RELION® 605 SERIES

REJ601, **REF601**, **REM601**

Application Manual

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This product complies with the directive of the Council of the European Communities on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive 2014/30/EU) and concerning electrical equipment for use within specified voltage limits (Low-voltage directive 2014/35/EU). This conformity is the result of tests conducted by the third party testing laboratory in accordance with the product standard EN 60255-26 for the EMC directive, and with the product standards EN 60255-1 and EN 60255-27 for the low voltage directive. The product is designed in accordance with the international standards of the IEC 60255 series.

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Section 1 Introduction

1.1 This manual

This manual contains application and functionality descriptions and connection diagrams, input and output signals, setting parameters and technical data. The manual can be used as a technical reference during the engineering phase, installation and commissioning phase, and during normal service. The manual can also be used when calculating settings. The manual provides instructions on how to operate the IED during normal service once it has been commissioned and to find out how to handle disturbances or view calculated and measured network data in order to determine the cause of a fault.

1.2 Intended audience

This manual addresses system engineers, installation and commissioning personnel, who use technical data during engineering, installation and commissioning, and in normal service. System engineer must have a thorough knowledge of protection systems, protection equipment, protection functions and the configured functional logics in the IEDs. The installation and commissioning personnel must have a basic knowledge in handling electronic equipment.

This manual addresses Protection and control engineer responsible for planning, pre-engineering and engineering. The protection and control engineer must be experienced in electrical power engineering and have knowledge of related technology, such as communication and protocols.

The manual also addresses the operator, who operates the relay on a daily basis. The operator must be trained in and have a basic knowledge of how to operate protection equipment. The manual contains terms and expressions commonly used to describe this kind of equipment.

1.3 Product documentation

1.3.1 Product documentation set

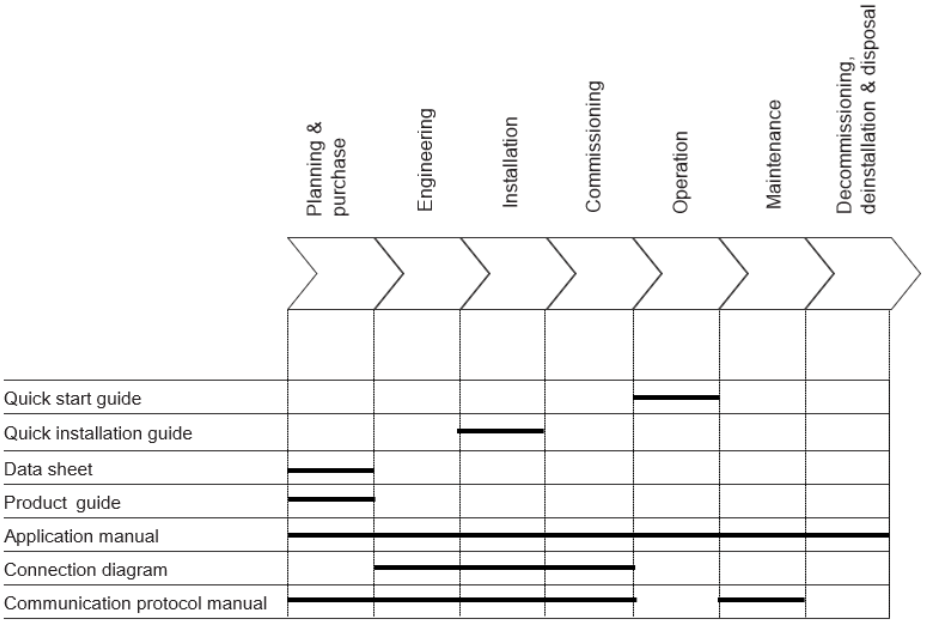


Figure 1: The intended use of the documents during the product life cycle

1.3.2 Document revision history

Document revision/date	Product version	Document history
A / 09.05.2017	2.2 FP2	Release of REF601/REJ601 with logic gates and timer functionality for version 2.2 FP2
B / 12.11.2024	2.5	Content updated

1.3.3 Related documentation

Download the latest documents from the ABB Web site abb.com/mediumvoltage.

1.4 Symbol and conventions

1.4.1 Symbols

The electrical warning icon indicates the presence of a hazard which could result in electrical shock.

The warning icon indicates the presence of a hazard which could result in personal injury

The caution icon indicates important information or warning related to the concept discussed in the text. It might indicate the presence of a hazard which could result in corruption of software or damage to equipment or property.

The information icon alerts the reader to important facts and conditions.

The tip icon indicates advice on, for example, how to design your project or how to use a certain function.

Although warning hazards are related to personal injury, it is necessary to understand that under certain operational conditions, operation of damaged equipment may result in degraded process performance leading to personal injury or death. Therefore, comply fully with all warning and caution notices.

1.4.2 Document conventions

A particular convention may not be used in this manual.

- Abbreviations and acronyms are spelled out in the glossary. The glossary also contains definitions of important terms.
- Push button navigation in the LHMI menu structure is presented by using the push button icons.
  To navigate between the options, use ^ and v
- Menu paths are presented in bold.
  Select **Main menu/Settings**.
- LHMI messages are shown in Courier font.
  To save the changes in nonvolatile memory, select `Yes` and press ↵ .
- Parameter names are shown in italics.
  The function can be enabled and disabled with the *Operation* setting.

- Parameter values are indicated with quotation marks.
  The corresponding parameter values are "On" and "Off".
- Input/output messages and monitored data names are shown in Courier font.
  When the function starts, the START output is set to TRUE.
- Values of quantities are expressed with a number and an SI unit. The corresponding imperial units may be given in parentheses.
- This document assumes that the parameter setting visibility is "Advanced".
- A functional earth terminal is indicated in figures with the symbol .
- Equipment protected throughout by double insulation or reinforced insulation (equivalent to class II of IEC 61140) is indicated in figures with the symbol ⧈.

1.4.3 Functions, codes and symbols

All available functions are listed in the table. All of them may not be applicable to all products.

Table 1: Functions included in relay

Function description	ANSI	IEC 60617
Protection		
Non-directional overcurrent protection, low-set stage	51	3I >
Non-directional overcurrent protection, high-set stage	50-1	3I >>
Non-directional overcurrent protection, instantaneous stage	50-2	3I >>>
Non-directional earth-fault protection, low-set stage	51N	Io>
Non-directional earth-fault protection, high-set stage	50N-1	Io>>
Non-directional earth-fault protection, instantaneous stage	50N-2	Io>>>
Three-phase thermal protection for feeders, cables, distribution transformers	49F	3Ith>F
Three-phase thermal protection for motor	49M	3Ith>M
Phase discontinuity / Single phasing protection	46PD	I2/I1>
Negative-sequence overcurrent protection	46	I2>
Phase reversal protection	46R	I2R>
Motor startup supervision	14/48/66/ 51LRS	I^2t n<
Locked rotor protection during running	51LR	Ist>
Under current protection	37	3I<
Circuit breaker failure protection	51BF/51NBF	3I>/Io>BF
Three phase transformer inrush detectors	68	3I2f>
Cold load pick up	62CLD	CLP
Master trip	86	Master Trip
Control		
Breaker control functionality	I <-> O CB	I <-> O CB
Auto-reclosing	79	O -> I
Emergency start-up	ESTART	EST, 62
Condition monitoring		
Trip circuit supervision	TCM	TCS
Breaker condition monitoring	CBCM	CBCM

Table 1: Functions included in relay, continue

Function description	ANSI	IEC 60617
Measurement		
Three-phase current measurement	3I	3I
Residual current measurement	In	Io
Negative phase sequence current	I2	I2
Thermal level	ϑ	Θ
Fault recording		
Event with date and time stamping	SER	SER
Analog fault record	FR	FAULTREC
Disturbance recorder in COMTRADE format	DFR	DR

Section 2 Relay overview

2.1 Overview

REF601 / REJ601 is a dedicated feeder protection relay intended for the protection of utility substations and industrial power systems, in primary and secondary distribution networks. REM601 is a dedicated motor protection relay, intended for the protection of medium voltage and low voltage asynchronous motors in manufacturing and process industry. REJ601, REF601and REM601 are the member of ABB's renowned Relion ® product family and part of its 605 series.

The relay provides an optimized composition of protection, monitoring and control functionality in one unit, with the best performance usability in its class and is based on ABB's in-depth knowledge of protection and numerical technology.

2.1.1 Product version history

Product version	Release date	Product History
1.0	20.03.2009	Product released
1.0 SP1	21.08.2009	Service Pack released
2.0	04.04.2012	Version 2.0 released
2.1	28.09.2012	Version 2.1 release with support of conventional current transformer
2.2	28.03.2013	Common version release for REF601 / REJ601 CT and REF601 Sensor variant
2.2 FP1	23.06.2014	REF601 / REJ601 Version 2.2 FP1 released
2.2 FP1	11.08.2014	REM601 Version 2.2 FP1 released
2.2 FP2	09.05.2017	REF601/ REJ601 Version 2.2 FP2 released
2.5	12.11.2024	Version 2.5 released

2.1.2 PCM600 and relay connectivity package version

- Protection and Control IED Manager PCM600 Ver.2.11 or later
- REX610 Connectivity Package Ver.1.0 or later

Download connectivity packages from the ABB Web site abb.com/mediumvoltage or directly with Update Manager in PCM600.

2.1.3 Communication

The relay supports two optional communication protocols MODBUS RTU and IEC 60870-5-103 on a two wire RS485 interface for rear communication.

The relay has front type-C USB port which is used for interface with Computer having ABB relay configuration tool PCM600.

2.1.4 1/5A CT configurability

The relay supports site selectable 1A and 5A primary phase and earth current transformers. Based on the available CT rating, user needs to set the primary and secondary rated current for both phase and earth CT in configuration section of the relay.

2.2 Other Functions

2.2.1 Self-Supervision

The relay is provided with an extensive self-supervision system which continuously supervises the software and the electronics. It handles run-time fault situations and informs the user about a fault via the LHMI.

At normal condition (no internal fault), the green Ready LED glow and the self-supervision output contact is closed. When an internal fault is detected in the relay, the green LED starts blinking and the self-supervision contact opens. Also, all other outputs are released.

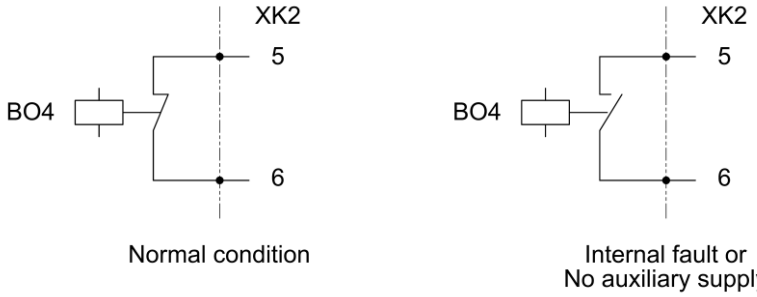


Figure 2: Behaviour of contact assigned for Unit ready / IRF

Internal fault indications have the highest priority on the LHMI. None of other LHMI indications can override the internal fault indication. An indication about the fault is shown as a message on the LHMI.

The internal fault code indicates the type of internal relay fault

Table 2: Internal fault indications and fault codes

Internal fault code	Type of fault	Fault category
IRF 1	Flash fault check	Warning
IRF 2	Power on RAM fault check	Error
IRF 3	Run time RAM fault check	Error
IRF 4	Internal supply voltage check	Error
IRF 5	Power on EEPROM fault check	Error
IRF 6	Run time EEPROM fault check	Error
IRF 7	Calibration check	Warning
IRF 8	Analog board fault check	Error
IRF 9	BIO board fault check	Error
IRF 10	LCD fault check	Warning
IRF 11	RTC failure check	Warning
IRF 12	PTS configuration check	Error
IRF 13	Watchdog check	Warning

The user can try to eliminate the fault by restarting the relay. If the fault is found to be permanent, the relay stays in internal fault mode.

2.2.2 Fault record and Trip counter

The relay stores records of analog values for last twenty trip events in non-volatile memory. The fault recording is triggered by the trip signal of a protection function. Each fault record includes the rms current values of fundamental component for all three phases and the neutral current at five different times along the trip event.

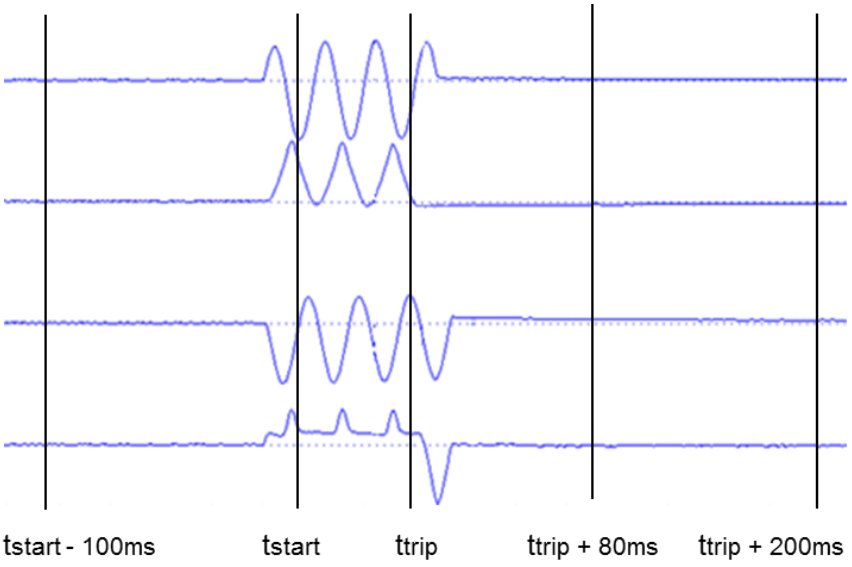


Figure 3: Analog fault record at various five instances

These records enable the user to analyze the twenty most recent power system events. The oldest recording is lost when a new fault recording is made.

Additionally, the relay count the number of phase fault trip and earth fault trip into dedicated trip counters. These trip counters cannot be reset by the user and are stored in nonvolatile memory.

The values of fault records and trip counters are accessible locally LHMI and remotely via communication interface of the relay.

2.2.3 Event Log

To collect sequence-of-events (SoE) information, the relay incorporates a non-volatile memory to store 250 external event logs. Each event log includes type of event along with date and time stamping. The event logs are stored sequentially, the most recent being first and so on.

The SoE information are accessible locally via LHMI and remotely via communication interface of the relay.

Table 3: List of event types and related description

Sr. No.	Event type	Description	Data considered
1	Power supply presence	Unit ready contact is activated when power supply is on and no internal relay fault detected	Unit Ready
2	Trip circuit supervision	When trip circuit becomes faulty, an event of trip circuit faulty will be recorded. When it becomes healthy shall also record it as an event	TCS fault ↑ TCS fault ↓
3	Protection start	When Start output of the protection functions available in the selected relay configuration	Example.. Start I> ↑ ; Start I>> ↑
4	Protection trip	When Trip output of the protection functions available in the selected relay configuration	Example.. Trip I> ↑ Trip I>> ↑
5	IRF	"IRF" – internal relay fault shall be captured as an event.	IRF codes
6	Logic gates*	When logic gates ANDx, ORx & NOTx output activates and deactivates	ANDx ↑ ; ORx ↑ NOTx ↑ ANDx ↓ ; ORx ↓ NOTx ↓
7	Timers*	When timer TON & TOFF output activates and deactivates	TONx ↑ ; TOFFx ↑ TONx ↓ ; TOFFx ↓
8	Fault identification	On occurrence of fault, based on faulty phase involved	L1 Fault ; L2 Fault L3 Fault L12 Fault ; L13 Fault L23 Fault L123 Fault
9	Memory read fail	In case unable to read Event from EEPROM, a message i.e. "Memory Read Fail" will be displayed for that particular event	Memory Read Fail
10	Local	When control authority is set to Local	Local ↓ ; Local ↑
11	Remote	When control authority is set to Remote	Remote ↑ ; Remote ↓
12	Local+Remote	When control authority is set to Local+Remote	Local + Remote ↑ Local + Remote ↓
13	Signal 1, 2, 3	On signal 1, 2, 3 output activation and deactivation respectively	Signal 1 ↑; Signal 2 ↑ Signal 3 ↑ Signal 1 ↓; Signal 2 ↓ Signal 3 ↓
14	Binary input 1, 2, 3, 4	On binary input 1, 2, 3, 4 activation and deactivation respectively	BI 1 ↑; BI 2 ↑; BI 3 ↑; BI 4 ↑ BI 1 ↓; BI 2 ↓, BI 3 ↓; BI 4 ↓
15	Binary Output 1, 2, 3, 4,5,6	On binary output 1, 2, 3, 4,5,6 activation and deactivation respectively	BO 1 ↑; BO 2 ↑; BO 3 ↑; BO 4 ↑; BO 5 ↑; BO 6 ↑; BO 1 ↓; BO 2 ↓ ; BO 3 ↓; BO 4 ↓; BO 5 ↓; BO 6 ↓
16	Prpgrammable LED 1,2,3,4,5,6,7,8	On Programmable LED 1,2,3,4,5,6,7,8 activation and deactivation	LED1 ↑; LED2 ↑; LED3 ↑; LED4 ↑; LED5 ↑; LED6 ↑; LED7 ↑; LED8 ↑; LED1 ↓; LED2 ↓; LED3 ↓; LED4 ↓; LED5 ↓; LED6 ↓; LED7 ↓; LED8 ↓

Table 3: List of event types and related description, continue

Sr. No.	Event type	Description	Data considered
17	General Start	An event for general start will be capture for both rising and falling which will be from any of start of protection functions available in selected relay configuration	General Start ↑ General Start ↓
18	General Trip	An event for general trip will be capture for both rising and falling which will be from any of start of protection functions available in selected relay configuration	General Trip ↑ General Trip ↓

2.2.4 Audit trail (internal) events

The critical system and protection relay security-related events are logged to a separate nonvolatile audit trail (internal) category.

Audit trail is a chronological record of system activities that allows the reconstruction and examination of the sequence of system and security-related events and changes in the protection relay The relay incorporates a non-volatile memory to store 100 external audit trail internal event logs. Each event log includes type of event along with date and time stamping. The event logs are stored sequentially, the most recent being first and so on.

The Audit trail (internal) event information are accessible locally via LHMI and remotely via communication interface of the relay.

Table 4: List of internal event types and related description

Sr. No.	Event type	Description	Data considered
1	Setting parameter change	Alteration of any settings of the protection functions available in the selected relay configuration will be captured as an event.	Settings of the respective protection function which is altered.
2	Protection function input	Change in any input signal status in the selected relay configuration.	Input signals of the respective protection function which is altered.
3	Breaker open	When breaker open cmd is issued	Breaker Open
4	Breaker close	When breaker close cmd is issued	Breaker Close
5	Reset	When reset of protection trip, LEDs is done	Reset
6	Test Mode	When device is in Test Mode	Test Mode Activate, Test Mode Deactivate
7	BI Power Off	When binary input is mapped to signal power off and power supply to relay is switched off.	BI Power Off
8	Setting group change	On change of setting group from one to another	Setting SG Edt. Setting SG No. Setting SG Act.
9	Clear Ext.events	Event for clearing external Events	Clear Ext.events
10	User Login	Event for operator Login	User Login
11	User Logout	Event for operator Logout	User Logout

Table 4: List of internal event types and related description, continue

Sr. No.	Event type	Description	Data considered
12	Firmware Update Success	Event for Firmware Update Success	Event for Firmware Update Success
13	Firmware Update Failure	Event for Firmware Update Failure	Event for Firmware Update Failure
14	DR memory Full	Event for DR memory Full	DR memory Full
15	Admin Login	Event for Admin Login	Admin Login
16	Engineer Login	Event for Engineer Login	Engineer Login
17	Power on	Event when auxiliary supply is available	Power on
18	Power off	Event when auxiliary supply is not available	Power off
19	Admin Logout	Event for Admin Logout	Admin Logout
20	Engineer Logout	Event for Engineer Logout	Engineer Logout
21	Factory default	Event for factory default	Factory Default

2.2.5 Disturbance recorder

The relay features an integrated disturbance recorder (DR) for recording monitored quantities. The recorder captures the wave forms of the currents as well as the status of various configured digital signals with date and time stamping which gets stored in the memory.

