the communication between the CPU and an I/O card. It generates critical error signal. Additionally, it will indicate the card which has suffered the failure:
  - Error card address x. Indicates that there is a communication error with the card with the address x.
- Front connection error. Indicates that a fault has been produced in the communications between the CPU and the unit's front card. It generates critical error signal.
- Shared analogue memory error. Indicates that a fault has been produced in the Data exchange memory between the CPU and the transformers card. It generates critical error signal.
- Error shared I/O memory. Indicates that a fault has been produced in the Data exchange memory between the CPU and the I/O cards. It generates critical error signal.
- RTC clock error. Indicates that the check has detected an error in the real time clock.
- Continuous component monitoring alarm. Indicates that an error in the continuous measurement monitoring has been detected in the transformers card.
- Alarm settings. Indicates that errors have been detected in the storage of the unit's settings. It generates critical error signal.
- Memory check alarm. Indicates that errors have been detected in the checking of the unit's memory. It generates critical error signal.
- Converter check alarm. Indicates that errors have been detected in the transformers card AD converter. It generates critical error signal.
- Converter voltage level alarm. Indicates that errors have been detected in the transformers card reference voltages. It generates critical error signal.
- Relay activation alarm. Indicates that an error has been detected in the activation of at least one of the I/O cards' relays. It generates critical error signal.
- I/O configuration error. Indicates that the configuration of the I/O cards does not coincide with the unit's correct configuration. It generates critical error signal.
- General Vdc error. Indicates a failure in the internal power supply levels. It generates critical error signal.
- Frequency configuration error. This is not a unit failure, but rather a configuration failure. Indicates that the frequency measurement of the signals being injected into the unit do not match the set measurement, that is, the unit is configured as 50Hz and the signals which are being injected are greater than 55Hz; or that the unit is configured as 60 Hz and the signals being injected are less than 55 Hz.
- Internal battery failure. Indicates that the data storage battery is below the security levels and that the data may be lost at shutdown.
- Version compatibility error. Indicates that the versions of the unit's firmware are not correct.
- Time setting configuration alarm. Indicates that there is an error in the configuration of the unit's time setting.
- For each I/O card there is are 5 signals, indicating:
  - Status OK. Indicates that the card is configured correctly and without errors.
  - Configured & No_detected. Indicates that the card is configured by the user, but not detected in the unit. This may be because it is not assembled or because it has an error. Equivalent to the current communication error.
  - Different configuration. The type indicated by the user and the type detected by the unit do not coincide.
  - No_configured & detected. Indicates that card that has not been configured by the user has been detected in an address.
  - Internal card error. A card check error has been received (includes relay check).

Table 117 Checking signals

Signal	Data	Attribute
Critical hardware error	HwCrAlm	stVal
CPU error	CPUAlm	stVal
Analogue error	AnaAlm	stVal
I/O micro error	ESAlm	stVal
Analogue connection error	AnaComAlm	stVal
I/O connection error	ESComAlm	stVal
Front connection error	MMIComAlm	stVal
Shared analogue memory error	AnDPMAlm	stVal
Shared I/O memory error	ESDPMAlm	stVal
RTC clock error	RTCAlm	stVal
Continuous component monitoring alarm	Harm0Alm	stVal
Alarm settings	SettingAlm	stVal
Firmware alarm	FwAlm	stVal
Memory check alarm	MemAlm	stVal
Converter check alarm	ADCAlm	stVal
Converter voltage level alarm	VRefAlm	stVal
Relay activation alarm	DOAlm	stVal
I/O configuration error	IOCnfError	stVal
Card address error 1	GGIO1Alm	stVal
Same as rest of I/O up to 8		
Card address error x (x from 2 to 8)	GGIOxAlm	stVal
General Vdc error	VccError	stVal
Frequency configuration error	FrConfAl	stVal
Internal battery failure	BatAlm	stVal
Version compatibility error	VerAlm	stVal
Time setting configuration alarm	HSetAlm	stVal
Card 1 ok	GGIO1Ok	stVal
Card 1 ConfiguredYNo_detected	GGIO1Nodet	stVal
Card 1 Different configuration	GGIO1Dif	stVal
Card 1 No_configured Y Detected	GGIO1NConf	stVal
Card 1 Internal card error	GGIO1HwErr	stVal
Same as rest of I/O up to 8		
Front ok	FRONTOk	stVal
Front Configured Y No_detected	FRONTNodet	stVal
Different front configuration	FRONTDif	stVal
Front No_configured Y Detected	FRONTNConf	stVal
Front Internal card error	FRONTHwErr	stVal

8. CONFIGURATION

8.1 CID

8.1.1 Data Storage

The unit has a CID file that follows the format defined in section 6 of the IEC 61850 standard. It is available via the following path by FTP “SCL/validated”, in which all the unit’s configuration information is saved, either structured in nodes that follow the IEC 61850 format or in private parts.

8.1.2 Updating CID.ParamRev

There are different ways to change the settings. They are listed below:

- Using MMS in IEC 61850
- Using local display
- Using the pacFactory (PC tool)
- By sending the CID by FTP to the “SCL/notvalidated” directory

Independently of the form used from among those listed above, the changes to the affected setting are stored in the unit’s CID file. When any setting is changed, the NamPlt field in the node in which the new setting has been written, as well as the LLN0 node of the device to which the node belongs, are updated in the CID file.

The format of the NamPlt data is as follows:

XXX year.month.day.time.minute.second [paramRev origin text]

- Where “XXX” is an integer counter that is incremented each time paramRev is updated by a setting change.
- "paramRev origin text“depends on the origin of the setting change:

Origin of settings change	paramRev text origin
MMS	IEC 61850 client BROWSER IP
Local display	USER DISPLAY
pacFactory	USER TOOL
New CID	CID UPDATE

In the case of “New CID”, only those settings in the CID sent to the unit and which are out of range will be updated in paramRev.

8.2 GENERAL

Two nodes are used for the general configuration of the unit

- GEN/LLN0. Includes the unit’s generic configuration settings
- PROT/LLN0. Includes the protection units’ generic configuration settings

The settings available in the GEN/LLN0 node are shown in protection events mask enablind. Allows the generation of protection events associated to the function. If set to "NO", the function's protection events are not generated. If set to "YES", the function's specific mask is contemplated:

- Language. Indicates the unit's language. Affects the display, reports, etc.
- Functional key block
- Command key block
- Remote functional key mode
- LED block. Allows the activation of the LEDs to be blocked.
- Blocks from commands
- IRIG B format. Select whether the year is taken into account in the synchronization by IRIG. The options are:
  - "B002". The year is not taken into account.
  - "B002 IEEE 1344". The year is taken into account.
- Local/remote mode change
- Queue deletion logical input. Indicates the logic input that, when activated, deletes the unit's report queues. Affects protection events, faults, disturbance reports, historical measurement reports, etc.
- CID load mode
- CID validation type
- Remote/ Local type. It indicates how the unit will behave when it has to block the commands it is sent. See 15.2.1
- Flicker Enable. Enables the digital inputs' swing supervising function.See 8.4.3
- Protection events mask enabled. Allows the generation of protection events associated to the function. If set to "NO", the function's protection events are not generated. If set to "YES", the function's specific mask is contemplated.

Table 118 General settings

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
Lang	Language				Spanish (0) / English (1)	Boolean
BlkFKeys	Functional key block				NO (0) / YES (1)	Boolean
BlkOKeys	Command key block				NO (0) / YES (1)	Boolean
FKeysRem	Remote functional key mode					Boolean
BlkFrCom	LED block				NO (0) / YES (1)	Boolean
BlkComm	Blocks from commands					Boolean
IrgType	IRIG-B format				B002 (without year) / B002 IEEE 1344 (with year)	enum
LogInLR	Local/remote mode change					Int32
LogInDelRe	Queue deletion logical input					Int32
LoadMod	CID load mode					enum
ValActAuto	CID validation type					Boolean
LRmode	Remote/Local Type	0	3	1	Not treated (0) Iberdrola (1) Exclusive (2) No frame (3)	enum
FlickerEna	Flicker Enable	0	1	1	NO (0) / YES (1)	enum
MaskEna	Protection event recordign enabled				NO (0) / YES (1)	

The settings available in the PROT/LLN0 node are shown in protection events mask enablind. Allows the generation of protection events associated to the function. If set to "NO", the function's protection events are not generated. If set to "YES", the function's specific mask is contemplated:

- Relay ON. Indicates whether the relay in service or not. If it is out of service, the protection functions do not act.
- Phase order. Selects the phase sequence ABC/CBA. Affects the direct and inverse sequences and, therefore, the functions that use them. To check whether the order corresponds to wiring, check that the values expected for the indicated configuration are obtained in the sequence measurements and that the phase current arguments (as seen in the status screen) match selected sequence.
- Select Setting group 1. Indicates the logic input which, when activated, selects the settings table 1 as active.

- Select Setting group 2. Indicates the logic input which, when activated, selects the settings table 2 as active.
- Select Setting group 3. Indicates the logic input which, when activated, selects the settings table 3 as active.
- Select Setting group 4. Indicates the logic input which, when activated, selects the settings table 4 as active.
- Select Setting group 5. Indicates the logic input which, when activated, selects the settings table 5 as active.
- Select Setting group 6. Indicates the logic input which, when activated, selects the settings table 6 as active.
- Fault reports (Prim./sec.). Select the measurements of the display fault reports between primary and secondary.
- Enable Events record. Allows the generation of protection events associated to the function. If set to “NO”, the function’s protection events are not generated. If set to “YES”, the function’s specific mask is contemplated.

Table 119 General protection settings

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
OnLine	Relay ON				NO (0) / YES (1)	Boolean
PhsOrd	Phase order				ABC (0) /CBA (1)	enum
LogInSet1	Select Setting group 1					Int32
LogInSet2	Select Setting group 2					Int32
LogInSet3	Select Setting group 3					Int32
LogInSet4	Select Setting group 4					Int32
LogInSet5	Select Setting group 5					Int32
LogInSet6	Setting change table 6					Int32
FaRepTy	Fault reports (Prim./sec.)				Secondary (0) / Primary (1)	enum
MaskEna	Enable Events record				NO (0) / YES (1)	Boolean

8.3 FRECUENCY, MEASUREMENT AND TRANSFORMERS

The current and voltage transformers are configured in independent nodes, in which the units’ rated values, transformation ratios and frequencies are indicated.

8.3.1 Current

Two PROT/TCTR nodes are used for the transformation ratios and PROT/TCIN for rated currents.

The settings used for the configuration of the current transformers ratios, which are used to provide primary measurements, are (see Table 120):

- Phase current ratio. Indicates the phase current transformation ratio.
- Neutral current ratio. Indicates the neutral current transformation ratio.
- Sensitive neutral ratio. Indicates the sensitive neutral current transformation ratio.
- Unbalance current. Indicates the unbalance current transformation ratio.
- Polarization current. Indicates the polarization current transformation ratio.

The settings used for configuring the rated currents are (see Table 121):

- I rated phases. Selects the value of the rated phase current.
- I rated neutral. Selects the value of the rated neutral current.
- I sensitive rated neutral. Selects the value of the rated sensitive neutral current.
- 3I0-IN measurement type. Selects the neutral measurement from between the measurement calculated for the phase currents and the transformer measurement.

Table 120 Current transformation ratios

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
PhsRat	Phase current ratio	1	3000	0.1		float
GndRat	Neutral current ratio	1	3000	0.1		float
SGndRat	Sensitive neutral ratio	1	3000	0.1		float
UnbRat1	Unbalance current	1	3000	0.1		float
PolARat	Polarization current	1	3000	0.1		float

Table 121 Rated currents

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
PhsInom	I rated phases				1A (1)/ 5A (2)	enum
GndInom	I rated neutral				1A (1)/ 5A (2)	enum
SgndInom	I sensitive rated neutral				0.025A (1)/ 1A (2)	enum
SelI0	3I0-IN measurement type				Calculated (0)/Trafo (1)	enum

8.3.2 Frequency and voltage

The PROT/TVTR node is used for the voltage and rated voltage transformation ratios (see Table 122).

- Phase transformation ratio. Indicates the phase voltage transformation ratio.
- Rated phase-earth V (V sec). Selects the rated voltage.
- Voltage phases used. Selects the voltage phases used in the protection functions. Different phase combinations (both earth to phase and phase to phase) can be selected:
  - None. No voltage is enabled
  - A. Earth-phase voltage only operates in phase A
  - B. Earth-phase voltage only operates in phase B
  - A-B. Earth-phase voltages operate in phases A and B
  - C. Earth-phase voltage only operates in phase C
  - A-C. Earth-phase voltages operate in phases A and C
  - B-C. Earth-phase voltages operate in phases B and C
  - A-B-C. The three earth-phase voltage operate
  - AB. The AB phase-phase voltage operates
  - BC. The BC phase-phase voltage operates
  - AB-BC. The AB and BC phase-phase voltage operates
  - CA. The CA phase-phase voltage operates
  - AB-CA. The AB and CA phase-phase voltage operates
  - BC-CA. The BC and CA phase-phase voltage operates
  - AB-BC-CA. The three phase-phase voltages operate

  If a phase-phase option is selected, the wiring is considered to be P-P. To the contrary, is considered P-N.
- Frequency. Selects the unit's rated operating frequency 50Hz or 60Hz
- VN transformation ratio. Indicates the neutral voltage transformer ratio.

Table 122 Voltage characteristics

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
VRat	Phase transformation ratio	1	10000	0.1		float
VRtg	Rated phase-earth V (V sec)	40	200	0.1		float
VSel	Voltage phases used	0	15	1		enum
HzRtg	Frequency				50Hz (0) /60Hz (1)	enum
VNRat	VN transformation ratio	1	10000	0.1		float

8.3.3 Power and energy

The PROT/MPWE node, which indicates the conditions for the power calculation, is used (see Table 123):

- Change sign P. Indicates if the sign change in the real power calculation is enabled.
- Change sign Q. Indicates if the sign change in the reactive calculation is enabled.
- Real energy constant. Indicates the real energy impulse factor, i.e., the number of kWh by virtue of which the counter is incremented by one unit.
- Reactive energy constant. Indicates the reactive energy impulse factor, i.e., the number of kWh by virtue of which the counter is incremented by one unit.

The energy counters value is available in the PROT/MMTR node, with the data:

- Positive real energy counter: SupWh.
- Negative real energy counter: DmdWh.
- Positive reactive energy counter: SupVArh.
- Negative reactive energy counter: DmdVArh.

Table 123 Power characteristics

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
PSiCh	Sign change P				NO (0) / YES (1)	float
QSiCh	Sing change Q				NO (0) / YES (1)	float
CorWh	Constant real power (kWh)	1	1000	1		enum
CorVArh	Constant reactive power	1	1000	1		enum

8.4 INPUTS/OUTPUTS

The unit can host a variable number of input-output cards variable (from 1 to 7). Each card is configured with an internal address from 2 to 7. The power supply is assigned address 1, which is not configurable.

Each card is represented in the IEC 61850 data model as an instance of the GGIO node in the Logical Device called “GEN”. Each GGIO has the internal address of the physical card as an instance. Thus, for example, if a unit has two input-output cards with internal addresses 1 and 4, the GEN/GGIO1 and GEN/GGIO4 nodes will exist in the data model.

The number of digital input settings and signals present in each GGIO depends on the type of card used. Continuing the example, if the card with the internal address 1 has 6 digital inputs and 4 digital outputs, the GGIO1 node will have 6 digital input signals and 4 digital output signals, as well as the settings corresponding to each digital input and output available.

The data model associated to the GGIOs is common to all and has 32 digital inputs and 16 digital outputs. Nevertheless, in each card only the data associated with its own inputs and outputs are updated.

For each GGIO there is a boolean setting called MaskEna (event record enabled). If set to “YES”, the activation/deactivation of the digital inputs and outputs will generate protection events. To the contrary, they will not be stored as event records.

8.4.1 Inputs

There are 2 settings available for each digital input:

- DIxTmms: Digital input time x (ms). This is a software filter for the activation/deactivation of digital inputs. It indicates the milliseconds (range 0 to 20 ms) which a digital input must be seen to be active in order to be considered active. In order to calculate an input's total activation time, the input’s hardware filter delay – which is approximately 1ms – must be added to this time.
- DIxType: Digital input type x. Defines whether the input is to be interpreted as active when it is seen as closed (NO) or when it is seen as open (NC)

Each digital input has an associated digital signal indicating its status (see Table 124). Each GGIO indicates the status of all its digital inputs (up to 32).

Table 124 Digital input signals

Signal	Data	Attribute
Digital input 1	Ind1	stVal
Digital input 2	Ind2	stVal
Remaining inputs		
Digital input 32	Ind32	stVal

8.4.2 Outputs

There are 3 settings available for each digital output:

- DOxSig: Assignment digital output x. Assigns the activation of the digital output. There are several assignment possibilities:
    - Signals: They can be signals generated by the unit (trips, logics, hw check, digital inputs and outputs)
    - Commands: All of the commands available in the unit can be directly programmed to a physical output
- DOxTmms: Digital output time x (ms). The output activation time defines the minimum operational time of each physical output following activation (in milliseconds). The range is 0.05 to 5000 ms. The output remains active in accordance with this time setting or the duration of the associated signal, whichever is greater.
- DOxTyp: Digital output type. Each output's type is defined from among the options:
    - "Not". The output follows the assigned signal, i.e., the output is activate when the signal is active. When the signal is deactivated, the output will deactivate if the digital output time has elapsed. To the contrary, the output will remain active until this time elapses.
    - "Stored". Once activated, the output remains active until the relay deactivation command is issued, with the signal assigned to the output deactivated. The command can be issued by the action of a digital input programmed as "Local reset", a command or by keyboard/display.
    - "Trip". Once activated, the output remains active until the following conditions are met: the signal assigned to the output is deactivated and the breaker is open.
    - "Close". Once activated, the output remains active until the following conditions are met: the signal assigned to the output is deactivated and the breaker is closed.

Each digital input has an associated digital signal indicating its status (see Table 126Table 126). Each GGIO indicates the status of all its digital outputs (up to 16).

Table 125 Input/output settings

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
MaskEna	Protection event recording enabled				NO (0) / YES (1)	Boolean
OscTms	Input oscillation time (s)	1	60	1		Int32
Nchanges	Number of changes	0	255	1		Int32
DI1Tmms	Digital Input Time 1 (ms)	0	20	1		Int32
DI1Type	Digital Input Type 1				NO (0) / NC (1)	enum
DI2Tmms	Digital Input Time 2 (ms)	0	20	1		Int32
DI2Type	Digital Input Type 2				NO (0) / NC (1)	enum
	Remaining inputs DI3x, DI4x..					
DO1Sig	Digital Output Assignment 1					Int32
DO1Tmms	Minimum Output Time 1 (ms)	0	5000	1		Int32
DO1Ty	Digital Output Type 1					enum
DO2Sig	Digital Output Assignment 2					enum
DO2Tmms	Minimum Output Time 2 (ms)	0	5000	1		enum
DO2Ty	Digital Output Type 2					Int32
	Remaining inputs DI3x, DI4x..					

Table 126 Digital output signals

Signal	Data	Attribute
Digital output 1	SPCSO1	stVal
Digital output 2	SPCSO2	stVal
Remaining outputs		
Digital output 16	SPCSO16	stVal

8.4.3 Treatment of digital input flicker

Flicker consists of a fast and continuous change of a digital input, usually associated with a failure in the input's contact. The function allows a control to be performed to disable the flickering digital inputs or signals in order to prevent them from interfering with the control system, as a disabled digital does not generate status changes.

The supervising of the swing in the digital inputs or the supervising of the flicker is conducted in accordance with certain user-configurable settings.

On the one hand, there is a general setting that allows this function to be enabled or disabled. If this setting is disabled, not flicker treatment is performed.

General setting for the configuration of the flicker treatment (Table 127):

- FlickerEna: Enables the digital inputs' swing supervising function.

Table 127 General flicker treatment setting

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
FlickerEna	Flicker enabled	0	1	1	NO (0) / YES (1)	enum

- GEN/LLN0 node

  Once the general flicker setting has been enabled (Table 127), there are two more setting per card for treating the swing. They are "OscTms" and "Nchanges" which can be seen in Table 125:

- OscTms: The time between changes in the same direction in order for a signal to be deemed to be swinging. When a signal is swinging a swinging signal is produced. The unit is seconds.
- Nchanges: The number of changes that must be produced in a swinging signal in order for the signal to become invalid and cease from sending changes. If this setting is set to zero, it disables the swing treatment for this card, i.e., the flicker treatment is not performed for this card.
- GEN/GGIOx node, in which x depends on the card's internal address (see section 8.4)

Once a signal has been detected as swinging, it becomes questionable and oscillatory.

If this situation continues and the number of set changes ("Nchanges" setting) is exceed, the signal becomes invalid and oscillatory. It ceases to send the changes and sends the signal's last known valid status.

When the time difference between two changes is greater than the inputs' swing time ("OscTms" setting), the signal changes to valid.

8.5 LEDS

8.5.1 Via GEN/IHMI node

The LEDs are programmed within the IHMI node located in the "GEN" logical device. There are 2 settings available for each LED:

- LexSig: Assignment led x. Assigns the activation of LED x using any of the signals generated by the unit
- LExTyp: LED type x. It can be programmed as "not" and "stored". In the first case, the activation of the LED follows the activation of the signal programmed in the setting described above. If it is programmed as "stored", the LED's activation will remain even if the signal that provoked its activation drops out, until the signal programmed in the LogInReLed setting available in the IHMI node is activated.

There is a general setting for all the LEDs that indicates the logic signal used to switch of the LEDs:

- LED reset. Selects the signal which, when active, switches off the LEDs.

The LEDs are updated every 200ms. Thus, for the correct activation of the LEDs, the assigned signal must remain active for at least 150 ms. To the contrary, the LED cannot be activated.

Table 128 LED settings

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
LogInReLed	LED reset					Int32
Le1Sig	Led 1 assignment	0	20	1		Int32
Le1Ty	Led 1 type				Not (0) /Stored (1)	enum
Le2Sig	Led 2 assignment	0	20	1		Int32
Le2Ty	Led 2 type				Not (0) /Stored (1)	enum
	Remaining LEDs up to 19					

8.5.2 Via CTRL/IHMI node

If the unit, in addition to the "GEN" logical device's IHMI node defined in the previous section, has an IHMI node located in "CTRL" logical device, the unit's treatment in relation to the configuration of the LEDs differs as follows:

- The parameterization of the assignment of LEDs is carried out by the settings present in the CTRL/IHMI node.
- The parameterization of the LEDs type is carried out by the settings present in the CTRL/IHMI node.

The settings present in this node are detailed below

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
InRef1	Led 1 assignment	-	-	-		InRef
LEDSe1	Led 1 type				Not (0) /Stored (1)	enum
InRef2	Led 2 assignment	-	-	-		InRef
LEDSe2	Led 2 type				Not (0) /Stored (1)	enum
	Remaining LEDs up to 19					

There are 2 settings available for each LED:

- InRefx: Assignment led x. Assigns the activation of LED x using any of the signals generated by the unit. The assignment is carried out by means of a character string (see next section "Configuration with InRef")
- LEDSex: LED type x. It can be programmed as "not" and "stored". In the first case, the activation of the LED follows the activation of the signal programmed in the setting described above. If it is programmed as "stored", the LED's activation will remain even if the signal that provoked its activation drops out, until the signal programmed in the LogInReLed setting available in the GEN/IHMI node (defined in the previous section) is activated.

8.6 CONFIGURATION WITH INREF

The InRef type settings are programmed by a string of characters in which the reference of the IEC 61850 object containing the value to be employed as an input is indicated. The following format, as defined in the part 7.2 of the IEC 61850 standard, is employed:

LDName/LNName.DataObjectName[.SubDataObjectName[. ...]].DataAttributeName

For example,

- In order to program InRef1 with the GGIO1 input signal 1, the reference to be written in the InRef is:
  GEN/GGIO1.Ind1.stVal
- In order to program the PTOC 1 phase A trip, the reference is:
  PROT/PTOC1.Op.phsA

8.7 NAMES

The PROT/LPHD node is used for the general configuration of the units' names and the installation.

Short names are used for the generation of the disturbance recorder and fault file names.

The settings for this node are shown in Table 129:

- Installation name: Full name of the installation.
- Short name of the installation. Short name of the installation. Limited to 10 characters, this is used in the generation of disturbance recorder and fault files. Neither spaces nor commas are permitted in the name.
- Relay name. Full name of the relay.
- Short relay name. Short name of the installation. Limited to 10 characters, this is used in the generation of disturbance recorder and fault files. Neither spaces nor commas are permitted in the name.
- Name of breaker 1. Full name of breaker 1.
- Name of breaker 2. Full name of breaker 1.

Table 129 Name settings

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
InstNam	Installation name					string
InstShNam	Short name of the installation				10 characters	String
RelNam	Relay name.					String
RelShNam	Short relay name				10 characters	String
BkrNam1	Name of breaker 1					String
BkrNam2	Name of breaker 2					String

8.8 CONFIGURATION WITH INREF

The InRef type settings are programmed by a string of characters in which the reference of the IEC 61850 object containing the value to be employed as an input is indicated. The following format, as defined in the part 7.2 of the IEC 61850 standard, is employed:

LDName/LNName.DataObjectName[.SubDataObjectName[. ...]].DataAttributeName

For example,

- In order to program InRef1 with the GGIO1 input signal 1, the reference to be written in the InRef is:
  GEN/GGIO1.Ind1.stVal
- In order to program the PTOC 1 phase A trip, the reference is:
  PROT/PTOC1.Op.phsA

9. SYNCHRONIZATION

9.1 DATE AND TIME

Several synchronization sources are permitted, with the following priority:

- IRIG-B. See configuration settings in GEN/LLN0 and wiring in Figure 1
- SNTP
- Communication protocols
- pacFactory (see specific user manual)
- Local display

In the event of the existence of synchronization by a source, all those of lower priority are blocked. Some examples:

- If there is synchronization by IRIG, synchronization for any other cause is not permitted. In order to consider the absence of IRIG synchronization and to allow other sources, one and a half minutes must elapse without the reception of correct IRIG frames.
- If there SNTP synchronization, the synchronization of protocols is not permitted, nor pacFactory nor display. However, if IRIG synchronization is received, the SNTP is blocked and IRIG is synchronized.
- Synchronization by PacFactory and by display have the same priority and can be run simultaneously.

9.2 SETTINGS

The unit's data model has a GEN/LTIM node for the configuring the summer/winter time change. The node has the following settings (see Table 130):

- Offset Local Time-UTC (min): Offset Local Time-UTC (min). A setting that indicates the number of minutes by which the time setting must be put forward/put back when changing between summer/winter time. Range between -720 and 720 minutes (-12 to + 12 hours)
- Summer-winter time change enabled: Time change enabled. A boolean setting that allows the time setting to be changed
- Summer Calendar Pattern: Summer Calendar Pattern. Three selectable values:
  - Last of month: Last week, refers to the weekday set in WkDayD
  - First of month: First week, refers to the weekday set in WkDayD
  - Second of month: Second week, refers to the weekday set in WkDayD
  - Third of month: Third week, refers to the weekday set in WkDayD
  - Fourth of month: Fourth week, refers to the weekday set in WkDayD
  - Day of month: Selects the day of the month indicated in DayD
- Day Week Summer: Indicates the day of the week for the change to summer time (Monday.. Sunday)
- Month Summer: Indicates the month in which the change to summer time occurs (January.. December)
- Day Summer: Indicates the day in which the change to summer time occurs (1.. 31)
- Time Summer: Indicates the time at which the time changes to summer time
- Minute Summer: Indicates the minute (within the time set on HrD) when the time changes to summer time
- Winter Calendar Pattern: Winter Calendar Pattern. Equivalent to OccD but from winter to summer
- Day Week Winter: Indicates the day of the week for the change to winter time (Monday.. Sunday)
- Month Winter: Indicates the month in which the change to winter time occurs (January.. December)
- Day Winter: Indicates the day in which the change to winter time occurs (1.. 31)

- Time Winter: Indicates the time at which the time changes to winter time
- Minute Winter: Indicates the minute (within the time set on HrS) when the time changes to winter time

Table 130 Synchronization settings

Name IEC 61850	Setting	Minimum	Maximum	Step	Remarks	Type
TmOfsTmm	Offset Local Time-UTC (min)	-720	720	1		Int32
TmUseDT	Summer-winter time change enabled				NO (0) / YES (1)	Boolean
OccD	Summer Calendar Pattern	0	2	1		enum
WkDayD	Day Week Summer	0	6	1		enum
MthD	Month Summer	1	12	1		enum
DayD	Day Summer	1	31	1		Int32
HrD	Time Summer	0	23	1		Int32
MnD	Minute Summer	0	59	1		Int32
OccS	Winter Calendar Pattern	0	2	1		enum
WkDayS	Day Week Winter	0	6	1		enum
Mths	Month Winter	1	12	1		enum
DayS	Day Winter	1	31	1		Int32
HrS	Time Winter	0	23	1		Int32
MnS	Minute Winter	0	59	1		Int32

- They are signals indicating the synchronization source (Table 131).
- Synchronization by IRIG-B. Active if the last synchronization has been received by IRIG-B.
- SNTP synchronization. Active if the last synchronization has been received by SNTP.
- Synchronization by protocols. Active if the last synchronization has been received by communications protocols.
- Synchronization by display. Active if the last synchronization has been received by the front keyboard.
- Synchronization by console. Active if the last synchronization has been received from the PacFactory console.

Table 131 Synchronization source

Signal	Data	Attribute
Synchronization by IRIG-B	SyncIRIGB	stVal
Synchronization by SNTP	SyncSNTP	stVal
Synchronization by protocols	SyncProt	stVal
Synchronization by display	SyncDispl	stVal
Synchronization by console	SyncCons	stVal

10. DATA ACQUISITION FUNCTIONS

The information generated by the unit is stored in xml format files, except the format the oscillograph, which is stored in comtrade format.

10.1 STATUS REPORT

The status report indicates the current status of the protection, showing instantaneous values. This report is updated approximately every 1 second.

The information available in the status message is:

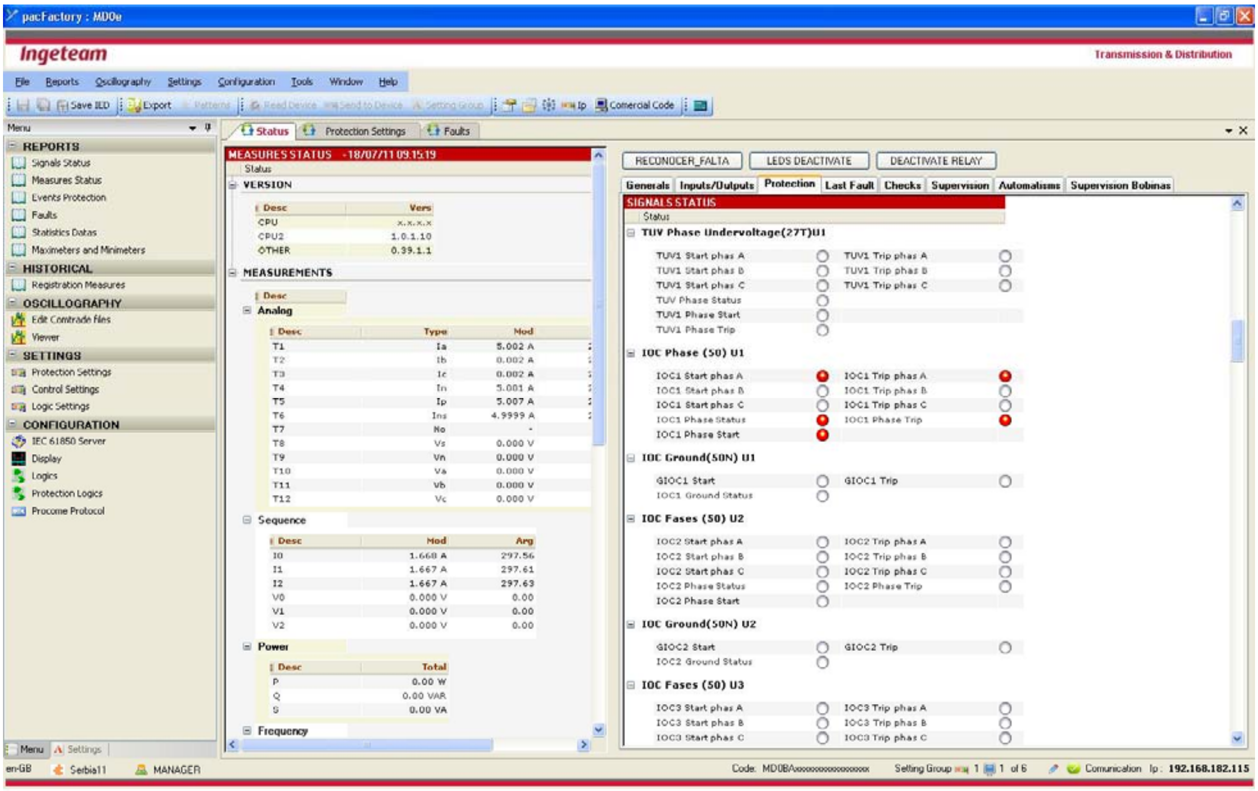
- Version. Indicates the unit version:
  - CPU: Shows the CPU's main firmware version
  - CPU2: Displays the firmware version of the FPGA and interface with I/O modules
  - OTHER: Displays the analogue card's firmware and I/O modules
- General. Displays the unit's general data:
  - Relay date and time. Within the <Date> tag, the date (Date) and time (Time) are shown
  - Active table. Within the <Setting Group> tag, the active table number is shown
- Measurements: Within the Measurements tag, the unit's measurements are shown. The measurements correspond to the fundamental frequency.
  - <Analog>: Type, module and angle of each of the unit's 12 transformers.
  - <Sequence>: Direct, inverse and zero sequences of currents and voltages (module and angle).
  - <Power>: Total real, reactive and apparent power.
  - <Frequency>. Frequency value.
  - <Battery> External power supply battery voltage.
  - <InternalBattery> Internal battery voltage for maintenance of Data.
  - <Maximeter>. Indicates the maximeter value for each current and voltage phase. It has a "Reset" button.
  - <Thermal>. Phase and neutral thermal image value. It also has a "Reset" button.
  - <Temperature> Indicates the unit's temperature.
- Input and output status. The status of the digital inputs and outputs is indicated in each of the cards available in the unit. Each card is distinguished by its address, indicated in GGIO1 to GGIO8.
  - Digital inputs. Ind1.stVal to Ind32.stVal indicate "Y" if enabled and "N" if not. There are as many values as there are inputs in the card.
  - Digital outputs. SPCSO1.stVal to SPCSO16.stVal indicate "Y" if enabled and "N" if not. There are as many values as there are outputs in the card.
- Protection units. Indicates the current status of each of the functions: enabled, pick up, trip and last trip. In each of the functions the data available in each node are indicated.
  - Status. In <StEna.stVal>, the function is indicated as active and not blocked with "Y". "N" is used to indicate that the function is not enabled or blocked or in operation
  - Pick up. Indicates in <Str> whether the unit is picked up "Y" or not "N". The data depends on the unit, for example, for phase A it would be Str.phsA.
  - Activation. Indicates in <Op> whether the unit is tripped "Y" or not "N". The data depends on the unit, for example, for phase A it would be Str.phsA.
  - Last trip. Indicated within <l>. "Y" is used to indicate if the last trip was due to this cause, whilst "N" is used to indicate otherwise.