The protection relay is provided with a disturbance recorder with 4 analog and configurable 16 binary signal channels for recording. Each binary signal can be configured from signals from various available signals list and same is used to trigger the start of disturbance recording. Additionally, disturbance record can be manually triggered.

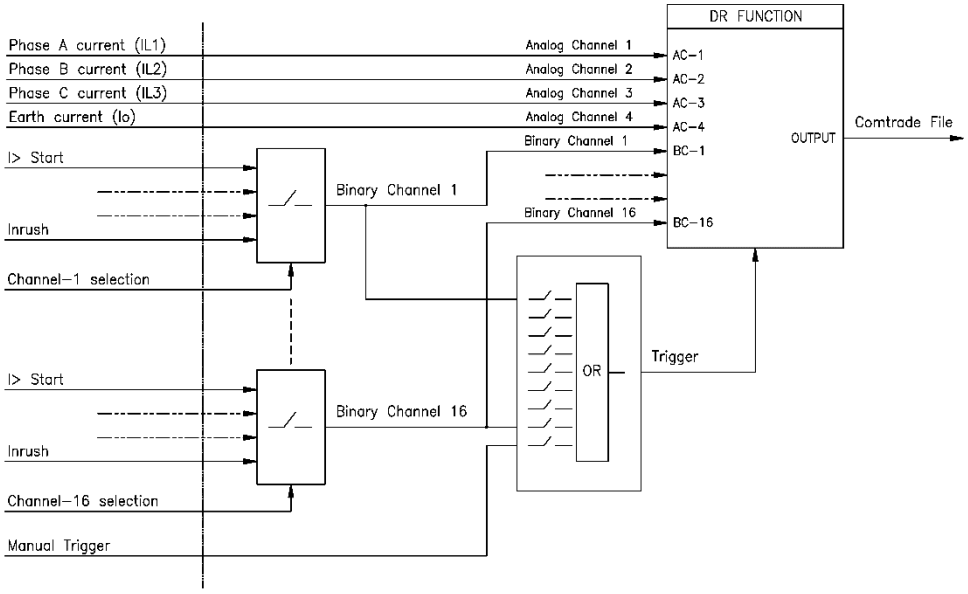


Figure 4: Disturbance recorder function block

2.2.5.1 Disturbance recorder operation

Disturbance record contains pre and post analog and binary channels value / status in non-volatile memory as COMTRADE file format. As soon as the recorder has been triggered and the recording has finished, the recording can be uploaded and analyzed from front USB port using PCM600 software.

Pre and post recording time defines data recording time before and after DR Trigger point respectively. Whereas Fault recording time defines the max recording time under fault condition. A recording of analog and digital value starts before the DR trigger point for time period equal to *Tpre* and it countinues for time *Tpost* after deactivation of DR Trigger signal. The pre-trigger and post-trigger time is settable as percentage value. Pre trigger time can be set from LHMI or PCM600.

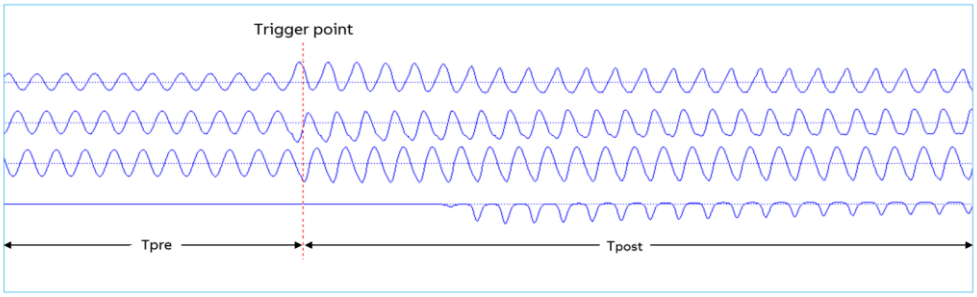


Figure 5: Pre and post fault trigger time of Disturbance recorder

The disturbance record lenght is 1 second. Total number of records stored in relay are 20 numbers.

Disturbance recorder has two operation modes: saturation and overwrite mode. The user can change the operation mode of the disturbance recorder with the *Operation mode* parameter. When *Operation mode* parameter is set to “No’ the operation mode gets selected as saturation wherein the captured recordings cannot be overwritten with new recordings. When *Operation mode* parameter is set to “Yes’ the operation mode gets selected as overwrite wherein when the recording memory is full, the oldest recording is overwritten with the pre-trigger data collected for the next recording.

2.2.5.2 Disturbance recorder settings

Table 5: Settings of disturbance recorder

Parameter	Range	Unit	Step	Default	Description
DR Block	1=ON; 2=OFF	-	-	1=ON	Disturbance recorder on/off
Pre-trigger length	10...100	%	10	50	Length of record preceding the trigger
Operation mode	1 = Overwrite 2 = Saturation	-	-	1	Operation mode for DR writing
Trigger recording	0 = Cancel 1 = Trigger	-	-	0	Manual trigger for disturbance recorder
Clear recording	0 = Cancel 1 = Clear	-	-	0	Clear all disturbance recording in the device

Table 6: Signals available for configuration to binary channels of disturbance recorder

Signal name	Description
I> Start	I> protection function start
I > Trip	I> protection function trip
I >> Start	I>> protection function start
I >> Trip	I>> protection function trip
I >>> Start	I>>> protection function start
I >>> Trip	I>>> protection function trip
Io > Start	I0> protection function start
Io > Trip	I0> protection function trip
Io >> Start	I0>> protection function start
Io >> Trip	I0>> protection function trip
Io >>> Start	I0>>> protection function start
Io >>> Trip	I0>>> protection function trip
I2 > Start	I2> protection function start
I2 > Trip	I2> protection function trip
I2/I1 > Start	I2/I1> protection function start
I2/I1 > Trip	I2/I1> protection function trip
I2R > Start	I2R> protection function start
I2R > Trip	I2R> protection function trip
3I < Start	3I< protection function start
3I < Trip	3I< protection function trip
3IRth> Trip	3IRth> protection function start
3ISth> Trip	3ISth> protection function trip
I2t Trip	I2t protection function start
LR Trip	Locked Rotor protection function trip

2.2.6 Real Time Clock

Relay comes with a real time clock with user settable date and time. Date can be set in “DD/MM/YYYY” format and time can be set in “HH:MM:SS” format. The time stamping have 1 ms resolution. RTC is used for time stamping the event logs and as well as fault records. In case of power failure RTC will have a stored energy backup for around 96 hrs. at ambient temperature when stored energy element is fully charged. Initial time setting is “01/01/2024” and “00:00:00:0000”.

2.2.7 Access Control

To protect the relay from unauthorized access and to maintain the integrity of information, the relay is armed with a three level, role-based user authentication system with individual password for the operator, engineer (Setting level) and administrator level. The relay supports two modes for password handling:

1. A combination of different navigation keys (default mode)
2. Alphanumeric password

2.2.8 Power-ON sequence

The Power-ON sequence takes around 6 sec.

Additionally, the relay can be powered up using USB port in case the auxiliary power supply is not available - however in the USB power mode, the relay runs with reduced functionality.

The protection functions will not be operational, and this mode is mainly intended for read/write the relay settings and configuration. In USB mode we can also read events and disturbance record.

i) Ensure that the USB Type-C cable is no longer than 2m in length.

ii) In USB mode trip counters will not be accessible.

2.2.9 Setting groups

The relay supports two setting groups. Customer can change the active setting groups at run time. The active setting group can be changed by a setting parameter or via binary input.

User has an option to select number of setting groups required in the relay via setting “No of SG”, default set as 1. When setting group is selected as 2, user needs to select active setting group via “Active SG”.

If binary based connection exists and in runtime if Active SG is changed via setting parameter, runtime Active SG gets changed based on setting parameter but on power reboot BI based SG will be effective.

Disable the binary connection to change active setting group using setting parameter.

Section 3 Technical Data

For detailed technical data please refer the product guide 1MDB07212-YN D.

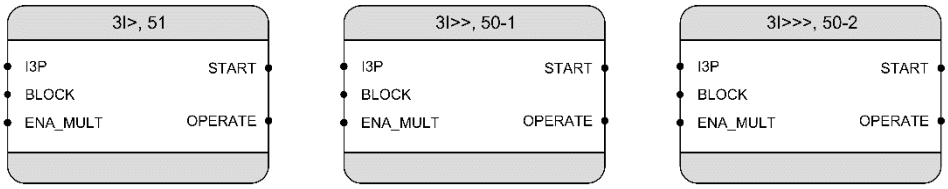
Section 4 Protection functions

4.1 Three-phase non-directional overcurrent protection

4.1.1 Identification

Function description	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase non-directional overcurrent protection, low stage	3I>	51
Three-phase non-directional overcurrent protection, high stage	3I>>	50-1
Three-phase non-directional overcurrent protection, instantaneous stage	3I>>>	50-2

4.1.2 Function block



4.1.3 Functionality

The three-phase overcurrent protections can be used as one-phase, two-phase or three phase non-directional overcurrent and short-circuit protection.

The function starts when the current exceeds the set limit. The operate time characteristics for low stage can be selected to be either definite time (DT) or inverse definite minimum time (IDMT). The high and instantaneous stage operates with the definite time (DT) or instantaneous characteristics.

4.1.4 Principle of operation

The three-phase overcurrent unit continuously measures all three phase currents of the protected object. The maximum current of the three phases is evaluated by the low stage (I> / 51), high stage (I>> / 50-1) and instantaneous stage (I>>> / 50-2) of phase overcurrent functions.

On occurrence of fault in the power system, fulfilling the trip condition of respective stage, the LED “Trip” and “Trip Ip” will be activated as configured. Additionally, the output relays (Trip and signalization) will be activated according to the binary output configuration.

Each of the stages could be blocked by settings or by configured logic gates / timer output or via binary input of the relay.

If the **Ena Mult** input is active, ***I>***, ***I>>*** and ***I>>>*** setting is multiplied by ***I> Mult***, ***I>> Mult*** and ***I>>> Mult*** respectively.

The start value multiplication is normally done when the inrush detection function (3I2f>, 68) is connected to the *ENA_MULT* input.

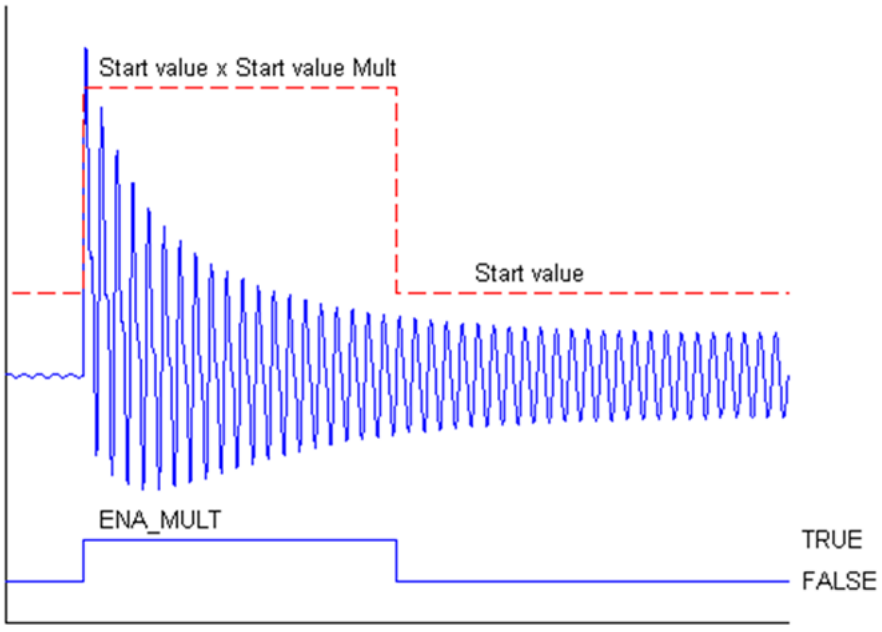


Figure 5: Start value behavior with ENA_MULT input activated

4.1.5 Signals

Table 6: I>, I>>, I>>> function input signals

Name	Type	Default	Description
I3P	Signal	-	Three phase current
Block	Boolean	0=False	Block signal for activating the blocking mode
ENA_MULT	Boolean	0=False	Enable signal for current multiplier

Table 7: I>, I>>, I>>> function output signals

Name	Type	Description
Start	Boolean	Protection start (pickup)
Operate	Boolean	Protection trip (operate)

4.1.6 Setting range of three phase overcurrent protection

Table 8: Setting ranges non-directional overcurrent protection, Low stage 3I>, 51

Parameter	Values (Range)	Unit	Step	Default	Description
I> Block	0=No 1=Yes			0=No	Block setting for blocking the output signals
Curve	1=ANSI EI 2=ANSI VI 3=ANSI NI 4=ANSI MI 5=DT 9=IEC NI 10=IEC VI 12=IEC EI 14=IEC LI 18=IEC RI			5=DT	Selection of time delay curve type
I>	0.050...2.500 (CT Variant) 0.100...2.500 (Sensor Variant)	X In	0.001	1.500	Start value
K	0.02...1.60		0.01	0.02	Time multiplier setting for IDMT curves
t>	0.04...64.00	Sec	0.01	1.00	Operate delay time
I > Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value

Table 9: Setting ranges non-directional overcurrent protection, High stage 3I>>, 50-1

Parameter	Values (Range)	Unit	Step	Default	Description
I>> Block	0=No 1=Yes			0=No	Block setting for blocking the output signals
I>>	0.200...25.000 (CT Variant) 0.200...20.000 (Sensor Variant)	X In	0.001	4.000	Start value
t>>	0.04...64.00	Sec	0.01	0.30	Operate delay time
I >> Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value

Table 10: Setting ranges non-directional overcurrent protection, Instantaneous stage 3I>>>, 50-2

Parameter	Values (Range)	Unit	Step	Default	Description
I>>> Block	0=No 1=Yes			0=No	Block setting for blocking the output signals
I>>>	0.200...25.000 (CT Variant) 0.200...20.000 (Sensor Variant)	X In	0.001	4.000	Start value
t>>>	0.04...64.00	Sec	0.01	0.30	Operate delay time
I>>> Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value

4.1.7 Technical Data

Table 11: 3I>, 3I>>, 3I>>> technical data

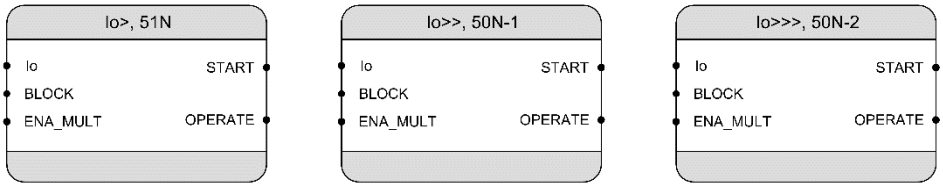
Description	Function	Value		
Operation accuracy	Low-set overcurrent (I> / 51) • CT variant • Sensor variant	Depending on the frequency of the current measured: fn ±2 Hz ±1.5% of the set value or ±0.004*I_n ±4.0% of the set value or ±0.015*I_n		
	High-set overcurrent (I>> / 50-1) • CT variant • Sensor variant	±1.5% of the set value or ±0.004*I_n ±2.0% of the set value or ±0.015*I_n		
	Instantaneous overcurrent (I>>> / 50-2) • CT variant • Sensor variant	±1.5% of the set value or ±0.004*I_n ±2.0% of the set value or ±0.015*I_n		
Start time [1) 2)]		Minimum	Typical	Maximum
	Instantaneous overcurrent (I>>> / 50-2) • I_{Fault} = 2 × set *Start value* • I_{Fault} = 10 × set *Start value*	25 ms 15 ms	20 ms 19 ms	38 ms 25 ms
	Low-set overcurrent (I> / 51) and High-set overcurrent (I>> / 50-1) • I_{Fault} = 2 × set *Start value*	25 ms	29 ms	34 ms
Reset time		Typically 40 ms		
Reset ratio	CT variant Sensor variant	Typically 0.94 to 0.97 Typically 0.89 to 0.96		
Operate time accuracy in definite time mode		± 1.0% of the set value or ±40 ms		
Operate time accuracy in inverse time mode	CT variant Sensor variant	± 5.0% of the set value or ±50 ms ± 5.0% of the set value or ±50 ms		

4.2 Non-directional earth-fault protection

4.2.1 Identification

Function description	IEC 60617 identification	ANSI/IEEE C37.2 device number
Non-directional earth-fault protection, low stage	Io>	51N
Non-directional earth-fault protection, high stage	Io>>	50N-1
Non-directional earth-fault protection, instantaneous stage	Io>>>	50N-2

4.2.2 Function block



4.2.3 Functionality

The earth-fault protection function is used as non-directional earth-fault protection for feeders. The earth current can be calculated internally or measured externally by core balance current transformer.

The operate time characteristics for low stage can be selected to be either definite time (DT) or inverse definite minimum time (IDMT). The high and instantaneous stage always operates with the definite time (DT) characteristics.

4.2.4 Principle of operation

The earth fault protection function continuously measures the neutral current of the protected object. The current is evaluated by the low stage (I0>), high stage (I0>>) and instantaneous stage (I0>>>) of earth fault over current functions.

On occurrence of fault in the power system, fulfilling the trip condition of respective stage, the LED “Trip” and “Trip Io” will be activated as configured. Additionally, the output relays (Trip and signalization) will be activated according to the binary output configuration.

Each of the stages could be blocked by settings or by configured logic gates / timer output or via binary input of the relay.

If the **Ena Mult** input is active, ***Io***>, ***Io***>> and ***Io***>>> setting is multiplied by ***Io***> ***Mult***, ***Io***>> ***Mult*** and ***Io***>>> ***Mult*** respectively.

The start value multiplication is normally done when the inrush detection function (3I2f>, 68) is connected to the *ENA_MULT* input.

4.2.5 Signals

Table 12: Io>, Io>>, Io>>> function input signals

Name	Type	Default	Description
Io	Signal	-	Residual current (Measured or calculated)
Block	Boolean	0=False	Block signal for activating the blocking mode
ENA_MULT	Boolean	0=False	Enable signal for current multiplier

Table 13: Io>, Io>>, Io>>> function output signals

Name	Type	Description
Start	Boolean	Protection start (pickup)
Operate	Boolean	Protection trip (operate)

4.2.6 Setting range of earth-fault protection

Table 14: Setting ranges non-directional earth-fault protection, Low stage Io>, 51N

Parameter	Values (Range)	Unit	Step	Default	Description
Io> Block	0=No 1=Yes			0=No	Block setting for blocking the output signals
Earth type	1=External 2=Internal			1=External	Selection of residual current measurement
Curve	1=ANSI EI 2=ANSI VI 3=ANSI NI 4=ANSI MI 5=DT 9=IEC NI 10=IEC VI 12=IEC EI 14=IEC LI 18=IEC RI			5=DT	Selection of time delay curve type
Io>	0.010...2.000 (External) 0.100...2.000 (Internal)	X In	0.001	0.500	Start value
Ko	0.02...1.60		0.01	0.02	Time multiplier setting for IDMT curves
to>	0.04...64.00	Sec	0.01	1.50	Operate delay time
Io> Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value

Table 15: Setting ranges non-directional earth-fault protection, High stage Io>>, 50N-1

Parameter	Values (Range)	Unit	Step	Default	Description
Io>> Block	0=No 1=Yes			0=No	Block setting for blocking the output signals
Earth type	1=External 2=Internal			1=External	Selection of residual current measurement
Io>>	0.050...12.500 (External) 0.500...12.500 (Internal)	X In	0.001	4.000	Start value
to>>	0.04...64.00	Sec	0.01	0.30	Operate delay time
Io>> Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value

Table 16: Setting ranges non-directional earth-fault protection, Instantaneous stage Io>>>, 50N-2

Parameter	Values (Range)	Unit	Step	Default	Description
Io>>> Block	0=No 1=Yes			0=No	Block setting for blocking the output signals
Earth type	1=External 2=Internal			1=External	Selection of residual current measurement
Io>>>	0.050...12.500 (External) 0.500...12.500 (Internal)	X In	0.001	4.000	Start value
to>>>	0.04...64.00	Sec	0.01	0.50	Operate delay time
Io>>> Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value

4.2.7 Technical Data

Table 17: Io>, Io>>, Io>>> technical data

Description	Function	Value		
Operation accuracy	Low-set earth-fault (Io> / 51N) High-set earth-fault (Io>> / 50N-1) Instant. earth-fault (Io>>> / 50N-2) - External measurement (CT) - External measurement (Sensor) - Internal measurement	Depending on the frequency of the current measured: fn ±2 Hz ±1.5% of the set value or ±0.004*I_n ±4% of the set value or ±0.03*I_n ±1.5% of the set value or ±0.004*I_n		
Start time [1) 2)]		Minimum	Typical	Maximum
	Instantaneous earth-fault (Io>>> / 50N-2) • I_{Fault} = 2 × set *Start value* • I_{Fault} = 10 × set *Start value*	 29 ms 15 ms	 34 ms 19 ms	 38 ms 25 ms
	Low-set earth-fault (Io> / 51N) and High-set earth-fault (Io>> / 50N-1) • I_{Fault} = 2 × set *Start value*	 29 ms	 34 ms	 39 ms
Reset time		Typically 40 ms		
Reset ratio	CT variant Sensor variant	Typically 0.94 to 0.97 Typically 0.89 to 0.96		

Table 17: Io>, Io>>, Io>>> technical data, continue

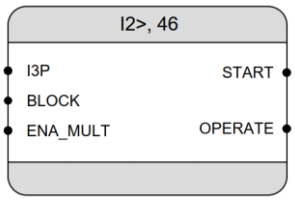
Description	Function	Value
Operate time accuracy in definite time mode	External measurement Internal measurement	± 1.0% of the set value or ±40 ms ± 1.0% of the set value or ±40 ms
Operate time accuracy in inverse time mode	CT variant Sensor variant	± 5.0% of the set value or ±50 ms ± 5.0% of the set value or ±50 ms

4.3 Negative-sequence overcurrent protection

4.3.1 Identification

Function description	IEC 60617 identification	ANSI/IEEE C37.2 device number
Negative sequence overcurrent protection	I2>	46

4.3.2 Functional block



4.3.3 Functionality

The negative-sequence overcurrent protection is used for increasing sensitivity to detect unbalance load or unsymmetrical feeder and motor voltages.

The operate time characteristics is based on either definite time (DT) or inverse definite minimum time (IDMT). The high stage always operates with the definite time (DT) characteristics.

4.3.4 Principle of operation

The function is based on the measurement of negative sequence current. In a fault situation, the function starts when the negative sequence current (I2) exceeds the set value. When the set definite time operation timer has reached or expected time of inverse time curve has reached, the OPERATE output is activated.

On occurrence of fault, fulfilling the trip condition of respective stage, the LED “Trip” and programmable LED if configured will be activated. Additionally, the output relays (Trip and signalization) will be activated according the binary output configuration.

The protection could be blocked by settings by configured logic gates / timer output or via binary input or via binary input of the relay. The protection could be blocked by settings or via binary input of the relay. If the **Ena Mult** input is active, the ***I2>*** setting is multiplied by the ***I2> Mult*** setting.

4.3.5 Signals

Table 18: I2> function input signals

Name	Type	Default	Description
I3P	Signal	-	Three phase current
Block	Boolean	0=False	Block signal for activating the blocking mode
ENA_MULT	Boolean	0=False	Enable signal for current multiplier

Table 19: I2> function output signals

Name	Type	Description
Start	Boolean	Protection start (pickup)
Operate	Boolean	Protection trip (operate)

4.3.6 Setting range of negative sequence overcurrent protection

Table 20: Setting ranges negative sequence overcurrent protection, I2>, 46

Parameter	Values (Range)	Unit	Step	Default	Description
I2> Block	0=No 1=Yes			0=No	Block setting for blocking the output signals
Curve	1=ANSI EI 2=ANSI VI 3=ANSI NI 4=ANSI MI 5=DT 9=IEC NI 10=IEC VI 12=IEC EI 14=IEC LI 18=IEC RI			5=DT	Selection of time delay curve type
I2>	0.10...1.50	X In	0.01	0.30	Start value
K2	0.02...1.60		0.01	0.02	Time multiplier setting for IDMT curves
t>	0.10...300.0	Sec	0.1	1.0	Operate delay time
I2> Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value

4.3.7 Technical Data

Table 21: I2> technical data

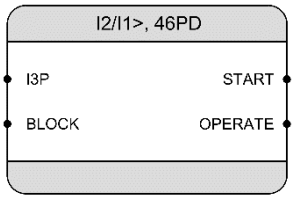
Description	Function	Value		
Operation accuracy	NPS, I2> / 46 • CT variant • Sensor variant	Depending on the frequency of the current measured: fn ±2 Hz ±1.5% of the set value or ±0.004*I_n ±2% of the set value or ±0.01*I_n		
Start time		Minimum	Typical	Maximum
	NPS, I2> / 46 • I_{Fault} = 2 × set *Start value* • I_{Fault} = 10 × set *Start value*	40 ms 20 ms	46 ms 26 ms	50 ms 28 ms
Reset time		Typically 40 ms		
Reset ratio	• CT variant • Sensor variant	Typically 0.94 to 0.97 Typically 0.87 to 0.96		
Operate time accuracy in definite time mode		± 1.0% of the set value or ±40 ms		
Operate time accuracy in inverse time mode		± 5.0% of the set value or ±50 ms		

4.4 Phase discontinuity / Single phasing protection

4.4.1 Identification

Function description	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase discontinuity / Single phasing protection	I2/I1>	46PD

4.4.2 Functional block



4.4.3 Functionality

The phase discontinuity / Single phasing protection is used for detecting unbalance situations caused by broken conductors.

The operate time characteristics is based on definite time (DT) i.e. function operates after a predefined operate time and resets when the fault current disappears.

4.4.4 Principle of operation

The unbalance of network is detected by monitoring the ratio of negative sequence current to positive sequence current I_2/I_1. The function operates when the ratio of unbalance current I_2/I_1 exceeds the set value. When the set definite time operation timer has reached the value set by the operate delay time, the OPERATE output is activated.

On occurrence of fault, fulfilling the trip condition of respective stage, the LED “Trip” and programmable LED if configured will be activated. Additionally the output relays (Trip and signalization) will be activated according the binary output configuration.

The phase discontinuity / Single phasing protection will be inhibited when all phase currents fall below 0.1 x In.

The protection could be blocked by settings or by configured logic gates / timer output or via binary input or via binary input of the relay or via binary input of the relay.

4.4.5 Signals

Table 22: I2/I1> function input signals

Name	Type	Default	Description
I3P	Signal	-	Three phase current
Block	Boolean	0=False	Block signal for activating the blocking mode

Table 23: I2/I1> function output signals

Name	Type	Description
Start	Boolean	Protection start (pickup)
Operate	Boolean	Protection trip (operate)

4.4.6 Setting range of phase discontinuity protection

Table 24: Setting ranges negative sequence overcurrent protection, I2/I1>, 46PD

Parameter	Values (Range)	Unit	Step	Default	Description
I2/I1> Block	0=No 1=Yes			0=No	Block setting for blocking the output signals
I2/I1>	10...100	%	1.00	15	Start value
tI2/I1>	0.10...64.0	Sec	0.1	0.1	Operate delay time

4.4.7 Technical Data

Table 25: I2/I1> technical data

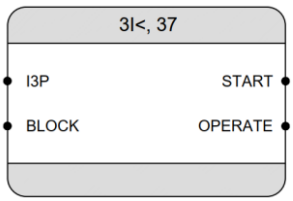
Description	Function	Value
Operation accuracy	PDN, I2/I1> / 46PD • CT variant • Sensor variant	Depending on the frequency of the current measured: fn ±2 Hz ±2.5% of the set value ±5.0% of the set value
Start time		Typically 72 ms
Reset time		Typically 40 ms
Reset ratio	• CT variant • Sensor variant	Typically 0.89 to 0.95 Typically 0.92 to 0.99
Operate time accuracy		± 1.0% of the set value or ±30 ms

4.5 Under current protection

4.5.1 Identification

Function description	IEC 60617 identification	ANSI/IEEE C37.2 device number
Under current protection	3I<	37

4.5.2 Functional block



4.5.3 Functionality

The under current protection is used to detect a sudden loss of load which is considered as a fault condition. Function starts when the current is less than the set limit. It operates with the definite time (DT) characteristics i.e. function operates after a predefined operate time and resets when the fault current disappears.

4.5.4 Principle of operation

The measured three phase current is compared to the set ***3I<*** value. If the measured value is less than the set ***3I<*** value, in all the three phases the level detector activates the timer module and will activate binary output **Start.**

The function is blocked internally when current in all three phases are below 0.10xIn (which is considered as breaker OFF / motor stopped condition).

The time characteristic is according to Definite Time (DT). When the operation timer has reached the value set by the t3I< value, the Trip output is activated. If the fault disappears before the module operates, the reset timer is activated. It is a fixed timer of 40ms, when the timer reaches 40ms, the operate timer resets.

The protection could be blocked by settings or via binary input of the relay.

4.5.5 Signals

Table 26: 3I< function input signals

Name	Type	Default	Description
I3P	Signal	-	Three phase current
Block	Boolean	0=False	Block signal for activating the blocking mode

Table 27: 3I< function output signals

Name	Type	Description
Start	Boolean	Protection start (pickup)
Operate	Boolean	Protection trip (operate)

4.5.6 Setting range of under current protection

Table 28: Setting ranges phase discontinuity protection, 3I<, 37

Parameter	Values (Range)	Unit	Step	Default	Description
3I< Block	0=No 1=Yes			0=No	Block setting for blocking the output signals
3I<	0.12...0.80	x Ib(REM) x In (REJ/REF)	0.01	0.40	Start value
t3I<	0.40...30.0	Sec	0.1	10.0	Operate delay time

4.5.7 Technical Data

Table 29: 3I> technical data

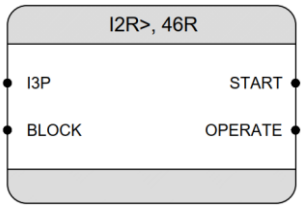
Description	Function	Value
Operation accuracy	PTUC 3I< / 37 • CT variant • Sensor variant	Depending on the frequency of the current measured: fn ±2 Hz ±1.5% of the set value or ±0.004*I_n ±3.0% of the set value or ±0.01*I_n
Start time		Typically 40 ms
Reset time		Typically 40 ms
Reset ratio		Typically 0.101 to 0.104
Operate time accuracy		± 1.0% of the set value or ±30 ms

4.6 Phase reversal protection

4.6.1 Identification

Function description	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase reversal protection	I2R>	46R

4.6.2 Functional block



4.6.3 Functionality

The phase reversal protection is used to detect the reversed connection of the phases to a three-phase motor by monitoring the negative phase sequence current (I2) of the motor. Function starts when the negative sequence current (I2) exceeds the set value. The operate time characteristics is based on definite time (DT) i.e. function operates after a predefined operate time.

4.6.4 Principle of operation

The measured negative sequence current is compared to the set I2R>. If the measured value exceeds the set I2R>, the level detector activates the timer module. On activation, timer activates the Start output. The time characteristic is according to definite Time (DT). When the operation timer has reached the value set by the tI2R>, the protection Trip output is activated. If the fault disappears before the module operates, the function resets immediately, and the protection Start output is deactivated.

The protection could be blocked by settings or via binary input of the relay.

4.6.5 Signals

Table 30: I2R> function input signals

Name	Type	Default	Description
I3P	Signal	-	Three phase current
Block	Boolean	0=False	Block signal for activating the blocking mode

Table 31: I2R> function output signals

Name	Type	Description
Start	Boolean	Protection start (pickup)
Operate	Boolean	Protection trip (operate)

Table 32: Setting ranges phase discontinuity protection, I2R>, 46R

Parameter	Values (Range)	Unit	Step	Default	Description
I2R> Block	0=No 1=Yes			0=No	Block setting for blocking the output signals
I2R>	0.10...1.50	x Ib	0.01	0.30	Start value
tI2R>	0.10...300.0	Sec	0.1	1.00	Operate delay time

4.6.6 Technical Data

Table 25: I2R>, 46R technical data

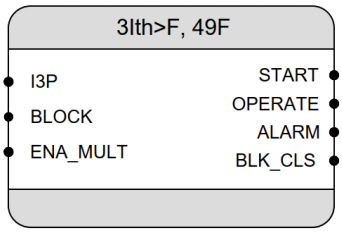
Description	Function	Value		
Operation accuracy	I2R> / 46R • CT variant • Sensor variant	Depending on the frequency of the current measured: fn ±2 Hz ±1.5% of the set value or ±0.004*In ±3.0% of the set value or ±0.01*In		
Start time		Typically 72 ms		
Start time		Minimum	Typical	Maximum
	NPS, I2> / 46 • I_{Fault} = 2 × set *Start value*	22 ms	25 ms	30 ms
Reset time		Typically 40 ms		
Reset ratio	• CT variant • Sensor variant	Typically 0.94 to 1.00 Typically 0.96 to 1.00		
Operate time accuracy		± 1.0% of the set value or ±40 ms		

4.7 Thermal overload protection for feeders, cables and distribution transformers

4.7.1 Identification

Function description	IEC 60617 identification	ANSI/IEEE C37.2 device number
Thermal overload protection for feeders, cables and distribution transformer	3Ith>F	49F

4.7.2 Functional block



4.7.3 Functionality

The phase reversal protection is used to detect the reversed connection of the phases to a three-phase motor by monitoring the negative phase sequence current

4.7.4 Principle of operation

The function continuously checks the highest measured TRMS phase current value.

The final temperature rise is calculated from the highest of the three-phase currents according to the expression

$$\Theta_{final} = \left(\frac{I}{I_{ref}}\right)^2 . T_{ref}$$

where,

I	the highest phase current
I_{ref}	set ***Cur Ref Stat***
T_{ref}	set ***Temp Rise***

The ambient temperature is added to the calculated final temperature rise estimation. If the final temperature estimation is higher than the set ***Max Temp***, the ***Start*** output is activated.

The actual temperature at the actual execution cycle is calculated as:

$$\Theta_n = \Theta_{n-1} + \left(\Theta_{final} - \Theta_{n-1}\right).\left(1 - e^{-\frac{\Delta t}{\tau}}\right)$$

where

Θ_n	calculated present temperature.
Θ_{n-1}	calculated temperature at previous time step
Θ_{final}	calculated final temperature with actual current
Δt	time step between calculation of actual temperature
τ	thermal time constant for the protected device, set ***Time Const***

The actual temperature of the protected component is calculated by adding the ambient temperature to the calculated temperature, as shown above. The ***Env Tmp Set*** setting is used to define the ambient temperature.

When the component temperature reaches the set alarm level ***Alm Val***, the output signal ***Alm*** is set. When the component temperature reaches the set trip level ***Max Temp***, the ***Trip*** output is activated. The ***Trip*** signal pulse length is fixed to 100 ms.

The restart inhibit signal ***Blkcl*** gets activated after the thermal overload trip which prevents re-connection of circuit till the thermal content of the device cooled down below the set value of the ***Re Cls Tmp*** setting. The ***Max Temp*** value must be set at least two degrees above the set value of ***Re Cls Tmp.***

In some applications, the measured current can involve number of parallel lines. By setting the ***Cur Mult*** parameter to the number of parallel lines, the actual current on one line is used in the protection algorithm. To activate this option, the **Ena Mult** input must be activated.

The temperature calculation is initiated from the value defined with the ***Initial Tmp*** setting parameter. This is done in case the protection relay is powered up or the function is reset. The temperature is also stored in the non-volatile memory and restored in case the protection relay is restarted.

The thermal time constant of the protected circuit is given in seconds with the ***Time Const*** setting.

Thermal model of the function complies with the IEC 60255-149 standard.

4.7.5 Signals

Table 33: 3Ith>F function input signals

Name	Type	Default	Description
I3P	Signal	-	Three phase current
Block	Boolean	0=False	Block signal for activating the blocking mode
ENA_MULT	Boolean	0=False	Enable signal for current multiplier

Table 34: 3Ith>F function output signals

Name	Type	Description
Alm	Boolean	Thermal alarm
Start	Boolean	Protection start (pickup)
Operate	Boolean	Protection trip (operate)
Blkcl	Boolean	Thermal overload indicator to inhibit reclose (Restart inhibit)

4.7.6 Setting range of thermal overload protection

Table 35: Setting ranges negative sequence overcurrent protection, 3Ith>F, 49F

Parameter	Values (Range)	Unit	Step	Default	Description
Thermal Block	0=No 1=Yes			0=No	Block setting for blocking the output signals
Env Tmp Set	-50...100	℃	1	40	Ambient temperature used
CurRef Stat	0.05...4.00	xIn	0.01	1.00	The load current leading to temperature raise
Temp Rise	0.0...200.0	℃	0.1	75.0	End temperature rise above ambient
Time Const	60...60000	s	1	2700	Time constant of the line in seconds.
Max Temp	20.0...200.0	℃	0.1	90.0	Temperature level for operate
Alm Val	20.0...150.0	℃	0.1	80.0	Temperature level for start
ReCls Tmp	20.0...150.0	℃	0.1	70.0	Temperature for reset of block reclose after operate
Cur Mult	1...5		1	1	Current multiplier when function is used for parallel lines
Initial Tmp	-50.0...100.0	℃	0.1	0.0	Temperature raise above ambient temperature at startup

4.7.7 Monitored data

Table 36: 3Ith>F function input signals

Name	Values (Range)	Unit	Description
Theta Measure Stat	0.00...99.99	%	The calculated temperature of the protected object relative to the operate level

4.7.8 Technical Data

Table 37: 3IthF>, 49F technical data

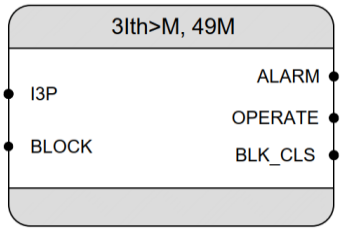
Description	Function	Value
Operation accuracy	TOL 3Ith>F / 49F • CT variant • Sensor variant	Depending on the frequency of the current measured: fn ±2 Hz ±1.5% of the set value or ±0.004*I_n ±5.0% of the set value or ±0.02*I_n
Operate time accuracy		± 2.0% of the set value or ±0.5 s

4.8 Thermal overload protection for motors

4.8.1 Identification

Function description	IEC 60617 identification	ANSI/IEEE C37.2 device number
Thermal overload protection for motor	3Ith>M	49M

4.8.2 Functional block



4.8.3 Functionality

The thermal overload protection function for motors protects the electric motors from overheating. It models the thermal behavior of motor based on the measured load current and disconnects the motor when the thermal content reaches 100 percent. The thermal overload conditions are the most often encountered abnormal conditions in industrial motor applications. The thermal overload conditions are typically the result of an abnormal rise in the motor running current, which produces an increase in the thermal dissipation of the motor and temperature or reduces cooling. Thermal overload protection function prevents an electric motor from drawing excessive current and overheating, which causes the premature insulation failures of the windings and, in worst cases, burning out of the motors.