- Recloser status: Indicates the current status of the recloser. The signals are in <RREC1>. "Y" is used to indicate active signals, whereas "N" is used to indicate inactive signals. The available signals and their references are indicated in the recloser section. These include:
  - in service/blocked
  - in stand-by
  - ongoing cycle, indicating the closure cycle that is currently active.
  - definitive trip.
  - internal block, distinguishing different causes.
  - External block.
  - "Put Into Service and "Put Out of Service" buttons
- Frequency recloser status: Indicates the current status of the frequency recloser. The signals are in <FRREC1>. "Y" is used to indicate active signals, whereas "N" is used to indicate inactive signals. The available signals and their references are indicated in the frequency recloser section.
- Synchronism check unit status. The general status of the synchronism is displayed in RSYN1 and the presence of voltage in RVRS1. "Y" is used indicated active signals and "N" for inactive signals. The available signals and their references are indicated in the synchronism section.
- Protection status. With the "PROT" data in LLN0, "Y" indicates whether the relay is in service, "N" indicates if the relay is out of service.
- General status. Indicated in LLN0 with the "GEN" data, in which the following is indicated:
  - Unit hw status. Indicating if there is failure "Y" or "N".
  - Local/remote mode. Indicating if it is local, "Y" or "N".
  - Events pending dispatch. Indicating if there is an event pending dispatch, "Y" or "N".
  - Failure in IRIG synchronization. Indicating if there is failure, "Y" or "N".
  - V2 and Vn voltage monitoring. Indicating if there is failure, "Y" or "N".
  - Check on internal communication between cards. Indicating if there is failure, "Y" or "N".
- Open pole logic status. Shown in POPD1, indicating:
  - StEna.stVal. Indicates whether the function is enabled, "Y" or "N".
  - OpenPole. For each pole and general, indicating whether open "Y" or closed "N"
  - Number of open poles. One (OneOpPole), two (TwoOpPole), three (ThreeOpPol) or at least one (OpenPole)
  - Broken conductor. Indicating whether the phase is broken for each of the poles, "Y" or "N".
  - Deal line. Indicating whether there is a dead line for each of the poles, "Y" or "N".
- Breaker status. Shown in XCBR, indicating:
  - BrDISt. For each pole and general, the status of the associated digital input: closed "Y", open "N".
  - CloseOrdBr. For each pole and general, the status of the closure command: active "Y", inactive "N".
  - OpenOrdBr. For each pole and general, the status of the opening command: active "Y", inactive "N".
  - ClsFailBr. For each pole and general, indicating whether there has been a failure in the closure command, "Y" or "N"
  - OpenFailBr. For each pole and general, indicating whether there has been a failure in the opening command, "Y" or "N"
- Breaker monitoring status. Shown in CBOU1, indicating the value of the ki2 sum for each pole.
- Monitoring units.
  - CCTS1. CT monitoring. There is function enabled data (StEna.stVal) and CT monitoring activation data (CTSpv.general)
  - CTSU1. Temperature monitoring. There is a function enabling data (StEna.stVal) and an indication of the temperature above (OverTemp) and below (UnderTemp) the threshold.
  - CESS1. External power supply monitoring. Indication of external power supply above (OverVcc) or below (UnderVcc) the threshold. Also indicates whether the function is enabled or not (StEna.stVal).
  - CSUS1. Indicates battery failure status (DFFA), if it is activated "Y" or deactivated "N".

The status data are displayed on the PacFactory console and in the unit's display:

- PacFactory. All the status message information is displayed, grouped in tabs according to the information:
  - General. The date, active table, versions and measurements are displayed.
  - I/O. The digital inputs and outputs are displayed.
  - Enableds. Indicates whether the units are operative (enabled and not blocked) or not.
  - Protection status. The status of the protection units is displayed, i.e., if they are picked up and/or tripped.
  - Breaker and monitoring. The breaker, breaker monitoring and circuits statuses are displayed
  - Recloser and synchronism. The status of the recloser and synchronism units is displayed.
  - Check. The results of the various checks that are carried out in the unit are displayed.
- Display. Grouped into several screens and displaying:
  - General: Date and active table
  - Transformer measurements and configuration
  - Current and voltage maximeters
  - I/O. The digital inputs and outputs are displayed.

Figure 109 PacFactory status screen



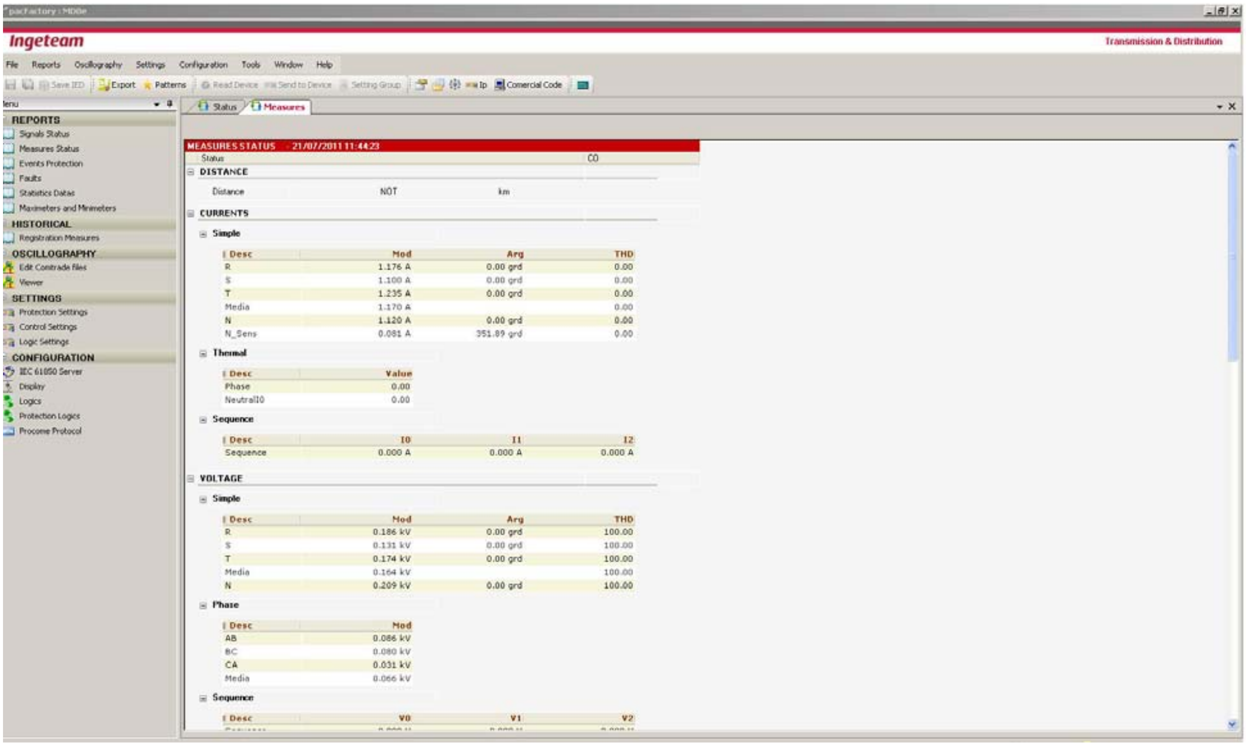
10.2 PRIMARY MEASUREMENTS REPORT

This report indicates the measurement transformers' primary measurements, applying the transformer ratio. The maximeter information is used for the maximeter reports.

The information available in the measurements message is:

- Distance. In the <Distance> tag, indicating the distance of the last fault.
- Currents. Within the <Currents> tag, showing the rms current measurements in primary:
  - Earth-phase.
    - The module and angle of each phase, neutral and sensitive neutral.
    - The average current module of the three phases.
    - THD of each phase, neutral and sensitive neutral.
  - Thermal image <Thermal>. Value of phase and neutral thermal image.
  - Sequences <Sequence>. Current sequences module (I0, I1, I2)
- Voltages Within the <Voltage> tag, showing the rms voltage measurements in primary:
  - Earth-phase.
    - The module and angle of each phase and neutral.
    - The average voltage module of the three phases.
    - THD of each phase and neutral.
  - Phase-phase <Phase>.
    - Phase pair module (AB, BC and CA) and average.
- Sequences. Voltage sequences module (V0, V1, V2)
  - Frequency. Frequency value.
  - Powers. Within the <Power> tag, showing the rms measurements for each phase and total:
  - Real power. Per phase and total.
  - Reactive power. Per phase and total.
  - Apparent power. Per phase and total.
  - Power factor <Power Factor>. Per phase and average.
  - Energy counters <Energy>. There is a reset button for the energy counters.
    - Last reset command date
    - Positive and negative real energy counter value
    - Positive and negative reactive energy counter value
- Maximeters. Shows the maximum value and the date on which it was produced. There is a reset button for the maximeter.
  - Current. For each phase.
  - Voltage. For each phase.
  - Real power. For phase and total.
  - Reactive power. For phase and total.
  - Apparent power. For phase and total.

Figure 110 PacFactory measurements screen



10.3 FAULT REPORT

The fault reports include information about the unit’s data during the fault, as well as the active settings during the fault. The last 20 faults are stored in a non-volatile memory.

The name of the file uses the standard IEEE C37.232-2007, using the fields:

Start Date, Start Time, Time Code, Station Identifier, Device Identifier, Company Name

For example, “100626, 46702262,+2h30t,Substation,Rele1,Ingeteam”, which means:

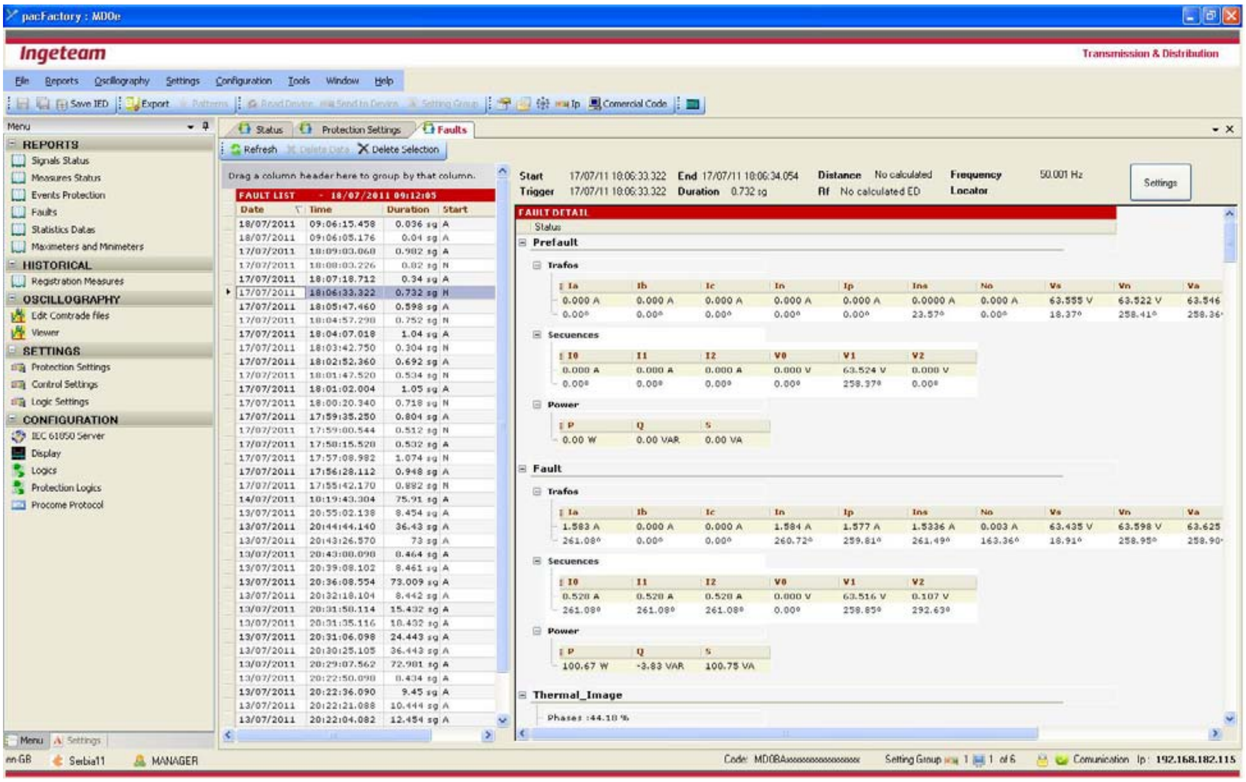
- Start Date: Trip date with a 2-character format for the year, the month and the day. For example, 26/june/2010 would be 100626.
- Start Time: Indicates the milliseconds as of 00:00 of the day, that is, milliseconds as of midnight.
- Time Code: Indicates the time zone amplitude sign, and can indicate minutes if necessary. For example, “t +2” indicates time zone 2, while “+2 h30t” indicates that the time zone is 2 hours 30 minutes.
- Station Identifier. Indicates the substation name. The installation’s short name (InsShNam) from the “PROT/LPHD1” node is used"
- Device Identifier. Indicates the unit’s name. The relay’s short name (RelShNam) from the “PROT/LPHD1” node is used"
- Company Name. Indicates the name of unit’s manufacturer, in this case, Ingeteam.

The information available in the fault is :

- Date and time: <Fecha>. Indicates the date as a string in the “dd/mm/yy hh:mm:ss.ms” format, i.e., “23/04/09 10_41_30_256”. There are three dates available
  - Start of the fault (first unit picked up): <Inicio>
  - Trip (first unit tripped): <Disparo>.
  - End of fault (when the trip signal disappears): <Fin>

- Configuration: <Config>. Indicates the configuration of each of the 12 transformers: type and scale range.
- Pre-fault and fault. Indicates the values measured before the fault and upon the fault. They are grouped into “Pre-fault” and “Fault”, and the same data is available in both cases:
  - Transformer measurements <Trafos>. It indicates the measurement in the module and the angle of each transformer.
  - Sequences. Indicates the measurements in the module and the angle of the current sequences (I0, I1 and I2) and the voltage (V0, V1 and V2).
  - Powers. Indicates the measurements of the total real, reactive and apparent powers.
- Distance to fault.
- Frequency in the moment of the fault.
- Thermal image upon trip. The thermal image is indicated as a % of phases and neutral.
- Breaker. Indicates breaker monitoring data upon the fault.
  - Open current. For each phase, indicates the current value upon the trip.
  - Sigma ki. For each phase, indicates the sigma ki2 value.
- Fault and trip type <Tipo/Type>: Summary of the fault with the 3-letter code formed by combinations of the characters A, B, C, N, NS and G (if tripped by a phase, neutral, sensitive neutral or ground), RTP (teleprotection), IF (phase overcurrent), IN (neutral overcurrent), D (current unbalance), VO (zero-sequence overvoltage), HV (overvoltage), LV (undervoltage), RTP (teleprotection), DT (transferred trip), DP (pole discordance), IT (thermal image). Example: AC is a two-phase fault in phases A and C.
  - Fault type: Indicates the pick up type.
  - Trip type: Indicates the trip type.
- Details of units. Indicates the picked up and tripped units. Indicates whether the unit is active “Y” or not “N” for each logical node available in the unit.
  - Pick up. Indicates in <Str> whether the unit is picked up “Y” or not “N”. The data depends on the unit, for example, for phase A it would be Str.phsA.
  - Activation. Indicates in <Op> whether the unit is tripped “Y” or not “N”. The data depends on the unit, for example, for phase A it would be Str.phsA.
- Active settings. Active settings in the moment of the fault. Indicates the setting file name. It can be accessed to consult the settings.

Figure 111 PacFactory fault screen



10.4 INCIDENT REPORT

The unit stores in a queue of 1000 non-simultaneous protection events in a non-volatile memory. Each protection event is recorded with its date and time, as well as the current and voltage measurements of all the transformers and the frequency.

The protection events can be masked individually, so that only protection events configured by the user are generated. These enablings are available in the GEN/RSUC node.

The information available in each record is:

- Date: With millisecond precision.
- Information. Within the <Inf> tag the protection event signal number and its status 0 (Deactivation) / 1 (Activation) are indicated. Each protection event record can have up to 16 simultaneous signals.
- Measurements. The trafo measurements at the time of the protection event (module and angle) and frequency measurement are shown for each of the unit's transformers.

Figure 112 Example of protection event record

```
<Reg Fecha="15-06-10 21:50:38:792">
        <Inf Sen="8426" Status="1"/>
        <Inf Sen="8433" Status="0"/>
        <Med>
                <T1 Mod="0.00" Arg="0.00"/>
                <T2 Mod="0.00" Arg="0.00"/>
                <T3 Mod="0.00" Arg="0.00"/>
```

<T4 Mod="0.00" Arg="0.00"/>

<T5 Mod="0.00" Arg="0.00"/>

<T6 Mod="0.00" Arg="38.10"/>

<T7 Mod="31.68" Arg="58.53"/>

<T8 Mod="99.94" Arg="-62.01"/>

<T9 Mod="99.95" Arg="178.00"/>

<T10 Mod="31.67" Arg="58.54"/>

<T11 Mod="99.98" Arg="-62.02"/>

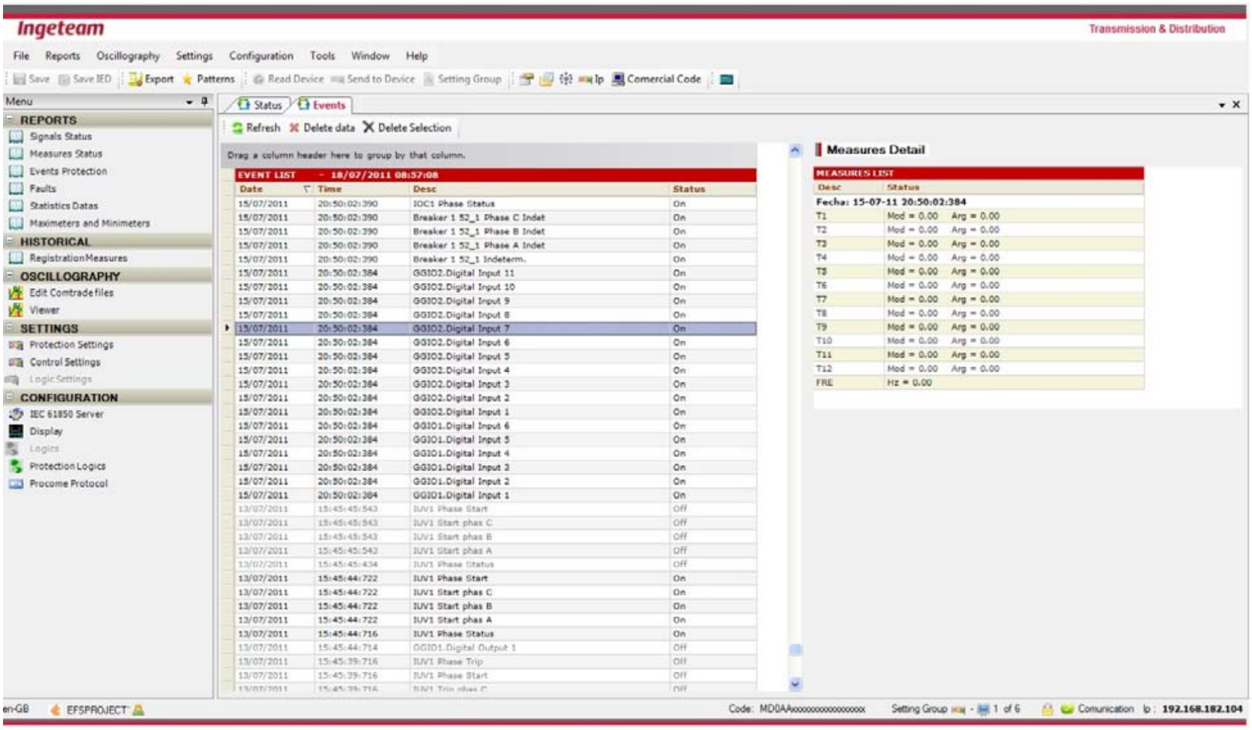
<T12 Mod="99.94" Arg="178.00"/>

<FRE Hz="50.00"/>

</Med>

</Reg>

Figure 113 PacFactory protection event screen



10.5 HISTORICAL MEASUREMENT REPORT

The unit saves a queue of 4000 historical measurement reports the non-volatile memory.

Each record includes the maximum and minimum average currents, the maximum and minimum average phase to earth voltages and the maximum and minimum real, reactive and apparent power (calculated within a programmable time window) detected during a programmable recording period. The measurements are secondary.

The historical measurement report is grouped into records in which the first corresponds to the oldest and the last to most recent, so that when the file is opened, the first item we see is the oldest.

- The format of this file for each record is:
- Record number
- Date: With second precision: Day and Time
- Measurements: Maximum/minimum/average magnitude values:
  - Current. The units are secondary amps.
  - Voltage. The units are secondary volts.
  - Real power. The units are secondary watts.
  - Reactive power. The units are secondary VAR.
  - Apparent power. The units are secondary VA.
  - Frequency. Units are Hz.
  - External power supply. The units are volts.

Figure 114 Example of records

```
<REG Num="0" Day="18/04/10" Time="00:00:37">
        <I_A Max="0.000" Min="0.000" Media="0.000"/>
        <V_V Max="0.000" Min="0.000" Media="0.000"/>
        <P_W Max="0.00" Min="0.00" Media="0.00"/>
        <Q_VAR Max="0.00" Min="0.00" Media="0.00"/>
        <S_VA Max="0.00" Min="0.00" Media="0.00"/>
        <f_Hz Max="0.000" Min="0.000" Media="0.000"/>
        <Batery_V Max="120.51" Min="120.51" Media="120.51"/>
</REG>
```

The settings employed by this unit are in the PROT/MHRE node:

- Sample time window. Indicates the time in minutes during which the average is calculated
- Record interval. Indicates the time in minutes in which each record is created
- Start time. Indicates the time after which the historical measurement record is started
- End time. Indicating the time up to which the historical measurements record is carried out
- Calendar mask. Indicates whether the historical measurements record is created every day (YES) or if it is only created on the days indicated in the day selection mask.
- Day selection. It indicated, for each day of the week, whether the record was created.

Table 132 Historical measurement settings

Data	Setting	Min.	Max	Step	Remarks	Type
SmTmm	Sample time window	1	15	1	minutes	uint32
RegIntTmm	Record interval	1	1440		minutes	uint32
StH	Start time	0	23	1		uint32
EndH	End time	0	23	1		uint32
DayEna	Calendar mask				YES/NO	Boolean
SunEna	Selection Sunday				YES/NO	Boolean
MonEna	Selection Monday				YES/NO	Boolean
TueEna	Selection Tuesday				YES/NO	Boolean
WedEna	Selection Wednesday				YES/NO	Boolean
ThuEna	Selection Thursday				YES/NO	Boolean
FriEna	Selection Friday				YES/NO	Boolean
SatEna	Selection Saturday				YES/NO	Boolean

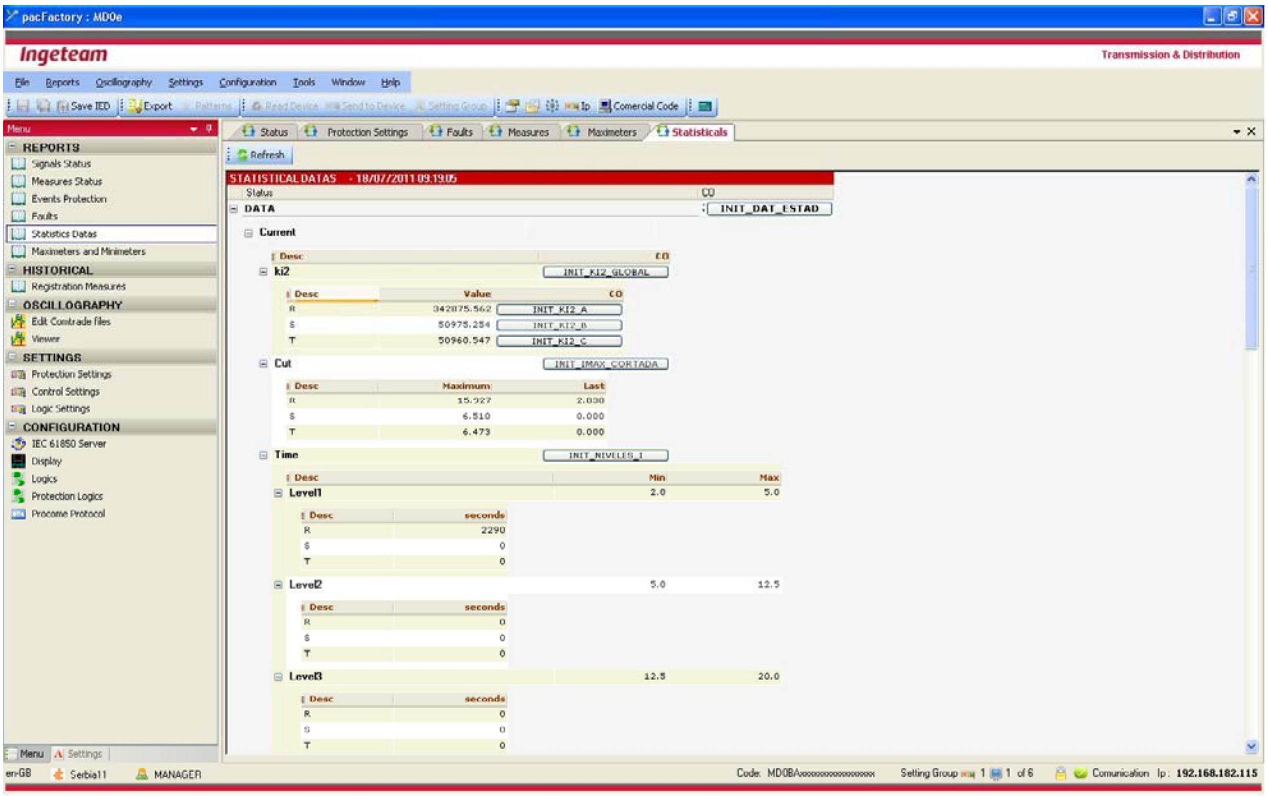
10.6 STATISTICAL DATA REPORT

Displays the statistical data calculated in the unit: currents, action times and counters. It has reset buttons.

The values available are:

- The current statistics are grouped in the <Current> tag and include:
  - <ki2> Ki2 accumulated by each of the 3 phases. Each phase can be independently reset to the initial value.
  - <Cut> Opened current. Indicates the last (Last) and maximum (Maximum) open current per phase
  - <Time> Indicates the time in seconds during which the current has been within specific ranges.
  - From 2 to 5 times In
  - From 5 to 12.5 times In
  - From 12.5 to 20 times In
  - From 20 to 40 times In
- The counters are grouped in the <Counters> tag and include:
  - <Reclose> Reclosure counter. Indicates the number of reclosures effected, separating them according to first, second, third and fourth reclosure. There is a command for resetting the counter.
  - <Openings>. Opening counter for each of the 3 phases, includes trips and manual openings. There are commands for resetting each phase's counter and a global counter for all the phases.
  - <Trip>. Trip counter for each of the 3 phases. There are commands for resetting each phase's counter and a global counter for all the phases.
  - <Close>. Closure counter for each of the 3 phases. There are commands for resetting each phase's counter and a global counter for all the phases.
- The timers are grouped in the <Timers> tag and include:
  - <Opening>. Indicates the electric (Electrical) and mechanical (Mechanical) opening times in milliseconds per phase and the dispersion for each pair of phases.
  - <Close>. Indicates the electric (Electrical) and mechanical (Mechanical) closure times in milliseconds per phase and the dispersion for each pair of phases.
  - <Inactivity> Indicates the days of breaker inactivity for each phase.

Figure 115 PacFactory statistics screen



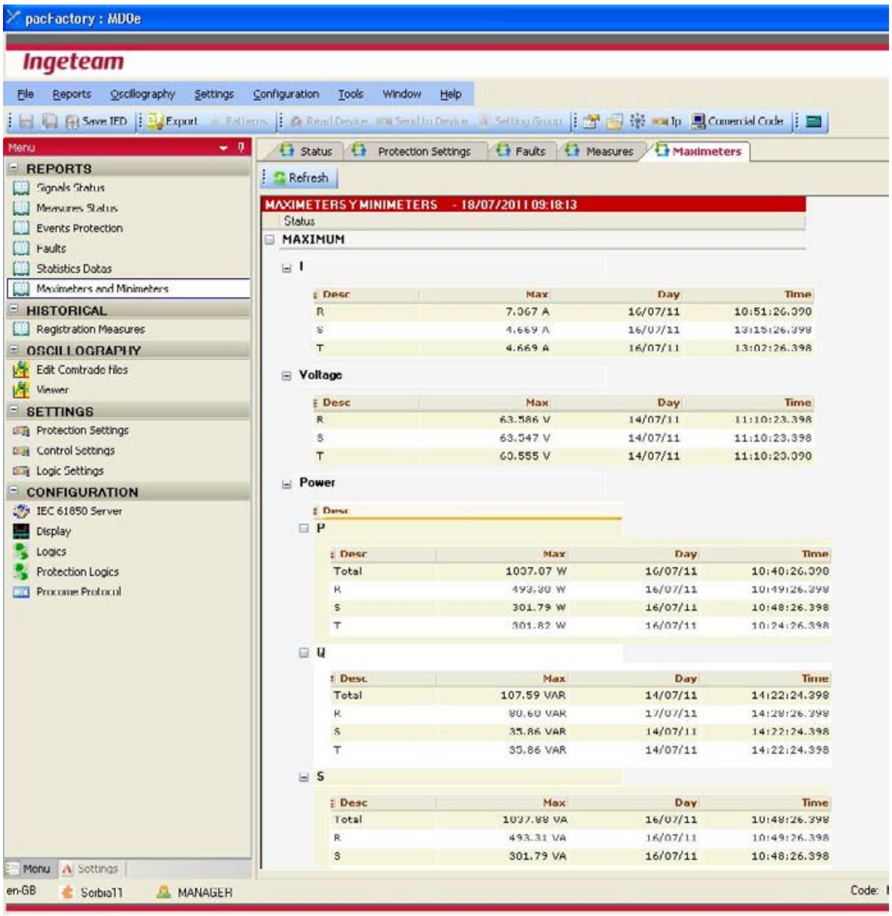
10.7 MAXIMETER/MINIMETER REPORT

Displays the maximum and minimum values integrated in the time. It has buttons to individually reset the maximeters and/or minimeters.

The Data displayed are:

- Each phase's current
- Each phase's voltage
- Real power per phase and total
- Reactive power per phase and total
- Apparent power per phase and total
- Frequency
- External battery measurement

Figure 116 PacFactory maximeter/minimeter screen



10.8 OSCILLOGRAPHY

The oscillography is stored in binary comtrade format. There is a CFG config file and a DAT data file for each.

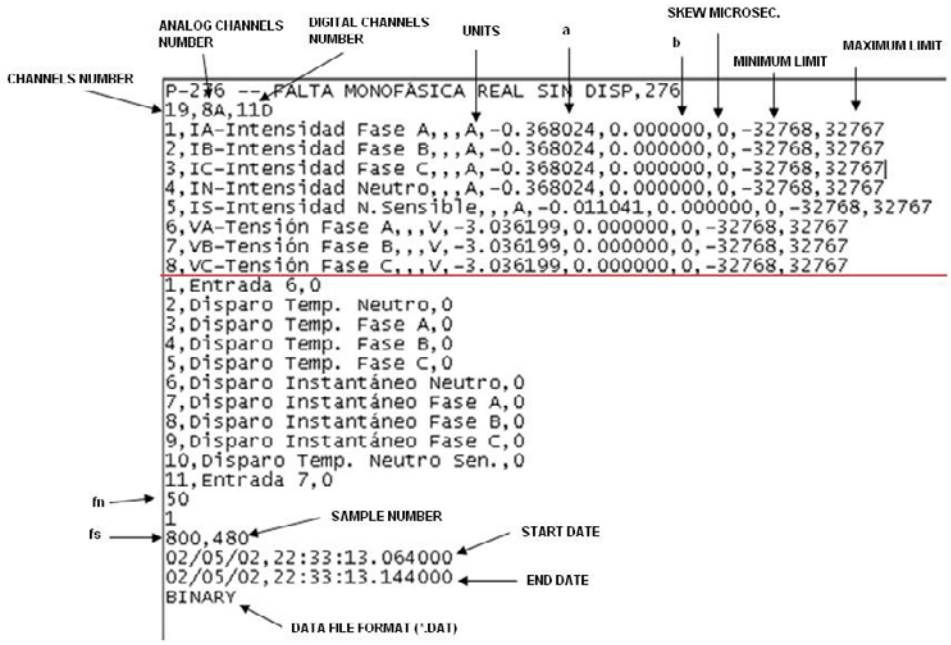
For additional information on "IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems".

- The disturbance record configuration file (CFG) contains the general disturbance recorder information (Figure 117):
- Total number of total analogue and digital channels available in the disturbance recorder
- Analogue channel data: bay, identification, measurement measures, scaled and limits
- Digital input data: bay and identification
- Sample data: signal frequency, sampling frequency, number of the last sample
- Disturbance recorder start and end dates.
- Data file format

The disturbance recorder data file (DAT) includes the information captured in the disturbance recorder, with the following available for each sample:

- Sample number
- Sample time
- Analogue sample values
- Digital signal values

Figure 117 Configuration file



The name of the file uses the standard IEEE C37.232-2007, using the fields:

Start Date, Start Time, Time Code, Station Identifier, Device Identifier, Company Name

For example, "100626, 46702262,+2h30t,Substation,Rele1,Ingeteam", which means:

- Start Date: Trip date with a 4-character format for the year, the month and the day. For example, 26/june/2010 would be 20100626.
- Start Time: Indicates the milliseconds as of 00:00 of the day, that is, milliseconds as of midnight.
- Time Code: Indicates the time zone amplitude sign, and can indicate minutes if necessary. For example, "t +2" indicates time zone 2, while "+2 h30t" indicates that the time zone is 2 hours 30 minutes.
- Station Identifier. Indicates the substation name. The installation's short name (InsShNam) from the "PROT/LPHD1" node is used"
- Device Identifier. Indicates the unit's name. The relay's short name (RelShNam) from the "PROT/LPHD1" node is used"
- Company Name. Indicates the name of unit's manufacturer, in this case, Ingeteam.

The settings employed by this unit are in the PROT/RDRE node:

- Duration of disturbance recorder (cycles). Indicates the total duration of disturbance recorder (in cycles).
- Pre-fault duration (cycles). Indicates the pre-fault cycles that are stored in each disturbance recorder
- Number of samples/cycle. Indicates the samples per cycle stored in the disturbance recorder.
- Recorded signal disturbance recorder 1. Indicates the signal that is stored in record 1. If programmed as -1, no signals are recorded.
- Trigger 1 signal. If the signal is configured, it indicates whether it provokes a disturbance recorder pick up or not.
- The trigger and recorded signals are repeated up to 100 possible signals.

Table 133 Historical measurement settings

Data	Setting	Min.	Max	Step	Remarks	Type
OscCyc	Duration of disturbance recorder (cycles)	20	420	1	cycles	Int32
PreCyc	Pre-fault duration (cycles)	1	415	1	cycles	Int32
NuSaCy	Number of samples/cycle					enum
OscReg1	Recorded signal disturbance recorder 1					Int32
OscTrg1	Trigger 1 signal	0	1	1	YES/NO	Boolean
OscReg2	Recorded signal disturbance recorder 2					Int32
OscTrg2	Trigger 2 signal	0	1	1	YES/NO	Boolean
	Recorded signal and trigger up to 100	0	1	1	YES/NO	Boolean

11. USB ACCESS

The unit can be accessed via the front USB to retrieve reports and CID from the device and to load a new CID.

11.1 DOWNLOADING REPORTS

When a pendrive is inserted, the following appears in the front above the current screen, indicating that the device has been detected:

```
USB Detected
```

The unit's reports are automatically dumped onto the pendrive.

While the data is being downloaded, the following appears in the front above the current screen:

```
USB Detected
Downloading data
```

Just in case there is a CID, an ICD or and IID in the pendrive, the user will be asked for a confirmation to load this file into the unit.

```
WANT TO START
THE CID UPDATE
  CANCEL
  ACCEPT
PRESS ENTER: RUN
OPTION
```

If accepted, the following appears on the screen:

```
USB Detected
Downloading data
```

If canceled, downloading is assumed to be complete, and the following appears on the screen for 5 seconds:

```
REMOVE THE
USB DEVICE
```

As of this moment, the pendrive can be removed.

Only the reports existent in the unit at the time of the download will appear in the pendrive, with the data structure:

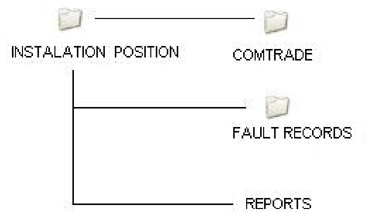
- Root with the short installation and relay name (PROT/LPHD node), and the iedName, separated by "_"·, i.e., "Instalacion_Rele_iedName"
- COMTRADE. This directory contains the disturbance recorders generated in the unit
- FAULT RECORDS. This directory contains the fault records generated in the unit.