4.8.4 Principle of operation

Internal FLC calculator

Full load current (FLC) of the motor is defined by the manufacturer at an ambient temperature of 40°C. Special considerations are required with an application where the ambient temperature of a motor exceeds or remains below 40°C. A motor operating at a higher temperature, even if at or below rated load, can subject the motor windings to excessive temperature similar to that resulting from overload operation at normal ambient temperature. The motor rating has to be appropriately reduced for operation in such high ambient temperatures. Similarly, when the ambient temperature is considerably lower than the nominal 40°C, the motor can be slightly overloaded. For calculating thermal level it is better that the FLC values are scaled for different temperatures. The scaled currents are known as internal FLC. An internal FLC is calculated based on the ambient temperature shown in the table. The ***Env Tmp Mode*** setting defines whether the thermal level calculations are based on FLC or internal FLC.

When the value of the ***Env Tmp Mode*** setting is set to the "FLC Only" mode, no internal FLC is calculated. Instead, the FLC given in the data sheet of the manufacturer is used. When the value of the ***Env Tmp Mode*** setting is set to "Set Amb Temp" mode, the internal FLC is calculated based on the ambient temperature taken as an input through the ***Env Temp Set*** setting.

Table 38: Modification of internal FLC

Ambient Temperature T_{amb}	Internal FLC
<20°C	FLC x 1.09
20 to <40°C	FLC x (1.18 - T_{amb} x 0.09/20)
40°C	FLC
>40 to 65°C	FLC x (1 – [(T_{amb} -40)/100])
>65°C	FLC x 0.75

Thermal level calculator

The function selects the highest measured TRMS phase current and calculates the thermal load considering the TRMS and negative-sequence currents. The heating up of the motor is determined by the square value of the load current.

However, in case of unbalanced phase currents, the negative-sequence current also causes additional heating. By deploying a protection based on both current components, abnormal heating of the motor is avoided.

The thermal load is calculated based on different situations or operations and it also depends on the phase current level. The equations used for the heating calculations are:

$$\theta_B = \left[\left(\frac{I}{k \times I_r}\right)^2 + K_2 \times \left(\frac{I_2}{k \times I_r}\right)^2\right] \times (1 - e^{-t/\tau}) \times p\%$$

$$\theta_A = \left[\left(\frac{I}{k \times I_r}\right)^2 + K_2 \times \left(\frac{I_2}{k \times I_r}\right)^2\right] \times (1 - e^{-t/\tau}) \times 100\%$$

where

I TRMS value of the measured max of phase currents
I_r set ***Cur Ref Rot***, FLC or internal FLC
I_2 measured negative sequence current
k set value of ***Ovl Factor***
K_2 set value of ***Neg Seq Fact***
p set value of ***Wgting Fact***
τ time constant

The equation θ_B is used when the values of all the phase currents are below the overload limit, that is, k x I_r. The equation θ_A is used when the value of any one of the phase currents exceeds the overload limit.

During overload condition, the thermal level calculator calculates the value of θ_B in background, and when the overload ends the thermal level is brought linearly from θ_A to θ_B with a speed of 1.66 percent per second.

For the motor at standstill, that is, when the current is below the value of 0.12 x I_r, the cooling is expressed as:

$$\theta = \theta_{02} \times e^{\frac{-t}{\tau}}$$

where,

θ_{02} initial thermal level when cooling begins.

The required overload factor and negative sequence current heating effect factor are set by the values of the ***Ovl Factor*** and ***Neg Seq Fact*** settings.

In order to accurately calculate the motor thermal condition, different time constants are used in the above equations. These time constants are employed based on different motor running conditions, for example starting, normal or stop, and are set through the ***Tm Cons Str, Tm Cons Nom*** and ***Tm Cons Stp*** settings. Only one time constant is valid at a time.

Table 39: Time constant and respective phase current values

Time constant (tau) in use	Phase current
Time constant start	Any current whose value is over 2.5 x I_r
Time constant normal	Any current whose value is over 0.12 x I_r and all currents are below 2.5 x I_r
Time constant stop	All the currents whose values are below 0.12 x I_r

The ***Wgting Fact*** setting determines the ratio of the thermal increase of the two curves θA and θB. The thermal level at the power-up of the protection relay is defined by the ***Ini Thm Val*** setting.

The temperature calculation is initiated from the value defined in the ***Ini Thm Val*** setting. This is done if the protection relay is powered up or the function is reset.

The calculated temperature of the protected object relative to the operate level is available through the monitored data view.

When the thermal level exceeds the set value of the ***Alm Thm Val*** setting, the ***Alm*** output is activated. Sometimes a condition arises when it becomes necessary to inhibit the restarting of a motor, for example in case of some extreme starting condition like long starting time. If the thermal content exceeds the set value of the ***Rstr ThmVal*** setting, the ***Blkcl*** output is activated.

When the emergency start signal ***EStart*** is set high, the thermal level is set to a value below the thermal restart inhibit level. This allows at least one motor startup, even though the thermal level has exceeded the restart inhibit level.

When the thermal content reaches 100 percent, the ***Trip*** output is activated. The ***Trip*** output is deactivated when the value of the measured current falls below 12 percent of ***Cur Ref Rot*** or the thermal content drops below 100 percent.

4.8.5 Signals

Table 40: 3Ith>M function input signals

Name	Type	Default	Description
I3P	Signal	-	Three phase current
Block	Boolean	0=False	Block signal for activating the blocking mode

Table 41: 3Ith>M function output signals

Name	Type	Description
Alm	Boolean	Thermal alarm
Operate	Boolean	Protection trip (operate)
Blkcl	Boolean	Thermal overload indicator to inhibit reclose (Restart inhibit)

4.8.6 Setting range of thermal overload protection for motor

Table 42: Setting ranges negative sequence overcurrent protection, 3Ith>M, 49M

Parameter	Values (Range)	Unit	Step	Default	Description
Thermal Block	0=No 1=Yes			0=No	Block setting for blocking the output signals
Alm Thm Val	50.0...100.0	%	0.1	95.0	Thermal level above which function gives an alarm
Ovl Factor	1.00...1.20		0.01	1.05	Overload factor (k)
Rstr ThmVal	20.0...80.0	%	0.1	40.0	Thermal level above which function inhibits motor restarting
Neg SeqFact	0.0...10.0		0.1	0.0	Heating effect factor for negative sequence current
Wgting Fact	20.0...100.0	%	0.1	50.0	Weighting factor (p)
Tm Cons Nom	80...4000	s	1	320	Motor time constant during the normal operation of motor
Tm Cons Str	80...4000	s	1	320	Motor time constant during the start of motor
Tm Cons Stp	80...60000	s	1	500	Motor time constant during the standstill condition of motor
Env Tmp Mod	1=FLC only 3=Set Amb Temp			1=FLC only	Mode of measuring ambient temperature
Env Temp Set	-20.0...70.0	℃	0.1	40.0	Ambient temperature used when no external temperature measurement available
Cur Ref Rot	0.30...2.00	xIn	0.01	1.00	Rated current (FLC) of the motor
Ini Thm Val	0.0...100.0	%	0.1	74.0	Initial thermal level of the motor

4.8.7 Monitored data

Table 43: 3Ith>F function input signals

Name	Values (Range)	Unit	Description
Theta Measure Rot	0.00...99.99	%	The calculated temperature of the protected object relative to the operate level

4.8.8 Technical Data

Table 44: 3IthM>, 49M technical data

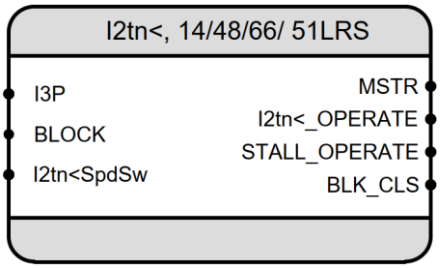
Description	Function	Value
Operation accuracy	TOL 3Ith>M / 49M • CT variant • Sensor variant	Depending on the frequency of the current measured: fn ±2 Hz ±1.5% of the set value or ±0.004*I_n ±5.0% of the set value or ±0.02*I_n
Operate time accuracy		± 2.0% of the set value or ±0.5 s

4.9 Motor start-up supervision / Stalling protection

4.9.1 Identification

Function description	IEC 60617 identification	ANSI/IEEE C37.2 device number
Motor start up supervision / Stalling protection	I2t n<	14/48/66/ 51LRS

4.9.2 Functional block



4.9.3 Functionality

Motor start up supervision function is designed for protection of motors against excessive starting time and locked rotor conditions during motor starting. The starting of the motor is supervised by monitoring the magnitude of all the phase currents. During startup period of the motor, function calculates the integral of the

I^2t value. If the calculated value exceeds the set ***I Start***> value, the **I2tn< Trip** signal is activated.

Function also has the provision to accept the speed switch input, which makes protection suitable for motors having permissible stalled time shorter than starting time. The function also covers repetitive (cumulative) startup function which protects motor from too frequent startup attempts, causing overheating of motor.

4.9.4 Principle of operation

Start up detection

The starting condition of the motor is detected by startup detection. The function initially recognizes the de-energized condition of the motor when the values of all three phase currents are less than ***Istartup*** for longer than 100ms. If any of the phase currents of the de-energized condition rises to a value equal to or greater than ***Istart***>, the ***I2tn<Mstr*** output signal is activated indicating that the motor startup is in progress. At the same time I2t protection is also enabled.

The motor start output remains active until the values of all three phase currents drops below 90 percent of the set value of ***Istart>*** and remains below that level for a time period of 500ms to take into consider short voltage dip or interruption into account.

I2tn<Mstr output signal can be used for enabling start value multiplier by connecting to ***Ena Mult*** input of current protection functions or can be used for blocking the functions.

The start time (t motor start) of the last motor startup is recorded and available as measurement. Also, the maximum startup current is recorded and available as measurement on LHMI as well as available over communication. Both measurements are available in non-volatile memory. The values are updated in memory for each new startup of motor.

Speed switch input

Speed switch is used to indicate whether a motor is accelerating during startup or not. At motor standstill, the ***Spd Sw*** input is active (i.e. the input available from speed switch), indicating that the rotor is not rotating. When the motor has started, at certain revolution the deactivation of the ***Spd Sw*** by the speed switch indicates that the rotor is rotating. If the input is not deactivated within the ***t lockrotor***, the ***I2tn< StallTrip*** output is activated indicating that the rotor is locked.

Thermal stress I^2t calculator

This function gets activated during startup detection and calculates the thermal stress developed in the motor during startup condition. The heat developed during the starting is equal to the integral of I^2t. The function integrates the value of I^2t and compares it to the limiting value obtained from the product of the square of the values of the ***Istartup*** and t startup settings. When the calculated value of the thermal stress exceeds this limit, the ***I2tn<Trip*** output is activated. The calculation is stopped once motor is in running condition.

Cumulative startup protection

This function protects the motor from an excessive number of startups. Whenever the motor is started, the latest value of t motor start is added to the cumulative start-up time. If the value of updated cumulative start-up time is greater than the value of ***Cum Tm Lim***, the ***I2tn<BlkCl*** output is activated and lockout condition for the restart of motor is enabled during the time the output is active. The **I2tn<BlkCl** output remains high until the cumulative start-up time value reduces to a value less than the value of ***Cum Tm Lim***. The start time counter reduces at the rate of the value of ***Cnt Rd Rte.***

The **I2tn<BlkCl** output becomes activated at the start of **I2tn<Mstr**. The output remains active for a period of ***Rstr Inh Tm***.

When the function inhibits further restart, it is possible to view the time remaining for next restart ***RStr_Ena_t*** in the measurement view.

When the ***Estart*** output is high, the value of the cumulative start-up time counter is set to ***Cum Tm Lim*** - 60s · ***EmgStrRdRte***. This disables ***I2tn<BlkCl*** and in turn makes the restart of the motor possible.

4.9.5 Signals

Table 45: I2t n< function input signals

Name	Type	Default	Description
I3P	Signal	-	Three phase current
Block	Boolean	0=False	Block signal for activating the blocking mode
I2tn<SpdSw	Boolean	0=False	Input from speed switch of motor

Table 46: I2t n< function output signals

Name	Type	Description
I2tn<Mstr	Boolean	Motor startup indication
I2tn<Trip	Boolean	Trip signal for thermal stress
I2tn<BlkCl	Boolean	Lockout condition for restart of motor (Restart inhibite)
Stall Trip	Boolean	Motor trip signal for stalling protection

4.9.6 Setting range of Motor start-up supervision / Stalling protection

Table 47: Setting ranges motor start-up supervision protection, I2t n<

Parameter	Values (Range)	Unit	Step	Default	Description
I2tn< Block	0=No 1=Yes			0=No	Block setting for blocking the output signals
I start>	1.0...10.0	xIb	0.1	1.3	Current value for detecting starting of motor

Table 47: Setting ranges motor start-up supervision protection, I2t n<

Parameter	Values (Range)	Unit	Step	Default	Description
Istartup	1.0...10.0	xIb	0.1	6.0	Motor starting current
t startup	5...120	s	1	12	Motor starting time
t lockrotor	2...200	s	1	12	Permitted stalling time
Cnt Rd Rte	2.0...250.0	s/h	0.1	60.0	Start time counter reduction rate
Cum Tm Lim	1...500	s	1	10	Cumulative time based restart inhibit limit
EmgStrRdRte	0.00...100.00	%	0.01	20.00	Start time reduction factor when Estart is active
Rstr Inh Tm	0...250	min	1	30	Time delay between consecutive startups

4.9.7 Monitored data

Table 48: I2t n< function input signals

Name	Values (Range)	Unit	Description
t motor start	0.0...999.9	s	Measured motor latest startup time in sec
Rstr Enable t	0...65535	min	Time left for restart in min when I2tn<BlkCl is activated
Istr max	0...65535	A	Highest current during motor start

4.9.8 Technical Data

Table 49: I2t n<, 14/48/66/51LRS technical data

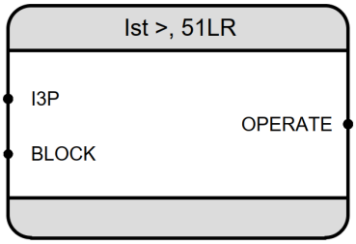
Description	Function	Value		
Operation accuracy	I2t n< / 14,48,66,51LRS • CT variant • Sensor variant	Depending on the frequency of the current measured: fn ±2 Hz ±1.5% of the set value or ±0.002*I_n ±5.0% of the set value or ±0.02*I_n		
Start time	I_{Fault} = 1.1 × set *Start value*	Minimum	Typical	Maximum
		31 ms	33 ms	36 ms
Reset ratio	CT variant Sensor variant	Typically 0.95 Typically 0.94		
Operate time accuracy		± 1.0% of the set value or ±30 ms		

4.10 Locked rotor (motor load jam) protection

4.10.1 Identification

Function description	IEC 60617 identification	ANSI/IEEE C37.2 device number
Locked rotor (motor load jam) protection	Ist>	51LR

4.10.2 Functional block



4.10.3 Functionality

The locked rotor protection function is used for protecting the motor in stall or mechanical jam situations during the running state. When the motor is started, a separate function is used for the startup protection.

Locked rotor protection is normally blocked during the startup period. When the motor has passed the starting phase, locked rotor protection function monitors the magnitude of phase currents. The function starts when the measured current exceeds the breakdown torque level, that is, above the set limit. The operation characteristic is definite time.

The protection could be blocked by settings or via binary input of the relay.

4.10.4 Principle of operation

The measured phase currents are compared to the ***LokRot I>>>*** value. The DFT values of the phase currents are considered for the level detection. The timer module is enabled if measured phase currents exceed the set start value in any one of the phase.

Once activated, the internal start signal is activated. The time characteristic is according to DT. When the operation timer has reached the ***LokRot t>>>*** value, the ***Trip*** output is activated.

When the timer has elapsed, but the motor stall condition still exists, the ***Trip*** output remains active until the phase currents values drop below the ***LokRot I>>>***, that is, until the stall condition persists. If the drop-off situation occurs while the operating time is still counting, the reset timer is activated and operating timer resets after 40ms.

4.10.5 Signals

Table 50: Ist> function input signals

Name	Type	Default	Description
I3P	Signal	-	Three phase current
Block	Boolean	0=False	Block signal for activating the blocking mode

Table 51: Ist> function output signals

Name	Type	Description
Trip	Boolean	Locked rotor protection trip command

4.10.6 Setting range of Motor start-up supervision / Stalling protection

Table 52: Setting ranges motor start-up supervision protection, Ist>

Parameter	Values (Range)	Unit	Step	Default	Description
LokRot Block	0=No 1=Yes			0=No	Block setting for blocking the output signals
LokRot I>>>	0.500...25.000 (CT Variant) 0.500...20.000 (Sensor Variant)	xIn	0.001	10.000	Start value
LokRot t>>>	0.03...64.00	s	0.01	0.03	Operate delay time

4.10.7 Technical Data

Table 53: Ist>, 51LR technical data

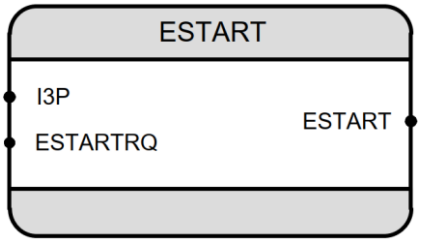
Description	Function	Value
Operation accuracy	Ist>/ 51LR • CT variant • Sensor variant	Depending on the frequency of the current measured: fn ±2 Hz ±1.5% of the set value or ±0.004*I_b ±3.0% of the set value or ±0.010*I_b
Reset time		Typically 40 ms
Reset ratio	CT variant Sensor variant	Typically 0.91 to 0.097 Typically 0.91 to 1.00
Operate time accuracy		± 1.0% of the set value or ±30 ms

4.11 Emergency start-up

4.11.1 Identification

Function description	IEC 60617 identification	ANSI/IEEE C37.2 device number
Emergency start-up	ESTART	ESTART

4.11.2 Functional block



4.11.3 Functionality

An emergency restart function helps to keep essential critical motors in running condition by allowing motor start up even though start inhibit is active. The emergency startup function allows motor startup during emergency conditions. After the **EStart** output is activated, the motor can be started normally.

4.11.4 Principle of operation

Emergency restart function has fixed timer of 10min. which can be activated when the binary input ***EStartRQ*** is activated and motor standstill condition (all the three phase currents are below 0.12xIn) is fulfilled.

Once ***EStartRQ*** input is activated, ***EStart*** output remains active for duration of 10min or until it is kept pressed whichever is higher.

4.11.5 Signals

Table 54: ESTART function input signals

Name	Type	Default	Description
I3P	Signal	-	Three phase current
EStartRQ	Boolean	0=False	Binary Input for the ESTART activation

Table 55: ESTART function output signals

Name	Type	Description
Estart	Boolean	Emergency start

4.11.6 Setting range of ESTART

Table 56: Setting ranges Emergency start, ESTART

Parameter	Values (Range)	Unit	Step	Default	Description
Estart Block	0=No 1=Yes			0=No	Block setting for blocking the output signals

4.11.7 Technical Data

Table 57: ESTART technical data

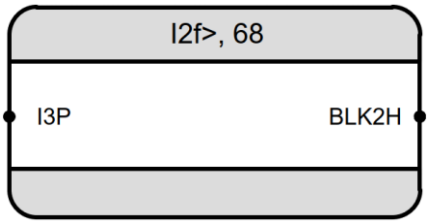
Description	Function	Value
Operation accuracy	ESTART • CT variant • Sensor variant	Depending on the frequency of the current measured: fn ±2 Hz ±1.5% of the set value or ±0.002*I_n ±5.0% of the set value or ±0.020*I_n

4.12 Three phase inrush detector

4.12.1 Identification

Function description	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three phase inrush detector	3I2f>	68

4.12.2 Functional block



4.12.3 Functionality

The three-phase inrush detector function is used to detect transformer inrush situations in distribution networks.

Transformer inrush detection is based on the following principle: the output signal ***Blk2H*** is activated once the numerically derived ratio of second harmonic current I_2H and the fundamental frequency current I_1H exceeds the set value.

The operate time for the function is 40ms and operate time characteristic is of definite time (DT) type.

4.12.4 Principle of operation

This function calculates the ratio of the second harmonic (I_2H) and fundamental frequency (I_1H) of the phase currents. The calculated value is compared to the set ***Ratio*** setting. If the calculated value exceeds the set ***Ratio*** setting and the fundamental frequency current I_1H exceeds the set inrush ***Threshold,*** the output is activated.