- The rest of the unit's reports are dependent on the root:
  - Maximetro.xml
  - Sucesos.xml
  - Informe_Estadisticos.xml
  - Registro.xml
  - CID

For detailed information about these reports, see Chapter 10, "DATA ACQUISITION FUNCTIONS

".

Figure 118 USB Tree



11.2 LOADING CID

When a pendrive is inserted into the front USB port, a check is run to see if an ICD exists. If there is an ICD, it is copied into the directory "public/SCL/notvalidated" in order that it may be operative in the unit.

Suring the search for the ICD, the existence of a file with an ICD, icd, CID, cid, IID or iid extension is checked. The file name need not be specific as only the extension is checked.

If there is more than one file with one of the indicated extensions, the ICD is considered invalid and not ICD is captured.

12. FTP ACCESS

The public user for ftp access is as follows:

- User: ftpuser
- Password: ftpuser

The user profile allows direct access to the LD and SCL directories.

13. MAPPING THE UNIT'S SIGNALS, MEASUREMENTS AND METERS

All the signals (trips, logics, hw check, digital inputs-outputs, etc.), measurements and meters that are generated in the unit are identified by a number that appears in the sAddress of each of these elements.

13.1 SIGNALS

The distribution of the unit's signals is effected using four numbers as a base: 0, 8192, 16384, 24576. All the unit's signals are divided into four types, taking these four digits as references:

13.1.1 Type A signals

This type of signal refers to all those signals with sAddress identification numbers between digits 0 and 8191.

These signals include digital inputs and Goose signals.

- Digital Inputs
  - Identification number between 0 and 287.

    Example: sAddr="S,0,5,0;TX1:GGIO1.Digital input 6,TX2:GGIO1.Digital Input 6,AC:1.2,ED:1.1,AD:0.0"

    In the example, we can see the identification number of digital input number six from the first card in the ICD sAddress.
  - GEN/GGIO node
- Goose Signals
  - In turn, the Goose signals are divided into RIO modules and LGOS nodes.
  - RIO modules
  - Identification number between 288 and 607.

    Example: sAddr="GS,0,288,0;TX1:RIO1.St,TX2:RIO1.St,AC:1.2,ED:1.1,AD:0.0"

    In the example, we can see the identification number of the first signal from the first RIO module in the ICD sAddress.
  - GEN/RIO node
- LGOS nodes
  - Identification number between 608 and 1663.

    Example: sAddr="GS,0,608,0;TX1:LGOS1.St,TX2:LGOS1.St,AC:1.2,ED:1.1,AD:0.1"

    In the example, we can see the identification number of the first signal from the first LGOS node in the ICD sAddress.
  - GEN/LGOS node

Therefore, the distribution of these signals based on their identification number is as follows:

Table 134 Type A signal mapping

DIGITAL INPUTS (0 - 287)

GOOSE SIGNALS (288 - 1663)

The number of this type of signal reserved in the unit is 1664.

13.1.2 Type B signals

This type of signal refers to all those signals with sAddress identification numbers between digits 8192 and 16383.

This type of signal includes type B protection signals, fast protection logic signals and fast control logic signals.

- Type B protection signals
  - Identification number between 8192 and 9215.
    Example: sAddr="S,0,9091,0;TX1:TOC1 Phase trip,TX2:TOC1 Phase Trip,AC:1.2,ED:1.1,AD:0.0"
    In the example, we can see the identification number of a type B protection signal in the ICD sAddress.
  - PROT node
- Fast protection logics
  - Identification number between 9216 and 9343.
    Example: sAddr="PS,0,9216,0;TX1:Protection logic 1,TX2:Protection logic 1,AC:1.2,ED:1.1,AD:0.0"
  - n the example, we can see the identification number of the first protection logic in the ICD sAddress.
  - GEN/pGGIO node
- Fast control logics
  - Identification number between 9344 and 9471.
    Example: sAddr="LS,0,9344,0;TX1:Fst logic 1,TX2:Fast logic 1,AC:1.2,ED:1.1,AD:0.0"
    In the example, we can see the identification number of the first fast control logic in the ICD sAddress.
  - CTRL/AutGGIO2 node
  - Therefore, the distribution of these signals based on their identification number is as follows:

Table 135.Type B signal mapping

PROTECTION SIGNALS TYPE B (8192 - 9215)
FAST PROTECTION LOGIC SIGNALS

(9216 - 9343)
FAST CONTROL LOGIC SIGNALS . (9344 - 9471)

The number of this type of signal reserved in the unit is 1280.

13.1.3 Type C signals

This type of signal refers to all those signals with sAddress identification numbers between digits 16384 and 24575.

These signals include the type C protection signals.

- Type C protection signals
  - Identification number between 16384 and 16575.

    Example: sAddr="S,0,16384,0;TX1:Recloser in service,TX2:,AC:1.2,ED:1.1,AD:0.0"

    In the example, we can see the identification number of the first type C protection signal in the ICD sAddress.
  - PROT node

Therefore, the distribution of these signals based on their identification number is as follows:

Table 136.Type C signal mapping

TYPE C PROTECTION SIGNALS (16384 - 16575)

The number of this type of signal reserved in the unit is 192.

13.1.4 Type D signals

This type of signal refers to all those signals with sAddress identification numbers between digits 24576 and higher.

This type of signal includes the type D protection signals, the communication failure signals for all the bays that are connected to the unit and the slow logic control signals.

- Type D protection signals
  - Identification number between 24576 and 24863.

    Example: sAddr="S,0,24576,0;TX1:Relay in service,TX2:OnLine,AC:1.2,ED:1.1,AD:0.0"

    In the example, we can see the identification number of the first type D protection signal in the ICD sAddress.
  - PROT node
- Communication failure control signals
  - Identification number between 24864 and 25887.
- Slow control logics
  - Identification number between 25888 and 26399.

    Example: sAddr="LS,0,25888,0;TX1:Slow logic 1,TX2:Slow logic 1,AC:1.2,ED:1.1,AD:0.0"

    In the example, we can see the identification number of the first slow control logic in the ICD sAddress.
  - CTRL/AutGGIO1 node

Therefore, the distribution of these signals based on their identification number is as follows:

Table 137 Type D signal mapping

TYPE D PROTECTION SIGNALS (24576 - 24863)
CONTROL SIGNALS (COM FAILURE) (24864 - 25887)
SLOW LOGIC CONTROL SIGNALS (25888 - 26399)

The number of this type of signal reserved in the unit is 1824.

13.2 MEASUREMENTS

All the unit's measurements are divided into three types:

- Protection measurements.
  - Identification number between 0 and 299.
    Example: sAddr="M,0,124,1;TX1:I average,TX2: AVERAGE I"
    In the example, we can see the identification number of a protection measurement in the ICD sAddress.
  - PROT node
- Goose Measurements
  - Identification number between 300 and 555.
    Example: sAddr="GM,0,300,0"
    In the example, we can see the identification number of the first Goose measurement in the ICD sAddress.
  - GEN/LGOS node
- Measurements resulting from logics
  - Identification number between 556 and 687.
    Example: sAddr="LM,0,556,0;TX1:Logic measurement 1,TX2:Logic analog 1"
    In the example, we can see the identification number of the first logic measurement in the ICD sAddress.
  - CTRL/AutGGIO1 node

Therefore, the distribution of these measurements based on their identification number is as follows:

Table 138 Measurement mapping

PROTECTION MEASUREMENTS (0 - 299)
GOOSE MEASUREMENTS (300 - 555)
MEASURERMENTS RESULTING FROM CONTROL LOGICS (556 - 687)

The number of measurements reserved in the unit is 688.

13.3 COUNTERS

All the unit's counters are divided into three types:

- Protection counters
  - Identification number between 0 and 31.
    Example: sAddr="C,0,0;TX1:Active energy out,TX2:Active Energy Out"
    In the example, we can see the identification number of the first protection counter in the ICD sAddress.

- PROT node
- Counters resulting from logics
  - Identification number between 32 and 149.
    Example: sAddr="LC,0,32;TX1:Logic counter 1,TX2:Logic counter 1"
    In the example, we can see the identification number of the first logic counter in the ICD sAddress.
  - CTRL/AutGGIO1 node

Therefore, the distribution of these counters based on their identification number is as follows:

Table 139 Counter mapping

PROTECTION COUNTERS (0 - 31)
COUNTERS RESULTING FROM CONTROL LOGICS (32 - 149)

The number of counters reserved in the unit is 150.

14. LOGICS

This document explains the operating mode of the logics generation tool for Ingeteam's EF family of logic devices.

The EF family's logics are fragments of executable code generated by the user using a PC tool, both in text and graphic formats. These logics can be defined in an IED's data model (using iedFactory) or in a particular instance (using substationFactory or the pacFactory settings tool).

There are two different types of logics: control logics and protection logics.

In this chapter the device logics are defined and an introduction to the configuration options is presented. For more details about the logics configuration consult the user manual of the software configuration tool (pacFactory / energyFactorySuite).

14.1 CONTROL LOGICS

The logics can be used to customize the behaviour of an IED. For example, automatism can be added or calculations between different magnitudes can be carried out.

The logics are run in two different tasks, each with different priorities: one for fast logics and one for slow logics.

The running time for the fast logics is 2 milliseconds. The running time for the slow logics is approximately 10 milliseconds, although given that this is a lower priority task it may occasionally be affected by other higher priority tasks.

Each configured logic must be included in one of these two tasks, in accordance with the manner in which they are to be run – fast logics or slow logics.

To edit a control logic from substationFactory, the user must select the corresponding IED and click on the editor icon. To edit the control logic from pacFactory, click on the "Logics" option in the “Configuration” menu or in the side menu.

The logics are defined in program blocks called POU (program organization unit). Two of the languages defined in the IEC-61131-3 standard are offered for the creation of each POU: one textual (ST) and one graphic (FBD).

The POUs can be defined at different levels, both in the model and in an instantiation: at the IED level, at the logical device (LD) level or at the logical node (LN) level.

There are three types of POU, as defined in the IEC-61131-3 standard: PROGRAM, FUNCTION_BLOCK and FUNCTION. The programs are the senior hierarchy POUs, with each one corresponding to a task to be run on the device. Each PROGRAM can refer to several FUNCTION_BLOCK and FUNCTION. In turn, a FUNCTION_BLOCK can refer to one or more FUNCTION.

At the IED level, two PROGRAM corresponding to the two above tasks are automatically defined: one for the fast logics (FastLog) and the other for the slow logics (SlowLog). These PROGRAM cannot be deleted nor can their names be modified. New PROGRAM cannot be created at any level, either.

14.2 PROTECTION LOGICS

The various protection functions can be configured by means of settings associated to the unit's internal signals, vg enablings or blocks. The protection functions treat these signals as inputs, although they do not modify their value. In order to assign them a value, the protection logics are used.

The protection logics have two main differences in relation to the control logics:

- The result of a protection logic is always a Boolean value, to be assigned in one of the protection function's settings.
- The protection logic editor has been simplified to facilitate the programming of this type of logic.

The number of available logics is defined by the unit's data model.

Each logic signal has a value obtained from an associated logic. These logics are fragments of code created in one of the two possible languages - ST (text) or FBD (graphic). The corresponding language must be selected when a logic corresponding to a signal is edited for the first time.

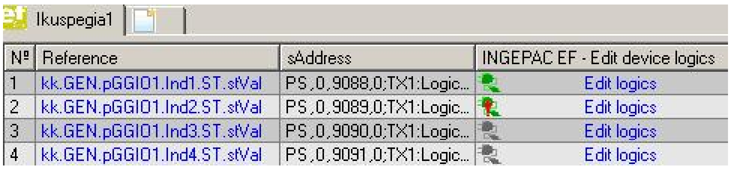
Each protection logic is independent from the rest and need not be included in a POU in order to be run. When a protection logic is saved in the editor, an attempt is made to compile the information. If no error is found, a call to the logic in question is automatically generated so that the logic is run when a CID (configured IED description) message is sent to the device or sent from pacFactory.

The protection logics are run every 2 milliseconds, as are the fast control logics.

To edit a protection logic from substationFactory, the user must select the corresponding logic signal and click on the editor icon. This icon has three statuses to indicate the status of the corresponding logic:

Icon	Logic statuses:
	No logic has been edited for this signal. The value of the signal will be 0 (false).
	Logic edited and ready to be run.
	Logic edited, but with errors. Logic will not be run.

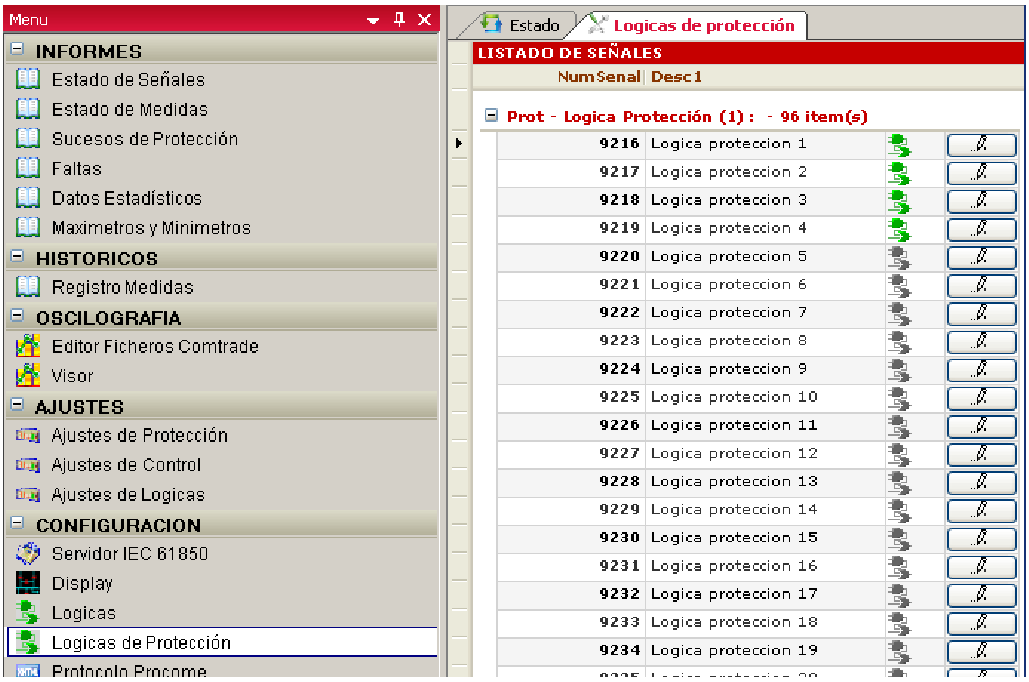
The following image shows a detail of the expander with four signals with logic signals of different statuses:



Details of the expander with protection logic signals

To edit a protection logic from pacFactory, click on the "Protection Logics" option in the “Configuration” menu or in the side menu.

A screen with a list of the available protection logic signals, along with the logic’s status icon and an access button for each logic’s editor, will be shown.



Details of the protection logics list in pacFactory

14.3 DATABASE SIGNALS

All of the IED's database signals, measurements, meters and commands can be accessed as readings from the logics (the data model's basic data with valid sAddress). There is a set of data within this database that can be modified from the control logics:

Signal type	Description
Critical signals	Digital signals that can be modified from the fast task (FastLog)
Non-critical signals	Digital signals that can be modified from the slow task (SlowLog)
Measurements	Floating point data that can be modified from both tasks
Meters	Whole numbers that can modified from both tasks
Commands	Commands can only be generated from the slow task (SlowLog)

Both the data's value and its quality can be accessed. If data is modifiable from the logic, the same will apply to the value and the quality.

The data that can be modified from the logic may be preset in the unit's data model or they can be configured in the engineering phase.

Only the status of the signal to which the logic in question is associated can be modified from the protection logics.

15. IEC 61850 COMMANDS

15.1 RUNNING IEC 61850 COMMANDS

Commands in the EF platform can be issued for controllable elements (elements whose functional constraint is “CO”) that may belong to different Data classes (detailed in IEC 61850-7-3) and, as defined in IEC 61850-7-2, paragraph 17 Control class model, may be:

- Controllable single point (SPC)
- Controllable double point (DPC)
- Controllable integer status (INC)
- Binary controlled step position information (BSC)
- Integer controlled step position information (ISC)
- Controllable analogue set point (APC)

The control model established by the standard consists of a series of services and an operational specification to be followed in accordance with the type of command.

The IEC 61850 standard defines the following services:

- Select (Sel) / SelectWithValue (SelVal)
- Cancel
- Operate (Oper) / TimeActivatedOperate (TimOper)
- CommandTermination (CmdTerm)

The operating model of a specific command is defined in the Ct1Model configuration parameter associated to the command, in accordance with the following table:

Table 140 Possible ctlModel

Value	Explanation	enum
status-only	The object is not controllable, only the services that apply to a status object are supported. The attribute ctlVal does not exist.	0
direct-with-normal-security	Direct control with normal security according to IEC 61850-7-2.	1
sbo-with-normal-security	SBO control with normal security according to IEC 61850-7-2.	2
direct-with-enhanced-security	Direct control with enhanced security according to IEC 61850-7-2.	3
sbo-with-enhanced-security	SBO control with enhanced security according to IEC 61850-7-2.	4

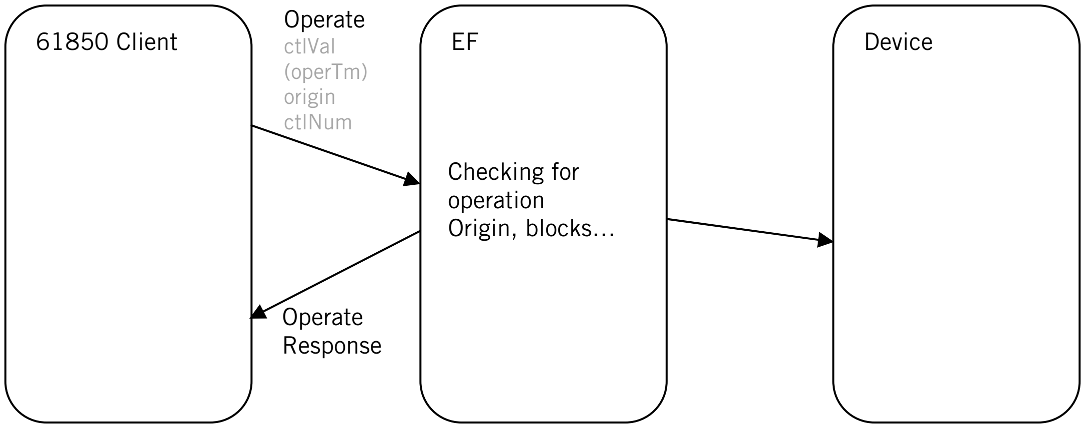
Furthermore, a series of parameters are defined for the command (IEC 61850-7-3-7.5), including the following fields:

- CtlVal. Command value. The type will be different, in accordance with element’s the CDC (Common Data Class). Nevertheless, it is obligatory in all cases.
- Origen. Origin of the command, divided into two fields:
  - orCat. Origen category. Indicates the type of client that issues the command (local, substation, remote command, etc.)
  - orIdent. For commands sent through IEC 61850 communications, this Data will include the client’s IP address, according to which the unit is able to decide whether to block the command or not, in accordance with its authorization.
  - PulseConfig. This Data is a structure that defines the command’s output pulse type (pulse, duration, pulse train)

- OperTimeOut. Maximum switching time following which a failure is recorded if the command has not been successfully run.
- sboTimeout. The time which the command selection remains active.

Thus, the operation of a specific command will depend on its configuration and ctlModel, as established by the IEC 61850-7-2-17 standard. If the command's ctlModel is DIRECT_WITH_NORMAL_SECURITY (1), the process to follow will be as shown in the following figure:

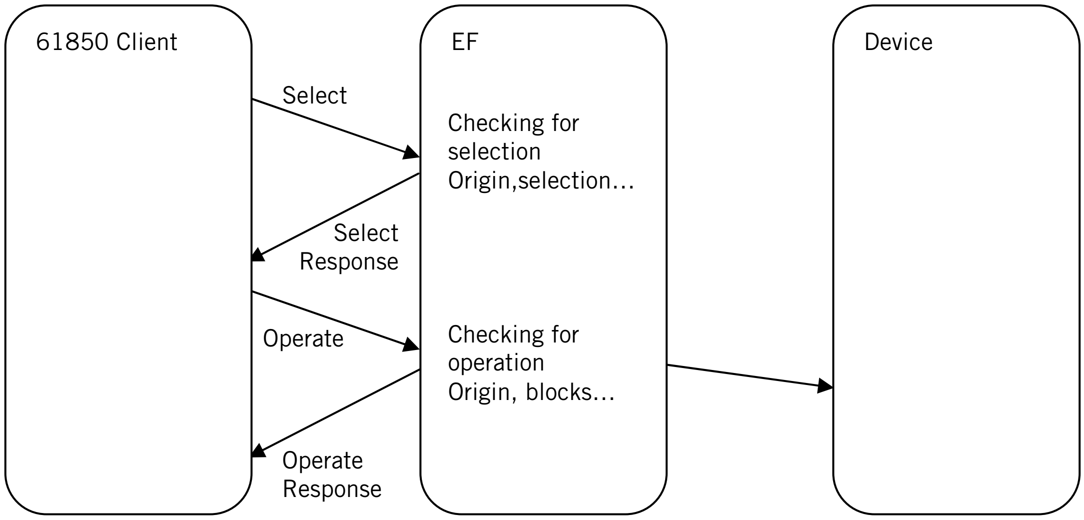
Figure 119 Direct command process with normal security



Upon receiving a request to run a command by means of an operate request, the unit analyses the validity of the request, checking the client's authorization and any possible blocks, and responds positively or negatively by means of an operate request to the client. If the response is negative, the AddCause field informs the client of the reason for the failure of the command. If the response is positive, the command is sent to the device.

If the command's ctlModel is SBO_WITH_NORMAL_SECURITY (2), the process is similar and includes a selection prior to running:

Figure 120 Command process with prior selection and normal security



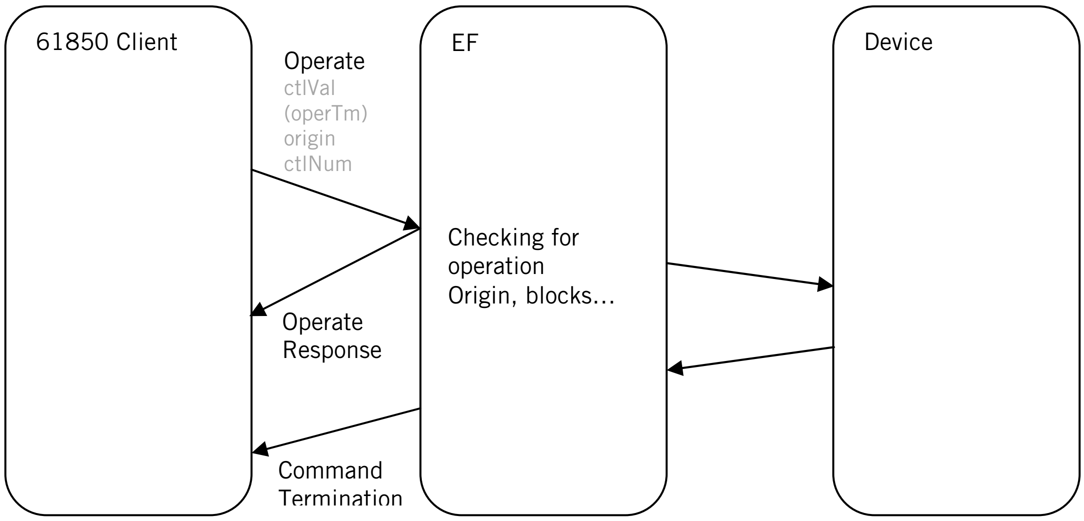
In this case, upon

receiving a selection request the selection's permission is checked and, when applicable, a positive response is sent. A timer then starts which, upon the elapse of the sboTimeOut timeout, cancels the selection. If a run request is received before the conclusion of the timeout, the same process as that described for the direct commands with normal security is followed.

If the selection is not been accepted, the response will be negative and the process is concluded. Similarly, if a run request is not received before the conclusion of the sboTimeOut, the selection is cancelled and the command process is concluded.

When the command's ctlModel is DIRECT_WITH_ENHANCED_SECURITY (3), the process starts exactly as with the direct commands with normal security, as shown in the diagram below:

Figure 121 Direct command process with enhanced security



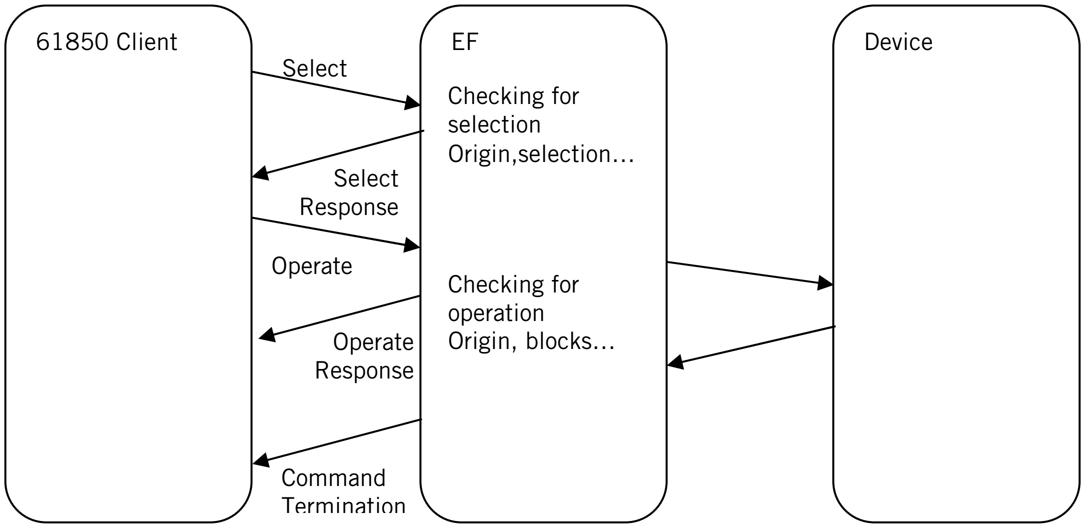
Due to the enhanced security, and after sending the run command to the device, there is a timeout for the reception of the return information from the element on which the command is to be run. The unit can thus inform the client by means of a Command termination whether the operation has been run successfully before the conclusion of the period set in operTimeout.

If the device's return information is received before the conclusion of the maximum run time and the position in question has been reached, the client is sent a positive Command Termination.

If the operTimeout time is exceeded without having received the information from the device, or if it is received but the position in question has not been reached, the Command Termination will be negative. As with the rest of the negative responses sent to the client, the cause of the failure of the command will be included in the AddCause field.

The ctlModel SBO_WITH_ENHANCED_SECURITY (4) includes, in addition to the enhanced security process of the commands modelled as DIRECT_WITH_ENHANCED_SECURITY, the selection process described above for the SBO_WITH_NORMAL_SECURITY commands, and as such the scheme to be followed is a as follows:

Figure 122 Command process with prior selection and enhanced security



Independently of CtlModel that is configured for the commands, or of the rest of the configuration parameters, the corresponding reports are generated whenever a change occurs, providing the report configuration allows this.

In addition to informing of the changes in the status signals of the elements on which the commands are to be run, the reports also provide information on the changes in the status of the two data associated with the command process itself: OpOpnOr and OpClsOr.

These data have four possible statuses:

Table 141 OpOpnOr and OpClsOr statuses

Value	Explanation	enum
STANDBY	Command in standby	0
IN PROGRESS	Command in process	1
SUCCESSFUL	Command run successfully	2
UNSUCCESSFUL	Failure in running of command	3

For opening commands in general, OpClsOr remains in STANDBY, the sequence for OpOpnOr would be STANDBY - IN PROGRESS - SUCCESSFUL / UNSUCCESSFUL – STANDBY. In the case of a closure command, OpOpnOr would remain in standby and OpClsOr would continue the complete sequence. If the command's CtlModel indicates that the command has normal security, no return information is available from the device and, therefore, the sequence would be STANDBY - IN PROGRESS – STANDY.

15.2 COMMAND BLOCKS

The commands sent to the unit can be blocked in specific cases in which the running must not be allowed. In part 7-2, paragraph 17.5.2.6 of the IEC 61850 standard, the possible reasons for failure of a command are detailed.

Table 142 Possible AddCause

Value	Cause	Explanation	enum
Unknown	Command accepted		0
Not-Supported	Not configured		1
Blocked-by-switching-hierarchy	Blocked by hierarchy	Not successful since one of the downstream Loc switches like in CSWI has the value TRUE	2
Select-failed	Selection failure	Cancelled due to an unsuccessful selection (select service)	3
Invalid-position	Invalid position	Control action is aborted due to invalid switch position (Pos in XCBR or XSWI)	4
Position-reached	Position reached	Switch is already in the intended position (Pos in XCBR or XSWI)	5
Parameter-change-in-execution	Parameter change in execution	Control action is blocked due to running parameter change	6
Step-limit		Control action is blocked, because tap changer has reached the limit (EndPosR or EndposL in YLTC)	7
Blocked-by-Mode		Control action is blocked, because the LN (CSWI or XCBR/XSWI) is in a mode (Mod) which does not allow any switching	8
Blocked-by-process		Control action is blocked due to some external even at process level that prevents a successful operation, for example, blocking indication (EEHealth in XCBR or XSWI)	9
Blocked-by-interlocking	Block signal activated	Control action is blocked due to interlocking of switching devices (in CILO attribute EnaOpn.stVal="FALSE" or EnaCls.stVal="FALSE"	10
Blocked-by-synchrocheck		Control action with synchrocheck is aborted due to the exceeding of the time limit and missing synchronism condition	11
Command-already-in-execution	Command in execution	Control service or cancel is rejected, because control action is already running	12
Blocked-by-health	Health signal activated	Control action is blocked due to some internal event that prevents a successful operation (Health)	13
1-of-n-control	1 of n block	Control action is blocked, because another control action in a domain (for example, substation) is already running (in any XCBR or XSWI, the DPC.stSeld="TRUE").	14
Abortion-by-cancel	Command cancelled	Control action is aborted due to cancel service	15
Time-limit-over	Time exceeded	Control action is terminated due to exceed of some time limit	16
Abortion-by-trip	Cancelled by trip	Control action is aborted due to a trip (PTRC with ACT.general="TRUE")	17
Object not selected	Object not selected	Operation can not be executed, since object is not selected	18

Due to the variety of situations in which a specific command might fail due to a block by hierarchy, and depending on the specific configuration of unit, as well as invalid position or unknown blocks, both cases are explained below in greater detail.

15.2.1 Command blocks by command hierarchies

Pursuant to the IEC 61850 standard, one of the possible causes of a command block is hierarchy (Part 7-2, section 17.5.2.6 AddCause - additional cause diagnosis), and therefore a command hierarchy that involves the blocking of commands in accordance with their origin and the unit's configuration is defined.

The "Local/Remote Type" setting indicates how the unit will behave when it has to block the commands it is sent. It is located in the cid in "GEN/LLN0/LRmode" or in the display in "protection/ general basic configuration/local type - Remote" settings and can accept the four possible values established in the following table:

Table 143 Possible values for Local/Remote Type

LOCAL/REMOTE TYPE	LRmode	NUMERIC VALUE
Not treated	Not treated	0
Iberdrola	Iberdrola	1
Exclusive	Exclusive	2
No frame	No frame	3

If Local/Remote Type is "Not treated", no block by hierarchy is applied to the commands. In the remaining cases, the status of the frame signals will be taken into account ("GEN/LLN0/Lockey"), as well as the unit's remote command ("GEN/LLN0/RemCtlBlk") and the commands origin.

The IEC 61850 standard, Part 7-3, section 6.8, defines the potential origins, three of which are affected by blockages due to the command hierarchy: "remote control", which corresponds to a remote command, "station-control", which corresponds to a console, and "bay-control" which corresponds to a bay-level console or to the display. Blocks by hierarchy will not be applied to any command from any other origin.

- If the Local/Remote Type is configured as "Iberdrola", the three cases will be distinguished in accordance with the origin of the command.
  - For commands originating from a remote control (remote control):

Table 144 Blocks for "Iberdrola" Local/Remote Type from remote control

Frame signal status (Lockey)	Remote control signal status (RemctlBlk)	Commands	Command to modify frame	Command to modify remote control
(0) frame	(0) remote control	permitted	blocked	blocked
(0) frame	(1) local	blocked	blocked	blocked
(1) no frame	(0) remote control	permitted	blocked	blocked
(1) no frame	(1) local	blocked	blocked	blocked

  - For commands originating from a console (station-control):

Table 145 Blocks for "Iberdrola" Local/Remote Type from console

Frame signal status (Lockey)	Remote control signal status (RemctlBlk)	Commands	Command to modify frame	Command to modify remote control
(0) frame	(0) remote control	blocked	blocked	permitted
(0) frame	(1) local	permitted	blocked	permitted
(1) no frame	(0) remote control	blocked	blocked	blocked
(1) no frame	(1) local	blocked	blocked	blocked

  - For orders originating in the display or a bay-level console (bay-control):

Table 146 Blocks for "Iberdrola" Local/Remote Type from bay

Frame signal status (Lockey)	Remote control signal status (RemctlBlk)	Commands	Command to modify frame	Command to modify remote control
(0) frame	(0) remote control	blocked	blocked	permitted
(0) frame	(1) local	permitted	permitted	permitted
(1) no frame	(0) remote control	blocked	blocked	permitted
(1) no frame	(1) local	permitted	permitted	permitted

- If the Local/Remote Type is configured as "Exclusive", the three cases will be distinguished in accordance with the origin of the command.
  - For commands originating from a remote control (remote control):

Table 147 Blocks for "Exclusive" Local/Remote Type from remote control

Frame signal status (Lockey)	Remote control signal status (RemctlBlk)	Commands	Command to modify frame	Command to modify remote control
(0) frame	(0) remote control	blocked	blocked	blocked
(0) frame	(1) local	blocked	blocked	blocked
(1) no frame	(0) remote control	permitted	blocked	blocked
(1) no frame	(1) local	blocked	blocked	blocked

- For commands originating from a console (station-control):

Table 148 Blocks for “Exclusive” Local/Remote Type from console

Frame signal status (Lockey)	Remote control signal status (RemctlBlk)	Commands	Command to modify frame	Command to modify remote control
(0) frame	(0) remote control	permitted	permitted	blocked
(0) frame	(1) local	blocked	blocked	blocked
(1) no frame	(0) remote control	blocked	permitted	blocked
(1) no frame	(1) local	blocked	blocked	blocked

- For orders originating in the display or a bay-level console (bay-control):

Table 149 Blocks for “Exclusive” Local/Remote Type from bay

Frame signal status (Lockey)	Remote control signal status (RemctlBlk)	Commands	Command to modify frame	Command to modify remote control
(0) frame	(0) remote control	blocked	blocked	permitted
(0) frame	(1) local	permitted	blocked	permitted
(1) no frame	(0) remote control	blocked	blocked	permitted
(1) no frame	(1) local	permitted	blocked	permitted

- If the Local/Remote Type is configured as "No frame", there is no frame signal and, therefore, the behaviour will depend exclusively on the status of the remote control signal and the command origin.
  - For commands originating from a remote control (remote control):

Table 150 Blocks for “No frame” Local/Remote Type from remote control

Remote control signal status (RemctlBlk)	Commands	Command to modify remote control
(0) remote control	permitted	blocked
(1) local	blocked	blocked

- For commands originating from a console (station-control):

Table 151 Blocks for “No frame” Local/Remote Type from console

Remote control signal status (RemctlBlk)	Commands	Command to modify remote control
(0) remote control	permitted	blocked
(1) local	blocked	blocked

- For orders originating in the display or a bay-level console (bay-control):

Table 152 Blocks for “No frame” Local/Remote Type from bay

Remote control signal status (RemctlBlk)	Commands	Command to modify remote control
(0) remote control	blocked	permitted
(1) local	permitted	permitted

15.2.2 Blocks due to invalid/unknown/reached bay

There is a “command mode” field in the sAddr associated to each command indicating the operating mode of the blocks due to the status of the element to which the command is to be issued.

The commands will be blocked in accordance with the following table:

Table 153 Blocks in accordance with the command mode

Command Mode (in sAddr)	Element Status	Opening command	Closure command
0 / -1	Open	Permitted	Permitted
	Closed	Permitted	Permitted
	Invalid	Permitted	Permitted
	Unknown	Permitted	Permitted
1	Open	Blocked (1)	Permitted
	Closed	Permitted	Blocked (1)
	Invalid	Blocked (2)	Blocked (2)
	Unknown	Blocked (2)	Blocked (2)
2	Open	Blocked (1)	Permitted
	Closed	Permitted	Blocked (1)
	Invalid	Permitted	Blocked (2)
	Unknown	Permitted	Blocked (2)
3	Open	Permitted	Permitted
	Closed	Permitted	Blocked (1)
	Invalid	Permitted	Blocked (2)
	Unknown	Permitted	Blocked (2)

Thus, the blocks marked with (1) are blocks by "position reached" and those marked with (2) are by "invalid position".

15.3 COMMAND SADDRESS

The sAddr associated with each command in the CID file has the following format:

sAddr = "a,b,c,d,e,f,g;TX1:TEXTO IDIOMA1,TX2:TEXTO IDIOMA2"

- a:= O (letter corresponding to the command)
- b:= Command UCL number. (Value 0 for internal Ucl). Maximum 4 characters.
- c:= Command number. Maximum 4 characters.
- Number of the first associated internal command. Each element with control two internal commands associated. The first corresponds to the “ON” command (ctlVal = 1) and the second to the “OFF” command (ctlVal = 0). The number of the first command, corresponding to the “ON” command, is always configured in the sAddress-
- d:= Off enabling signal number. Maximum 5 characters.
- This is the number of the signal that permits the OFF command or opening in the case of being active and which blocks when deactivated.
- e:= On enabling signal number. Maximum 5 characters.
- This is the number of the signal that permits the ON command or closure in the case of being active and which blocks when deactivated.
- f:= Expected status (0=Direct, 1=Inverted) (1 character)
- g:= Element Health signal number (Obtained from the Data Attribute “ST” of the Data Object “EEHealth” of the element on which the command is to be run).
- h:= Command Mode: in accordance with this field and the different situations, the unknown or unreached invalid position commands will be blocked or not. The absence of this field gives rise to the same functioning as when the field contains a 0 or a -1. It can accept four possible values (0-3), will determine whether or not each command by "invalid position" or "position reached" is blocked or not.

Table 154 Blocks in accordance with the command mode

Command Mode (in sAddr)	Element Status	Opening command	Closure command
0 / -1	Open	Permitted	Permitted
	Closed	Permitted	Permitted
	Invalid	Permitted	Permitted
	Unknown	Permitted	Permitted
1	Open	Blocked (1)	Permitted
	Closed	Permitted	Blocked (1)
	Invalid	Blocked (2)	Blocked (2)
	Unknown	Blocked (2)	Blocked (2)
2	Open	Blocked (1)	Permitted
	Closed	Permitted	Blocked (1)
	Invalid	Permitted	Blocked (2)
	Unknown	Permitted	Blocked (2)
3	Open	Permitted	Permitted
	Closed	Permitted	Blocked (1)
	Invalid	Permitted	Blocked (2)
	Unknown	Permitted	Blocked (2)

(1) blocks by position reached / (2) blocks by invalid position.

- TX1:= Command text language1. Maximum 16 characters.
- TX2:= Command text language2. Maximum 16 characters.

16. RIO MODULES

16.1 CONFIGURATION

The RIO modules are configured using the RIOGGIO logic nodes A maximum of 8 nodes of this type is contemplated.

Each node has series of attributes that allow us to select the RIO modules with which we are to communicate and to configure the outputs to be published:

Table 155 RIO module configuration attributes

ATTRIBUTE	DESCRIPTION
NumRIO.stVal	The RIO number to which we want to associate the current node. It is a configurable value between 1 and 99.The value 0 is reserved to indicate that the node is not configured.
TypeRIO.stVal	The RIO module to which we want to associate. It can accept the 1 (12 inputs / 4 outputs) or 2 (8 inputs / 2 outputs). The value 0 is reserved to indicate that the node is not configured.
InRef1.setRef	IEC 61850 reference to the RIO module's first output.
InRef2.setRef	IEC 61850 reference to the RIO module's second output.
InRef3.setRef	IEC 61850 reference to the RIO module's third output.
InRef4.setRef	IEC 61850 reference to the RIO module's fourth output.

16.2 OPERATION

When we have configured a RIOGGIO logical node correctly, the expected performance in the different attributes is as follows:

Table 156 Operation of RIO module attributes

ATTRIBUTE	DESCRIPTION
St.stVal	Status of the communication with the associated RIO module. The value 1 indicates that it is correct.
CfgErr.stVal	Indicates that the configured RIO type does not match that which is being received. This value is only displayed in IEC 61850, it has no associated signal in the internal data base.
Ind[1..17].stVal	The values received from the RIO module.
SPSCO[1..4].stVal	The values sent to the RIO module. The value always coincides with the signals configured in the InRefs in the same index.

Both the elements received and the communication status has associated signals with fixed position in the internal database. The signals are distributed as follows:

Table 157 Internal signals associated with RIO modules

LOGICAL NODE	ELEMENT	ASSOCIATED INTERNAL SIGNALS
RIOGGIO1	Communication status	288
	Values received in command	From 289 to 305.
RIOGGIO2	Communication status	306
	Values received in command	From 307 to 323.
RIOGGIO3	Communication status	324
	Values received in command	From 325 to 341.
RIOGGIO4	Communication status	342
	Values received in command	From 343 to 359.
RIOGGIO5	Communication status	360
	Values received in command	From 361 to 377.
RIOGGIO6	Communication status	378
	Values received in command	From 379 to 395.
RIOGGIO7	Communication status	396
	Values received in command	From 397 to 413.
RIOGGIO8	Communication status	414
	Values received in command	From 415 to 431.

17. CHANGES REQUIRING THE REBOOTING OF THE SERVER

17.1 MANUAL

The modification of the value of certain attributes requires the resetting of the unit in order for the modification to have effect. In order to inform of the need to manually reset of the unit, the ResetDev.stVal signal has been defined within the GEN node's LLN0.

The writing of the following settings via IEC 61850 communication activates the mentioned signal:

Table 158 Setting changes that require the manual reset of the unit

LOGICAL NODE	ATTRIBUTE	DESCRIPTION
LGOS	MAC.setRef	The multicast reception MAC associated to the goose.
RIOGGIO	NumRIO.stVal	The RIO number associated to this logical node. Involves modifying the associated multicast reception and transmission MAC.

17.2 AUTOMATIC

The modification of the unit's IP configuration may cause - depending on the configuration of the IPRV logic node, the IEC 61850 server to automatically stop and restart.

The configuration that causes this operation consists of setting the IPRV logic node's ConfTD.tipoServ attribute to "1". If, when modifying the network cards' IP address/mask, the new address/mask does not coincide with the configuration in the icd communications section, the IEC 61850 server will reboot.

18. RECEPTION GOOSES

18.1 LGOS MODEL

This model makes it possible to configure and supervise the complete status of each reception goose within a single logic node.

18.1.1 Configuration values

Used to establish the desired subscription parameters for each goose.

Table 159 LGOS model configuration values

ATTRIBUTE	DESCRIPTION
ConfRev.setVal	Must match the value received in the goose.
GoCBRef.setRef	The goose reference to which we subscribe.
GoDatSetRef.setRef	The reference of the dataset to which we subscribe.
GoID.setRef	The identifier of the goose to which we subscribe.
InRef[..].intAddr	The reference to the signal in which the goose element established by the InRef index is received. It must be a mapped signal within the goose signals range.
MAC.setRef	The multicast MAC to which we subscribe.

18.1.2 Supervision values

They indicate information about the status of the goose subscription at all times. The status signal conditions the updating of the rest of the Data. If the status is incorrect, the rest of the signals will not be updated with the values received.

Table 160 LGOS model supervision values

ATTRIBUTE	DESCRIPTION
St.stVal	Subscription status. Value “1” indicates that the subscription was successful.
Sim.stVal	Activated when the subscription is received in test mode.
NdsCom.stVal	Activated when the subscription has the “Needs Commissioning” flag activated.
LastStNum.stVal	The last status number received.
ConfRevNum.stVal	The configuration revision received.

18.2 GOOSERX MODEL

This model uses the IED's GOOSERx logical device. In order to configure each goose subscription, an element must be added to the corresponding private part and the following parameters must be defined:

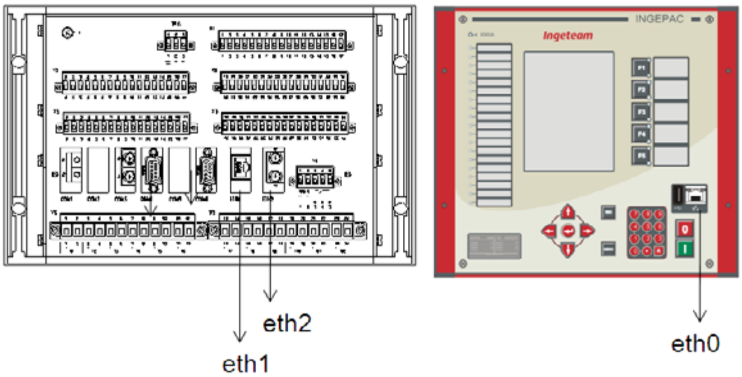
Table 161 Goose subscription parameters

ATTRIBUTE	DESCRIPTION
name	Name for the internal identification of the subscription.
mAddr	The multicast MAC to which we subscribe.
type	In this case it is the fixed value "GOOSE".
datSet	The internal dataset into which the received data is copied. It must coincide in elements and element types with the data received
appID	The identifier of the goose to which we subscribe.
subscribedGoCB	The goose reference of the goose to which we subscribe.
subscribedDatSet	The dataset reference of the goose to which we subscribe.

19. TCP/IP NETWORK CONFIGURATION

19.1 DESCRIPTION

In the device has a front Ethernet interface and may have up to two rear Ethernet interfaces. Each of which can be configured to belong to the network that the user wants, as seen in the figure below:



- eth 0, frontal Ethernet.
- eth1, rear Ethernet.
- eth2, rear Ethernet.

The configuration of each network can be made:

- From the device Display (see section of the display).
- From PacFactory configuration tool (see user manual pacFactory).

19.2 GENERAL CONSIDERATIONS ABOUT NETWORK CONFIGURATION

When configuring the network of the device it must be taken into account the following considerations:

- Basic concepta about networks:
    - The format of the IP address or mask have the dotted decimal notation. The checks are performed according to this standard.
    - Addresses ending in 0 correspond to networks, not devices. For example : 192.168.200.0
    - Addresses ending in 255 correspond to broadcast messages. For example : 192.168.200.255
    - All network traffic for an IP address that is not included in the configured networks, will be redirected to the default gateway configured.
- It is not allowed the IP address or mask 0.0.0.0.
- It is not allowed the IP address or mask 255.255.255.255.
- It is not allowed to configure several IP addresses in the same ethernet interface.
- Gateways configuration:
    - There can be only one default Gateway in the devices and it will be associated to a specific Ethernet interface.

  - If a Gateway is configurec, the static routes for the ethernet traffic will be determined by up to 10 groups or three parameters:
    - IP address of the network or destination host. This IP address indicates the network or the device you want to connect to.
    - Network mask or destination host mask.
    - Gateway IP address. Debe pertenecer al mismo segmento de red que la dirección IP que tenga configurada en esa interfaz Ethernet, ya que de otra forma no sería accesible el Gateway desde el equipo.
  - If the IP address of the network or destination host or the mask of the network or destination host are not configured, the default values are:
    - IP address: 0.0.0.0, it will be all the networks or default gateway.
    - Network Mask: 255.255.255.255, it will be all networks or default gateway.
  - The configuration of gateways can only be done from the Display.
- When changing the IP address, the gateways that are no longer accessible by the new IP will be removed permanently.
- The IP change command keeps the mask that was associated with that Ethernet interface.
- Do not configure two different Ethernet interfaces within the same network segment. When you configure two interfaces within the same network segment, the device will use only one of them.

19.3 GOOSES

GOOSE messages (IEC 61850 peer-to-peer communications) are not on the TCP/IP layer, they are Ethernet packets and are configured at the MAC level.

The devices subscribes to multicast MAC addresses for receiving messages and transmit to a specific Multicast MAC address.

Ethernet interface eth0 is not ready to receive / transmit packets GOOSE.

20. KEYBOARD AND GRAPHIC DISPLAY

20.1 GENERAL OPERATION

20.1.1 Display structure

The screens are grouped into the following types:

- Graphic pages
- I/O pages
- Secuence of Events (SOE)
- Protection events pages
- Alarm pages
- Protection status pages
- Fault pages
- Measurements pages (Multitrans)
- Grouping of other screens

Each display type has its own treatment.

There are also menu pages (which include the protection, control and general settings, such as the date and time, password, FW versions, etc.), which are treated differently to those mentioned above.

20.1.2 Organization of the pages

The pages are organized into screen types, whose order of presentation is configurable using an external tool. The tool also enables the unit's start page to be assigned. The keys "←(Left), →(Right)" allow the user to scroll through the different screen types defined as main screens. The screens can be scrolled in both directions: upon reaching the last screen type the display returns to the first screen, and vice-versa.

By clicking on the "↑ (Up), ↓ (Down)" keys in any screen, the screens belonging to the same type are shown. The I/O, SOE, protection events and fault pages are presented in a preconfigured order. However, in the graphic and alarm screens the presentation order is defined using an external tool.

If, when in any screen belonging to specific type, we press "←(Left), →(Right)", the following screen type is displayed whilst the screen position remains within the type in question. Thus, when scrolling through the screen types the last screen types selected when exiting a specific type are shown.

If no keys are pressed within a period greater than 5 minutes, the unit returns to the start page and the first page of each type is selected.

By pressing on <ESC> from any screen we return to the start page, whilst the current page of each screen type is maintained.

There is a special screen type called "Menu to Other Screens" that contains an index of screens not considered important enough to have been defined as main screens and which enables access to the same. This screen is configurable via a PC tool.

By pressing <MENU> from within any screen, the first page of the settings menus is displayed.

The possibility of multi-language is available.

Device with IP protection covers

If the unit is fitted with an IP protection cover, only certain buttons will be accessible from the front, depending on the model in question:

- ❑ Preset Keys (1/2 chassis – 5U and 19” chassis – 4U)

The only keys available are I, O, SEL, INF and DES.

The INF button allows the different screens to be displayed in a circular mode, whilst the order is configurable via a PC tool.

- ❑ Functional Keys (1/2 chassis – 5U and 19” chassis – 4U)

The only keys available are I, O, F1, F2, F3, F4, F5 and the DOT key.

The DOT button allows the different screens to be displayed in a circular mode, whilst the order is configurable via a PC tool.

20.1.3 Treatment of the functional keys

The functional keys are configured with the PC tool, with the control and associated status being configured for each key.

The operation of the functional keys is as follows:

- ❑ The possible values of the status signal associated to the functional key and its corresponding representation via the LEDs is:
  - Unprogrammed: the 2 LEDs at OFF.
  - Unknown Status: the 2 LEDs at ON.
  - Open Status: upper LED OFF and lower LED ON.
  - Closed Status: upper LED ON and lower LED OFF.
  - Invalid Status: the 2 LEDs at ON.
- ❑ The operation of these keys is as follows:
  - By pressing the key, the associated item is selected and the corresponding LED or LEDs flash.
  - Once the item has been selected, the associated command can be run by pressing the “I” or “O” keys.
  - Once the above-mentioned key has been pressed, the unit runs the command and the lit LED or LEDs cease to flash.
  - Once a command has been run, the status of the associated LED or LEDs is updated. In the event of a failure, a window indicating the cause of the same will appear in the display.

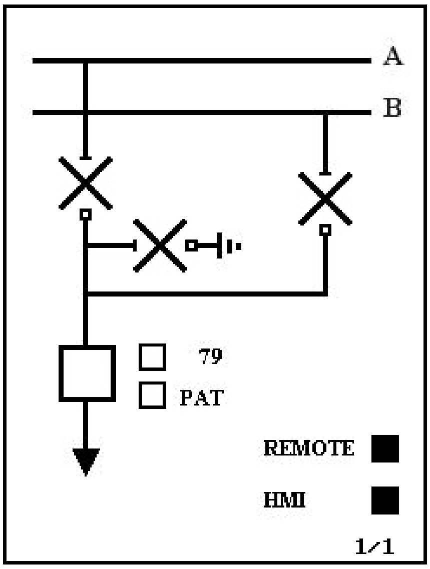
20.1.4 Graphics pages

The maximum number of graphic screens is 9.

Use the “↑ (Up), ↓ (Down)” keys to switch from one group of graphic screens to another.

The order of the “live points” that have commands and the sequence of the graphic screens can be modified using the PC tool.

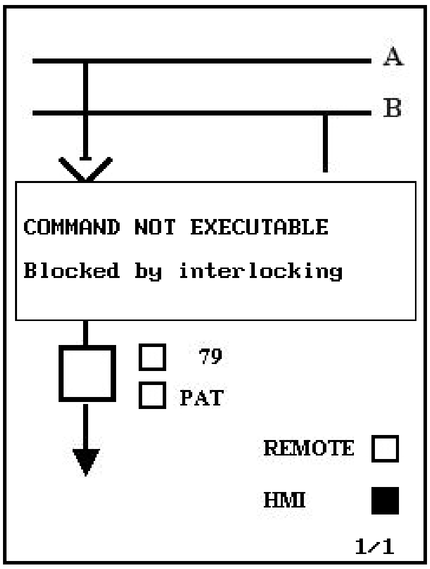
Figure 123. Single Line diagram



The treatment of controls WITH Preset Keys:

- To run a command, we must first select the item to be sent. To do so, and once we have selected the screen containing the item to be sent, we must press “SEL”. The symbol of the item that has been configured to priority 1 and which has an associated command will appear and begin to flash.
- By pressing “SEL” we scroll through the different “live points” with commands, in accordance with the preset order.
- Once the item to be sent has been selected, the process is as follows:
  - Press the key “I” for the following commands: close, in service, automatic, remote control, etc.
  - Press the key “O” for the following commands: open, out of order, manual, local, etc.
  - By pressing the key “DES” (if the item has maintenance configured), the command will be run, in accordance with the item's status – if it is set to maintenance, the command will be “remove maintenance”, if it is not in maintenance, the command will be “set to maintenance”.
- If the command fails or if it can not be run due to a block, a small screen indicating the reason for the failure will be displayed.

Figure 124. Single Line diagram with indication of non-run command



This indication appears for 5 seconds, during which no operations can be carried out on the item.

- If the command is successful, no additional screen will be shown and the item's status will be refreshed.

If it is in the control selection, only the “SEL”, <ESC> and “I, O, DES” keys are allowed.

The treatment of controls WITHOUT Preset Keys:

- To run a command, we must first select the item to be sent. To do so, and once we have selected the screen containing the item to be sent, we must press ↵ (Enter). The symbol of the item that has been configured to priority 1 and which has an associated command will appear and begin to flash.
- By pressing the “←(Left), →(Right)” keys, we scroll through the different “live points” with commands, in accordance with the preset order.
- Once the item to be sent has been selected, the process is as follows:
  - Press the key “I” for the following commands: close, in services, automatic, remote control, etc.
  - Press the key “O” for the following commands: open, out of order, manual, local, etc.
- If the command fails or if it can not be run due to a block, a small screen indicating the reason for the failure will be displayed. This indication appears for 5 seconds, during which no operations can be carried out on the item.
- If the command is successful, no additional screen will be shown and the item's status will be refreshed to show "normal".

By pressing <ESC>, we exit the control selection, as we also do if we refrain from pressing any keys for a period of more than “10 sec”.

If it is in the control selection, only the <ESC>, ←(Left), →(Right) and “I, O” keys are allowed.

The measurements are displayed with the number of decimal points and digits preset with the configuration tool. The possible situations that are covered when viewing a measurement are:

- Invalid: An '*' is placed in front of the measurement, there is no associated flashing. E.g.: * 25.3
- Outside range: '####' is displayed without flashing when the measurement’s value exceeds the maximum value for the specified nº of digits and decimal points. E.g.: measurement value = 100 and number of digits = 2.
- Alarm: An 'A' is displayed in front of the measurement, with flashing, when the measurement exceeds the set range. There is an upper and a lower limit. E.g.: If an alarm is activated when the upper limit is greater than 200 A, the measurement will be displayed as follows: A 202.

Each of the measurements displayed in the graphic screens can be configured so that their values are referred to the primary or the secondary.

20.1.5 I/O pages

The unit may be equipped with different types of cards, which are distinguished by the combination of inputs and outputs grouped in 2 columns. Each card’s information is grouped in a page.

A text indicating the type of card, the address of the module assigned by HW and an indication of the current page number/number of total pages, which is the same as that of the card, is displayed at the top of the screen.

An indication of a card failure is shown in the lower part of the screen. If the circle is filled, the card is in failure, whereas if it is empty, the card is functioning correctly (Figure 125).The order of this type of screen is defined by the different card’s addresses – the card with the lowest address is displayed first and the pages can be scrolled using the “↑ (Up), ↓ (Down)” keys.

Representation of the digital I/Os

The digital I/O data are listed in 2 columns. Each column contains a graphic symbol (a circle), followed by the input or output text and the corresponding number of terminals:

Figure 125. I/O Screen

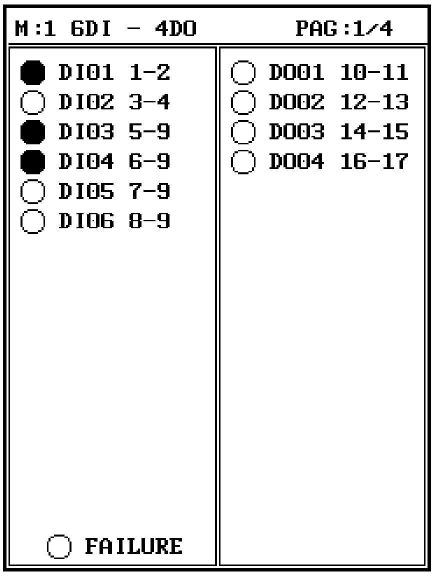
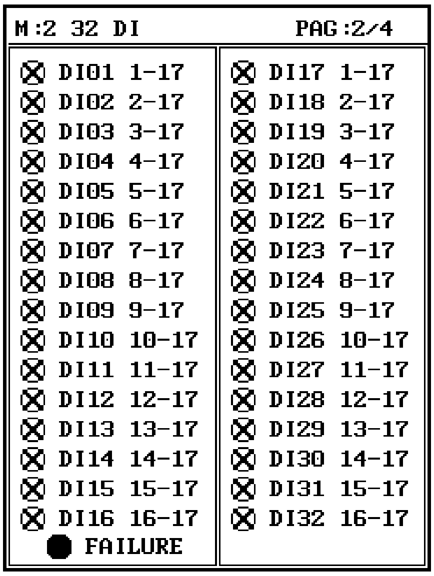


Figure 126. I/O Screen with card failure



The digital signals are displayed as an empty circle, when disabled, or a filled circle, when enabled. In the event of an invalid signal, an empty circle with a cross is displayed to represent a disabled status and a filled circle with an inverted cross is displayed to represent an enabled status (Figure 126).

20.1.6 Event pages

The event screens display a chronological record of all the changes that take place in the signals that have been configured as events in the display.

Each event's presentation includes the date and time to the millisecond, a 29 character text and a 7 character acronym.

The texts to be displayed, as well as the signals' identification, are set in attributes of the CID and may be modified using an external tool.

The screen order is defined chronologically. Their display order goes from the newest to the oldest. Within each screen, the most recent are shown at the top of the page and the oldest at the bottom.

We can scroll through the pages using the "↑ (Up), ↓ (Down)" keys, going from the last page to the first, and vice-versa. The page order runs from the first page, which has the most recent events, to the last page, which has the oldest events. The "↓ (Down)" key is used to scroll from the first page to the following in increasing order, whereas the "↑ (Up)" key is used to scroll from the last page to the previous pages.

Only the last 160 events are displayed in these pages.

The total number of pages and the number of the page currently displayed, as well as the number of events in the display, is shown in the last row.

Figure 127 Event Screen

```
CONTROL EVENTS     NEW CHANGES
07/06/11 14:34:21:405 OFF
GGIO1.Digital Input 3
07/06/11 14:34:21:405 OFF
GGIO1.Digital Input 4
07/06/11 14:30:27:146 OFF
Table 1 Settings Change
07/06/11 14:30:17:516 ON
Table 1 Settings Change
07/06/11 14:30:03:226 OFF
Active Settings Change
07/06/11 14:30:03:226 OFF
Display Settings Change
07/06/11 14:30:02:786 ON
Active Settings Change
07/06/11 14:30:02:756 ON
Display Settings Change
 E:64    Page  2/8
```

Treatment:

When accessing this screen for the first time, the most recent events are displayed. The "↓ (Down)" and "↑ (Up)" arrows are used to scroll through the pages, as indicated above.

If new changes are registered whilst we are viewing the 1st page of this type of screen, the Display is refreshed accordingly and the older changes are moved downwards.

When viewing any page other than the 1st page if new changes are registered, the Display will not be refreshed and the previous data is shown. In such a case, a flashing, inverted video "NEW CHANGES" message is shown at the top of the page.

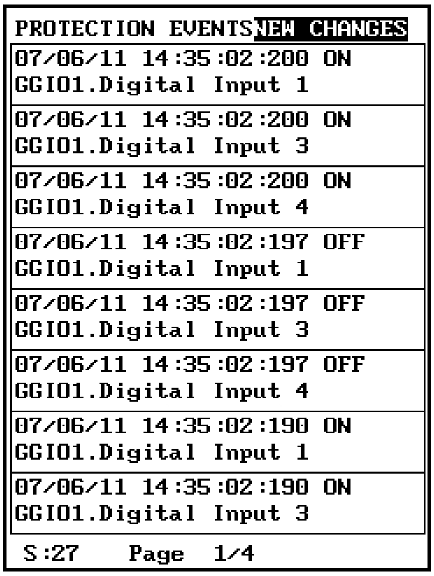
This indication is cleared when the most recent changes are viewed. To do so, we must go to the first screen.

20.1.7 Protection event pages

The protection event screens display a chronological record of all the changes that take place in the signals that have been set as such. Each protection event's presentation includes the date and time to the millisecond, a 29 character text and a 7 character acronym.

The texts to be displayed are defined in attributes of the CID. Signals are identified as protection events by means of the corresponding enabling function in the corresponding settings node and by configuring the event masks. They can be modified using the PC tool.

Figure 128 Protection event Screen



The screen order is defined chronologically. Their display order goes from the most recent to the oldest. Within each screen, the most recent are shown at the top of the page and the oldest at the bottom (Figure 128). If the protection event list is empty, a text indicating that the protection event queue is empty will appear.

We can scroll through the pages using the "↑ (Up), ↓ (Down)" keys, going from the last page to the first, and vice-versa. The page order runs from the first page, which has the most recent protection events, to the last page, which has the oldest protection events. The "↓ (Down)" key is used to scroll from the first page to the following in increasing order, whereas the "↑ (Up)" key is used to scroll from the last page to the previous pages.

Only the last 160 protection events are displayed in these pages.

The ↵ (Enter) key is used to select the first protection event from the screen being viewed, whilst the "↑ (Up), ↓ (Down)" keys are used to scroll to the next protection event, with the following treatments:

- If, whilst at the bottom of the page, we press "↓ (Down)", we are taken to the next page with the first selected protection event, unless we are already viewing the last page, which case the display will not be changed.
- If we are in the protection event selected and we press "↑ (Up)" key, we are taken to the previous page, although the last protection event remains activated, unless we are in the first page and in which case the display will remain unchanged.

Once this protection event has been selected, we can press ↵ (Enter) to view the page with the measurements associated to the protection event. Use the "↑ (Up), ↓ (Down)" keys to switch from one page to another if there is more than one measurements page per protection event. These pages are browsed in a cyclical manner, going from the first to the last, and vice-versa, as corresponds.

Use <ESC> to exit the screen displaying the measurements associated to the protection event. Within the protection events' screen, the change is deselected by clicking on <ESC> once again.

The total number of pages and the number of the page is currently displayed, as well as the number of protection events in the display's queue, is shown in the last row.

Treatment:

When accessing this screen for the first time, the most recent protection events are displayed.

The "↓ (Down)" and "↑ (Up)" arrows are used to scroll through the pages, as indicated above

If the appearance of new protection events is detected, a flashing, inverted video "NEW INC" (new protection event) message is shown at the top of the page.

This indication is cleared when the latest protection events are viewed. To do so, no protection events must be selected and we must go to the first screen. Once we have arrived at this screen, if we scroll back the first screen with the most recent protection events to have been registered will be displayed.

20.1.8 Alarm pages

These screens emulate an alarm panel, displaying each alarm as a rectangle with a text inside. The page format is set and includes 2 columns containing 6 rectangles each. There will be a maximum of 20 alarm pages, i.e., a maximum of 160 alarms.

2 lines of 12 characters can be displayed within each rectangle.

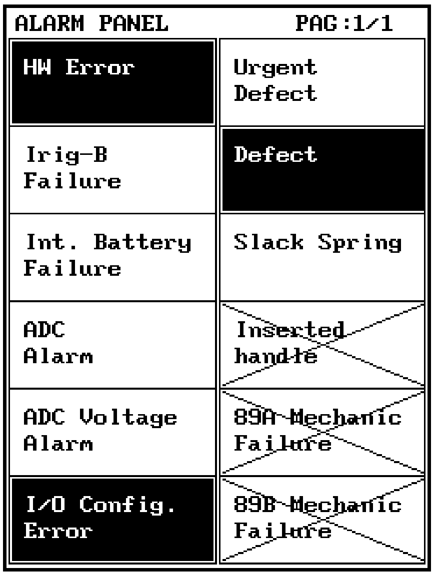
Each alarm's texts, identification and the number of alarms are configured using an external tool.

When in standby status, the text is displayed in a normal video with white background and, when enabled, in an inverted video with a dark background.

When the alarm changes status, the signal's text begins to flash and appears and disappears within the new status.

If the signal is invalid, the text will be displayed with a cross covering the entire rectangle. If the signal does not exist, the corresponding alarm's gap will be displayed.

Figure 129 Alarm panel



Use the "↑ (Up), ↓ (Down)" keys to switch from page to another.

Individual acknowledgements of receipt are not issued for the alarms. Instead, it is possible to issue acknowledgement for all the alarms displayed in the page that is being viewed. To do so, we must press ↵ (Enter) in an active alarm page and the following message will appear in a small screen:

Confirm receipt of all alarms of the page?

If we then press <ESC>, the message is cleared and no acknowledgment of the alarms is issued. If we press ↵ (Enter), the message disappears and an acknowledgment is issued for all the alarms displayed on the page.

An indication of the total pages and the number of the page displayed will appear at the top of the page.

20.1.9 Protection status pages

There are 3 pages which describe the protection status.

- General data screen
  - Relay date and time.
  - Frequency value.
  - Active table number.
  - External power supply battery voltage.
  - Phase and neutral thermal image value.
  - Maximeter value for each current and voltage phase.
  - Device temperature.

Figure 130 Protection Status page 1

```
PROTECTION STATUS    pag. 1/3

D/H    07/06/11   14:36:54

F 0.00    Hz       Table  1
V Battery     130.22 V

Ph Thermal Overload 0.00
N. Thermal Overload 0.00

  I max.            V max.
Ia     0.000 A    Va     0.00 V
Ib     0.000 A    Vb     0.00 V
Ic     0.000 A    Vc     0.00 V

T    46.2 °C


MEASURE PRI -> PRESS ENTER
```

- Measurements screen (I)
  - Type, module and angle of each of the unit's 12 transformers.

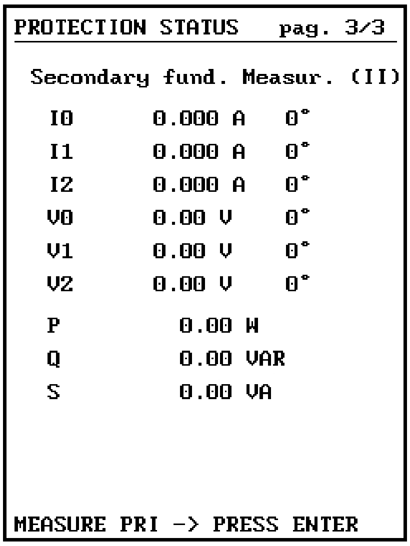
Figure 131 Protection Status page 2

```
PROTECTION STATUS    pag. 2/3

 Secondary fund. Measur. (I)
 T 1 - Ia     0.000   A    0°
 T 2 - Ib     0.000   A    0°
 T 3 - Ic     0.000   A    0°
 T 4 - In     0.000   A    0°
 T 5 - Ip     0.000   A    0°
 T 6 - Isn    0.0000  A  163°
 T 7 - Not    ---        ---
 T 8 - Vs     0.00    V    0°
 T 9 - Vn     0.00    V    0°
 T10 - Va     0.00    V    0°
 T11 - Vb     0.00    V    0°
 T12 - Vc     0.00    V    0°
MEASURE PRI -> PRESS ENTER
```

- Measurements screen (II)
  - Direct, inverse and zero sequences of currents and voltages (module and angle).
  - Total real, reactive and apparent power.

Figure 132 Protection Status page 3



The values can refer to the primary or to the secondary.

NOTE: The measurements correspond to the fundamental frequency.

20.1.10 Fault pages

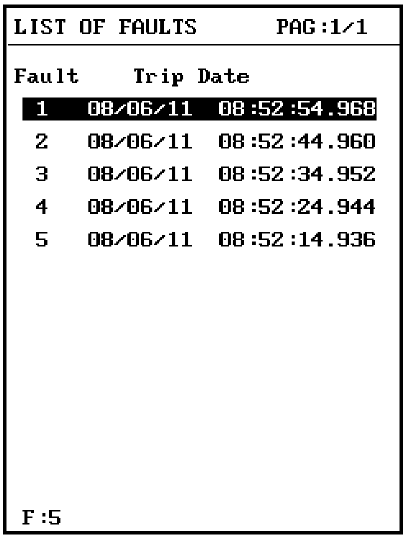
These pages display the last 20 fault reports filed by the protection.

These screens are divided into two levels. The first level displays a list of the most recent faults, as well as the fault number and the fault trip date for each case (Figure 133). The total number of pages and the number of the page being displayed is shown at the top, whilst the number of faults stored in the unit is shown in the last row.

If the fault list is empty, a text indicating that the fault queue is empty will appear.

The faults are ordered from the most recent or latest (Fault nº 1) to the oldest.

Figure 133 1st level Fault Screens



The second level displays all the information related to the fault, organized in several pages. The page is displayed with the number of the fault being displayed, as well as an indication of the number of the current page and the total number of pages per fault.

Use the "↑ (Up), ↓ (Down)" keys to navigate through the first level screen. The page scroll is cyclical - when the end of the page is reached we are taken to the next first level page and we are taken from the first page to the last page and vice-versa in accordance with the key we press.

By pressing ↵ (Enter), we access the second level of the selected fault. Use the "↑ (Up), ↓ (Down)" keys to move between the second level screens pertaining to a single fault. Use <ESC> to return to the first level page.

The values can refer to the primary or to the secondary.

Each screen's content will be displayed as follows:

- Start Screen, which includes fault's data.