4.12.5 Signals

Table 58: 3I2f> function input signals

Name	Type	Default	Description
I3P	Signal	-	Three phase current

Table 59: 3I2f> function output signals

Name	Type	Description
Blk2H	BOOLEAN	Second harmonic based block

4.12.6 Setting range of three phase inrush detector

Table 60: Setting ranges three phase inrush detector, 3I2f>

Parameter	Values (Range)	Unit	Step	Default	Description
Threshold	0.200...25.000 (CT Variant) 0.200...20.000 (Sensor Variant)	xIn	0.001	0.500	Minimum fundamental component of phase current for activation
Ratio	5...50	%	5	30	Ratio of the 2. to the 1. harmonic leading to restraint

4.12.7 Technical Data

Table 61: 3I2f> technical data

Description	Function	Value
Operation accuracy	3I2f> / 68 • CT variant • Sensor variant	Depending on the frequency of the current measured: fn ±2 Hz ±1.5% of the set value or ±0.002*I_n ±5.0% of the set value or ±0.020*I_n
Reset time		Typically 40 ms
Reset ratio	CT variant Sensor variant	Typically 0.96 Typically 0.94
Operate time accuracy		+55 ms [1]

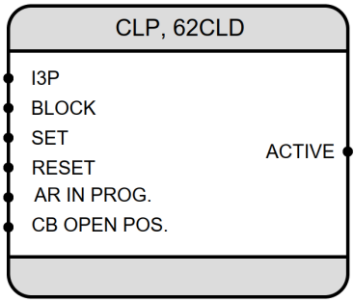
1) Includes the delay of the signal output contact

4.13 Cold load pickup function

4.13.1 Identification

Function description	IEC 60617 identification	ANSI/IEEE C37.2 device number
Cold load pick up function	CLP	62CLD

4.13.2 Functional block



4.13.3 Functionality

Cold Load Pickup function is used to avoid unintentional tripping of protection element when a feeder is reenergized after an extended outage. Cold load pickup function checks the cold load condition and enables start multiplier of protection functions or blocks protection functions to avoid un-necessary trip during system energization.

4.13.4 Principle of operation

This operation of the cold load pickup function (CLP) can be described using a module diagram.

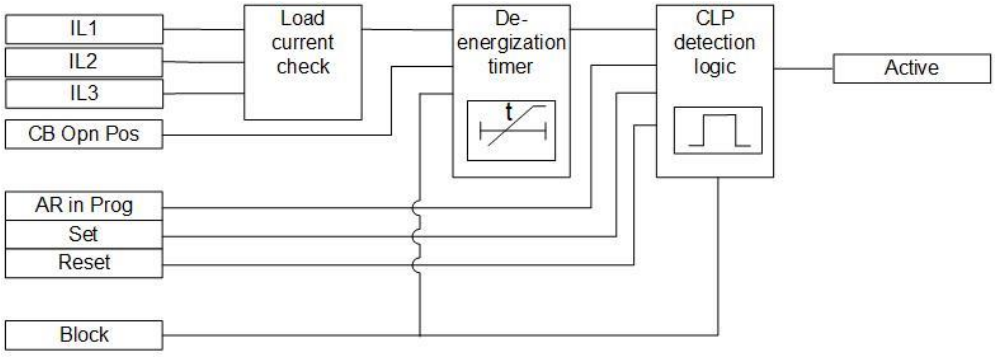


Figure 6: CLP functional module diagram

Load current check

If ***Auto Ini*** setting is set as “Enable”, the measured phase currents are compared phase wise to the ***Min Cur Lvl*** setting. If the maximum of three phase current

measured value is less than the ***Min Cur Lvl*** setting, the output of load current check is activated. If ***Auto Ini*** setting is "Disable" level detector output will not be considered.

De-energization timer

De-energization timer is activated either by output of level detector or via rising edge of ***CB Opn Pos*** signal. Once activated, the timer starts counting and the output of the timer is enabled after the time set by the ***DeEnerg Tm*** setting has elapsed. The activation of ***Block*** input resets the de-energization timer.

CLP detection logic

If the ***DeEnerg Tm*** criteria is fulfilled by the timer, the cold load pickup condition is confirmed, and **Active** output is activated. It will remain active for time set under ***CLP Dur***. It is also possible to initiate and reset CLP condition by activating **Set** and **Reset** over communication/input (i.e., during rising edge of the command). The initiation of **Active** condition over communication can be done irrespective of ***Auto Ini*** setting.

CLP function can operate in two modes, with ***Auto Ini*** enabled or disabled. If ***Auto Ini*** is set as “Enable”, cold load function is activated when either CB is in open position or maximum of three phase current is lower than ***Min Cur Lvl*** setting, for the time set under ***DeEnerg Tm***. If ***Auto Ini*** is set as “Disable”, the activation and deactivation of CLP function is through **Set/Reset** input, which is either binary input or control commands.

Signal **Set** can be activated anytime to initiate the **Active** output and **Reset** can also be activated anytime to reset CLP before ***CLP Dur***. For resetting of CLP via **Reset**, it is not required that activation of CLP should have been done via **Set.**

The initiation and reset of output **Active** can be done by **Set** and **Reset** signals irrespective of ***Auto Ini*** setting. The **Set** command can be activated anytime, i.e, it doesn’t check for any condition except an ongoing auto recloser process. Similarly, **Reset** command can be activated if one needs to reset **Active** before ***CLP Dur*** is elapsed.

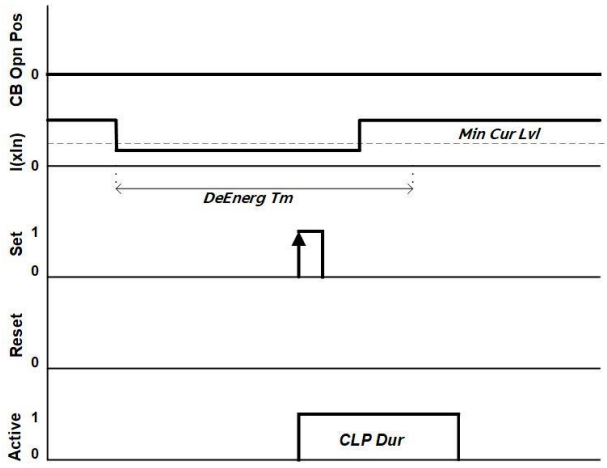


*Figure 7: Activation of CLP using the **Set** command*

The Cold load pickup function is not operational during a normal reclose sequence. If **AR in Prog** is getting activated in between the CLP cycle, the **Active** output will be deactivated, and the timers will be reset.

Active output can be reset using **Reset** command, even if it was not activated via **Set** command. The **Active** output activated by **Set** command will reset normally after the ***CLP Dur***, even if no **Reset** command is given.

The CLP function could be blocked by settings or via binary input of the relay.

4.13.5 Signals

Table 62: CLP function input signals

Name	Type	Default	Description
I3P	Signal	-	Three phase current
Block	BOOLEAN	0=False	Block signal for blocking the output signals
Set	BOOLEAN	0=False	Set the CLP
Reset	BOOLEAN	0=False	Reset the CLP
AR in Prog	BOOLEAN	0=False	Auto recloser in progress
CB Opn Pos	BOOLEAN	0=False	CB open position

Table 63: CLP function output signals

Name	Type	Description
Active	BOOLEAN	CLP active signal

4.13.6 Setting range of cold load pick up function

Table 64: Setting ranges cold load pick , CLP

Parameter	Values (Range)	Unit	Step	Default	Description
CLP Block	0=No 1=Yes			0=No	Block setting for blocking the output signals
Auto Ini	0=Disable 1=Enable			1=Enable	Auto initiation for Cold load pickup
DeEnerg Tm	1...180	min	1	10	Minimum time for which system remain de-energized after which cold load pickup function activates
CLP Dur	0.040...3600.000	s	0.001	0.100	Duration of CLP Active pulse
Min Cur Lvl	0.05...1.00	xIn	0.01	0.05	Minimum current below which system considered as de-energized

4.13.7 Technical Data

Table 65: CLP technical data

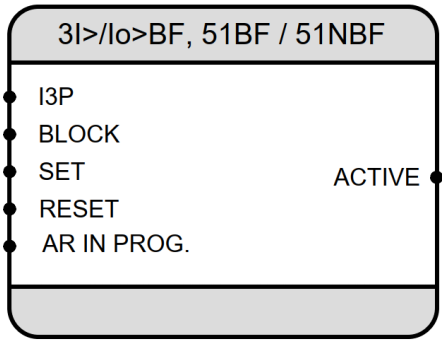
Description	Function	Value
Operation accuracy	CLP / 62CLD • CT variant • Sensor variant	Depending on the frequency of the current measured: fn ±2 Hz ±1.5% of the set value or ±0.002*I_n ±5.0% of the set value or ±0.020*I_n
Operate time accuracy		±1.0 % of the set value or ±40 ms

4.14 Circuit breaker failure protection

4.14.1 Identification

Function description	IEC 60617 identification	ANSI/IEEE C37.2 device number
Circuit breaker failure protection	3I>/Io>BF	51BF/51NB

4.14.2 Functional block



4.14.3 Functionality

The circuit breaker failure protection function provides re-trip and back-up trip signal in case circuit breaker under operation fails to open. Function is activated by trip commands from the protection functions or via external protection trip using binary input.

The function has two independent timers for trip purposes: a re-trip timer for the repeated tripping of its own breaker and a back-up timer for the trip logic operation for upstream breakers

The protection could be blocked by binary input or using ***BFBlock*** setting.

4.14.4 Principle of operation

This operation of the breaker failure protection can be described using a module diagram.

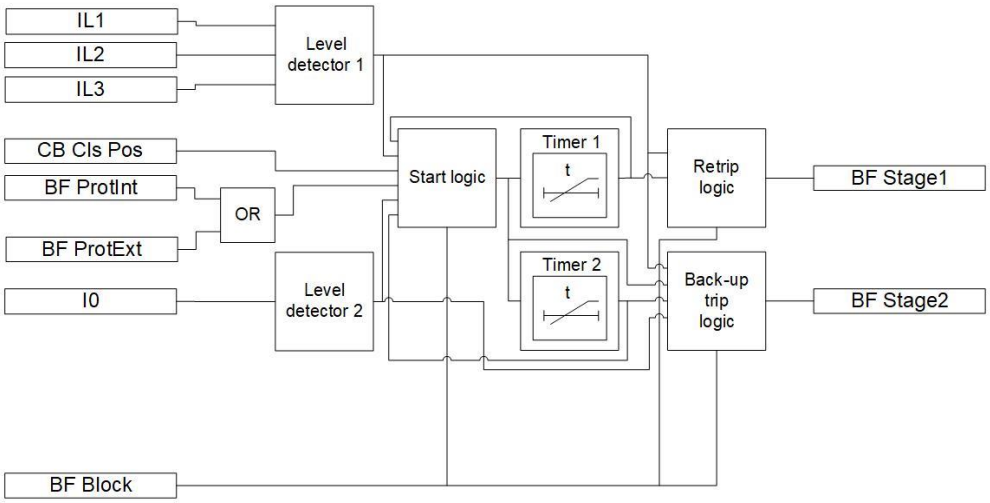


Figure 6: Circuit breaker failure protection functional module diagram

The measured phase currents are compared phasewise to the set ***Icbfp***. If the measured value exceeds the set ***Icbfp***, the level detector reports the exceeding of the value to the start, retrip and backup trip logics. Similarly, the neutral current is compared to the set ***I0cbfp***. If the measured value exceeds the set ***I0cbfp***, the level detector reports the exceeding of the value to the start and backup trip logics.

The CBFP initiation logic is triggered by the rising edge of the **BFProtInt** (from protection function I>, I>>, I>>>, I0> ,I0>> and I0>>>) input or by the rising edge of the **BFProtExt** input wired to digital input of relay as external protection trip.

Start logic is used to manage the starting of Timer 1 and Timer 2. It also resets the function after the circuit breaker failure is handled.

The start logic module resets when either of the following is true:

- CB is in open position.
- All phase currents drop below ***Icbfp*** setting and the residual current drops below ***I0cbfp*** setting.

However, the resetting is possible only after 150ms from the activation of start logic. This time is for ensuring correct operation incase of oscillation in the starting signal.

In addition, the function is immediately resets if the **BFBlock** input is activated.

Retrip function

Once activated, the timer 1 runs until the set ***t Retrip*** value has elapsed. The time characteristic is according to DT. When the operation timer has reached the value set with ***t Retrip***, the retrip logic is activated. **BFStage1** is activated after Timer 1 elapses and CB is in closed position and any phase current exceeds ***Icbfp*** setting.

Once activated, **BFStage1** remains active for 200ms or until the reasons for activation are reset. **BFStage1** is also reset if **BFBlock** is activated.

Backup trip function

Once activated, the timer 2 runs until the set ***t Backup*** value has elapsed. The time characteristic is according to DT. When the operation timer has reached the set ***t Backup***, the backup trip logic is activated. It gives a backup trip **BFStage2** for the upstream circuit breaker if the main circuit breaker fails to clear the fault.

Conditions for activating backup trip logic:

For activating backup trip logic, CB should be in closed position and either of the following is true:

- Any phase current exceeds ***Icbfp*** setting.
- The residual current exceeds ***I0cbfp*** setting.

Once activated, **BFStage2** remains active until the set Trip pulse time or until the reasons for activation are reset.

4.14.5 Signals

Table 66: CBFP function input signals

Name	Type	Default	Description
I3P	Signal	-	Three phase current
BFBlock	BOOLEAN	0=False	Block signal for blocking the output signals
BFProtExt	BOOLEAN	0=False	External protection trip
CB Cls Pos	BOOLEAN	0=False	CB in closed position
BFProtint	BOOLEAN	0=False	Internal protection trip

Table 67: CBFP function output signals

Name	Type	Description
BFStage1	BOOLEAN	Retrip
BFStage2	BOOLEAN	Backup trip

4.14.6 Setting range of circuit breaker failure function

Table 64: Setting ranges CBFP function

Parameter	Values (Range)	Unit	Step	Default	Description
BF Block	0=No 1=Yes			0=No	Block setting for blocking the output signals
Earth Type	1=External 2=Internal			1=External	Selection of residual current
Icbfp	0.2...2.0	xIn	0.1	1.1	Operating phase current
I0cbfp	0.1...2.0	xIn	0.1	1.1	Operating neutral current
t Retrip	0.06...0.50	s	0.01	0.10	Time delay for retrip
t Backup	0.06...0.50	s	0.01	0.12	Time delay for backup protection

4.14.7 Technical Data

Table 65: 3I> / Io> / 51BF / 51NBF technical data

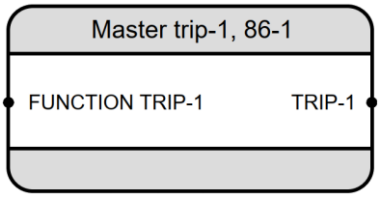
Description	Function	Value
Operation accuracy	CBFP/ 51BF - 51NBF • CT variant • Sensor variant	Depending on the frequency of the current measured: fn ±2 Hz ±1.5% of the set value or ±0.002*I_n ±5.0% of the set value or ±0.020*I_n
Reset time		Typically 40 ms
Operate time accuracy		±1.0 % of the set value or ±40 ms

4.15 Master trip 1

4.15.1 Identification

Function description	IEC 60617 identification	ANSI/IEEE C37.2 device number
Master trip 1	Master Trip	86-1

4.15.2 Functional block



4.15.3 Functionality

The trip 1 function is used as a trip command collector and handler after the protection functions.

4.15.4 Principle of operation

The duration of the **Trip1** output signal will be 200ms. Trip 1 has a single input **Function trip 1**, through which all trip output signals are routed from the protection functions within the protection relay. Any predefined set of trip signals to the Trip 1 function can be connected through the **Function trip 1** from the function tab of the signal matrix tool. **Function trip 1** signal will be OR-ed with the output signals of three phase overcurrent protection (**I> Trip**, **I>> Trip**, **I>>> Trip**) and **CB Opn Cmd**. The function has a single trip output **Trip1** for connecting the function to one or more of the protection relay's binary outputs, and to other functions within the protection relay requiring this signal.

4.15.5 Signals

Table 66: Master trip-1 / 86-1 function input signals

Name	Type	Default	Description
Function trip 1	BOOLEAN	0=False	Trip

Table 67: Master trip-1 / 86-1 function output signals

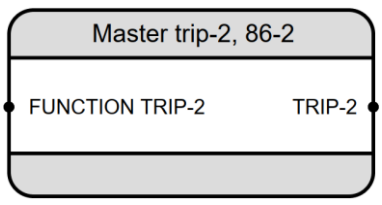
Name	Type	Description
Trip1	BOOLEAN	General trip output signal

4.16 Master trip 2

4.16.1 Identification

Function description	IEC 60617 identification	ANSI/IEEE C37.2 device number
Master trip 2	Master Trip	86-2

4.16.2 Functional block



4.16.3 Functionality

The trip 2 function is used as a trip command collector and handler after the protection functions.

4.16.4 Principle of operation

The duration of the **Trip2** output signal will be 200ms. Trip 2 has a single input **Function trip 2**, through which all trip output signals are routed from the protection functions within the protection relay. Any predefined set of trip signals to the Trip 2 function can be connected through the **Function trip 2** from the function tab of the signal matrix tool. **Function trip 2** signal will be OR-ed with the output signals of earth fault protection (**I0> Trip**, **I0>> Trip**, **I0>>> Trip**) and **CB Opn Cmd**. The function has a single trip output **Trip2** for connecting the function to one or more of the protection relay's binary outputs, and to other functions within the protection relay requiring this signal.

4.16.5 Signals

Table 68: Master trip-2 / 86-2 function input signals

Name	Type	Default	Description
Function trip 2	BOOLEAN	0=False	Trip

Table 69: Master trip-2 / 86-2 function output signals

Name	Type	Description
Trip2	BOOLEAN	General trip output signal

4.17 Protection characteristics

4.17.1 Time / current characteristics

Relay offers three-stage overcurrent and three stage earth-fault protection functions. The low-set stage of overcurrent protection and earth-fault protection are equipped with standard Inverse Definite Minimum Time (IDMT) characteristics – (Normal Inverse (NI), Extreme Inverse (EI), Long Inverse (LI), and Very Inverse (VI)) along with definite time (DT) characteristics for better co-ordination with rest of the network. Additionally special characteristic curve RI is also provided. The high stage and instantaneous stage for over current protection and high stage earth fault protection come with DT characteristics.

When IDMT characteristic has been selected, the operating time of the stage will be a function of the current; the higher the current, the shorter the operating time. The stage includes ten different time/current curve sets – four according to the BS 142 and IEC 60255 standards namely normal inverse, very inverse, extremely inverse, longtime inverse, four according to ANSI C37.xxx standard namely moderate inverse, normal inverse, very inverse, extremely inverse and one special curve, named RI type curve along with definite time characteristics.