Figure 134 2nd level Fault Screens, page 1

```
Fault Report n  1   pag. 1/4
Start    08/06/11 08:54:00.028
Trip     08/06/11 08:54:05.024
End      08/06/11 08:54:05.030
F 0.00 Hz          Group 1
Start Type   abc
Trip Type   abc
Distance:  NOT CALCULATED
Rf:        NOT CALCULATED
LOC: DISABLED
Ph Thermal Overload 0.00
N. Thermal Overload 0.00
 I Opened            ki2
Ia  0.000 A           0.0
Ib  0.000 A           0.0
Ic  0.000 A           0.0

MEASURE PRI -> PRESS ENTER
```

- Date and time: Indicates the date in the "dd/mm/yy hh:mm:ss.ms" format. There are three dates:
    - Start of the fault (first unit picked up).
    - Trip (first unit tripped).
    - End of fault (when the trip signal disappears).
- Frequency in the moment of the fault.
- Pick up and trip types: Summary of the fault with the 3-letter code formed by combinations of the characters A, B, C, N, NS and G (if tripped by a phase, neutral, sensitive neutral or ground), RTP (teleprotection), IF (phase overcurrent), IN (neutral overcurrent), D (current unbalance), VO (zero-sequence overvoltage), HV (overvoltage), LV (undervoltage), RTP (teleprotection), DT (transferred trip), DP (pole discordance), IT (thermal image). Example: AC is a two-phase fault in phases A and C.
    - Pick up type.
    - Trip type.
- Distance: distance to the fault.
- Rf: resistance fault.
- LOC: locator code.
- Thermal image upon trip. The thermal image is indicated as a % of phases and neutral.
- Breaker. Indicates breaker monitoring data upon the fault:
    - Open current. For each phase, indicates the current value upon the trip.
    - Sigma ki. For each phase, indicates the sigma ki2 value.

- Fault screen, with the text "Fault information (I)".

Figure 135 2nd level Fault Screens, page 2

```
Fault Report n  1   pag. 2/4
  Fault Information (I)
        Prefault       Fault
Ia      0.000A    0 |  0.000A    0
Ib      0.000A    0 |  0.000A    0
Ic      0.000A    0 |  0.000A    0
In      0.000A    0 |  0.000A    0
Ip      0.000A    0 |  0.000A    0
Isn   0.0000A 248 | 0.0000A    5
Not
Vs      0.00V     0 |  0.00V     0
Vn      0.00V     0 |  0.00V     0
Va      0.00V     0 |  0.00V     0
Vb      0.00V     0 |  0.00V     0
Vc      0.00V     0 |  0.00V     0
MEASURE PRI -> PRESS ENTER
```

- Pre-fault and fault. Indicates the values measured before the fault and upon the fault. This screen displays the following values:
  - Transformer measurements <Trafos>. It indicates the measurement in the module and the angle of each transformer.

- Fault screen, with the text “Fault information (II)”.

Figure 136 2nd level Fault Screens, page 3

```
Fault Report n  1   pag. 3/4
  Fault Information(II)
        Prefault       Fault
I0      0.000A    0 |  0.000A    0
I1      0.000A    0 |  0.000A    0
I2      0.000A    0 |  0.000A    0
V0      0.00V     0 |  0.00V     0
V1      0.00V     0 |  0.00V     0
V2      0.00V     0 |  0.00V     0
P           0.00 W  |     0.00 W
Q           0.00 VAR|     0.00 VAR
S           0.00 VA |     0.00 VA

MEASURE PRI -> PRESS ENTER
```

- Pre-fault and fault. Indicates the values measured before the fault and upon the fault. This screen displays the following values:
  - Sequences. Indicates the measurements in the module and the angle of the current sequences (I0, I1 and I2) and the voltage (V0, V1 and V2).
  - Power. Indicates the measurements of the total real, reactive and apparent powers.

- Tripped units screen, displays the picked up and the tripped units.

Figure 137 2nd level Fault Screens, page 4

```
Fault Report n  1    pag. 4/4
   TRIPPED UNITS
IUV1 Trip phas A
IUV1 Trip phas B
IUV1 Trip phas C

   STARTED UNITS
IUV1 Start phas A
IUV1 Start phas B
IUV1 Start phas C
```

NOTE: only the first 7 picked up and tripped units are displayed. If the number is greater than 7, a text appears at the bottom of the screen indicating that there are more picked up units.

20.1.11 Measurement pages

There are 5 screens displaying the unit's rms measurements referred to the primary (only available for devices with Multitrans measure module).

NOTE: Certain wiring diagrams have invalid measurements that do not exist. They are represented by "---".

- Measurements screen (I)
  - Module and angle of each of the unit's 8 transformers and phase to phase voltages.

Figure 138 Measurements screen (I)

```
DEVICE MEASUREMENTS pag. 1/5
 Primary rms Measur. (I)
  Ia:           0.00 A      0°
  Ib:           0.00 A      0°
  Ic:           0.00 A      0°
  In:           0.00 A      0°
  I average:    0.00 A
  Va:           0.00 KV     0°
  Vb:           0.00 KV     0°
  Vc:           0.00 KV     0°
  Vn:           0.00 KV     0°
  V average:    0.00 KV
  Vab:          0.00 KV
  Vbc:          0.00 KV
  Vca:          0.00 KV
  Vc average:   0.00 KV
```

- Measurements screen (II)
  - Direct, inverse and zero sequences of currents and voltages (module and angle).

Figure 139 Measurements screen (II)

```
DEVICE MEASUREMENTS pag. 2/5
 Primary rms Measur. (II)

  I0:      0.00 A    0°
  I1:      0.00 A    0°
  I2:      0.00 A    0°

  V0:      0.00 KV   0°
  V1:      0.00 KV   0°
  V2:      0.00 KV   0°

  F:       0.00 Hz
```

- Measurements screen (III)
  - Power by real and reactive phase and apparent rms.
  - Power factor per phase.

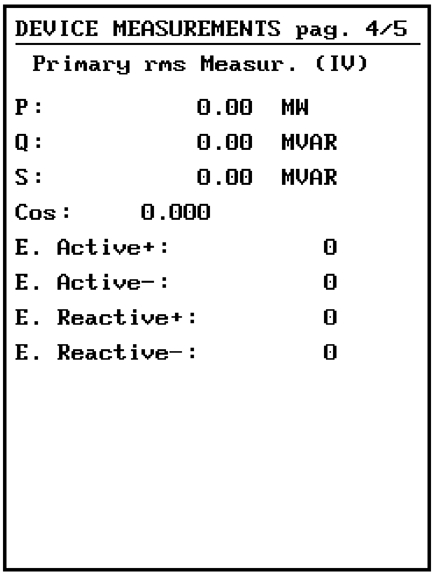
Figure 140 Measurements screen (III)

```
DEVICE MEASUREMENTS pag. 3/5
 Primary rms Measur. (III)

  Pa:          0.00  MW
  Pb:          0.00  MW
  Pc:          0.00  MW
  Qa:          0.00  MVAR
  Qb:          0.00  MVAR
  Qc:          0.00  MVAR
  Sa:          0.00  MVA
  Sb:          0.00  MVA
  Sc:          0.00  MVA
  CosA:  0.000
  CosB:  0.000
  CosC:  0.000
```

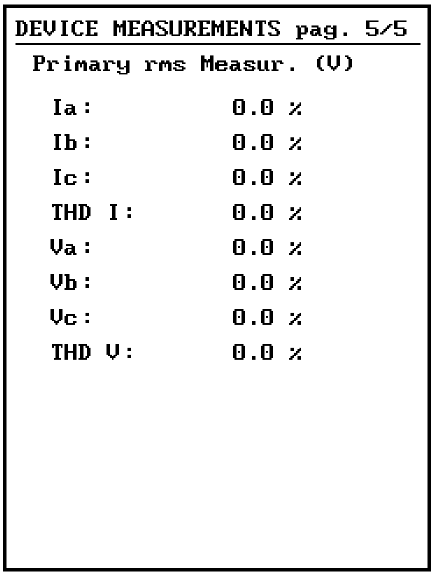
- Measurements screen (IV)
  - Total real, reactive and apparent rms power.
  - Total power factor.
  - Real and Reactive Energy.

Figure 141 Measurements screen (IV)



- Measurements screen (V)
  - The harmonic distortion (%) of the 8 transformers' measurements.

Figure 142 Measurements screen (V)



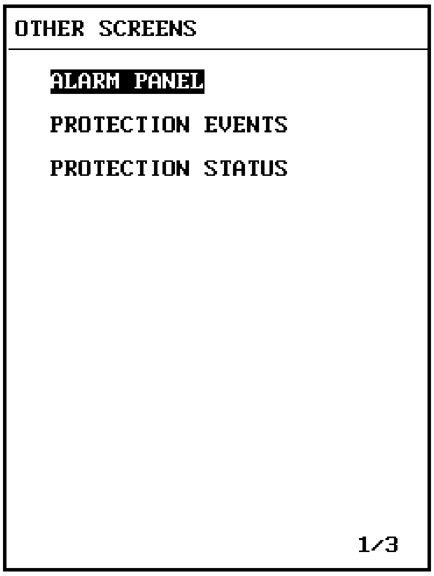
20.1.12 Menu to other screens page

This screen allows an access menu for the other types of screen that have not been given the consideration of main screens to be displayed. We can group little-used screens within this screen and thus reduce the size of the main loop, making the movement between those screens that are considered the most important quicker.

The content of this screen is set using the external configuration tool. Screens that are included in the main screen list cannot be included in this menu.

The image below shows the following types of screen grouped in this screen: Alarm panel, Protection events and Protection status.

Figure 143 Other screens



20.1.13 Shortcut menu page

This screen appears when we press “R”.

It contains those commands that can be given to the unit without having to enter a Password. The commands will vary in accordance with the unit’s family.

- Recloser command.
- Bank automatism command (for unit’s with a capacitor bank).
- .....

By pressing “R”, this page appears showing the first selected command. By clicking on the “↑ (Up), ↓ (Down)” keys we can move between the commands. By pressing “↵ (Enter)”, the selected command is run.

Figure 144 Quick access menu

20.2 CONTROL AND PROTECTION MENUS PAGES

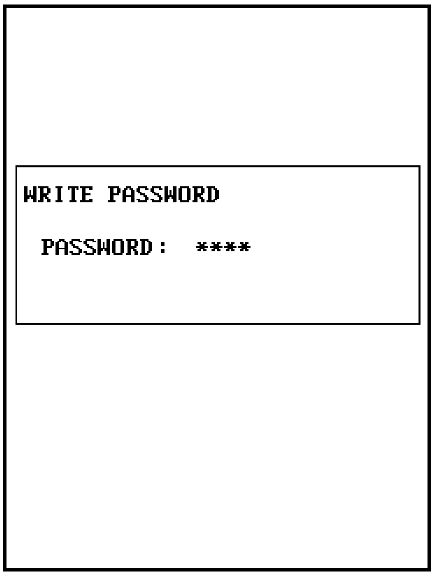
20.2.1 Operation of the menus

These screens enable us to view and modify the control and protection settings values. They consist of several levels of menus and sub-menus.

20.2.1.1 Access to settings Menus

By pressing <MENU> from any of the other types of screen, a screen such as the one shown in Figure 145 will appear and request that a password be entered.

Figure 145 Password request screen



We can access the menu pages with either viewing or modification permissions.

If we enter the correct password and press ↵ (Enter), we will have permission to change settings. The "♦" symbol will appear in the bottom left of the screen, as will the text "CHANGE SETTINGS". However, if we press <ESC>, we will only be permitted to consult the settings. Further more, a text indicating "VIEW SETTINGS" will be shown. The <ESC> key will function even when some of the password's numbers have been entered.

For more information, consult the point 4.2 of the Password Management section in this manual.

20.2.1.2 General operation

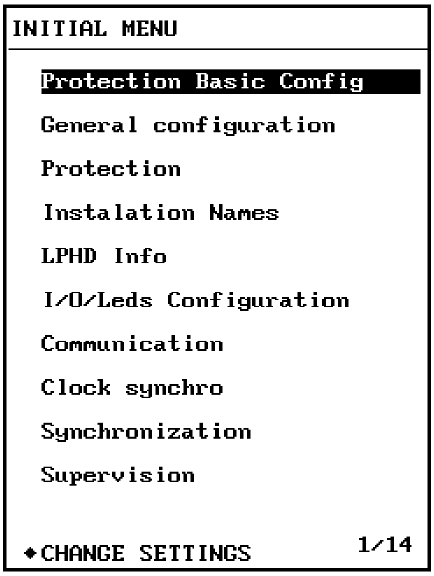
We can access the start menu screen by pressing <MENU> from any of the other pages described in the preceding paragraphs. To exit the menus pages from the start page we must press <MENU> or <ESC>.

To move from a menu to a submenu we must select the menu that we want to explore and press ↵ (Enter). To return to the previous menu, we must press <ESC>. The <MENU> key enables us to return to the start menu from any submenu.

The ↑ (Up), ↓ (Down) keys can be used to change a menu's active line. If all the menu's options can be displayed on the screen, only the active line is changed when we change line. On the other hand, if not all of the menu's options can be displayed on the screen at the same time and the cursor is situated over the first or the last of the screen's menus, the menu will scroll up or down, in accordance with the key used.

An indication of the number of the item selected from the total number of items in the menu on the screen currently displayed is shown in the bottom right of the screen.

Figure 146 Initial Settings Menu



20.2.1.3 Settings change operation

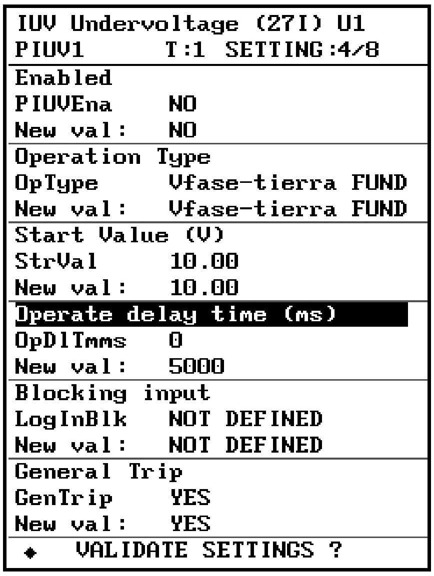
By pressing ↵ (Enter) on an item from a settings menu screen that has no submenus, the settings changes screen will appear (Figure 147). This screen displays the data corresponding to the first 6 settings. The selected setting can be modified using ↑ (Up), ↓ (Down).

If all the node's settings can be displayed on the screen, only the selected setting is changed when we change setting. On the other hand, if not all of the menu's options can be displayed on the screen at the same time and the cursor is situated over the first or the last of the screen's settings, the settings will scroll up or down, in accordance with the key used. To return to the menu screen, we must press <ESC>.

The following data can be seen on this screen:

- The following will appear at the top of the screen:
  - Description of the settings node.
  - Name of the settings node in IEC 61850.
  - Current table (for settings which have the possibility of multiple tables).
  - The number of the selected setting and the total number of the node's settings.
- There are 3 lines for each setting, indicating the following:
  - Description of the setting.
  - Name of the setting in IEC 61850 and its corresponding value.
  - New value of the setting. When this screen is accessed for the first time, the current value and the new value coincide.
- The "VALIDATE PARAMETERS?" text appears in the last line. When selected and after pressing ↵ (Enter), all the changes to the screen's settings are validated. Until we press ↵ (Enter) with the last line selected the changed settings will not be validated.
- WARNING: If the user only has viewing permissions, the last line will not appear on the settings change screens.

Figure 147 Settings change screen



By pressing <ESC> after modifying a setting in the page, a confirmation message indicating that the user is about exit without saving the settings in the CID appears:

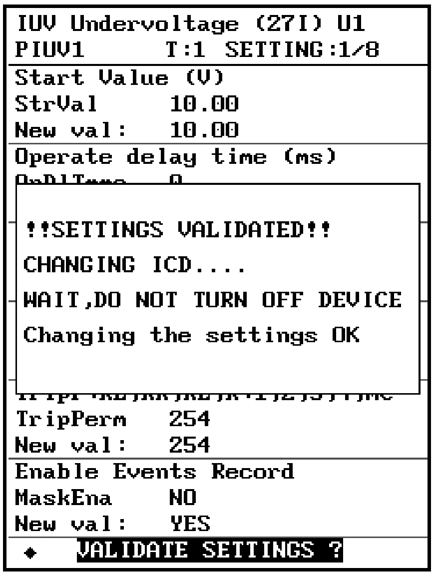
Exit without changing settings?

Thus, by pressing ↲ (Enter) we exit the screen and all the changes made so far in that menu are cleared. If we press <ESC> when the message appears, we remain where we were.

By pressing ↲ (Enter) after having modified one of the page's settings, another window appears. At this point, the user has 2 options:

- Wait until the CID modification process is completed with the new settings. At this point there are 3 possible situations:
  - If the modification is carried out successfully, a “Changing the settings OK” text will appear (Figure 148).
  - If an error occurs during the CID modification process, an “Error in changing settings” text will appear.
  - If a time out failure occurs whilst saving the modified settings, a “Time out in changing settings " message will appear.
- Press ↲ (Enter) and return to the settings change screen without the assurance of having modified the CID.

Figure 148 Setting Validated



20.2.1.4 Settings Types

By pressing ↵ (Enter) on one of the items that enables settings to be changed, and providing that the user has modification permissions, one of different types of small window will appear:

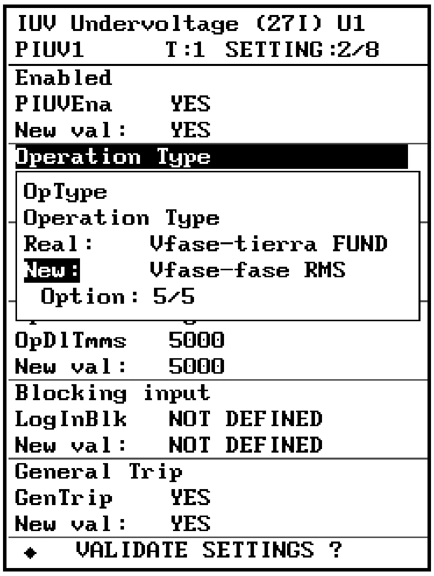
20.2.1.4.1 Option Type

By pressing ↵ (Enter) on a setting of this type, a small window (Figure 149) displaying the following data appears:

- ❑ Setting name in IEC 61850.
- ❑ Setting description.
- ❑ Current setting value.
- ❑ New value of the setting. When this screen is accessed for the first time, the current value and the new value coincide.
- ❑ The number of the current option from among the options available

Using the ↑ (Up), ↓ (Down) keys, we can move through the different options in a circular manner, that is, when we reach the last option we are returned to the first option. The selection option is chosen by pressing ↵ (Enter). To exit without selecting, press <ESC>.

Figure 149 Small screen for modifying OPTION type setting



20.2.1.4.2 Numeric Type

These can be changed using the numeric keys. The number is validated by pressing ↵ (Enter), whilst <ESC> is used to cancel and start again. The following data is displayed in each small window:

- Setting name in IEC 61850.
- Setting description.
- Current setting value.
- The setting's new value. This field, which is empty, is where the value of the new setting entered via the keyboard will be displayed.
- Maximum setting value.
- Minimum setting value.
- Setting step or increase.

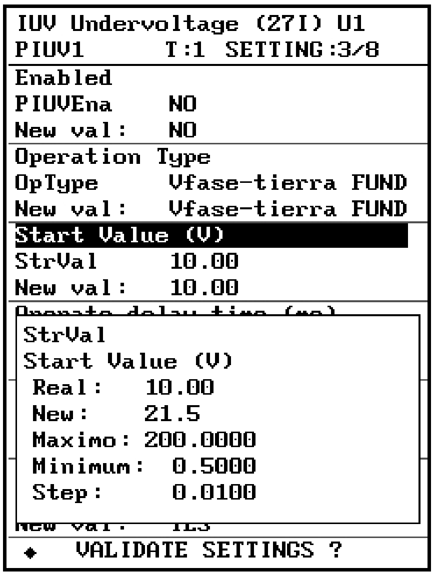
There are 2 possibilities within this type, depending on the number, decimal or integer format.

Decimal

The valid keys are numbers and dot. The desired value is entered directly. Each digit pressed is captured, followed by the selection of the next digit, until we press ↵ (Enter). The decimal point is entered by pressing "."“·". The digits are entered from left to right. For example, to enter the number 123.45, we must successively press 1, 2, 3, ".", 4“·”44, 5, ↵ (Enter).

The entered value is checked in order to ensure that it meets the maximum, minimum and step restrictions. Should it fail to meet any of these restrictions, the "INVALID VALUE" text is shown. This text disappears when a number key is pressed.

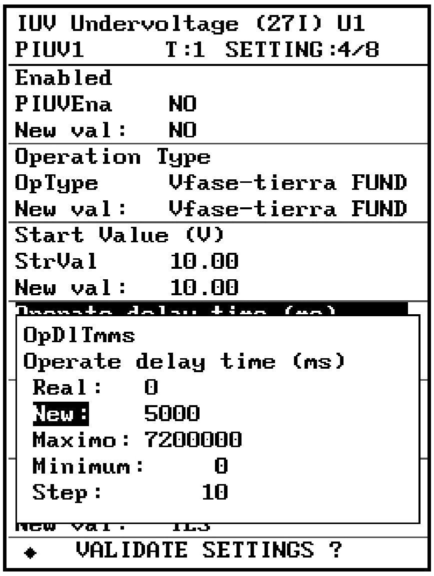
Figure 150 Small screen for modifying DECIMAL type setting



Integer

The valid keys are numbers. The desired value is entered directly. Each digit pressed is captured, followed by the selection of the next digit, until we press ↵ (Enter). The decimal point is not allowed in such settings. The digits are entered from left to right. For example, to enter the number 2345, we must successively press 2, 3, 4, 5, ↵ (Enter).

Figure 151 Small screen for modifying INTEGER type setting



The entered value is checked in order to ensure that it meets the maximum, minimum and step restrictions. Should it fail to meet any of these restrictions, the "INVALID VALUE" text is shown. This text disappears when a number key is pressed.

There are some integer type settings whose value is a signal number. In such cases, the “NOT DEFINED” text (Figure 152) indicates that this setting has no associated signal. If we wish to associate a signal, we must enter the desired signal number with numeric keypad and press ↵ (Enter).

On the other hand, if we wish to assign the undefined value to a setting, we must press “R” and the “NOT DEFINED” text will appear in the New field.

Figure 152 Small screen for modifying INTEGER type setting

```
IUV Undervoltage (27I) U1
PIUV1       T:1  SETTING:5/8
Enabled
PIUVEna     YES
New val:    YES
Operation Type
OpType      Vfase-tierra FUND
New val:    Vfase-tierra FUND
Start Value (V)
StrVal      10.00
New val:    10.00
 LogInBlk
 Blocking input
  Real:     NOT DEFINED
  New:      _
  Maximo:   99999
  Minimum:     -1
  Step:         1
◆  VALIDATE SETTINGS ?
```

20.2.1.4.3 Unit Network Parameters Type

Ethernet interface

The unit’s network parameters can also be viewed and modified from the display: IP address, mask and gateway. Figure 153 shows how the network 1 interface, IP address, network mask and MAC address parameters, as well as the link status indicating if the network cable is connected, would be viewed via the display.

Figure 153 Screen with Ethernet parameters

```
Ethernet 1

IP:        192.168.182.108

MASK:         255.255.255.0

MAC:       00:16:A3:00:2a:9E

LINK STATUS:     YES

 PRESS ENTER: Edit ethernet
 PRESS ESC:   Exit

◆CHANGE SETTINGS
```

If we press ↵ (Enter) in the previous screen and we have permission to change settings, the screen shown in Figure 154 will appear with the current data and a second row into which the new values can be entered. Using the ↑ (Up), ↓ (Down) keys, we can navigate through the IP and MASK fields in a circular manner, that is, when we reach the last option we are returned to the first option.

To exit, press <ESC>.

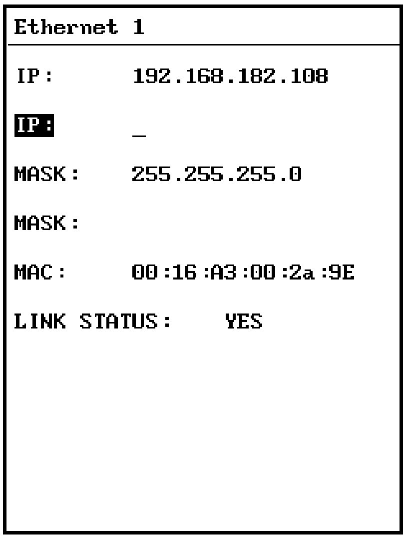
If we want to modify the IP, select the IP field and then enter the values. For example, to enter the IP address 192.168.182.1, we must press 1, 9, 2,”.”, 1, 6, 8, “.”, 1, 8, 2, “.”,1, ↲ (Enter).

Only the IP and MASK fields can be modified.

If the user enters an incorrect value, the last character entered can be deleted with the “←” (Left) key.

Once the correct data have been entered, press ↲ (Enter) to check that the values entered are valid. In the event of an error, a small screen displaying the cause of the error will be shown.

Figure 154 Ethernet parameters setting changes screen



Gateway

The Gateway’s that are configured in the unit can also be viewed, added, modified and deleted from the display. Up to 10 gateways can be configured, ONLY 1 of which can be a default gateway.

Figure 155 Network configuration screen

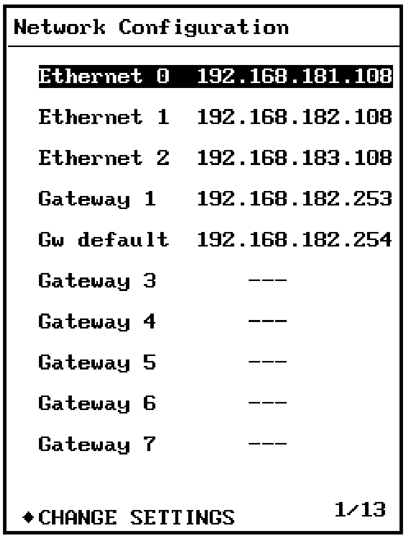
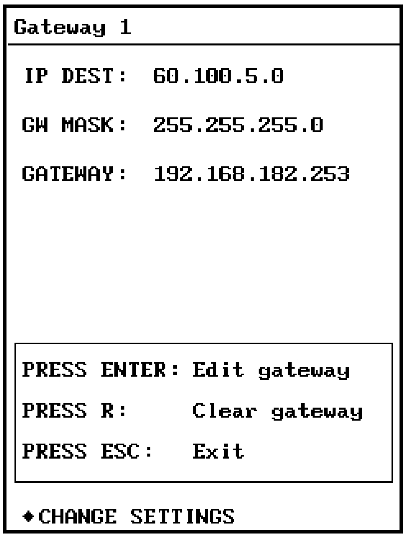


Figure 155 shows the screen with the different interfaces for the unit’s network and gateways. We can see that a default gateway with IP address 192.169.182.254 and a gateway with IP address 192.168.182.253 have been configured. The remaining gateways have not been configured.

Viewing a Gateway

If we select Gateway 1 and press ↲ (Enter), the following screen appears (Figure 156) showing the Gateway’s data values and a legend at the bottom with the different options available to the user.

Figure 156 Gateway display screen



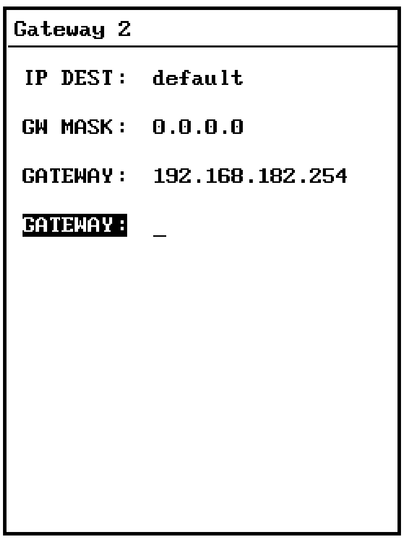
Editing or creating a Gateway

If we press ↵ (Enter) in the Gateway configuration screen and we have permission to change settings (having entered the correct password into the password screen), the Gateway edition and creation screen will appear with the current data and a second row into which the new values can be entered.

The following situations may arise when configuring a Gateway:

- Gateway Not Configured
  - To add a default Gateway, we only have to complete the GATEWAY field (the Gateway IP address) and press ↵ (Enter). If not, an error will occur.
  - To add a Gateway with a specific network destination, we must complete the 3 fields and press ↵ (Enter). If not, an error will occur.
- Gateway Configured
  - To edit a default Gateway (Figure 157), we only have to modify the GATEWAY field (the Gateway's IP address) and, once the desired value has been entered, press ↵ (Enter) for the change to become effective.
  - To edit a Gateway with a specific network destination, we change the desired parameter(s) and press ↵ (Enter). Any parameters that are not modified will retain the current values.

Figure 157 Default Gateway edition screen



To add a new Gateway, select a non-configured gateway, for example Gateway 3, and press ↵ (Enter).

This screen shows the values of the Gateway's 3 fields as non-configured. In such a case, we can only exit or edit (add) the Gateway. By pressing ↵ (Enter) again, the Gateway edition/creation screen will be displayed.

The ↑ (Up), ↓ (Down) keys are used to move between destination IP address, destination network mask and the Gateway IP address fields in a circular manner. This is not possible in the default Gateway, which has a single editable field.

If the user enters an incorrect value, the last character entered can be deleted with the "←" (Left) key.

To exit without saving any changes, press <ESC>.

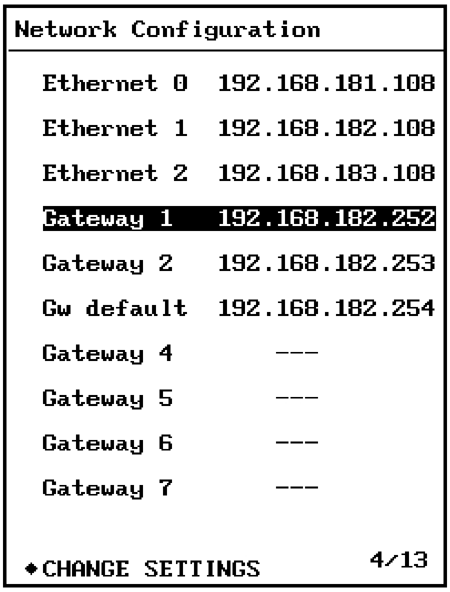
If we want to enter the Gateway with the destination IP 10.15.1.6, Gateway mask 255.255.255.255 and Gateway IP address 192.168.182.252, we must press 1,0,".",1,5,".",1,".",6 and then ↓ (Down) to complete the Gateway mask by pressing 2,5,5,".",2,5,5,".",2,5,5,".",2,5,5. Next, we must use ↓ (Down) and complete the Gateway ip address by entering 1, 9, 2,".", 1, 6, 8, ".", 1, 8,2, ".", 2, 5, 2.

Once the correct data have been entered, press ↵ (Enter) to check that the values entered are valid. In the event of an error, a small screen displaying the cause of the error will be shown.

The screen will display the new configuration and the new Gateway introduced.

NOTE: If a default Gateway is configured, the last Gateway will ALWAYS be displayed, even if more gateways with a specific network destination are added.

Figure 158 Gateway parameters setting changes screen



Deleting a Gateway

If we press "R" in the Gateway configuration screen and we have permission to change settings (having entered the correct password into the password screen), the Gateway that is being displayed will be deleted.

Network Configuration Restrictions

- The IP address and mask formats follow the dot-decimal notation. Checks are to be carried out following this standard.
- IP addresses or masks equal to 0 are not permitted.
- The ip address 255.255.255.255 is not permitted.
- The mask address 255.255.255.255 is not permitted.

- When changing the ip address, the route table is recalculated with the new ip value and previously configured GWs. If the mentioned configuration is possible it is to be carried out both running and permanently. However, if it not possible these GWs are to be removed permanently.

20.2.1.4.4 Date Type

Equivalent to a numeric, although the numeric data entered are successively allocated in blocks of two to Day, month, year, hour, minute, second. When the seconds have been entered, no further data can be entered until we have press ↵ (Enter) or <ESC> (the latter key deletes the data entered. If no data has been entered, we exit the settings modification). The format displayed on the screen is: Day/Month/Year Hour:Min:sec

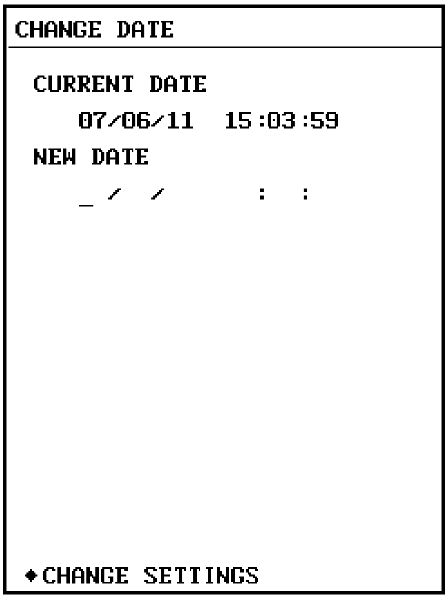
2 digits must always be entered for year, month and date. This means that in order to enter “1” we must enter “01”.

If the user enters an incorrect value, the last character entered can be deleted with the “←” (Left) key.

To exit without saving any changes, press <ESC>.

Once the correct data have been entered, press ↵ (Enter) to check that the values entered are valid. In the event of an error, an “INCORRECT DATE” text will be shown. If the data are valid, no windows will be shown.

Figure 159 Unit date and time setting screen



20.2.2 Password management

20.2.2.1 Changing the Settings Menu Password

The password may contain between 4 and 8 digits. The password is 1357 by default.

When we press a numeric key within the password screen, each keystroke will be considered part of the password and will be indicated in the display with “*”. When we have entered between 4 and 8 characters and pressed "Enter", the data entered will be validated against the unit’s password. If the password entered is incorrect, a warning text will be displayed.

Pressing <ESC> enables us to access the settings menus with viewing only permissions. If we enter the correct password we will be able to view and modify. <ESC> will function even when certain of the password’s numbers have been entered, i.e., if we press <ESC> while we are entering the password we will access the menu with viewing only permission.

The user can change the password, providing that he or she knows the former password.

You will be asked to type the password twice before changing it. The password numbers will appear hidden as they are entered (the “*” will appear for each number entered). Once the first password has been entered, press ↵ (Enter) and enter the second password. Once the second password has been entered, press ↵ (Enter) and the password will be changed (providing the two passwords entered are the same). As with the numbers, they are entered from left to right.

Figure 160 Password modification screen

20.2.2.2 Changing FTP Passwords

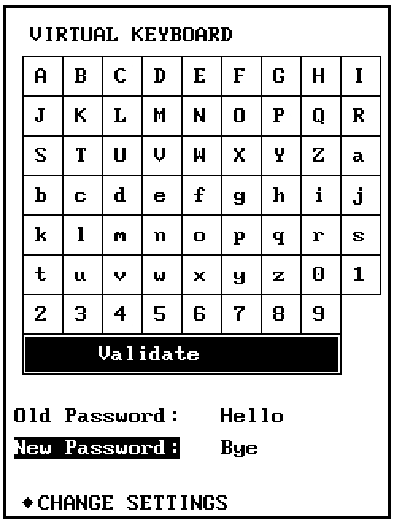
The FTP password modification screen is accessed via the settings menu. This screen shows a virtual keyboard with numbers from 0 to 9, the alphabet in uppercase and in lowercase.

Operation

- We must use the ↑ (Up), ↓ (Down), ← (Left) and → (Right) keys to navigate around the virtual keyboard, whilst ↵ (Enter) is used to confirm the selected keyboard field.
- We must enter the old password and select the "Validate" field before finally pressing ↵ (Enter).
- We must then enter the new password and select the "Validate" field before finally pressing ↵ (Enter).
- A small window showing the result of the password modification (OK or the cause of the failure) will be displayed.

If the user enters an incorrect value, the last character entered can be deleted with the “R” key.