4.17.1.1 IEC 60255-3 IDMT characteristic

The relationship between current and time for standard normal inverse, very inverse, extremely inverse and long-time inverse complies with the BS 142.1966 and IEC 60255-3 standards and can be expressed as follows:

$$t = \frac{(K * \beta)}{(\frac{I}{Iset})^{\alpha} - 1}$$

Where,

t = operate time in seconds
K = time multiplier
I = measured current value
Iset = set start current value

The slope of the time/current characteristics shall be determined by the constants **α** and **ß** as indicated below:

Table 70: Values of constant α and β

Slope of the time/current curve set	α	β
IEC – Normal inverse	0.02	0.14
IEC – Very inverse	1.0	13.5
IEC – Extremely inverse	2.0	80
IEC – Long time inverse	1.0	120

4.17.1.2 ANSI C37.112 IDMT characteristic

The relationship between current and time for standard moderate inverse, normal inverse, very inverse, extremely inverse complies with the ANSI C37.112 standards and can be expressed as follows:

Where:

$$t = \left(\frac{\beta}{\left(\frac{I}{Iset}\right)^{\alpha} - 1} + \gamma \right) * K$$

Where,

t = operate time in seconds
K = time multiplier
I = measured current value
Iset = set start current value

The slope of the time/current characteristics shall be determined by the constants α and β and γ as indicated below:

Table 71: Values of constant α, β and γ

Slope of the time/current curve set	α	β	γ
ANSI – Moderate inverse	0.02	0.0515	0.1140
ANSI – Normal inverse	0.02	0.0086	0.0185
ANSI – Very inverse	2.0	19.61	0.491
ANSI – Extremely inverse	2.0	28.2	0.1217

4.17.1.3 RI type characteristic

The RI-type characteristic is a special characteristic used mainly in combination with existing mechanical relays. The characteristic is based on the following mathematical expression:

$$t = \frac{K}{\alpha - \beta\left(\frac{Iset}{I}\right)}$$

Where,

t = operate time in seconds
K = time multiplier
I = measured current value
Iset = set start current value
α = 0.339
β = 0.236

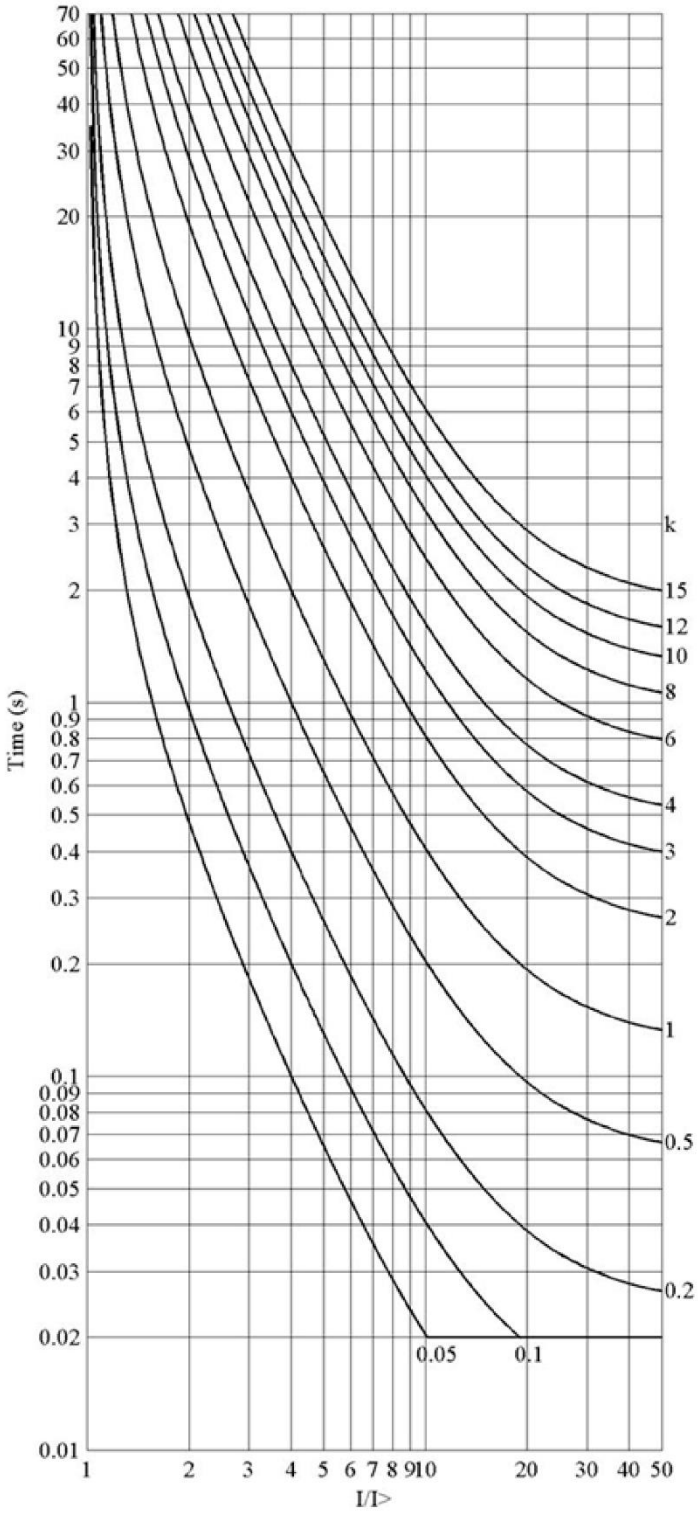


Figure 6: ANSI extremely inverse-time characteristics

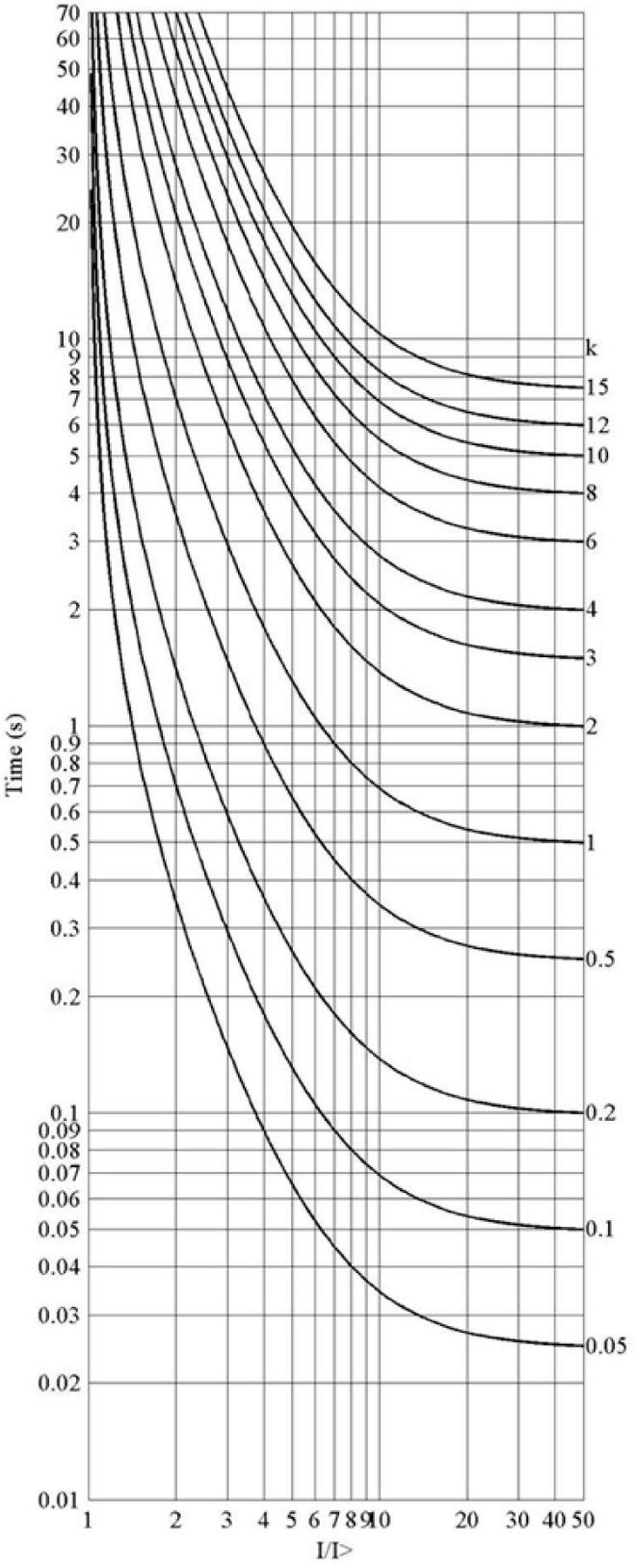


Figure 7: ANSI very inverse-time characteristics

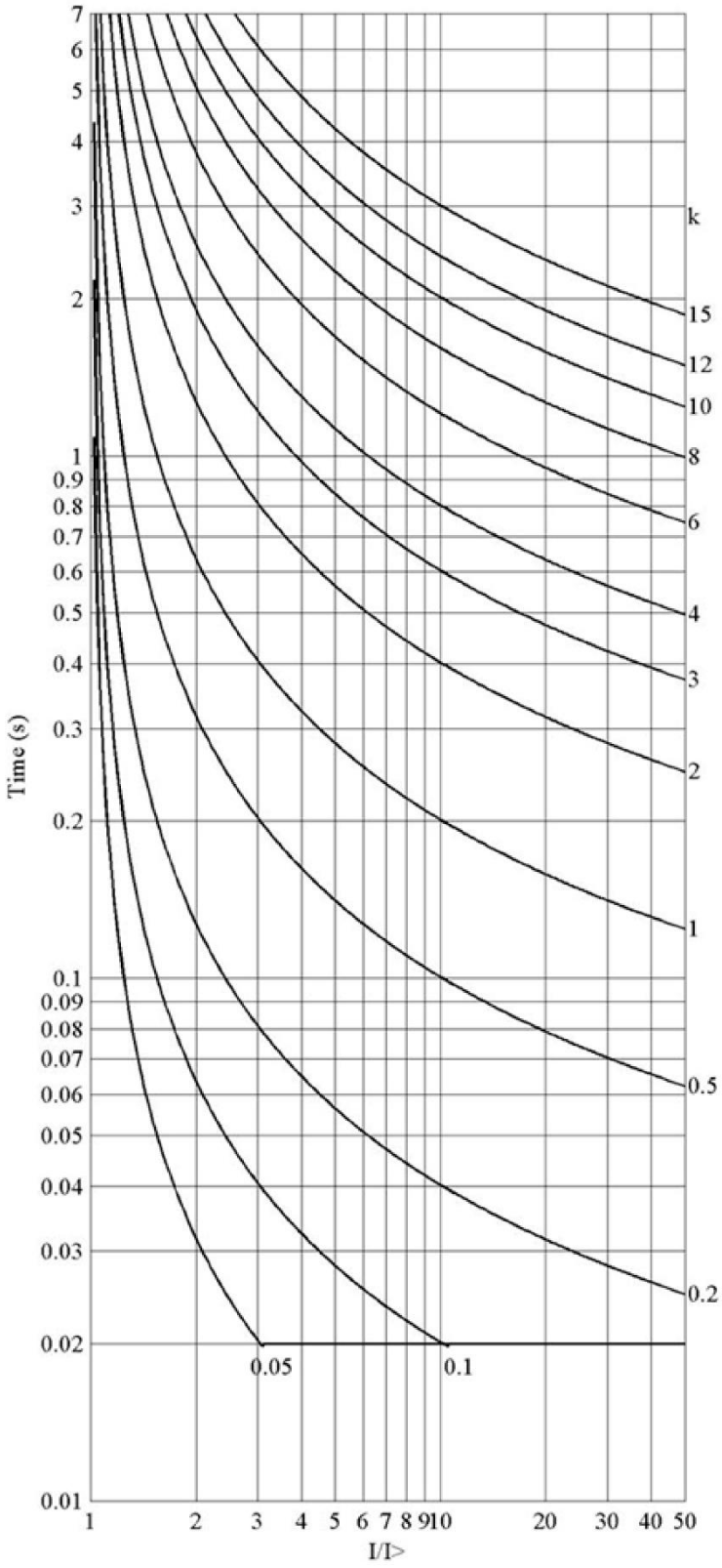


Figure 8: ANSI normal inverse-time characteristics

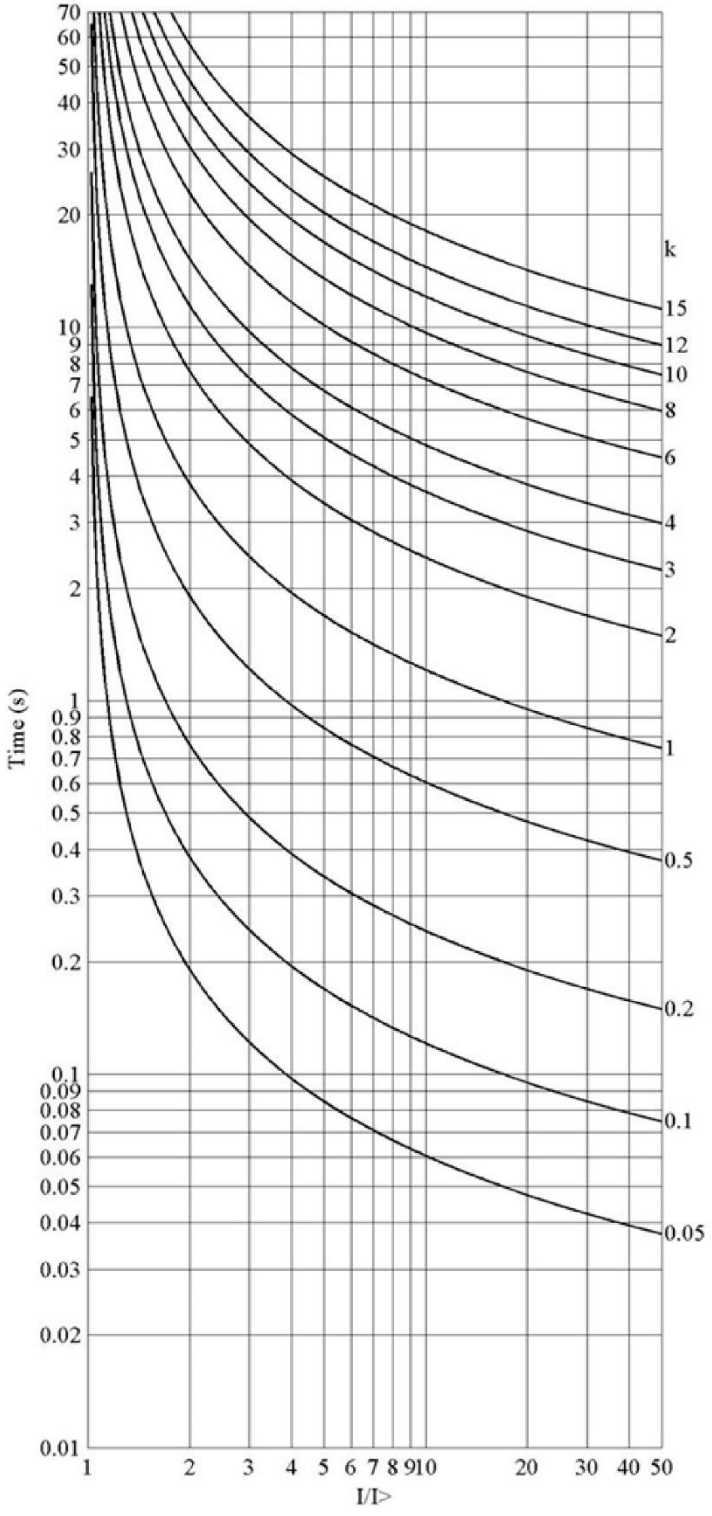


Figure 9: ANSI moderately inverse-time characteristics

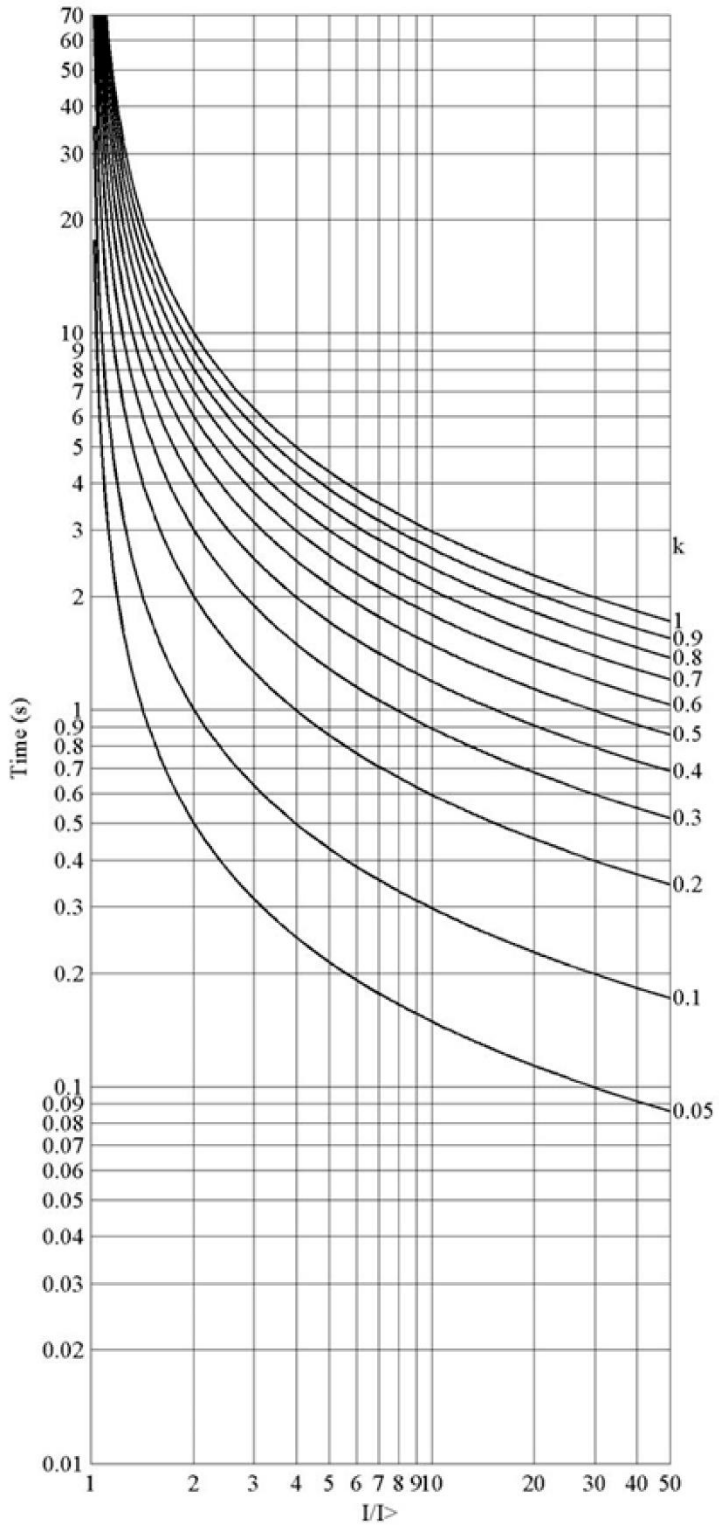


Figure 10: IEC normal inverse-time characteristics

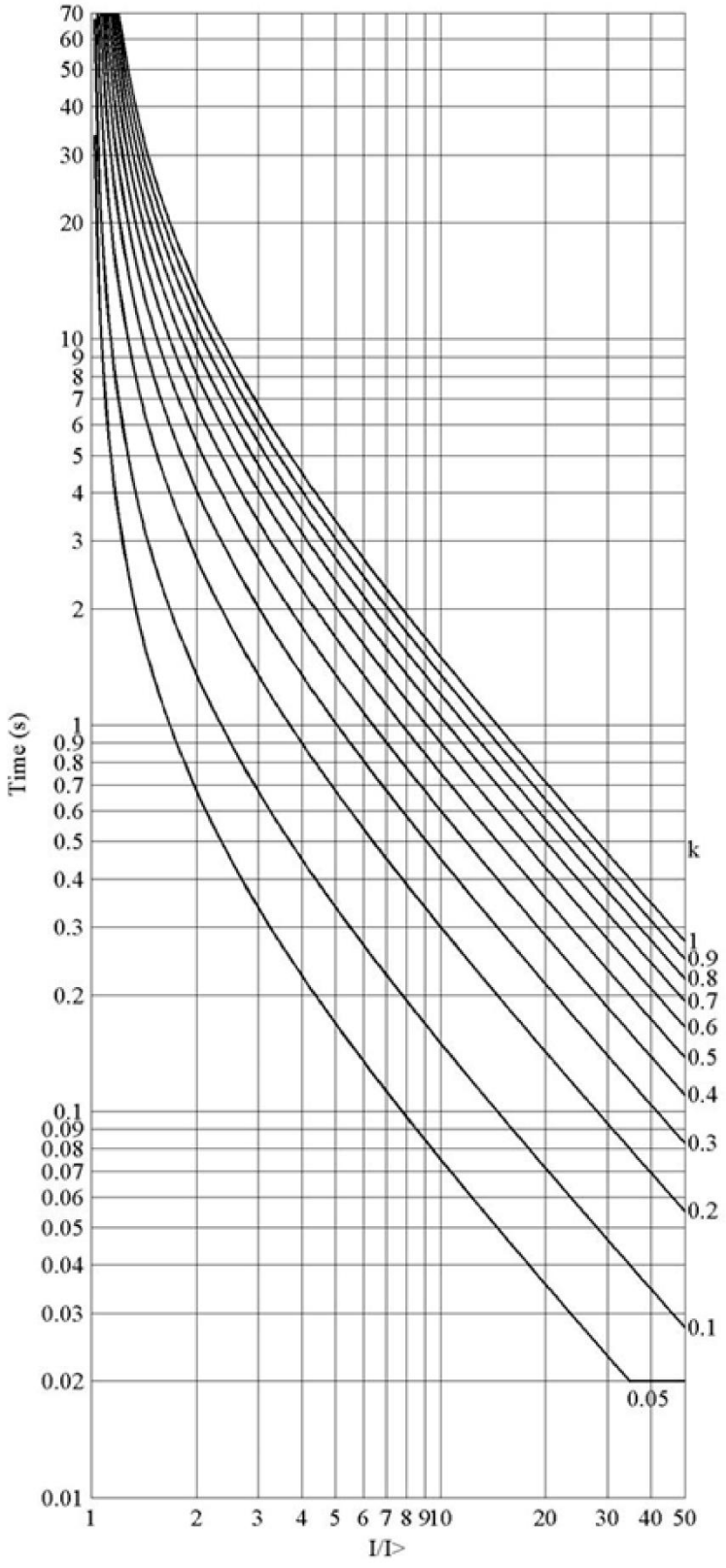


Figure 11: IEC very inverse-time characteristics

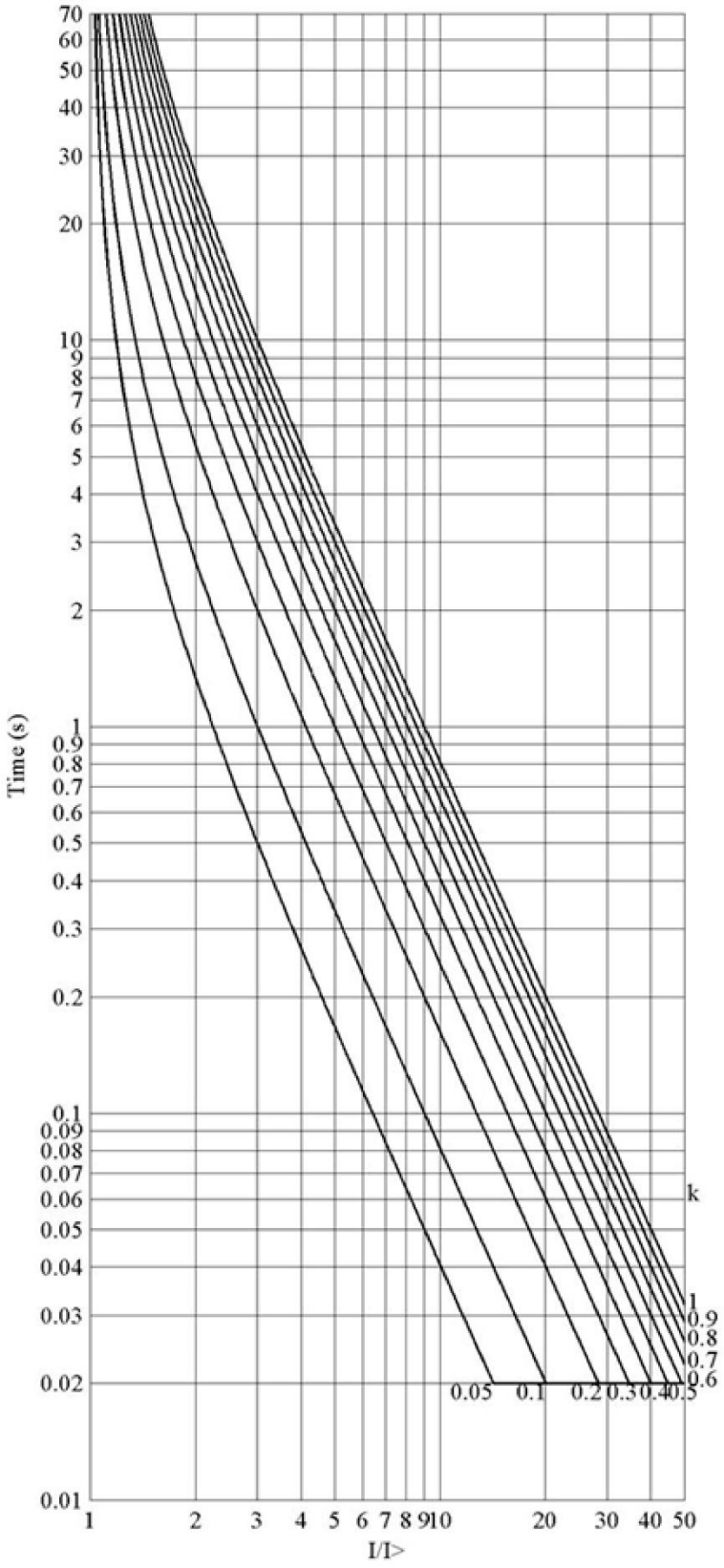


Figure 12: IEC extremely inverse-time characteristics

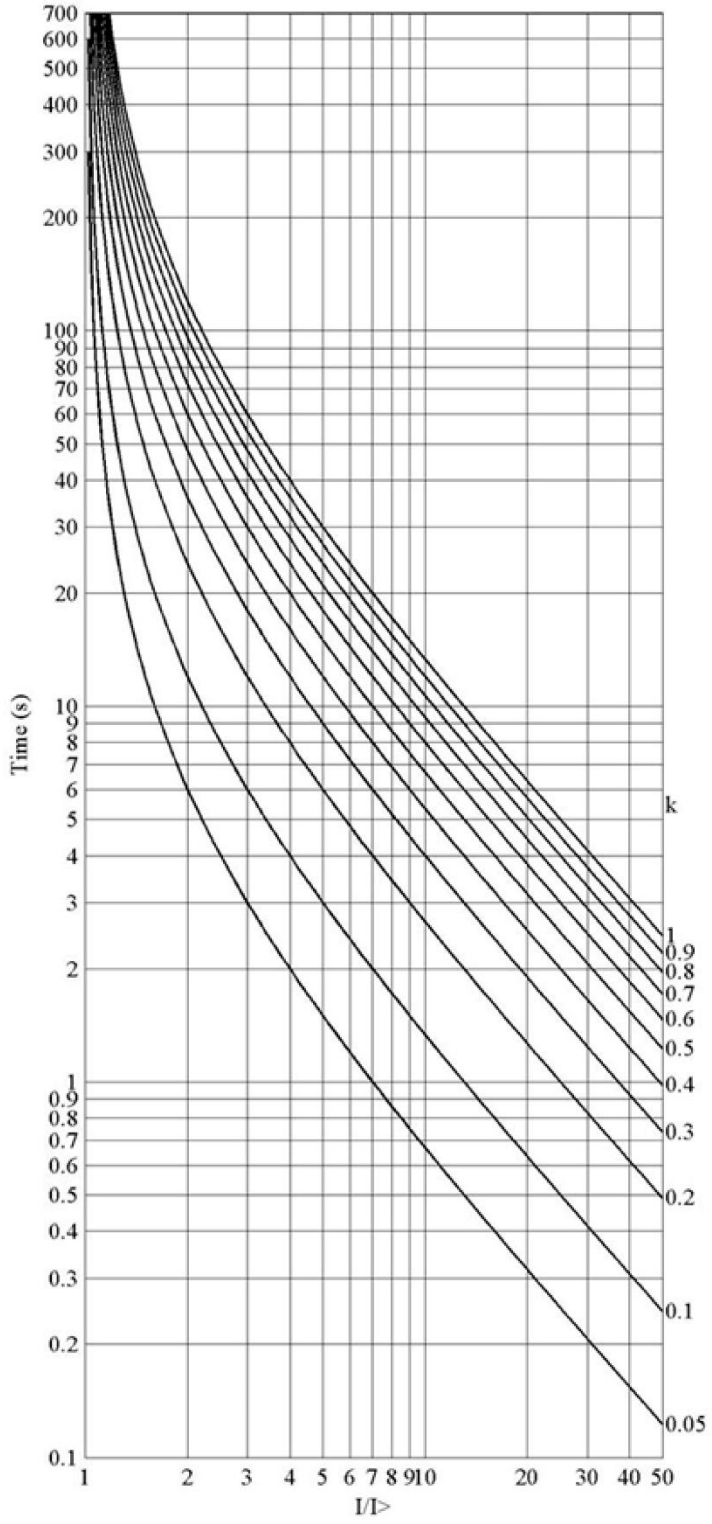


Figure 13: IEC long-time inverse-time characteristics

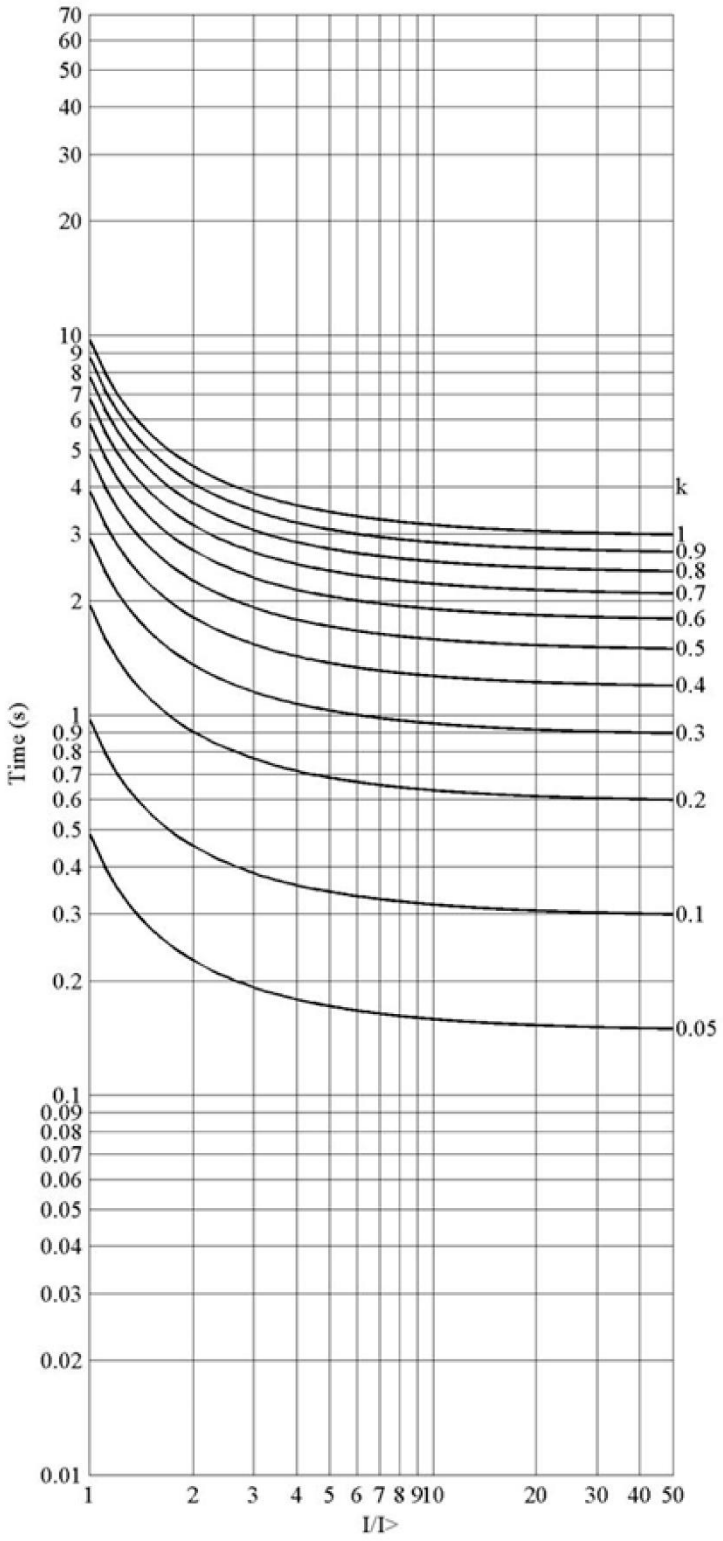


Figure 14: RI-type inverse-time characteristics

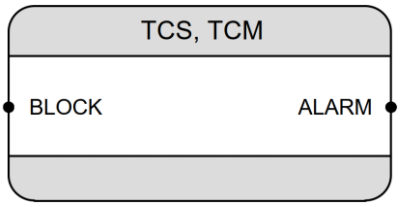
Section 5 Supervision and monitoring functions

5.1 Trip circuit supervision

5.1.1 Identification

Function description	IEC 60617 identification	ANSI/IEEE C37.2 device number
Trip circuit supervision	TCS	TCM

5.1.2 Function block



5.1.3 Functionality

The trip circuit supervision function is designed to supervise the control circuit of the circuit breaker. The invalidity of a control circuit is detected by using a dedicated output contact that contains the supervision functionality. The failure of a circuit is reported to the corresponding function block in the relay configuration.

The function starts and operates when trip circuit supervision detects a trip circuit failure. The operating time characteristic for the function is DT. The function operates after a predefined operating time and resets when the fault disappears.

The function can be blocked using both binary input and block setting

5.1.4 Principle of operation

The **TCS** input receives the trip circuit status from the hardware. A detected failure in the trip circuit activates the timer.

Once activated, the timer runs until the set value of ***TCS operating time*** has elapsed. When the operation timer has reached the maximum time value, the **TCS Fault** output is activated. If a drop-off situation occurs during the operate time up counting, the fixed 0.5 s reset timer is activated. After that time, the operation timer is reset.

The function detects faults in the electrical trip / open control circuit (which includes trip coil, trip contact, wiring and auxiliary voltage) of circuit. It can supervise trip circuit in breaker open as well as breaker close condition.

For the TCS functionality the BI2 need to be connected in parallel to the trip output BO2 as shown in the figure 15. Additionally, the BI2 need to be configured for the TCS functionally.

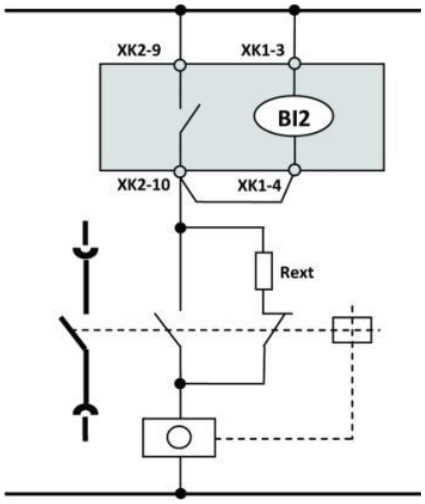


Figure 15: Application diagram of TCS function

When the circuit breaker is open, TCS measure the voltage across the trip contact through Rext (external shunt resistance shown in below figure) and trip coil. When the circuit breaker is close, TCS measure the voltage across the trip contact through CB internal contact and trip coil. Below table shows the specification for the Rext for the TCS circuit.

Table 72: TCS functionality specification

Description	Value
Auxiliary voltage range	48-250V AC/DC
Current drain through the supervision circuit	~1.5 mA
Minimum voltage over the TCS contact	20 V AC/DC
Operating voltage Vaux 48 V DC 60 V DC 110 V DC 220 V DC	Recommended shunt resistor Rext 1.2 kΩ, 5 W 5.6 kΩ, 5 W 22 kΩ, 5 W 33 kΩ, 5 W

5.1.5 Signals

Table 73: TCS function input signals

Name	Type	Default	Description
BFBlock	BOOLEAN	0=False	Block signal for blocking the output signals

Table 74: TCS function output signals

Name	Type	Description
TCS fault	BOOLEAN	TCS fault alarm output

5.1.6 Setting range of trip circuit supervision function

Table 75: Setting ranges CBFP function

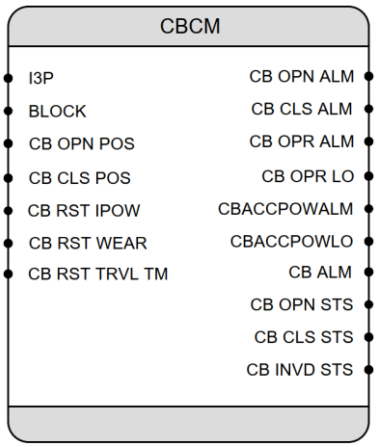
Parameter	Values (Range)	Unit	Step	Default	Description
TCS operating time	1...300	S	1	1	Operate delay time
TCS Block	0 = No 1 = Yes			0 = No	Block setting for blocking the output signals

5.2 Circuit breaker condition monitoring

5.2.1 Identification

Function description	IEC 60617 identification	ANSI/IEEE C37.2 device number
Circuit breaker condition monitoring	CBCM	CBCM

5.2.2 Function block



5.2.3 Functionality

The circuit-breaker condition monitoring function is used to monitor different parameters of the circuit breaker. The breaker requires maintenance when the number of operations has reached a predefined value. The energy is calculated from the measured input currents as a sum of Iyt values. Alarms are generated when the calculated values exceed the threshold settings. The function contains a blocking functionality which can be used to block the function outputs.

5.2.4 Principle of operation

The circuit breaker condition monitoring function monitors the position of the circuit breaker, that is, whether the breaker is in open, closed, or invalid position.

The **CB Opn Sts** output is activated when the auxiliary input contact **CB Cls Pos** is FALSE, the **CB Opn Pos** input is TRUE and all the phase currents are below value 10 A.

The **CB Cls Sts** output is activated when the auxiliary **CB Opn Pos** input is FALSE and the **CB Cls Pos** input is TRUE.

The **CB Invd Sts** output is activated when both the auxiliary contacts have the same value, that is, both are in the same logical level, or if the auxiliary input contact **CB Cls Pos** is FALSE and the **CB Opn Pos** input is TRUE and any of the phase currents exceed 10 A.

The status of the breaker is indicated by the binary outputs **CB Opn Sts**, **CB Invd Sts** and **CB Cls Sts** for open, invalid and closed position respectively.
The function calculates the number of days the circuit breaker has remained inactive, that is, has stayed in the same open or closed state. The calculation is done by monitoring **CB Opn Pos** and **CB Cls Pos**.

The inactive days **CB Inactive Days** is available in the monitored data view. It is also possible to set the initial inactive days with the ***Ini Ina Days*** parameter. When the inactive days exceed the limit value defined with the ***Ina Alm Days*** setting, **the CB Alm alarm** is initiated. The time in hours at which this alarm is activated can be set with the ***Ina Alm Hrs*** parameter.

The function also calculates the breaker contact travel time for the closing and opening operation. The contact travel time of the breaker is calculated from the time between auxiliary contacts' state change (From Pos to Pos). The opening travel time is measured between the opening of the **CB Cls Pos** auxiliary contact and the closing of the **CB Opn Pos** auxiliary contact. The travel time is also measured between the opening of the **CB Opn Pos** auxiliary contact and the closing of the **CB Cls Pos** auxiliary contact.