Figure 161 FTP Password modification screen

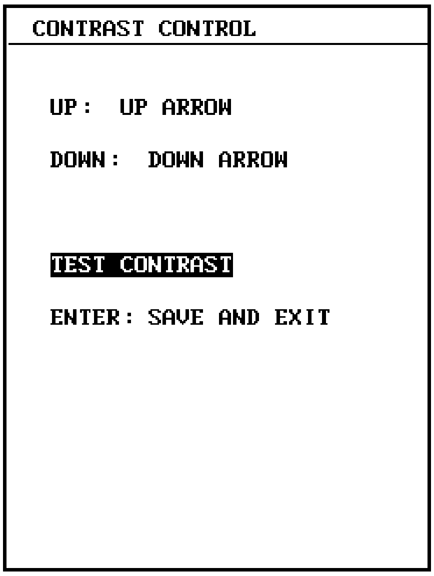


20.3 OTHER SCREENS

20.3.1 Contrast setting

To access the contrast setting screen we must press “0” and “9” at the same time in a screen that is not within the unit's settings menu. Once we have pressed these two keys, the following image will appear in the display:

Figure 162 Contrast setting screen

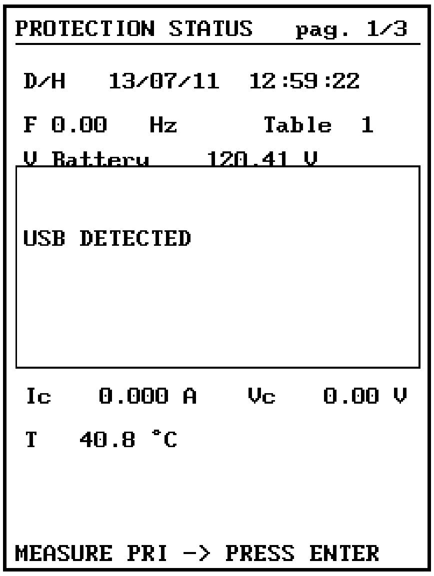


If we then press ↑ (Up) the contrast’s intensity will increase, and if we press ↓ (Down), the intensity will decrease. To exit this screen, press ↵ (Enter).↵ (Enter)

20.3.2 USB treatment

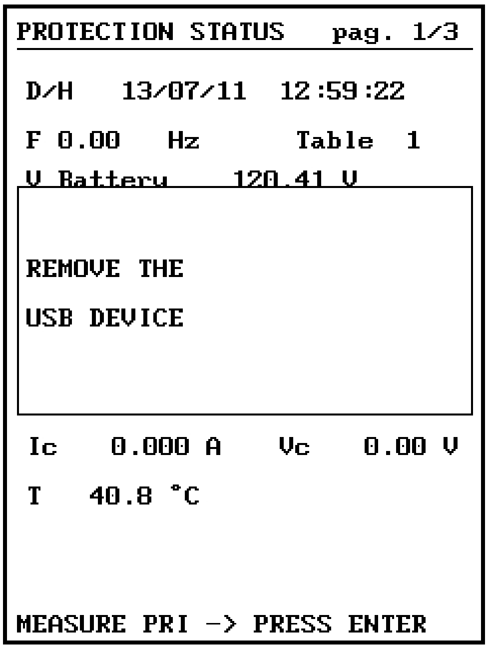
When the user inserts a USB key, a small window will appear in the display indicating that a USB device has been detected and the USB treatment will begin.

Figure 163 USB detected



Once the treatment has terminated, the following window will appear in the display indicating that we can remove the USB device.

Figure 164 Remove the USB device



NOTE: If the USB device is not removed within 5 seconds, the small screen will disappear and the display will return to the previous screen.

APENDICE I CURVES FOR TIMED CHARACTERISTICS

I.1. CEI 255-4 / BS142 CURVES

Enclosed below are the groups of curves, according to BS142, which correspond to the following types:

- Normal Inverse Characteristic.
- Very Inverse Characteristic.
- Extremely Inverse Characteristic.
- User Curve.

These curves comply with the general formula

$$T := M \cdot \frac{k}{\left(\frac{I}{I_0}\right)^{\alpha} - 1} \qquad T_{RECAIDA} := M \cdot \frac{tr}{\left(\frac{I}{I_0}\right)^{2} - 1}$$

in which:

- T : trip time (sec)
- TDROP : drop time (sec)
- M : multiplier (“time dial”). Valid range 0.05 to 1.09, in steps of 0.01
- I: Measured current
- Io: Pickup current setting
- K, α, tr: constants which depend on the type of curve:

Constants	Normal inverse	Short inverse	Long inverse	Very inverse	Extreme. inverse	MIEspecial
K	0.14	0.05	120	13.50	80.00	2.60
α	0.02	0.04	1	1.00	2.00	1.00
tr	9.7	0.5	120	43.2	58.2	21.2

The following represent the curves which correspond to indexes 0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.0 for each type of characteristic. Bear in mind that there are another 9 curves between each of the two curves illustrated, except between 0.05 and 0.1, between which there are another 4.

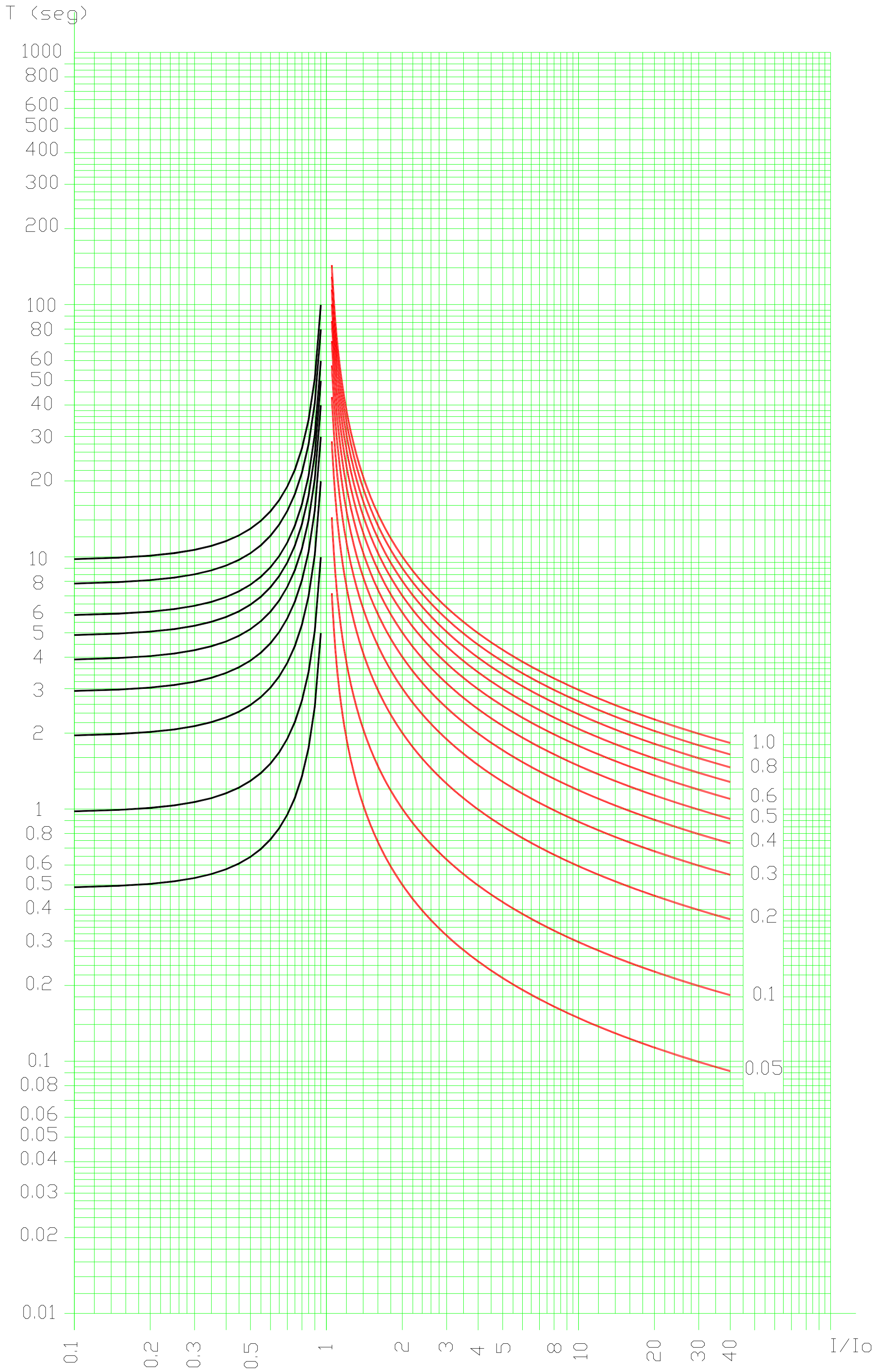
Inverse curve

$$T := M \cdot \frac{k}{\left(\frac{I}{I_0}\right)^{\alpha} - 1} \qquad T_{RECAIDA} := M \cdot \frac{tr}{\left(\frac{I}{I_0}\right)^{2} - 1}$$

K = 0,14, α = 0,02 tr = 9.7

Theoretical values given by the formula:

M\I/Io	0	0.25	0.5	0.75	1.05	1.10	1.20	1.30	1.50	2.00	2.50	3.00	5.00	10.00	20.00	40.00
0.05	0.485	0.517	0.647	1.109	7.170	3.669	1.916	1.331	0.860	0.501	0.378	0.315	0.214	0.149	0.113	0.091
0.06	0.582	0.621	0.776	1.330	8.604	4.402	2.299	1.597	1.032	0.602	0.454	0.378	0.257	0.178	0.136	0.110
0.07	0.679	0.724	0.905	1.552	10.038	5.136	2.683	1.863	1.204	0.702	0.530	0.441	0.300	0.208	0.159	0.128
0.08	0.776	0.828	1.035	1.774	11.472	5.870	3.066	2.129	1.376	0.802	0.606	0.504	0.342	0.238	0.181	0.146
0.09	0.873	0.931	1.164	1.995	12.906	6.604	3.449	2.395	1.547	0.903	0.681	0.567	0.385	0.267	0.204	0.165
0.10	0.970	1.035	1.293	2.217	14.340	7.337	3.832	2.661	1.719	1.003	0.757	0.630	0.428	0.297	0.227	0.183
0.11	1.067	1.138	1.423	2.439	15.774	8.071	4.216	2.927	1.891	1.103	0.833	0.693	0.471	0.327	0.249	0.201
0.12	1.164	1.242	1.552	2.661	17.208	8.805	4.599	3.193	2.063	1.203	0.908	0.756	0.514	0.356	0.272	0.219
0.13	1.261	1.345	1.681	2.882	18.642	9.539	4.982	3.459	2.235	1.304	0.984	0.819	0.556	0.386	0.295	0.238
0.14	1.358	1.449	1.811	3.104	20.076	10.272	5.365	3.725	2.407	1.404	1.060	0.882	0.599	0.416	0.317	0.256
0.15	1.455	1.552	1.940	3.326	21.510	11.006	5.749	3.992	2.579	1.504	1.135	0.945	0.642	0.446	0.340	0.274
0.16	1.552	1.655	2.069	3.547	22.944	11.740	6.132	4.258	2.751	1.605	1.211	1.008	0.685	0.475	0.363	0.293
0.17	1.649	1.759	2.199	3.769	24.378	12.474	6.515	4.524	2.923	1.705	1.287	1.071	0.728	0.505	0.385	0.311
0.18	1.746	1.862	2.328	3.991	25.812	13.207	6.898	4.790	3.095	1.805	1.363	1.134	0.770	0.535	0.408	0.329
0.19	1.843	1.966	2.457	4.213	27.246	13.941	7.282	5.056	3.267	1.906	1.438	1.197	0.813	0.564	0.431	0.347
0.20	1.940	2.069	2.587	4.434	28.680	14.675	7.665	5.322	3.439	2.006	1.514	1.260	0.856	0.594	0.453	0.366
0.25	2.425	2.587	3.233	5.543	35.850	18.344	9.581	6.653	4.299	2.507	1.892	1.575	1.070	0.743	0.567	0.457
0.30	2.910	3.104	3.880	6.651	43.021	22.012	11.497	7.983	5.158	3.009	2.271	1.891	1.284	0.891	0.680	0.549
0.35	3.395	3.621	4.527	7.760	50.191	25.681	13.413	9.314	6.018	3.510	2.649	2.206	1.498	1.040	0.794	0.640
0.40	3.880	4.139	5.173	8.869	57.361	29.350	15.329	10.644	6.878	4.012	3.028	2.521	1.712	1.188	0.907	0.731
0.45	4.365	4.656	5.820	9.977	64.531	33.018	17.246	11.975	7.737	4.513	3.406	2.836	1.926	1.337	1.020	0.823
0.50	4.850	5.173	6.467	11.086	71.701	36.687	19.162	13.305	8.597	5.015	3.785	3.151	2.140	1.485	1.134	0.914
0.55	5.335	5.691	7.113	12.194	78.871	40.356	21.078	14.636	9.457	5.516	4.163	3.466	2.354	1.634	1.247	1.006
0.60	5.820	6.208	7.760	13.303	86.041	44.025	22.994	15.966	10.317	6.017	4.542	3.781	2.568	1.782	1.360	1.097
0.65	6.305	6.725	8.407	14.411	93.211	47.693	24.910	17.297	11.176	6.519	4.920	4.096	2.782	1.931	1.474	1.188
0.70	6.790	7.243	9.053	15.520	100.381	51.362	26.827	18.627	12.036	7.020	5.299	4.411	2.996	2.079	1.587	1.280
0.75	7.275	7.760	9.700	16.629	107.551	55.031	28.743	19.958	12.896	7.522	5.677	4.726	3.210	2.228	1.701	1.371
0.80	7.760	8.277	10.347	17.737	114.721	58.700	30.659	21.288	13.755	8.023	6.056	5.042	3.424	2.376	1.814	1.463
0.85	8.245	8.795	10.993	18.846	121.891	62.368	32.575	22.619	14.615	8.525	6.434	5.357	3.638	2.525	1.927	1.554
0.90	8.730	9.312	11.640	19.954	129.062	66.037	34.491	23.949	15.475	9.026	6.813	5.672	3.852	2.674	2.041	1.646
0.95	9.215	9.829	12.287	21.063	136.232	69.706	36.408	25.280	16.335	9.528	7.191	5.987	4.066	2.822	2.154	1.737
1.00	9.700	10.347	12.933	22.171	143.402	73.374	38.324	26.611	17.194	10.029	7.570	6.302	4.280	2.971	2.267	1.828
1.05	10.185	10.864	13.580	23.280	150.572	77.043	40.240	27.941	18.054	10.530	7.948	6.617	4.494	3.119	2.381	1.920


T (seg)
1000
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400
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200
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0.6
0.5
0.4
0.3
0.2
0.1
0.08
0.06
0.05
0.04
0.03
0.02
0.01
1.0
0.8
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.1
0.2
0.3
0.5
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5
8
10
20
30
40
I/Io

Long duration curve (IEC)

$$T := M \cdot \frac{k}{\left(\frac{I}{I_0}\right)^{\alpha} - 1}$$

@Fig.160.png-H:61,65-W:103,7@

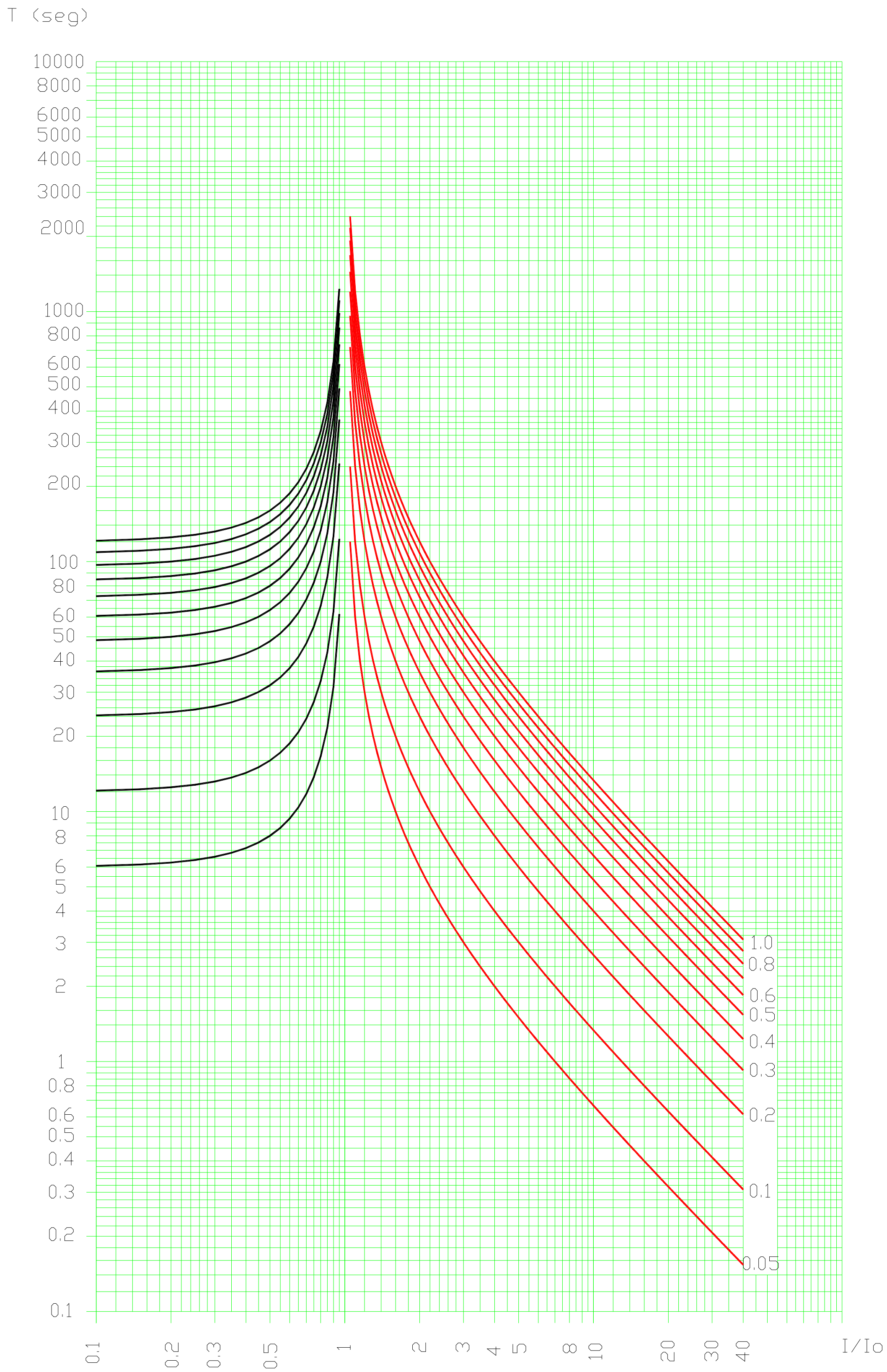
$$T_{RECAIDA} := M \cdot \frac{tr}{\left(\frac{I}{I_0}\right)^{2} - 1}$$

@Fig.161.png-H:62,2-W:145,75@

K = 120, α = 1 tr = 120

Theoretical values given by the formula:

M\I/Io	0	0.25	0.50	0.75	1.05	1.10	1.20	1.30	1.50	2.00	2.50	3.00	5.00	10.00	20.00	40.00
0.05	6.000	6.400	8.000	13.714	120.000	60.000	30.000	20.000	12.000	6.000	4.000	3.000	1.500	0.667	0.316	0.154
0.06	7.200	7.680	9.600	16.457	144.000	72.000	36.000	24.000	14.400	7.200	4.800	3.600	1.800	0.800	0.379	0.185
0.07	8.400	8.960	11.200	19.200	168.000	84.000	42.000	28.000	16.800	8.400	5.600	4.200	2.100	0.933	0.442	0.215
0.08	9.600	10.240	12.800	21.943	192.000	96.000	48.000	32.000	19.200	9.600	6.400	4.800	2.400	1.067	0.505	0.246
0.09	10.800	11.520	14.400	24.686	216.000	108.000	54.000	36.000	21.600	10.800	7.200	5.400	2.700	1.200	0.568	0.277
0.10	12.000	12.800	16.000	27.429	240.000	120.000	60.000	40.000	24.000	12.000	8.000	6.000	3.000	1.333	0.632	0.308
0.11	13.200	14.080	17.600	30.171	264.000	132.000	66.000	44.000	26.400	13.200	8.800	6.600	3.300	1.467	0.695	0.338
0.12	14.400	15.360	19.200	32.914	288.000	144.000	72.000	48.000	28.800	14.400	9.600	7.200	3.600	1.600	0.758	0.369
0.13	15.600	16.640	20.800	35.657	312.000	156.000	78.000	52.000	31.200	15.600	10.400	7.800	3.900	1.733	0.821	0.400
0.14	16.800	17.920	22.400	38.400	336.000	168.000	84.000	56.000	33.600	16.800	11.200	8.400	4.200	1.867	0.884	0.431
0.15	18.000	19.200	24.000	41.143	360.000	180.000	90.000	60.000	36.000	18.000	12.000	9.000	4.500	2.000	0.947	0.462
0.16	19.200	20.480	25.600	43.886	384.000	192.000	96.000	64.000	38.400	19.200	12.800	9.600	4.800	2.133	1.011	0.492
0.17	20.400	21.760	27.200	46.629	408.000	204.000	102.000	68.000	40.800	20.400	13.600	10.200	5.100	2.267	1.074	0.523
0.18	21.600	23.040	28.800	49.371	432.000	216.000	108.000	72.000	43.200	21.600	14.400	10.800	5.400	2.400	1.137	0.554
0.19	22.800	24.320	30.400	52.114	456.000	228.000	114.000	76.000	45.600	22.800	15.200	11.400	5.700	2.533	1.200	0.585
0.20	24.000	25.600	32.000	54.857	480.001	240.000	120.000	80.000	48.000	24.000	16.000	12.000	6.000	2.667	1.263	0.615
0.25	30.000	32.000	40.000	68.571	600.001	300.000	150.000	100.000	60.000	30.000	20.000	15.000	7.500	3.333	1.579	0.769
0.30	36.000	38.400	48.000	82.286	720.001	360.000	180.000	120.000	72.000	36.000	24.000	18.000	9.000	4.000	1.895	0.923
0.35	42.000	44.800	56.000	96.000	840.001	420.000	210.000	140.000	84.000	42.000	28.000	21.000	10.500	4.667	2.211	1.077
0.40	48.000	51.200	64.000	109.714	960.001	480.000	240.000	160.000	96.000	48.000	32.000	24.000	12.000	5.333	2.526	1.231
0.45	54.000	57.600	72.000	123.429	1080.001	540.000	270.000	180.000	108.000	54.000	36.000	27.000	13.500	6.000	2.842	1.385
0.50	60.000	64.000	80.000	137.143	1200.001	600.000	300.000	200.000	120.000	60.000	40.000	30.000	15.000	6.667	3.158	1.538
0.55	66.000	70.400	88.000	150.857	1320.001	660.000	330.000	220.000	132.000	66.000	44.000	33.000	16.500	7.333	3.474	1.692
0.60	72.000	76.800	96.000	164.571	1440.002	720.000	360.000	240.000	144.000	72.000	48.000	36.000	18.000	8.000	3.789	1.846
0.65	78.000	83.200	104.000	178.286	1560.002	780.000	390.000	260.000	156.000	78.000	52.000	39.000	19.500	8.667	4.105	2.000
0.70	84.000	89.600	112.000	192.000	1680.002	840.000	420.000	280.000	168.000	84.000	56.000	42.000	21.000	9.333	4.421	2.154
0.75	90.000	96.000	120.000	205.714	1800.002	900.000	450.000	300.000	180.000	90.000	60.000	45.000	22.500	10.000	4.737	2.308
0.80	96.000	102.400	128.000	219.429	1920.002	960.000	480.000	320.000	192.000	96.000	64.000	48.000	24.000	10.667	5.053	2.462
0.85	102.000	108.800	136.000	233.143	2040.002	1020.000	510.000	340.000	204.000	102.000	68.000	51.000	25.500	11.333	5.368	2.615
0.90	108.000	115.200	144.000	246.857	2160.002	1080.000	540.000	360.000	216.000	108.000	72.000	54.000	27.000	12.000	5.684	2.769
0.95	114.000	121.600	152.000	260.571	2280.003	1140.000	570.000	380.000	228.000	114.000	76.000	57.000	28.500	12.667	6.000	2.923
1.00	120.000	128.000	160.000	274.286	2400.003	1200.000	600.000	400.000	240.000	120.000	80.000	60.000	30.000	13.333	6.316	3.077
1.05	126.000	134.400	168.000	288.000	2520.003	1260.000	630.000	420.000	252.000	126.000	84.000	63.000	31.500	14.000	6.632	3.231


T (seg)
10000
8000
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500
400
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200
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4
3
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0.5
0.4
0.3
0.2
0.1
1.0
0.8
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.1
0.2
0.3
0.5
1
2
3
4
5
8
10
20
30
40
I/Io

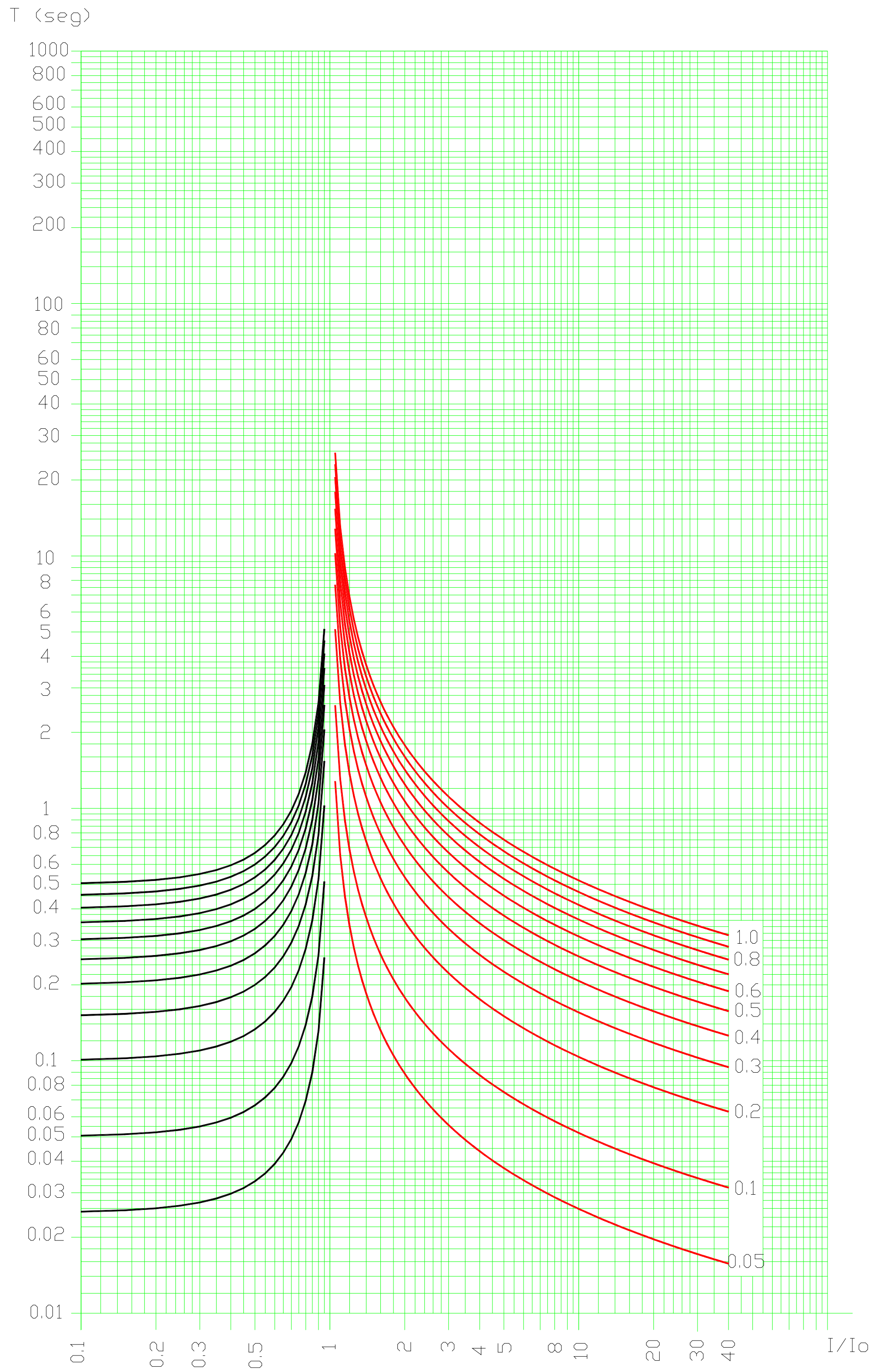
Short duration curve IEC

$$T := M \cdot \frac{k}{\left(\frac{I}{I_0}\right)^{\alpha} - 1} \qquad T_{RECAIDA} := M \cdot \frac{tr}{\left(\frac{I}{I_0}\right)^{2} - 1}$$

K = 0.05, α = 0.04 tr = 0.5

Theoretical values given by the formula:

M\I/Io	0	0.25	0.5	0.75	1.05	1.10	1.20	1.30	1.50	2.00	2.50	3.00	5.00	10.00	20.00	40.00
0.05	0.025	0.027	0.033	0.057	1.280	0.655	0.342	0.237	0.153	0.089	0.067	0.056	0.038	0.026	0.020	0.016
0.06	0.030	0.032	0.040	0.069	1.536	0.785	0.410	0.284	0.183	0.107	0.080	0.067	0.045	0.031	0.024	0.019
0.07	0.035	0.037	0.047	0.080	1.792	0.916	0.478	0.332	0.214	0.124	0.094	0.078	0.053	0.036	0.027	0.022
0.08	0.040	0.043	0.053	0.091	2.048	1.047	0.546	0.379	0.245	0.142	0.107	0.089	0.060	0.041	0.031	0.025
0.09	0.045	0.048	0.060	0.103	2.304	1.178	0.615	0.427	0.275	0.160	0.121	0.100	0.068	0.047	0.035	0.028
0.10	0.050	0.053	0.067	0.114	2.559	1.309	0.683	0.474	0.306	0.178	0.134	0.111	0.075	0.052	0.039	0.031
0.11	0.055	0.059	0.073	0.126	2.815	1.440	0.751	0.521	0.336	0.196	0.147	0.122	0.083	0.057	0.043	0.035
0.12	0.060	0.064	0.080	0.137	3.071	1.571	0.820	0.569	0.367	0.213	0.161	0.134	0.090	0.062	0.047	0.038
0.13	0.065	0.069	0.087	0.149	3.327	1.702	0.888	0.616	0.398	0.231	0.174	0.145	0.098	0.067	0.051	0.041
0.14	0.070	0.075	0.093	0.160	3.583	1.833	0.956	0.664	0.428	0.249	0.188	0.156	0.105	0.073	0.055	0.044
0.15	0.075	0.080	0.100	0.171	3.839	1.964	1.025	0.711	0.459	0.267	0.201	0.167	0.113	0.078	0.059	0.047
0.16	0.080	0.085	0.107	0.183	4.095	2.094	1.093	0.758	0.489	0.285	0.214	0.178	0.120	0.083	0.063	0.050
0.17	0.085	0.091	0.113	0.194	4.351	2.225	1.161	0.806	0.520	0.302	0.228	0.189	0.128	0.088	0.067	0.053
0.18	0.090	0.096	0.120	0.206	4.607	2.356	1.230	0.853	0.550	0.320	0.241	0.200	0.135	0.093	0.071	0.057
0.19	0.095	0.101	0.127	0.217	4.863	2.487	1.298	0.900	0.581	0.338	0.254	0.211	0.143	0.098	0.075	0.060
0.20	0.100	0.107	0.133	0.229	5.119	2.618	1.366	0.948	0.612	0.356	0.268	0.223	0.150	0.104	0.079	0.063
0.25	0.125	0.133	0.167	0.286	6.399	3.273	1.708	1.185	0.764	0.445	0.335	0.278	0.188	0.130	0.098	0.079
0.30	0.150	0.160	0.200	0.343	7.678	3.927	2.049	1.422	0.917	0.534	0.402	0.334	0.226	0.155	0.118	0.094
0.35	0.175	0.187	0.233	0.400	8.958	4.582	2.391	1.659	1.070	0.622	0.469	0.390	0.263	0.181	0.137	0.110
0.40	0.200	0.213	0.267	0.457	10.238	5.236	2.732	1.896	1.223	0.711	0.536	0.445	0.301	0.207	0.157	0.126
0.45	0.225	0.240	0.300	0.514	11.518	5.891	3.074	2.133	1.376	0.800	0.603	0.501	0.338	0.233	0.177	0.142
0.50	0.250	0.267	0.333	0.571	12.797	6.545	3.416	2.370	1.529	0.889	0.670	0.556	0.376	0.259	0.196	0.157
0.55	0.275	0.293	0.367	0.629	14.077	7.200	3.757	2.607	1.682	0.978	0.737	0.612	0.414	0.285	0.216	0.173
0.60	0.300	0.320	0.400	0.686	15.357	7.854	4.099	2.844	1.835	1.067	0.804	0.668	0.451	0.311	0.236	0.189
0.65	0.325	0.347	0.433	0.743	16.637	8.509	4.440	3.081	1.988	1.156	0.871	0.723	0.489	0.337	0.255	0.204
0.70	0.350	0.373	0.467	0.800	17.916	9.163	4.782	3.318	2.141	1.245	0.938	0.779	0.526	0.363	0.275	0.220
0.75	0.375	0.400	0.500	0.857	19.196	9.818	5.123	3.555	2.293	1.334	1.005	0.835	0.564	0.389	0.295	0.236
0.80	0.400	0.427	0.533	0.914	20.476	10.472	5.465	3.792	2.446	1.423	1.071	0.890	0.602	0.415	0.314	0.252
0.85	0.425	0.453	0.567	0.971	21.756	11.127	5.806	4.029	2.599	1.512	1.138	0.946	0.639	0.441	0.334	0.267
0.90	0.450	0.480	0.600	1.029	23.035	11.781	6.148	4.265	2.752	1.601	1.205	1.002	0.677	0.466	0.353	0.283
0.95	0.475	0.507	0.633	1.086	24.315	12.436	6.489	4.502	2.905	1.690	1.272	1.057	0.714	0.492	0.373	0.299
1.00	0.500	0.533	0.667	1.143	25.595	13.090	6.831	4.739	3.058	1.778	1.339	1.113	0.752	0.518	0.393	0.314
1.05	0.525	0.560	0.700	1.200	26.875	13.745	7.173	4.976	3.211	1.867	1.406	1.169	0.790	0.544	0.412	0.330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I/Io

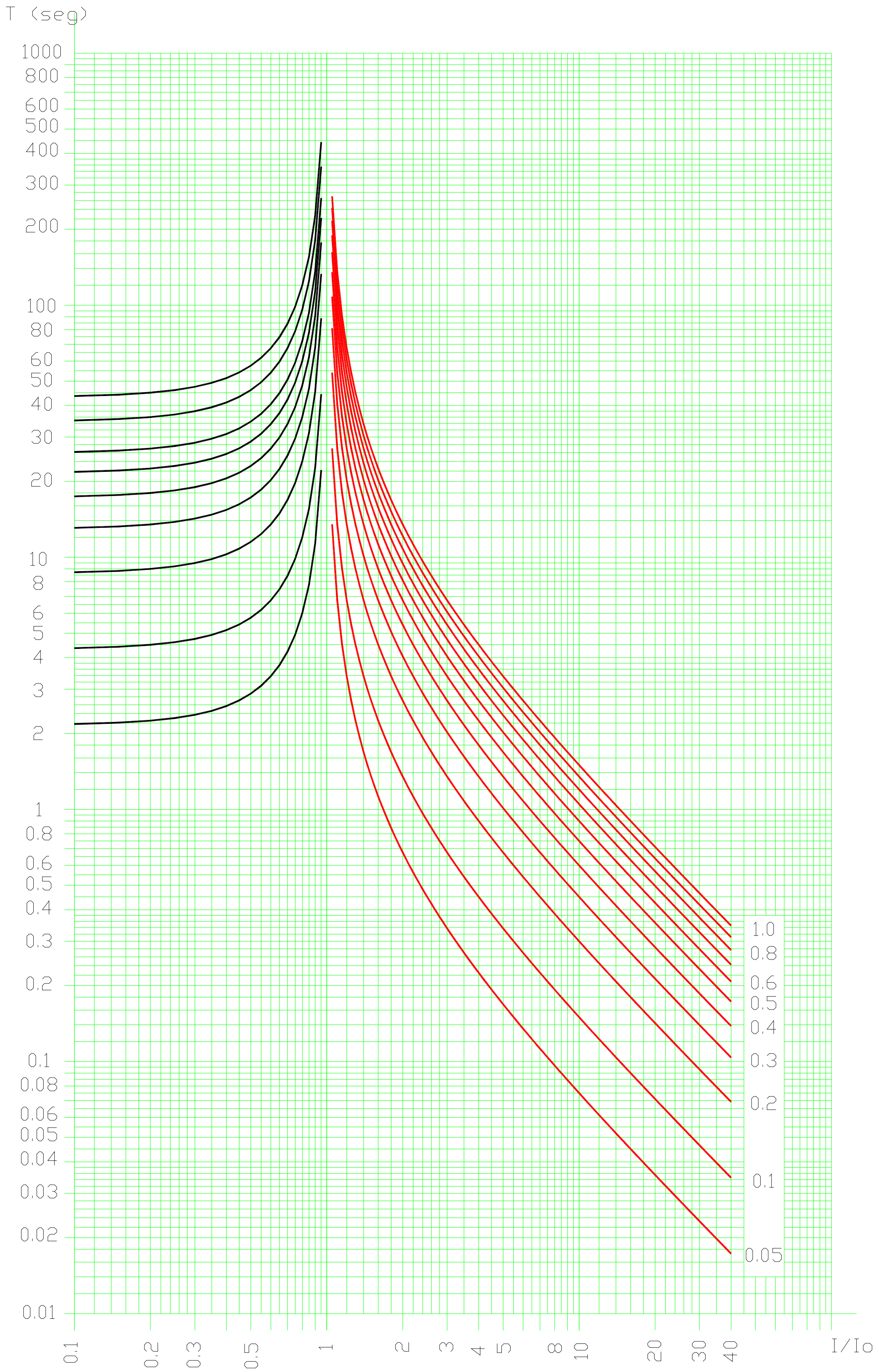
Very inverse curve

$$T := M \cdot \frac{k}{\left(\frac{I}{I_0}\right)^{\alpha} - 1} \qquad T_{RECAIDA} := M \cdot \frac{tr}{\left(\frac{I}{I_0}\right)^{2} - 1}$$

K = 13,5, α = 1 tr = 43.2

Theoretical values given by the formula:

M\I/Io	0	0.25	0.5	0.75	1.05	1.10	1.20	1.30	1.50	2.00	2.50	3.00	5.00	10.00	20.00	40.00
0.05	2.160	2.304	2.880	4.937	13.500	6.750	3.375	2.250	1.350	0.675	0.450	0.338	0.169	0.075	0.036	0.017
0.06	2.592	2.765	3.456	5.925	16.200	8.100	4.050	2.700	1.620	0.810	0.540	0.405	0.203	0.090	0.043	0.021
0.07	3.024	3.226	4.032	6.912	18.900	9.450	4.725	3.150	1.890	0.945	0.630	0.472	0.236	0.105	0.050	0.024
0.08	3.456	3.686	4.608	7.899	21.600	10.800	5.400	3.600	2.160	1.080	0.720	0.540	0.270	0.120	0.057	0.028
0.09	3.888	4.147	5.184	8.887	24.300	12.150	6.075	4.050	2.430	1.215	0.810	0.607	0.304	0.135	0.064	0.031
0.10	4.320	4.608	5.760	9.874	27.000	13.500	6.750	4.500	2.700	1.350	0.900	0.675	0.337	0.150	0.071	0.035
0.11	4.752	5.069	6.336	10.862	29.700	14.850	7.425	4.950	2.970	1.485	0.990	0.742	0.371	0.165	0.078	0.038
0.12	5.184	5.530	6.912	11.849	32.400	16.200	8.100	5.400	3.240	1.620	1.080	0.810	0.405	0.180	0.085	0.042
0.13	5.616	5.990	7.488	12.837	35.100	17.550	8.775	5.850	3.510	1.755	1.170	0.877	0.439	0.195	0.092	0.045
0.14	6.048	6.451	8.064	13.824	37.800	18.900	9.450	6.300	3.780	1.890	1.260	0.945	0.472	0.210	0.099	0.048
0.15	6.480	6.912	8.640	14.811	40.500	20.250	10.125	6.750	4.050	2.025	1.350	1.013	0.506	0.225	0.107	0.052
0.16	6.912	7.373	9.216	15.799	43.200	21.600	10.800	7.200	4.320	2.160	1.440	1.080	0.540	0.240	0.114	0.055
0.17	7.344	7.834	9.792	16.786	45.900	22.950	11.475	7.650	4.590	2.295	1.530	1.148	0.574	0.255	0.121	0.059
0.18	7.776	8.294	10.368	17.774	48.600	24.300	12.150	8.100	4.860	2.430	1.620	1.215	0.608	0.270	0.128	0.062
0.19	8.208	8.755	10.944	18.761	51.300	25.650	12.825	8.550	5.130	2.565	1.710	1.283	0.641	0.285	0.135	0.066
0.20	8.640	9.216	11.520	19.749	54.000	27.000	13.500	9.000	5.400	2.700	1.800	1.350	0.675	0.300	0.142	0.069
0.25	10.800	11.520	14.400	24.686	67.500	33.750	16.875	11.250	6.750	3.375	2.250	1.688	0.844	0.375	0.178	0.087
0.30	12.960	13.824	17.280	29.623	81.000	40.500	20.250	13.500	8.100	4.050	2.700	2.025	1.013	0.450	0.213	0.104
0.35	15.120	16.128	20.160	34.560	94.500	47.250	23.625	15.750	9.450	4.725	3.150	2.363	1.181	0.525	0.249	0.121
0.40	17.280	18.432	23.040	39.497	108.000	54.000	27.000	18.000	10.800	5.400	3.600	2.700	1.350	0.600	0.284	0.138
0.45	19.440	20.736	25.920	44.434	121.500	60.750	30.375	20.250	12.150	6.075	4.050	3.038	1.519	0.675	0.320	0.156
0.50	21.600	23.040	28.800	49.371	135.000	67.500	33.750	22.500	13.500	6.750	4.500	3.375	1.688	0.750	0.355	0.173
0.55	23.760	25.344	31.680	54.309	148.500	74.250	37.125	24.750	14.850	7.425	4.950	3.713	1.856	0.825	0.391	0.190
0.60	25.920	27.648	34.560	59.246	162.000	81.000	40.500	27.000	16.200	8.100	5.400	4.050	2.025	0.900	0.426	0.208
0.65	28.080	29.952	37.440	64.183	175.500	87.750	43.875	29.250	17.550	8.775	5.850	4.388	2.194	0.975	0.462	0.225
0.70	30.240	32.256	40.320	69.120	189.000	94.500	47.250	31.500	18.900	9.450	6.300	4.725	2.363	1.050	0.497	0.242
0.75	32.400	34.560	43.200	74.057	202.500	101.25	50.625	33.750	20.250	10.125	6.750	5.063	2.531	1.125	0.533	0.260
0.80	34.560	36.864	46.080	78.994	216.000	108.00	54.000	36.000	21.600	10.800	7.200	5.400	2.700	1.200	0.568	0.277
0.85	36.720	39.168	48.960	83.931	229.500	114.75	57.375	38.250	22.950	11.475	7.650	5.738	2.869	1.275	0.604	0.294
0.90	38.880	41.472	51.840	88.869	243.000	121.50	60.750	40.500	24.300	12.150	8.100	6.075	3.038	1.350	0.639	0.312
0.95	41.040	43.776	54.720	93.806	256.500	128.25	64.125	42.750	25.650	12.825	8.550	6.413	3.206	1.425	0.675	0.329
1.00	43.200	46.080	57.600	98.743	270.000	135.00	67.500	45.000	27.000	13.500	9.000	6.750	3.375	1.500	0.711	0.346
1.05	45.360	48.384	60.480	103.68	283.500	141.75	70.875	47.250	28.350	14.175	9.450	7.088	3.544	1.575	0.746	0.363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I/Io

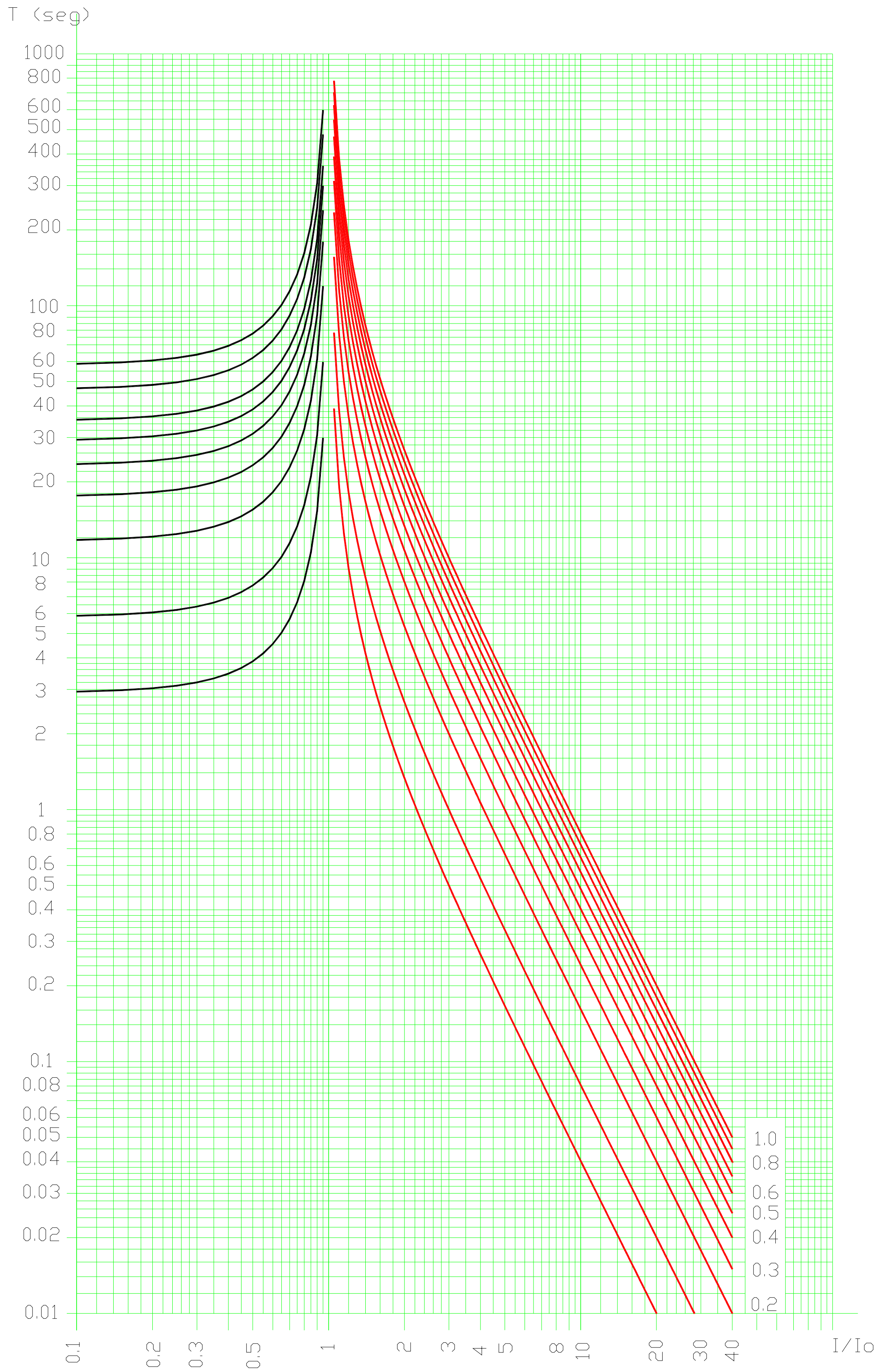
Extremely inverse curve

$$T := M \cdot \frac{k}{\left(\frac{I}{I_0}\right)^{\alpha} - 1} \qquad T_{RECAIDA} := M \cdot \frac{tr}{\left(\frac{I}{I_0}\right)^{2} - 1}$$

K = 80, α = 2   tr =58.2

Theoretical values given by the formula:

M\I/Io	0	0.25	0.5	0.75	1.05	1.10	1.20	1.30	1.50	2.00	2.50	3.00	5.00	10.00	20.00	40.00
0.05	2.910	3.104	3.880	6.651	39.024	19.048	9.091	5.797	3.200	1.333	0.762	0.500	0.167	0.040	0.010	0.003
0.06	3.492	3.725	4.656	7.982	46.829	22.857	10.909	6.957	3.840	1.600	0.914	0.600	0.200	0.048	0.012	0.003
0.07	4.074	4.346	5.432	9.312	54.634	26.667	12.727	8.116	4.480	1.867	1.067	0.700	0.233	0.057	0.014	0.004
0.08	4.656	4.966	6.208	10.642	62.439	30.476	14.545	9.275	5.120	2.133	1.219	0.800	0.267	0.065	0.016	0.004
0.09	5.238	5.587	6.984	11.973	70.244	34.286	16.364	10.435	5.760	2.400	1.371	0.900	0.300	0.073	0.018	0.005
0.10	5.820	6.208	7.760	13.303	78.049	38.095	18.182	11.594	6.400	2.667	1.524	1.000	0.333	0.081	0.020	0.005
0.11	6.402	6.829	8.536	14.633	85.854	41.905	20.000	12.754	7.040	2.933	1.676	1.100	0.367	0.089	0.022	0.006
0.12	6.984	7.450	9.312	15.963	93.659	45.714	21.818	13.913	7.680	3.200	1.829	1.200	0.400	0.097	0.024	0.006
0.13	7.566	8.070	10.088	17.294	101.464	49.524	23.636	15.072	8.320	3.467	1.981	1.300	0.433	0.105	0.026	0.007
0.14	8.148	8.691	10.864	18.624	109.268	53.333	25.455	16.232	8.960	3.733	2.133	1.400	0.467	0.113	0.028	0.007
0.15	8.730	9.312	11.640	19.954	117.073	57.143	27.273	17.391	9.600	4.000	2.286	1.500	0.500	0.121	0.030	0.008
0.16	9.312	9.933	12.416	21.285	124.878	60.952	29.091	18.551	10.240	4.267	2.438	1.600	0.533	0.129	0.032	0.008
0.17	9.894	10.554	13.192	22.615	132.683	64.762	30.909	19.710	10.880	4.533	2.590	1.700	0.567	0.137	0.034	0.009
0.18	10.476	11.174	13.968	23.945	140.488	68.571	32.727	20.870	11.520	4.800	2.743	1.800	0.600	0.145	0.036	0.009
0.19	11.058	11.795	14.744	25.275	148.293	72.381	34.545	22.029	12.160	5.067	2.895	1.900	0.633	0.154	0.038	0.010
0.20	11.640	12.416	15.520	26.606	156.098	76.190	36.364	23.188	12.800	5.333	3.048	2.000	0.667	0.162	0.040	0.010
0.25	14.550	15.520	19.400	33.257	195.122	95.238	45.455	28.986	16.000	6.667	3.810	2.500	0.833	0.202	0.050	0.013
0.30	17.460	18.624	23.280	39.909	234.147	114.286	54.545	34.783	19.200	8.000	4.571	3.000	1.000	0.242	0.060	0.015
0.35	20.370	21.728	27.160	46.560	273.171	133.333	63.636	40.580	22.400	9.333	5.333	3.500	1.167	0.283	0.070	0.018
0.40	23.280	24.832	31.040	53.211	312.195	152.381	72.727	46.377	25.600	10.667	6.095	4.000	1.333	0.323	0.080	0.020
0.45	26.190	27.936	34.920	59.863	351.220	171.429	81.818	52.174	28.800	12.000	6.857	4.500	1.500	0.364	0.090	0.023
0.50	29.100	31.040	38.800	66.514	390.244	190.476	90.909	57.971	32.000	13.333	7.619	5.000	1.667	0.404	0.100	0.025
0.55	32.010	34.144	42.680	73.166	429.269	209.524	100.000	63.768	35.200	14.667	8.381	5.500	1.833	0.444	0.110	0.028
0.60	34.920	37.248	46.560	79.817	468.293	228.571	109.091	69.565	38.400	16.000	9.143	6.000	2.000	0.485	0.120	0.030
0.65	37.830	40.352	50.440	86.469	507.318	247.619	118.182	75.362	41.600	17.333	9.905	6.500	2.167	0.525	0.130	0.033
0.70	40.740	43.456	54.320	93.120	546.342	266.667	127.273	81.159	44.800	18.667	10.667	7.000	2.333	0.566	0.140	0.035
0.75	43.650	46.560	58.200	99.771	585.367	285.714	136.364	86.957	48.000	20.000	11.429	7.500	2.500	0.606	0.150	0.038
0.80	46.560	49.664	62.080	106.423	624.391	304.762	145.455	92.754	51.200	21.333	12.190	8.000	2.667	0.646	0.160	0.040
0.85	49.470	52.768	65.960	113.074	663.415	323.810	154.545	98.551	54.400	22.667	12.952	8.500	2.833	0.687	0.170	0.043
0.90	52.380	55.872	69.840	119.726	702.440	342.857	163.636	104.348	57.600	24.000	13.714	9.000	3.000	0.727	0.180	0.045
0.95	55.290	58.976	73.720	126.377	741.464	361.905	172.727	110.145	60.800	25.333	14.476	9.500	3.167	0.768	0.190	0.048
1.00	58.200	62.080	77.600	133.029	780.489	380.952	181.818	115.942	64.000	26.667	15.238	10.000	3.333	0.808	0.201	0.050
1.05	61.110	65.184	81.480	139.680	819.513	400.000	190.909	121.739	67.200	28.000	16.000	10.500	3.500	0.848	0.211	0.053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I/Io
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Very Inverse Special Curve

$$T := M \cdot \frac{k}{\left(\frac{I}{I_0}\right)^{\alpha} - 1}$$

@Fig.170.png-H:61,65-W:103,7@

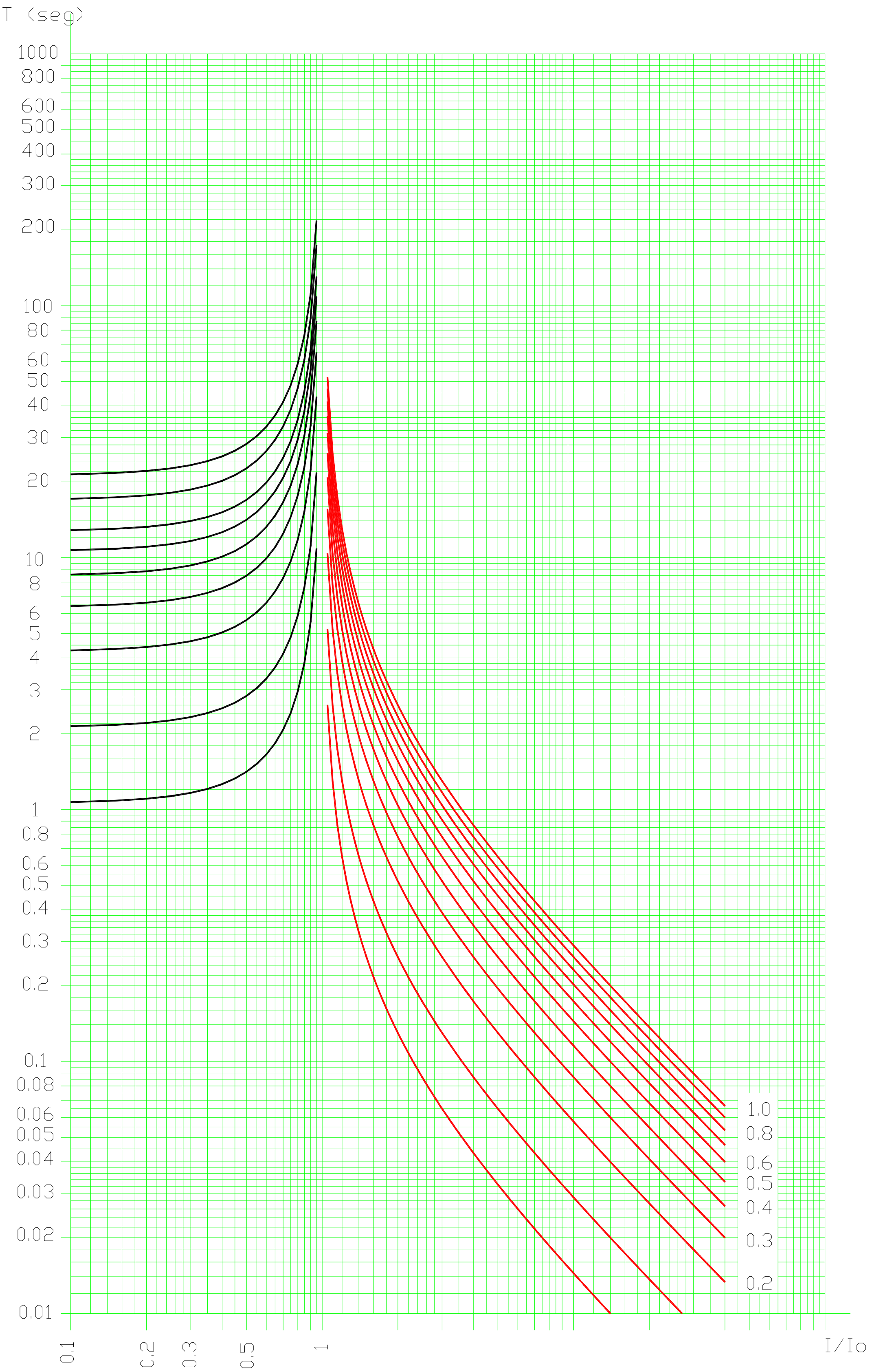
$$T_{RECAIDA} := M \cdot \frac{tr}{\left(\frac{I}{I_0}\right)^{2} - 1}$$

@Fig.171.png-H:62,2-W:145,75@

K = 2,6 $\alpha = 1$

Theoretical values given by the formula:

M \ I/Io	1.05	1.10	1.20	1.30	1.40	1.50	2.00	2.50	3.00	4.00	5.00	7.00	10.00	12.00	15.00	20.00	30.00	40.00
0.05	2.600	1.300	0.650	0.433	0.325	0.260	0.130	0.087	0.065	0.043	0.032	0.022	0.014	0.012	0.009	0.007	0.004	0.003
0.06	3.120	1.560	0.780	0.520	0.390	0.312	0.156	0.104	0.078	0.052	0.039	0.026	0.017	0.014	0.011	0.008	0.005	0.004
0.07	3.640	1.820	0.910	0.607	0.455	0.364	0.182	0.121	0.091	0.061	0.045	0.030	0.020	0.017	0.013	0.010	0.006	0.005
0.08	4.160	2.080	1.040	0.693	0.520	0.416	0.208	0.139	0.104	0.069	0.052	0.035	0.023	0.019	0.015	0.011	0.007	0.005
0.09	4.680	2.340	1.170	0.780	0.585	0.468	0.234	0.156	0.117	0.078	0.058	0.039	0.026	0.021	0.017	0.012	0.008	0.006
0.10	5.200	2.600	1.300	0.867	0.650	0.520	0.260	0.173	0.130	0.087	0.065	0.043	0.029	0.024	0.019	0.014	0.009	0.007
0.11	5.720	2.860	1.430	0.953	0.715	0.572	0.286	0.191	0.143	0.095	0.071	0.048	0.032	0.026	0.020	0.015	0.010	0.007
0.12	6.240	3.120	1.560	1.040	0.780	0.624	0.312	0.208	0.156	0.104	0.078	0.052	0.035	0.028	0.022	0.016	0.011	0.008
0.13	6.760	3.380	1.690	1.127	0.845	0.676	0.338	0.225	0.169	0.113	0.084	0.056	0.038	0.031	0.024	0.018	0.012	0.009
0.14	7.280	3.640	1.820	1.213	0.910	0.728	0.364	0.243	0.182	0.121	0.091	0.061	0.040	0.033	0.026	0.019	0.013	0.009
0.15	7.800	3.900	1.950	1.300	0.975	0.780	0.390	0.260	0.195	0.130	0.098	0.065	0.043	0.035	0.028	0.021	0.013	0.010
0.16	8.320	4.160	2.080	1.387	1.040	0.832	0.416	0.277	0.208	0.139	0.104	0.069	0.046	0.038	0.030	0.022	0.014	0.011
0.17	8.840	4.420	2.210	1.473	1.105	0.884	0.442	0.295	0.221	0.147	0.111	0.074	0.049	0.040	0.032	0.023	0.015	0.011
0.18	9.360	4.680	2.340	1.560	1.170	0.936	0.468	0.312	0.234	0.156	0.117	0.078	0.052	0.043	0.033	0.025	0.016	0.012
0.19	9.880	4.940	2.470	1.647	1.235	0.988	0.494	0.329	0.247	0.165	0.124	0.082	0.055	0.045	0.035	0.026	0.017	0.013
0.20	10.400	5.200	2.600	1.733	1.300	1.040	0.520	0.347	0.260	0.173	0.130	0.087	0.058	0.047	0.037	0.027	0.018	0.013
0.25	13.000	6.500	3.250	2.167	1.625	1.300	0.650	0.433	0.325	0.217	0.163	0.108	0.072	0.059	0.046	0.034	0.022	0.017
0.30	15.600	7.800	3.900	2.600	1.950	1.560	0.780	0.520	0.390	0.260	0.195	0.130	0.087	0.071	0.056	0.041	0.027	0.020
0.35	18.200	9.100	4.550	3.033	2.275	1.820	0.910	0.607	0.455	0.303	0.228	0.152	0.101	0.083	0.065	0.048	0.031	0.023
0.40	20.800	10.400	5.200	3.467	2.600	2.080	1.040	0.693	0.520	0.347	0.260	0.173	0.116	0.095	0.074	0.055	0.036	0.027
0.45	23.400	11.700	5.850	3.900	2.925	2.340	1.170	0.780	0.585	0.390	0.293	0.195	0.130	0.106	0.084	0.062	0.040	0.030
0.50	26.000	13.000	6.500	4.333	3.250	2.600	1.300	0.867	0.650	0.433	0.325	0.217	0.144	0.118	0.093	0.068	0.045	0.033
0.55	28.600	14.300	7.150	4.767	3.575	2.860	1.430	0.953	0.715	0.477	0.358	0.238	0.159	0.130	0.102	0.075	0.049	0.037
0.60	31.200	15.600	7.800	5.200	3.900	3.120	1.560	1.040	0.780	0.520	0.390	0.260	0.173	0.142	0.111	0.082	0.054	0.040
0.65	33.800	16.900	8.450	5.633	4.225	3.380	1.690	1.127	0.845	0.563	0.423	0.282	0.188	0.154	0.121	0.089	0.058	0.043
0.70	36.400	18.200	9.100	6.067	4.550	3.640	1.820	1.213	0.910	0.607	0.455	0.303	0.202	0.165	0.130	0.096	0.063	0.047
0.75	39.000	19.500	9.750	6.500	4.875	3.900	1.950	1.300	0.975	0.650	0.488	0.325	0.217	0.177	0.139	0.103	0.067	0.050
0.80	41.600	20.800	10.400	6.933	5.200	4.160	2.080	1.387	1.040	0.693	0.520	0.347	0.231	0.189	0.149	0.109	0.072	0.053
0.85	44.200	22.100	11.050	7.367	5.525	4.420	2.210	1.473	1.105	0.737	0.553	0.368	0.246	0.201	0.158	0.116	0.076	0.057
0.90	46.800	23.400	11.700	7.800	5.850	4.680	2.340	1.560	1.170	0.780	0.585	0.390	0.260	0.213	0.167	0.123	0.081	0.060
0.95	49.400	24.700	12.350	8.233	6.175	4.940	2.470	1.647	1.235	0.823	0.618	0.412	0.274	0.225	0.176	0.130	0.085	0.063
1.00	52.000	26.000	13.000	8.667	6.500	5.200	2.600	1.733	1.300	0.867	0.650	0.433	0.289	0.236	0.186	0.137	0.090	0.067
1.05	54.600	27.300	13.650	9.100	6.825	5.460	2.730	1.820	1.365	0.910	0.683	0.455	0.303	0.248	0.195	0.144	0.094	0.070


T (seg)
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I.2. ANSI CURVES

Enclosed below are the groups of curves, according to ANSI, which correspond to the following types:

- Normal Inverse Characteristic.
- Very Inverse Characteristic.
- Extremely Inverse Characteristic.
- Moderately Inverse Characteristic.

These curves comply with the general formula

$$T := M \cdot \left[A + \frac{B}{\left(\frac{I}{I_0} - C\right)} + \frac{D}{\left(\frac{I}{I_0} - C\right)^2} + \frac{E}{\left(\frac{I}{I_0} - C\right)^3} \right]$$

@Fig.172.png-H:47,8-W:219,45@

$$T_{RECAIDA} := M \cdot \frac{tr}{\left(\frac{I}{I_0}\right)^2 - 1}$$

@Fig.173.png-H:51,25-W:119,25@

in which:

- T : trip time (sec)
- TDROP : drop time (sec)
- M : multiplier (“time dial”). Valid range 0.05 to 30.0, in steps of 0.1
- I: Measured current
- Io: Pickup current setting
- A, B, C, D, E, tr: constants which depend on the type of curve:

Constants	Inverse character.	Very inverse	Extreme. inverse	Moder. inverse
A	0.0274	0.0615	0.0399	0.1735
B	2.2614	0.7989	0.2294	0.6791
C	0.3000	0.3400	0.5000	0.8000
D	-4.1899	-0.2840	3.0094	-0.0800
E	9.1272	4.0505	0.7222	0.1271
tr	0.99	4.678	6.008	1.2

The following represent the curves which correspond to indexes 0.5, 1.0, 2.0, 3.0, 4.0, 6.0, 8.0, 10.0, 15.0, 20.0 and 30.0 for each type of characteristic. Take into account that between every two curves differentiated in 1.0 there are another 9 curves.

Normal inverse curve

$$T := M \cdot \left[A + \frac{B}{\left(\frac{I}{I_0} - C\right)} + \frac{D}{\left(\frac{I}{I_0} - C\right)^2} + \frac{E}{\left(\frac{I}{I_0} - C\right)^3} \right]$$

@Fig.174.png-H:54,7-W:250@

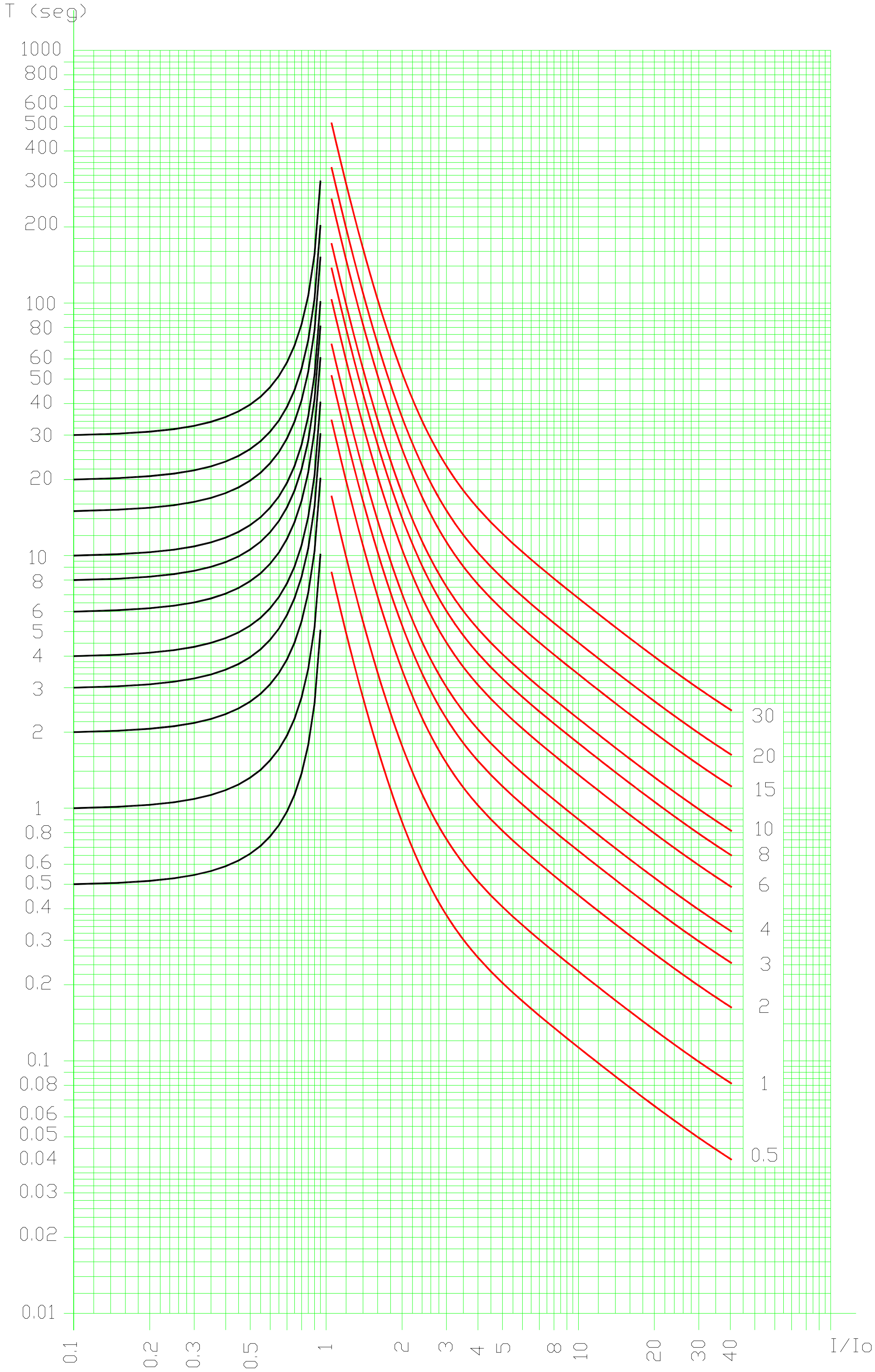
$$T_{RECAIDA} := M \cdot \frac{tr}{\left(\frac{I}{I_0}\right)^2 - 1}$$

@Fig.175.png-H:61,65-W:143,4@

A = 0.0274, B = 2.2614, C = 0.3000, D = -4.1899, E = 9.1272 tr = 0.99

Theoretical values given by the formula:

M \ I/Io	0	0.25	0.5	0.75	1.05	1.10	1.20	1.30	1.50	2.00	2.50	3.00	5.00	10.00	20.00	40.00
0.5	0.495	0.528	0.660	1.131	8.614	7.067	4.944	3.613	2.142	0.883	0.523	0.377	0.203	0.113	0.066	0.041
1.0	0.990	1.056	1.320	2.263	17.229	14.134	9.888	7.226	4.284	1.766	1.047	0.754	0.407	0.226	0.133	0.082
2.0	1.980	2.112	2.640	4.526	34.457	28.268	19.775	14.452	8.568	3.531	2.094	1.508	0.814	0.452	0.265	0.164
3.0	2.970	3.168	3.960	6.789	51.686	42.402	29.663	21.678	12.853	5.297	3.140	2.262	1.220	0.678	0.398	0.246
4.0	3.960	4.224	5.280	9.051	68.915	56.536	39.550	28.904	17.137	7.062	4.187	3.016	1.627	0.904	0.530	0.327
5.0	4.950	5.280	6.600	11.314	86.144	70.670	49.438	36.131	21.421	8.828	5.234	3.770	2.034	1.130	0.663	0.409
6.0	5.940	6.336	7.920	13.577	103.372	84.804	59.325	43.357	25.705	10.594	6.281	4.524	2.441	1.356	0.796	0.491
7.0	6.930	7.392	9.240	15.840	120.601	98.938	69.213	50.583	29.989	12.359	7.328	5.277	2.848	1.582	0.928	0.573
8.0	7.920	8.448	10.560	18.103	137.830	113.072	79.100	57.809	34.274	14.125	8.374	6.031	3.254	1.808	1.061	0.655
9.0	8.910	9.504	11.880	20.366	155.059	127.206	88.988	65.035	38.558	15.890	9.421	6.785	3.661	2.034	1.193	0.737
10.0	9.900	10.560	13.200	22.629	172.287	141.340	98.875	72.261	42.842	17.656	10.468	7.539	4.068	2.260	1.326	0.818
11.0	10.890	11.616	14.520	24.891	189.516	155.474	108.763	79.487	47.126	19.422	11.515	8.293	4.475	2.486	1.458	0.900
12.0	11.880	12.672	15.840	27.154	206.745	169.608	118.650	86.713	51.410	21.187	12.562	9.047	4.881	2.712	1.591	0.982
13.0	12.870	13.728	17.160	29.417	223.974	183.742	128.538	93.939	55.694	22.953	13.608	9.801	5.288	2.938	1.724	1.064
14.0	13.860	14.784	18.480	31.680	241.202	197.876	138.425	101.165	59.979	24.719	14.655	10.555	5.695	3.164	1.856	1.146
15.0	14.850	15.840	19.800	33.943	258.431	212.010	148.313	108.392	64.263	26.484	15.702	11.309	6.102	3.390	1.989	1.228
16.0	15.840	16.896	21.120	36.206	275.660	226.144	158.200	115.618	68.547	28.250	16.749	12.063	6.509	3.616	2.121	1.310
17.0	16.830	17.952	22.440	38.469	292.889	240.278	168.088	122.844	72.831	30.015	17.796	12.817	6.915	3.842	2.254	1.391
18.0	17.820	19.008	23.760	40.731	310.117	254.412	177.975	130.070	77.115	31.781	18.842	13.571	7.322	4.068	2.387	1.473
19.0	18.810	20.064	25.080	42.994	327.346	268.546	187.863	137.296	81.400	33.547	19.889	14.324	7.729	4.294	2.519	1.555
20.0	19.800	21.120	26.400	45.257	344.575	282.680	197.750	144.522	85.684	35.312	20.936	15.078	8.136	4.520	2.652	1.637
21.0	20.790	22.176	27.720	47.520	361.803	296.814	207.638	151.748	89.968	37.078	21.983	15.832	8.543	4.746	2.784	1.719
22.0	21.780	23.232	29.040	49.783	379.032	310.948	217.525	158.974	94.252	38.843	23.030	16.586	8.949	4.972	2.917	1.801
23.0	22.770	24.288	30.360	52.046	396.261	325.082	227.413	166.200	98.536	40.609	24.076	17.340	9.356	5.198	3.050	1.883
24.0	23.760	25.344	31.680	54.309	413.490	339.216	237.300	173.426	102.821	42.375	25.123	18.094	9.763	5.424	3.182	1.964
25.0	24.750	26.400	33.000	56.571	430.718	353.350	247.188	180.653	107.105	44.140	26.170	18.848	10.170	5.650	3.315	2.046
26.0	25.740	27.456	34.320	58.834	447.947	367.484	257.075	187.879	111.389	45.906	27.217	19.602	10.576	5.876	3.447	2.128
27.0	26.730	28.512	35.640	61.097	465.176	381.618	266.963	195.105	115.673	47.671	28.264	20.356	10.983	6.102	3.580	2.210
28.0	27.720	29.568	36.960	63.360	482.405	395.752	276.850	202.331	119.957	49.437	29.310	21.110	11.390	6.328	3.713	2.292
29.0	28.710	30.624	38.280	65.623	499.633	409.886	286.738	209.557	124.242	51.203	30.357	21.864	11.797	6.554	3.845	2.374
30.0	29.700	31.680	39.600	67.886	516.862	424.020	296.625	216.783	128.526	52.968	31.404	22.618	12.204	6.780	3.978	2.455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I/Io

Very inverse curve

$$T := M \cdot \left[A + \frac{B}{\left(\frac{I}{I_0} - C\right)} + \frac{D}{\left(\frac{I}{I_0} - C\right)^2} + \frac{E}{\left(\frac{I}{I_0} - C\right)^3} \right]$$

@Fig.176.png-H:54,7-W:250@

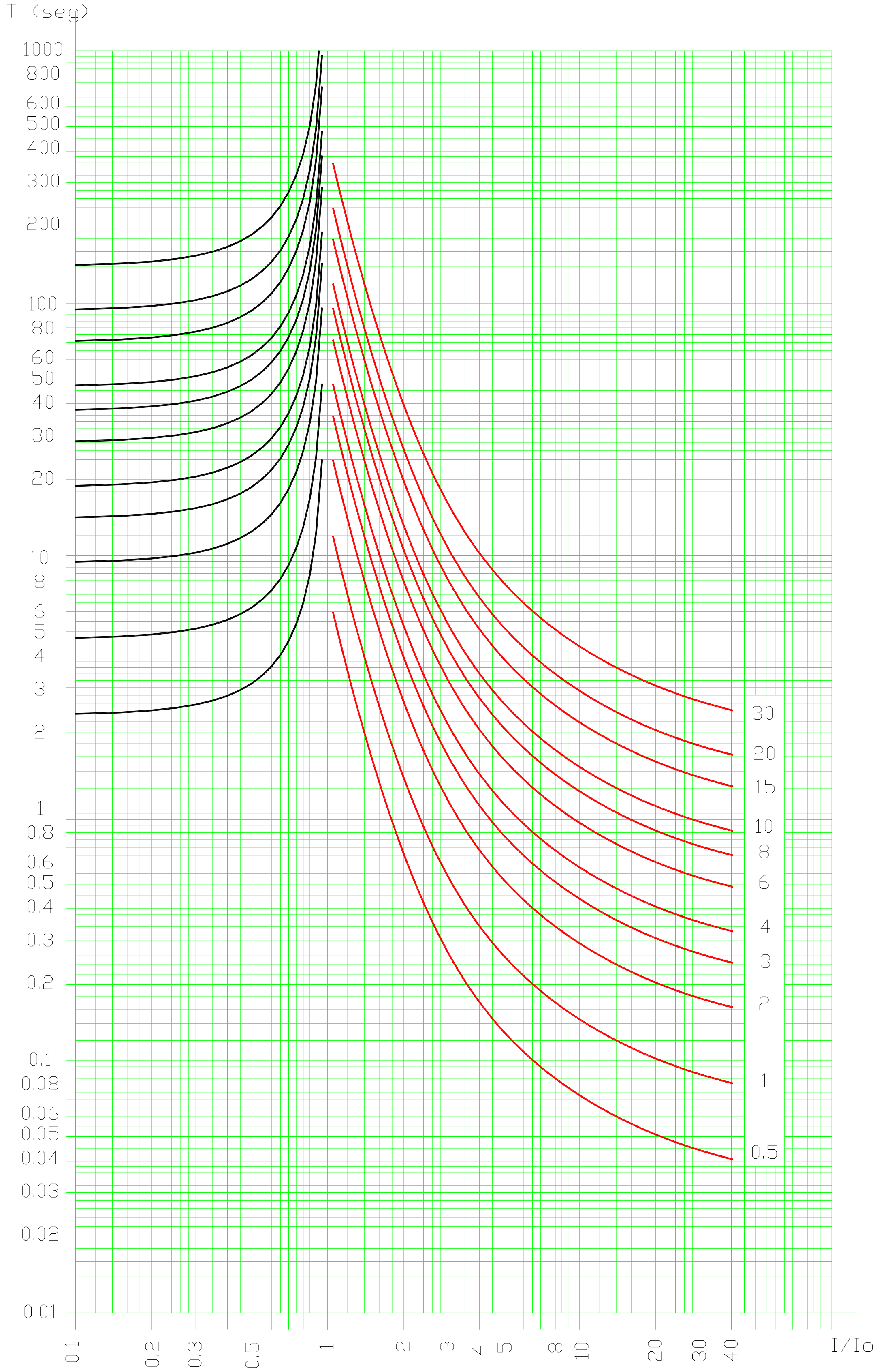
$$T_{RECAIDA} := M \cdot \frac{tr}{\left(\frac{I}{I_0}\right)^2 - 1}$$

@Fig.177.png-H:61,65-W:143,4@

A = 0.0615, B = 0.7989, C = 0.3400, D = -0.2840, E = 4.0505 tr = 4.678

Theoretical values given by the formula:

M \ I/Io	0	0.25	0.5	0.75	1.05	1.10	1.20	1.30	1.50	2.00	2.50	3.00	5.00	10.00	20.00	40.00
0.5	2.339	2.495	3.119	5.346	5.970	4.924	3.487	2.582	1.567	0.663	0.386	0.268	0.130	0.073	0.051	0.041
1.0	4.678	4.990	6.237	10.693	11.940	9.848	6.975	5.164	3.134	1.325	0.772	0.537	0.260	0.146	0.102	0.082
2.0	9.356	9.980	12.475	21.385	23.881	19.696	13.949	10.327	6.268	2.650	1.545	1.074	0.520	0.291	0.204	0.163
3.0	14.034	14.970	18.712	32.078	35.821	29.544	20.924	15.491	9.402	3.976	2.317	1.611	0.780	0.437	0.306	0.245
4.0	18.712	19.959	24.949	42.770	47.762	39.393	27.898	20.655	12.537	5.301	3.090	2.148	1.040	0.583	0.408	0.326
5.0	23.390	24.949	31.187	53.463	59.702	49.241	34.873	25.819	15.671	6.626	3.862	2.685	1.299	0.728	0.510	0.408
6.0	28.068	29.939	37.424	64.155	71.642	59.089	41.848	30.982	18.805	7.951	4.635	3.221	1.559	0.874	0.612	0.489
7.0	32.746	34.929	43.661	74.848	83.583	68.937	48.822	36.146	21.939	9.276	5.407	3.758	1.819	1.020	0.714	0.571
8.0	37.424	39.919	49.899	85.541	95.523	78.785	55.797	41.310	25.073	10.602	6.179	4.295	2.079	1.165	0.815	0.652
9.0	42.102	44.909	56.136	96.233	107.464	88.633	62.771	46.474	28.207	11.927	6.952	4.832	2.339	1.311	0.917	0.734
10.0	46.780	49.899	62.373	106.926	119.404	98.481	69.746	51.637	31.341	13.252	7.724	5.369	2.599	1.457	1.019	0.815
11.0	51.458	54.889	68.611	117.618	131.344	108.330	76.721	56.801	34.475	14.577	8.497	5.906	2.859	1.602	1.121	0.897
12.0	56.136	59.878	74.848	128.311	143.285	118.178	83.695	61.965	37.610	15.902	9.269	6.443	3.119	1.748	1.223	0.978
13.0	60.814	64.868	81.085	139.003	155.225	128.026	90.670	67.128	40.744	17.228	10.041	6.980	3.379	1.893	1.325	1.060
14.0	65.492	69.858	87.323	149.696	167.165	137.874	97.645	72.292	43.878	18.553	10.814	7.517	3.638	2.039	1.427	1.141
15.0	70.170	74.848	93.560	160.389	179.106	147.722	104.619	77.456	47.012	19.878	11.586	8.054	3.898	2.185	1.529	1.223
16.0	74.848	79.838	99.797	171.081	191.046	157.570	111.594	82.620	50.146	21.203	12.359	8.591	4.158	2.330	1.631	1.304
17.0	79.526	84.828	106.035	181.774	202.987	167.419	118.568	87.783	53.280	22.528	13.131	9.127	4.418	2.476	1.733	1.386
18.0	84.204	89.818	112.272	192.466	214.927	177.267	125.543	92.947	56.414	23.853	13.904	9.664	4.678	2.622	1.835	1.468
19.0	88.882	94.807	118.509	203.159	226.867	187.115	132.518	98.111	59.549	25.179	14.676	10.201	4.938	2.767	1.937	1.549
20.0	93.560	99.797	124.747	213.851	238.808	196.963	139.492	103.275	62.683	26.504	15.448	10.738	5.198	2.913	2.039	1.631
21.0	98.238	104.787	130.984	224.544	250.748	206.811	146.467	108.438	65.817	27.829	16.221	11.275	5.458	3.059	2.141	1.712
22.0	102.916	109.777	137.221	235.237	262.689	216.659	153.441	113.602	68.951	29.154	16.993	11.812	5.718	3.204	2.243	1.794
23.0	107.594	114.767	143.459	245.929	274.629	226.507	160.416	118.766	72.085	30.479	17.766	12.349	5.977	3.350	2.344	1.875
24.0	112.272	119.757	149.696	256.622	286.569	236.356	167.391	123.930	75.219	31.805	18.538	12.886	6.237	3.496	2.446	1.957
25.0	116.950	124.747	155.933	267.314	298.510	246.204	174.365	129.093	78.353	33.130	19.310	13.423	6.497	3.641	2.548	2.038
26.0	121.628	129.737	162.171	278.007	310.450	256.052	181.340	134.257	81.487	34.455	20.083	13.960	6.757	3.787	2.650	2.120
27.0	126.306	134.726	168.408	288.699	322.391	265.900	188.314	139.421	84.622	35.780	20.855	14.497	7.017	3.933	2.752	2.201
28.0	130.984	139.716	174.645	299.392	334.331	275.748	195.289	144.584	87.756	37.105	21.628	15.034	7.277	4.078	2.854	2.283
29.0	135.662	144.706	180.883	310.085	346.271	285.596	202.264	149.748	90.890	38.431	22.400	15.570	7.537	4.224	2.956	2.364
30.0	140.340	149.696	187.120	320.777	358.212	295.444	209.238	154.912	94.024	39.756	23.173	16.107	7.797	4.370	3.058	2.446


T (seg)
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0.5

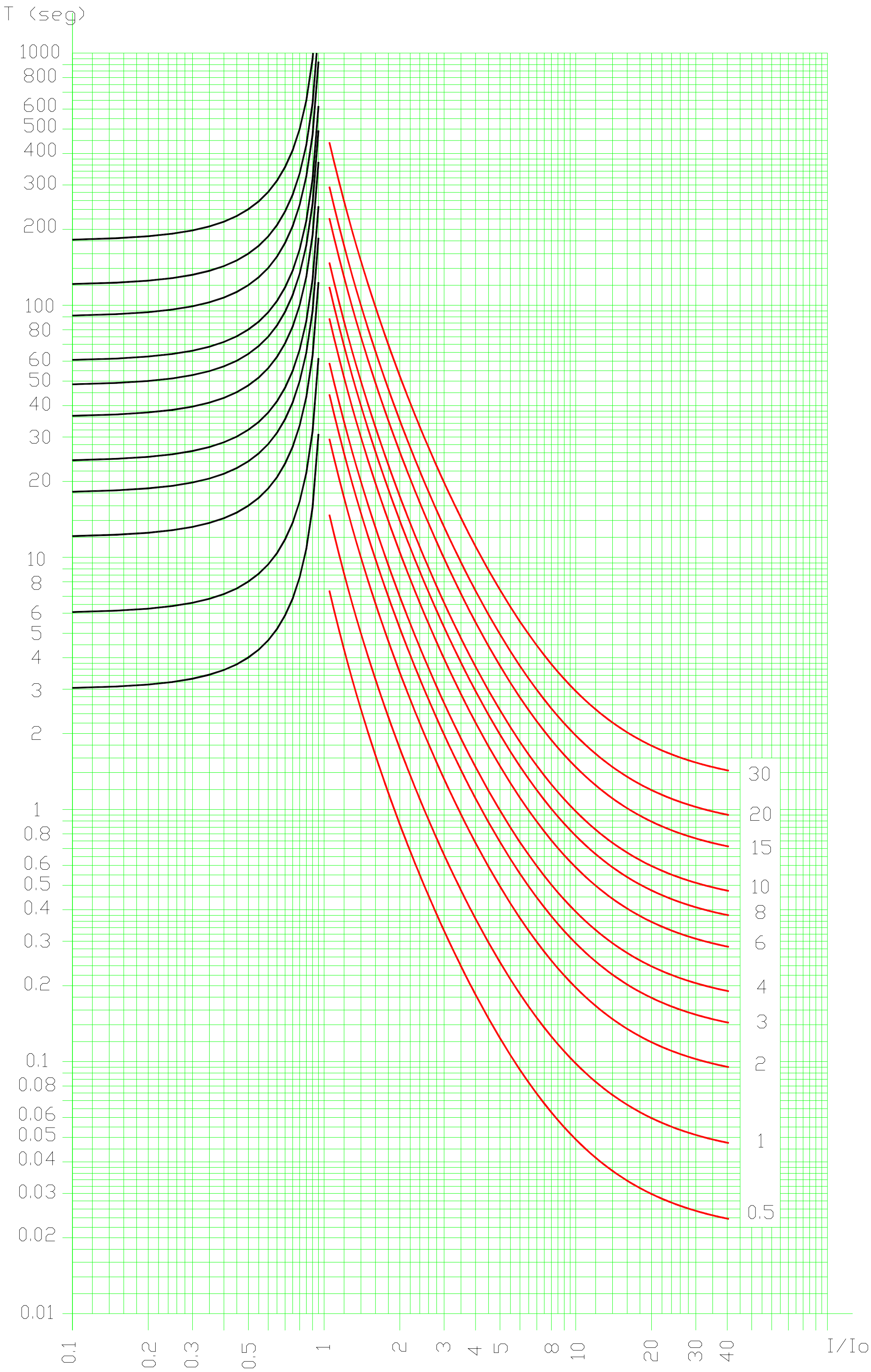
Extremely inverse curve

$$T := M \cdot \left[A + \frac{B}{\left(\frac{I}{I_0} - C\right)} + \frac{D}{\left(\frac{I}{I_0} - C\right)^2} + \frac{E}{\left(\frac{I}{I_0} - C\right)^3} \right] \qquad T_{RECAIDA} := M \cdot \frac{tr}{\left(\frac{I}{I_0}\right)^2 - 1}$$

A = 0.0399, B = 0.2294, C = 0.5000, D = 3.0094, E = 0.7222 tr = 6.008

Theoretical values given by the formula:

M \ I/Io	0	0.25	0.5	0.75	1.05	1.10	1.20	1.30	1.50	2.00	2.50	3.00	5.00	10.00	20.00	40.00
0.5	3.004	3.204	4.005	6.866	7.373	6.063	4.307	3.220	2.000	0.872	0.499	0.330	0.124	0.049	0.030	0.024
1.0	6.008	6.409	8.011	13.733	14.746	12.125	8.615	6.439	4.001	1.744	0.997	0.659	0.247	0.098	0.060	0.048
2.0	12.016	12.817	16.021	27.465	29.492	24.250	17.230	12.879	8.002	3.489	1.994	1.319	0.495	0.196	0.119	0.095
3.0	18.024	19.226	24.032	41.198	44.239	36.376	25.844	19.318	12.003	5.233	2.992	1.978	0.742	0.295	0.179	0.143
4.0	24.032	25.634	32.043	54.930	58.985	48.501	34.459	25.758	16.004	6.977	3.989	2.638	0.990	0.393	0.239	0.191
5.0	30.040	32.043	40.053	68.663	73.731	60.626	43.074	32.197	20.004	8.722	4.986	3.297	1.237	0.491	0.298	0.238
6.0	36.048	38.451	48.064	82.395	88.477	72.751	51.689	38.636	24.005	10.466	5.983	3.956	1.484	0.589	0.358	0.286
7.0	42.056	44.860	56.075	96.128	103.224	84.876	60.303	45.076	28.006	12.210	6.981	4.616	1.732	0.688	0.418	0.334
8.0	48.064	51.268	64.085	109.861	117.970	97.002	68.918	51.515	32.007	13.955	7.978	5.275	1.979	0.786	0.477	0.381
9.0	54.072	57.677	72.096	123.593	132.716	109.127	77.533	57.954	36.008	15.699	8.975	5.934	2.227	0.884	0.537	0.429
10.0	60.080	64.085	80.107	137.326	147.462	121.252	86.148	64.394	40.009	17.443	9.972	6.594	2.474	0.982	0.597	0.476
11.0	66.088	70.494	88.117	151.058	162.208	133.377	94.763	70.833	44.010	19.188	10.969	7.253	2.722	1.081	0.656	0.524
12.0	72.096	76.902	96.128	164.791	176.955	145.502	103.377	77.273	48.011	20.932	11.967	7.913	2.969	1.179	0.716	0.572
13.0	78.104	83.311	104.139	178.523	191.701	157.628	111.992	83.712	52.012	22.676	12.964	8.572	3.216	1.277	0.776	0.619
14.0	84.112	89.719	112.149	192.256	206.447	169.753	120.607	90.151	56.013	24.421	13.961	9.231	3.464	1.375	0.835	0.667
15.0	90.120	96.128	120.160	205.989	221.193	181.878	129.222	96.591	60.013	26.165	14.958	9.891	3.711	1.474	0.895	0.715
16.0	96.128	102.537	128.171	219.721	235.940	194.003	137.837	103.030	64.014	27.909	15.956	10.550	3.959	1.572	0.955	0.762
17.0	102.136	108.945	136.181	233.454	250.686	206.128	146.451	109.470	68.015	29.654	16.953	11.210	4.206	1.670	1.014	0.810
18.0	108.144	115.354	144.192	247.186	265.432	218.254	155.066	115.909	72.016	31.398	17.950	11.869	4.453	1.768	1.074	0.858
19.0	114.152	121.762	152.203	260.919	280.178	230.379	163.681	122.348	76.017	33.142	18.947	12.528	4.701	1.866	1.134	0.905
20.0	120.160	128.171	160.213	274.651	294.924	242.504	172.296	128.788	80.018	34.887	19.944	13.188	4.948	1.965	1.194	0.953
21.0	126.168	134.579	168.224	288.384	309.671	254.629	180.910	135.227	84.019	36.631	20.942	13.847	5.196	2.063	1.253	1.001
22.0	132.176	140.988	176.235	302.117	324.417	266.754	189.525	141.666	88.020	38.375	21.939	14.506	5.443	2.161	1.313	1.048
23.0	138.184	147.396	184.245	315.849	339.163	278.879	198.140	148.106	92.021	40.120	22.936	15.166	5.691	2.259	1.373	1.096
24.0	144.192	153.805	192.256	329.582	353.909	291.005	206.755	154.545	96.022	41.864	23.933	15.825	5.938	2.358	1.432	1.144
25.0	150.200	160.213	200.267	343.314	368.655	303.130	215.370	160.985	100.022	43.608	24.931	16.485	6.185	2.456	1.492	1.191
26.0	156.208	166.622	208.277	357.047	383.402	315.255	223.984	167.424	104.023	45.353	25.928	17.144	6.433	2.554	1.552	1.239
27.0	162.216	173.030	216.288	370.779	398.148	327.380	232.599	173.863	108.024	47.097	26.925	17.803	6.680	2.652	1.611	1.286
28.0	168.224	179.439	224.299	384.512	412.894	339.505	241.214	180.303	112.025	48.841	27.922	18.463	6.928	2.751	1.671	1.334
29.0	174.232	185.847	232.309	398.245	427.640	351.631	249.829	186.742	116.026	50.586	28.920	19.122	7.175	2.849	1.731	1.382
30.0	180.240	192.256	240.320	411.977	442.387	363.756	258.444	193.182	120.027	52.330	29.917	19.782	7.422	2.947	1.790	1.429


T (seg)
1000
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0.2
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0.05
0.04
0.03
0.02
0.01
0.1
0.2
0.3
0.5
1
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30
40
I/Io
30
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15
10
8
6
4
3
2
1
0.5

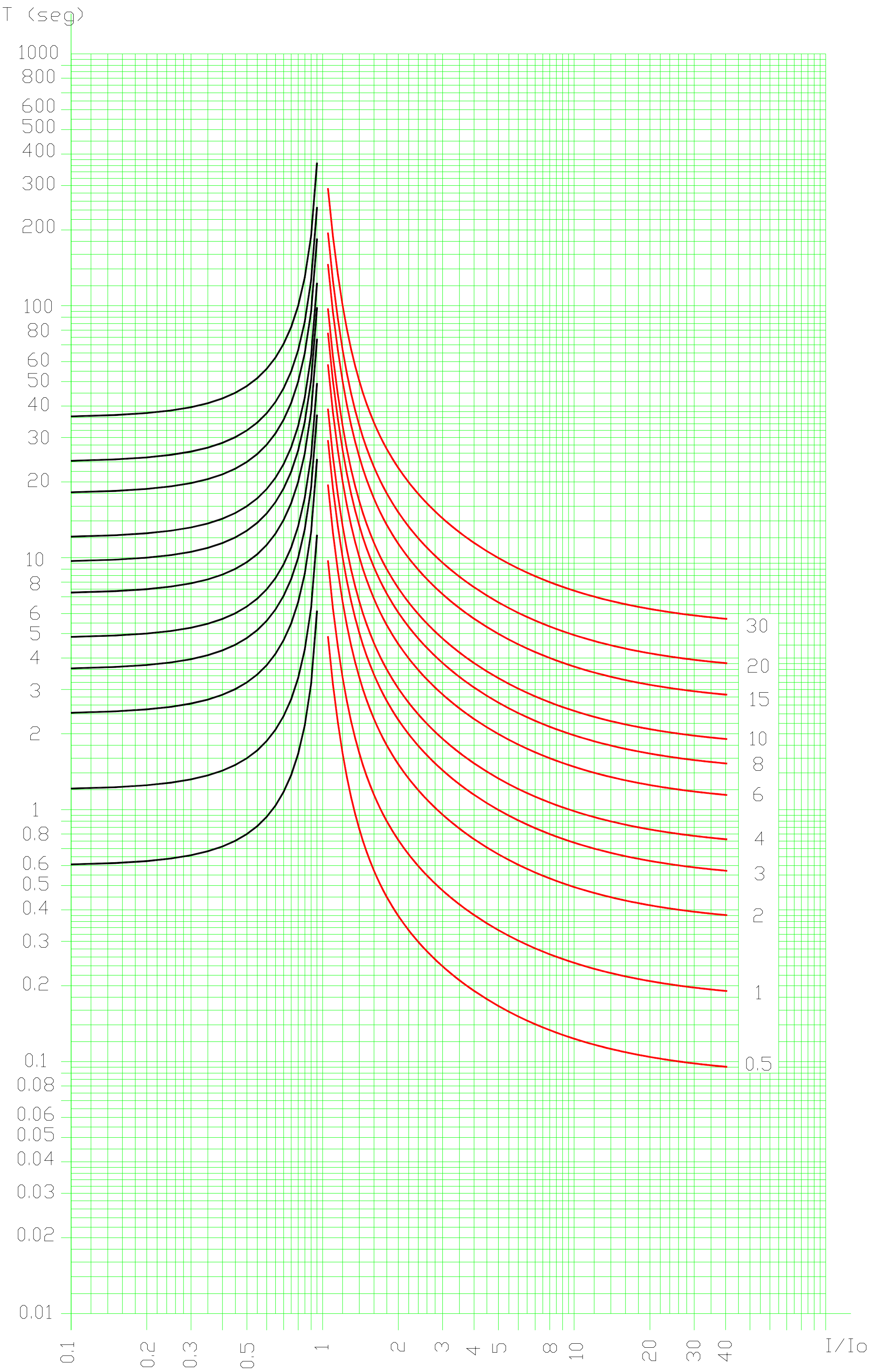
Moderately inverse curve

$$T := M \cdot \left[A + \frac{B}{\left(\frac{I}{I_0} - C\right)} + \frac{D}{\left(\frac{I}{I_0} - C\right)^2} + \frac{E}{\left(\frac{I}{I_0} - C\right)^3} \right] \qquad T_{RECAIDA} := M \cdot \frac{tr}{\left(\frac{I}{I_0}\right)^2 - 1}$$

A = 0.1735, B = 0.6791, C = 0.8000, D = -0.0800, E = 0.1271 tr = 1.2

Theoretical values given by the formula:

M \ I/Io	0	0.25	0.5	0.75	1.05	1.10	1.20	1.30	1.50	2.00	2.50	3.00	5.00	10.00	20.00	40.00
0.5	0.600	0.640	0.800	1.371	4.872	3.128	1.679	1.114	0.675	0.379	0.286	0.239	0.166	0.123	0.104	0.095
1.0	1.200	1.280	1.600	2.743	9.744	6.256	3.357	2.229	1.351	0.757	0.571	0.478	0.332	0.247	0.209	0.191
2.0	2.400	2.560	3.200	5.486	19.489	12.511	6.714	4.457	2.702	1.515	1.142	0.955	0.665	0.493	0.417	0.382
3.0	3.600	3.840	4.800	8.229	29.233	18.767	10.072	6.686	4.053	2.272	1.713	1.433	0.997	0.740	0.626	0.572
4.0	4.800	5.120	6.400	10.971	38.977	25.023	13.429	8.914	5.404	3.030	2.285	1.910	1.329	0.986	0.835	0.763
5.0	6.000	6.400	8.000	13.714	48.722	31.278	16.786	11.143	6.755	3.787	2.856	2.388	1.662	1.233	1.043	0.954
6.0	7.200	7.680	9.600	16.457	58.466	37.534	20.143	13.371	8.106	4.544	3.427	2.866	1.994	1.479	1.252	1.145
7.0	8.400	8.960	11.200	19.200	68.210	43.790	23.500	15.600	9.457	5.302	3.998	3.343	2.327	1.726	1.461	1.335
8.0	9.600	10.240	12.800	21.943	77.954	50.045	26.857	17.828	10.807	6.059	4.569	3.821	2.659	1.972	1.669	1.526
9.0	10.800	11.520	14.400	24.686	87.699	56.301	30.215	20.057	12.158	6.817	5.140	4.298	2.991	2.219	1.878	1.717
10.0	12.000	12.800	16.000	27.429	97.443	62.557	33.572	22.285	13.509	7.574	5.712	4.776	3.324	2.465	2.087	1.908
11.0	13.200	14.080	17.600	30.171	107.187	68.813	36.929	24.514	14.860	8.332	6.283	5.253	3.656	2.712	2.295	2.099
12.0	14.400	15.360	19.200	32.914	116.932	75.068	40.286	26.742	16.211	9.089	6.854	5.731	3.988	2.958	2.504	2.289
13.0	15.600	16.640	20.800	35.657	126.676	81.324	43.643	28.971	17.562	9.846	7.425	6.209	4.321	3.205	2.713	2.480
14.0	16.800	17.920	22.400	38.400	136.420	87.580	47.001	31.199	18.913	10.604	7.996	6.686	4.653	3.451	2.921	2.671
15.0	18.000	19.200	24.000	41.143	146.165	93.835	50.358	33.428	20.264	11.361	8.567	7.164	4.986	3.698	3.130	2.862
16.0	19.200	20.480	25.600	43.886	155.909	100.091	53.715	35.656	21.615	12.119	9.139	7.641	5.318	3.945	3.339	3.052
17.0	20.400	21.760	27.200	46.629	165.653	106.347	57.072	37.885	22.966	12.876	9.710	8.119	5.650	4.191	3.547	3.243
18.0	21.600	23.040	28.800	49.371	175.398	112.602	60.429	40.113	24.317	13.633	10.281	8.597	5.983	4.438	3.756	3.434
19.0	22.800	24.320	30.400	52.114	185.142	118.858	63.787	42.342	25.668	14.391	10.852	9.074	6.315	4.684	3.965	3.625
20.0	24.000	25.600	32.000	54.857	194.886	125.114	67.144	44.570	27.019	15.148	11.423	9.552	6.647	4.931	4.173	3.815
21.0	25.200	26.880	33.600	57.600	204.630	131.369	70.501	46.799	28.370	15.906	11.994	10.029	6.980	5.177	4.382	4.006
22.0	26.400	28.160	35.200	60.343	214.375	137.625	73.858	49.027	29.720	16.663	12.565	10.507	7.312	5.424	4.591	4.197
23.0	27.600	29.440	36.800	63.086	224.119	143.881	77.215	51.256	31.071	17.421	13.137	10.985	7.645	5.670	4.799	4.388
24.0	28.800	30.720	38.400	65.829	233.863	150.136	80.572	53.484	32.422	18.178	13.708	11.462	7.977	5.917	5.008	4.579
25.0	30.000	32.000	40.000	68.571	243.608	156.392	83.930	55.713	33.773	18.935	14.279	11.940	8.309	6.163	5.217	4.769
26.0	31.200	33.280	41.600	71.314	253.352	162.648	87.287	57.941	35.124	19.693	14.850	12.417	8.642	6.410	5.425	4.960
27.0	32.400	34.560	43.200	74.057	263.096	168.903	90.644	60.170	36.475	20.450	15.421	12.895	8.974	6.656	5.634	5.151
28.0	33.600	35.840	44.800	76.800	272.841	175.159	94.001	62.398	37.826	21.208	15.992	13.373	9.306	6.903	5.843	5.342
29.0	34.800	37.120	46.400	79.543	282.585	181.415	97.358	64.627	39.177	21.965	16.564	13.850	9.639	7.149	6.051	5.532
30.0	36.000	38.400	48.000	82.286	292.329	187.671	100.716	66.855	40.528	22.722	17.135	14.328	9.971	7.396	6.260	5.723


T (seg)
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0.2
0.1
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0.05
0.04
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I/Io

I.3. USER CURVES

The user can programme FOUR curves by entering the desired points into the “User curve 1” to “User curve 4” user curve nodes.

The time corresponding to each I/Ia is programmed in seconds, with a minimum value of 0.020 seconds. These times correspond to the curve of index 1, but as in curves IEC, the user can programme a time index between 0.05 and 1.09 in the overcurrent protection settings.

It is not necessary to programme all the points on the curve, the unit will assign the time of the first programmed point to all those I/Ia of a lower value and the last programmed time to all those of a higher I/Ia, that is to say, the graph will generally start and finish with straight, horizontal lines. The points between the two programmed points will be calculated by the console as a lineal interpolation.

I/Ia values for times which are superior to that which corresponds to an inferior I/Ia are not admitted, that is to say, ascendant straight lines are not allowed.

The nodes for the configuration of the curves are:

- PROT/RUSC1 user curve 1
- PROT/RUSC2 user curve 2
- PROT/RUSC3 user curve 3
- PROT/RUSC4 user curve 4

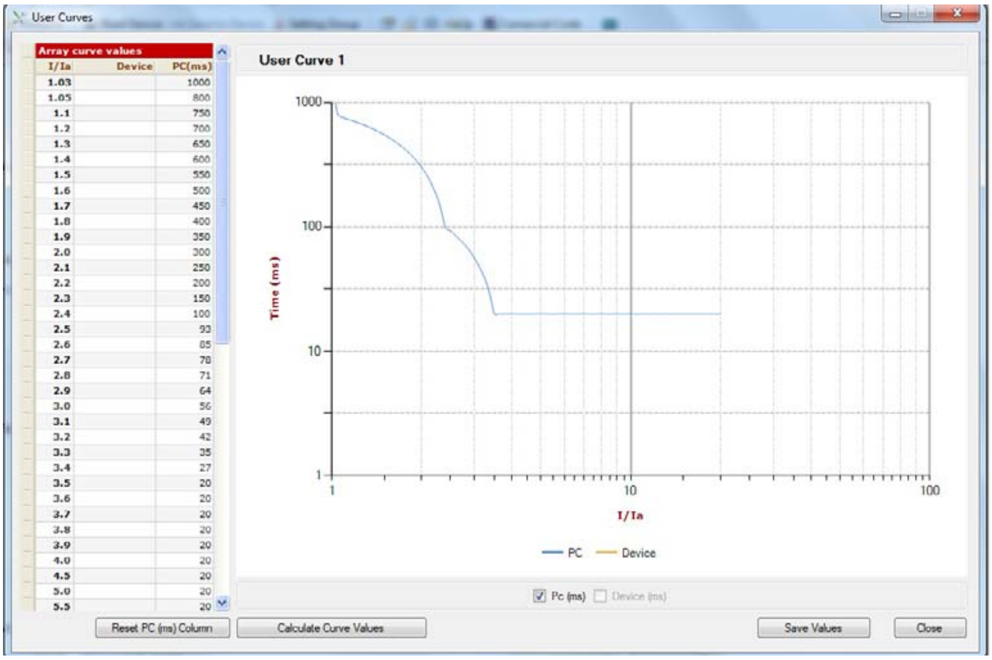
Each node uses 3 settings frames, into which the milliseconds of activation for each I/IAJ are entered, with a range of 20 to 600,000 milliseconds.

- Crv0 (Low Frame Curve). For setting (milliseconds) the activation times for 1.03 and 1.05 I/IAJ ratios.
- Crv1 (Medium Frame Curve). For setting (milliseconds) the activation times for 1.1 and 4 I/IAJ ratios, with steps of 0.1.
- Crv1 (High Frame Curve). For setting (milliseconds) the activation times for 4 and 20 I/IAJ ratios, with steps of 0.5.

The programming carried out via PacFactory is done using the programming screen shown in Figure 165, in which:

- The times of the curves different points are entered (left table) and the curve’s graph is displayed (right table).
- Interpolate points of the curve and enter the known points. By clicking on “Calculate Curve Values”, the missing values are calculated for the curve.
- Reset the curve values “Reset PC column”.
- “Save values”. Saves the values entered in order to send them to unit.
- “Close”. Returns to the general settings screen, from where they can be sent to the unit.

Figure 165. User curve configuration screen



An example is shown below

I/Ia	2	4	8	12	15
T (s)	200	100	70	50	5

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