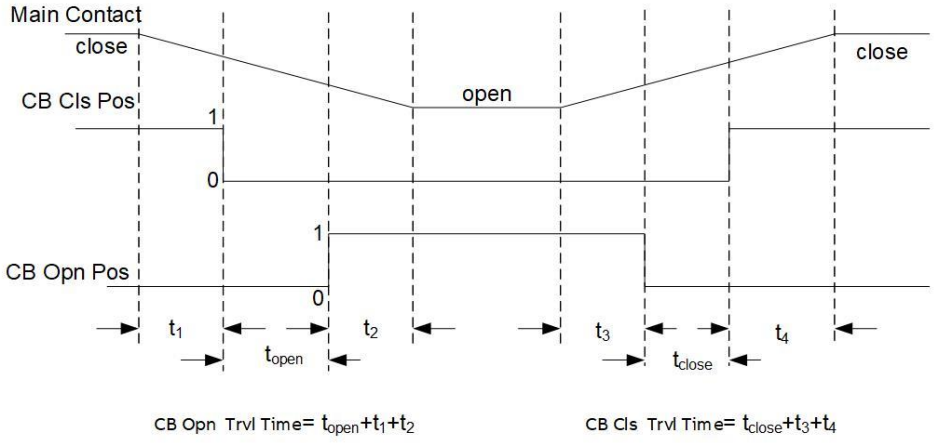


Figure 16: Circuit breaker travel time calculation when calculated from "Pos to Pos"

There is a time difference t1 between the start of the main contact opening and the opening of the **CB Cls Pos** auxiliary contact. Similarly, there is a time gap t2 between the time when the **CB Opn Pos** auxiliary contact opens, and the main contact is completely open. To incorporate the time t1 + t2, a correction factor needs to be added with topen to get the actual opening time. This factor is added with the ***CBOpnCorTm*** (= t1 + t2) setting. The closing time is calculated by adding the value set with the ***CBClsCorTm*** (t3 + t4) setting to the measured closing time.

The last measured opening travel time **CB Opn Trvl Time** and the closing travel time **CB Cls Trvl Time** are available in the monitored data view.

When the measured opening travel time is longer than the value set with the ***CB Opn AlmTm*** setting, the **CB Opn Alm** output is activated. Respectively, when the measured closing travel time is longer than the value set with the ***CB Cls AlmTm*** setting, the **CB Cls Alm** output is activated.

The function calculates the number of breaker operation cycles. The opening and closing operations are both included in one operation cycle. The operation counter value is updated after each opening operation.

The operation counter counts the number of operations based on the state change of the binary auxiliary contacts inputs **CB Cls Pos** and **CB Opn Pos**. The number of operations **CB Opr counter** is available in the monitored data view. The old circuit breaker operation counter value can be taken into use by writing the value to the ***Cnt Ini Val*** parameter and by setting the signal **CB Rst Wear**. Counter reset command can be given either through LHMI or using binary input.

The **CB Opr Alm** operation alarm is generated when the number of operations exceeds the value set with the ***CBAlmOprNum*** setting. However, if the number of operations increases further and exceeds the limit value set with the ***CBLOOprNum*** setting, the **CB Opr LO** output is activated.

The function also calculates the accumulated energy I^yt $[(kA)^y s]$. The factor y is set with the ***Cur Expnt*** setting. The calculation is initiated with the **CB Cls Pos** input opening events. It ends when the RMS current becomes below 10 A.

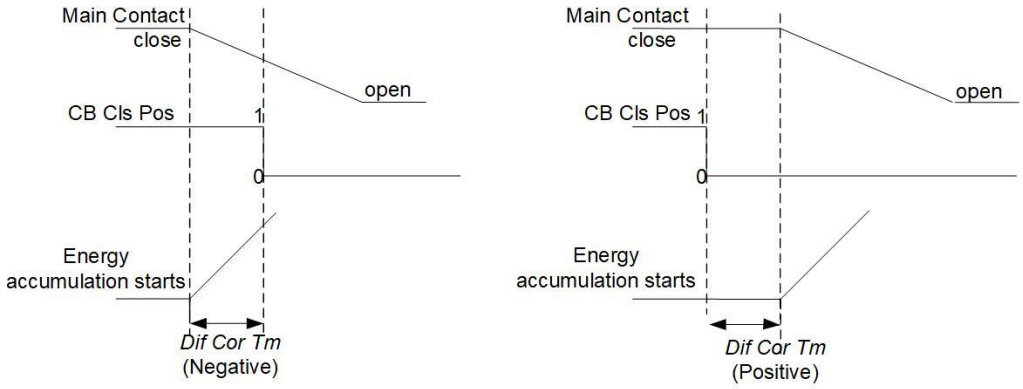


Figure 17: Significance of Dif Cor Tm

The ***Dif Cor Tm*** setting is used instead of the auxiliary contact to accumulate the energy from the time the main contact opens. If the setting is positive, the calculation of energy starts after the auxiliary contact has opened and when the delay is equal to the value set with the ***Dif Cor Tm*** setting. When the setting is negative, the calculation starts in advance by the correction time before the auxiliary contact opens.

The accumulated energy outputs **Acc Current Pow A (B, C)** are available in the monitored data view.

The **CBAccPowAlm** alarm is activated when the accumulated energy exceeds the value set with the ***Alm Acc Cur*** threshold setting. However, when the energy exceeds the limit value set with the ***LO Acc Cur*** threshold setting, the **CBAccPowLO** output is activated.

5.2.5 Signals

Table 76: CBCM function input signals

Name	Type	Default	Description
I3P	Signal	-	Three phase current
CBCM Block	BOOLEAN	0=False	Block signal for blocking the output signals
CB Opn Pos	BOOLEAN	0=False	Signal for open position of apparatus from I/O
CB Cls Pos	BOOLEAN	0=False	Signal for close position of apparatus from I/O
CB Rst IPow	BOOLEAN	0=False	Reset accumulation energy
CB Rst Wear	BOOLEAN	0=False	Reset input for CB remaining life and operation counter
CB Rst Trvl Tm	BOOLEAN	0=False	Reset input for CB closing and opening travel times

Table 77: CBCM function output signals

Name	Type	Description
CB Opn Alm	BOOLEAN	CB open travel time exceeded set value
CB Cls Alm	BOOLEAN	CB close travel time exceeded set value
CB Opr Alm	BOOLEAN	Number of CB operations exceeds alarm limit
CB Opr LO	BOOLEAN	Number of CB operations exceeds lockout limit
CBAccPowAlm	BOOLEAN	Accumulated currents power (Iyt), exceeded alarm limit
CBAccPowLO	BOOLEAN	Accumulated currents power (Iyt), exceeded lockout limit
CB Alm	BOOLEAN	CB 'not operated for long time' alarm
CB Opn Sts	BOOLEAN	CB is in open position
CB Invd Sts	BOOLEAN	CB is in invalid position (not positively open or closed)
CB Cls Sts	BOOLEAN	CB is in closed position

5.2.6 Setting range of circuit breaker condition monitoring

Table 78: Setting ranges CBCM function

Parameter	Values (Range)	Unit	Step	Default	Description
CBCM Block	0=No 1=Yes			0=No	Block setting for blocking the output signals
CB OpnAlmTm	0.000...0.200	s	0.001	0.040	Alarm level setting for open travel time in s
CB ClsAlmTm	0.000...0.200	s	0.001	0.040	Alarm level setting for close travel time in s
CB LOOprNum	0...99999		1	300	Lock out limit for number of operations
Cur Expnt	0.00...2.00		0.01	2.00	Current exponent setting for energy calculation
Dif Cor Tm	-0.010...0.010	s	0.001	0.005	Corr. factor for time dif in aux. and main contacts open time
Alm Acc Cur	0.00...20000.00		0.01	2500.00	Setting of alarm level for accumulated currents power
LO Acc Cur	0.00...20000.00		0.01	2500.00	Lockout limit setting for accumulated currents power
Ina AlmDays	0...9999		1	2000	Alarm limit value of the inactive days counter
Ini InaDays	0...9999		1	0	Initial value of the inactive days counter
Ina Alm Hrs	0...23	h	1	0	Alarm time of the inactive days counter in hours
CBOpnCorTm	0.000...0.100	s	0.001	0.010	Correction factor for open travel time in s
CBClsCorTm	0.000...0.100	s	0.001	0.010	Correction factor for CB close travel time in s
Cnt Ini Val	0...99999		1	0	The operation numbers counter initialization value
CBAlmOprNum	0...99999		1	200	Alarm limit for number of operations

5.2.7 Monitoring data

Table 79: Monitoring data CBCM function

Parameter	Values (Range)	Unit	Description
CB Inactive Days	0...9999		CB Inactive Days
CB Opn Trvl Time	0.000...60.000	s	CB Opn Trvl Time
CB Cls Trvl Time	0.000...60.000	s	Travel time of the CB during closing operation
CB Opr Counter	0...99999		Number of CB operation cycle
Acc Current Pow A	0.00...1000000.00		Accumulated currents power (Iyt), phase A
Acc Current Pow B	0.00...1000000.00		Accumulated currents power (Iyt), phase B
Acc Current Pow C	0.00...1000000.00		Accumulated currents power (Iyt), phase C

5.2.8 Technical Data

Table 80: CBCM technical data

Description	Function	Value
Current measuring accuracy	CBCM • CT variant • Sensor variant	Depending on the frequency of the current measured: fn ±2 Hz ±1.5% of the set value or ±0.002*I_n ±5.0% of the set value or ±0.020*I_n
Operate time accuracy		±1.0 % of the set value or ±40 ms

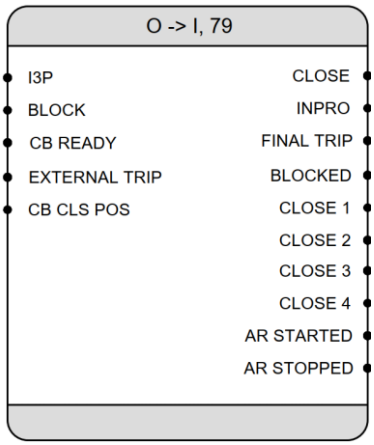
Section 6 Control functions

6.1 Auto reclosing

6.1.1 Identification

Function description	IEC 60617 identification	ANSI/IEEE C37.2 device number
Auto reclosing	O -> I	79

6.1.2 Function block



6.1.3 Functionality

Majority of overhead line faults are transient in nature and automatically cleared by momentarily de-energizing the line. De-energizing of the fault location for a selected time-period is implemented through automatic reclosing, during which most of the faults can be cleared.

In case of a permanent fault, the automatic reclosing is followed by final tripping. The auto-reclose function can be used with any circuit breaker suitable for auto-reclosing. The function provides programmable auto-reclose shots and can be set to perform successive auto-reclosures of desired duration.

6.1.4 Principle of operation

Initialization logic

There are two modes by which function can be activated, the mode to be used depends on ***Mode*** setting.

Possible options for this setting are

Mode 1 = “Trip”
Mode 2 = “Str Trip”

In mode 1 ("Ext trip"), the activation is based on input **External Trip**, received as binary input or through Modbus. In mode 2 ("Str Trip"), the activation signal is based on Start and Trip internal signals. The Start signal will be an OR of **Start** output of I>, I>>, I>>>, Io>, Io>>, I2>, and I2/I1> and Trip will be an OR of **Trip** output I>, I>>, I>>>, Io>, Io>>, I2> and I2/I1>.

The function will be initialized either through **External Trip** in mode 1 or if the Trip signal is received within the time set via ***Activate t*** setting after the receipt of Start signal in mode 2. In addition, it is required that (a) circuit breaker is in closed position (b) auto-reclose is not blocked (c) circuit breaker is in ready condition. The initialization of the auto reclosures function will be registered as an event “O→I Started” and will activate **InPro** output.

CB Ready setting has two options OCO or CO, if it is selected as OCO then **CBReady** input will be checked for initialization of first shot and will not be checked for subsequent shots. **CBReady** input will not be checked for initialization of any of the shots if ***CB Ready*** setting is selected as CO.

If **Block** input is high, the function will not activate.

The auto-reclose function can be set off by setting ***Shot*** to “0”. In case if no binary inputs are configured for indicating circuit breaker position, the setting ***Shot*** will automatically set to “0” (Auto Reclose not in use) to avoid any mal operation.

Auto reclose controller

Auto reclose controller is responsible for issuing necessary circuit breaker close command. Typical auto-reclose sequence is as follows: Once the function is initialized, it initiates the first auto-reclose shot. At the time of shot initiation, the timer for ***t1Cycle*** will start. Just 20ms before ***t1Cycle*** is elapsed, the function will check for the necessary conditions needed for issuing a reclosing command. The conditions checked are:

a. CB should be in open position
b. CB should be ready (sufficient energy available), **CB ready** signal should be monitored to activate **Close** output.
c. No protection trip is active (by any of the protection function i.e. I>, I>>, I>>>, Io>, Io>>, I2>, I2/I1> or External trip).

if ***CB Ready*** setting is selected as OCO then **CBReady** input will not be checked for issuing a reclosing command during first shot. In all other cases **CBReady** input will be checked for issuing a reclose command.

A reclosing command will be issued at the binary output **Close** if the above mentioned conditions are satisfied. The duration of **Close** shot can be set with setting ***Pulse tp***. The reclaim timer will start at the end of reclose time with the value set in ***tr***. If the network fault is cleared (i.e., no new trip signal received)

during reclaim time, the auto-reclosure is successful. If the circuit breaker is detected in closed position or if any trip signal is received from any of the protection functions before the ***t1Cycle*** is lapsed, autorecloser will activate the binary output **FinalTrip**, and will activate **Stopped** output. Activation of **Stopped** output is registered as an event "O→I Stopped".

However, if the network fault is not cleared, i.e., auto-reclosure is unsuccessful, and the protection based on autorecloser initiation logic trips the breaker before expiration of the reclaim time, the next shot will be initiated. At the time of shot initiation, the ***t2Cycle*** will start. The conditions need to be satisfied for issuing Shot 2...4 is same as that of for Shot 1. If network fault persists, i.e., auto-reclosure is unsuccessful then the next shot will be initiated. At the time of shot initiation, the ***t3Cycle*** will start, again the function will check for necessary conditions needed for issuing a reclosing command. If the network fault is not cleared, the ***t4Cycle*** will start. Even after the end of fourth reclosure, if the network fault has still not cleared, i.e., all selected auto-reclose shots have been unsuccessful, and protection based on autorecloser initiation logic trips the circuit breaker before expiration of set ***tr***. The auto-reclose function will activate **Blocked** output and circuit breaker will now remain in open position indicating unsuccessful auto reclosing. Also, unsuccessful auto reclosing after all the four shots (or as per defined by AR shot) should be registered as an event O->I FinalTrip.

Generation of circuit breaker closing pulse at end of each auto reclosures shot, should be registered as an event O->I Close 1…4.

Output **InPro** is activated when the auto-reclosure sequence is started (i.e., activated during reclose timer is active). This output will get deactivated once **Close** output is activated, or if due to some reason function goes into blocked mode i.e., **Blocked** output gets activated.

A condition may arise wherein closing of the circuit breaker does not happen after issuing a reclosing command within set ***tr***. In such case auto-reclose function goes to blocked mode. Once the function enters block mode it remains in blocked mode for time set equal to ***tb***. Auto reclosure entering blocked mode is registered as an event O->I Blocked.

The protection could be blocked by settings or via binary input of the relay. The activation of the Block input deactivates all outputs and resets the timers.

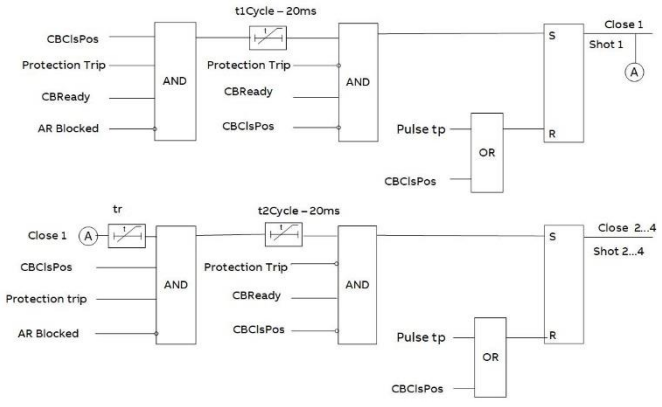


Figure 18: Auto reclose control shots 1…4

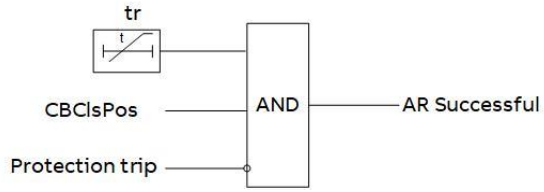


Figure 19: Reclose controller AR successful

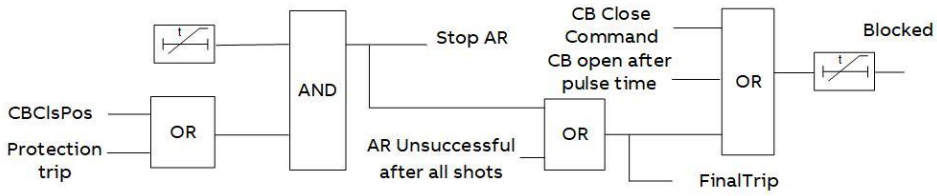


Figure 20: Reclose controller AR Blocked

6.1.5 Signals

Table 81: O -> I function input signals

Name	Type	Default	Description
I3P	Signal	-	Three phase current
CBReady	BOOLEAN	0=False	Circuit breaker ready information
External Trip	BOOLEAN	0=False	External trip input
CBClsPos	BOOLEAN	0=False	CB close position
Block	BOOLEAN	0=False	Block signal for blocking the output signals
CBReady	BOOLEAN	0=False	Circuit breaker ready information

Table 82: O -> I function output signals

Name	Type	Description
CB Opn Alm	BOOLEAN	CB open travel time exceeded set value
CB Cls Alm	BOOLEAN	CB close travel time exceeded set value
CB Opr Alm	BOOLEAN	Number of CB operations exceeds alarm limit
CB Opr LO	BOOLEAN	Number of CB operations exceeds lockout limit
CBAccPowAlm	BOOLEAN	Accumulated currents power (Iyt), exceeded alarm limit
CBAccPowLO	BOOLEAN	Accumulated currents power (Iyt), exceeded lockout limit
CB Alm	BOOLEAN	CB 'not operated for long time' alarm
CB Opn Sts	BOOLEAN	CB is in open position
CB Invd Sts	BOOLEAN	CB is in invalid position (not positively open or closed)
CB Cls Sts	BOOLEAN	CB is in closed position

6.1.6 Setting range of auto reclosing function

Table 83: Setting ranges O -> I function

Parameter	Values (Range)	Unit	Step	Default	Description
O->I Block	0=No 1=Yes			0=No	Block setting for blocking the output signals
Mode	1=Trip 2=Str Trip			1=Trip	Auto reclose initialization mode
CB Ready	1=OCO 2=CO			1=OCO	Type of CB ready signal available
Shot	0...4		1	1	Number of auto reclose cycles (0 = Auto-reclose not in use)
t1Cycle	0.20...300.00	s	0.01	0.50	Dead time for first auto reclose cycle
t2Cycle	0.20...300.00	s	0.01	0.50	Dead time for second auto reclose cycle
t3Cycle	0.20...300.00	s	0.01	0.50	Dead time for third auto reclose cycle
t4Cycle	0.20...300.00	s	0.01	0.50	Dead time for fourth auto reclose cycle
tr	1...300	s	1	1	Reclaim time
tb	1...300	s	1	5	Auto recloser block time.
Activate t	0.1...5.0	s	0.1	0.8	Time between General Start and General Trip for activation of O→I in Mode 2
Pulse tp	0.2...20.0	s	0.1	0.2	Auto reclose pulse time

6.1.7 Technical Data

Table 84: O -> I technical data

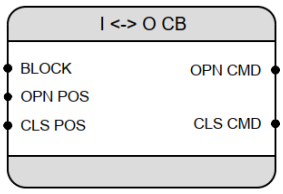
Description	Function	Value
Operate time accuracy	O -> I	±1.0 % of the set value or ±40 ms

6.2 Circuit breaker control

6.2.1 Identification

Function description	IEC 60617 identification	ANSI/IEEE C37.2 device number
Circuit breaker control	I <-> O CB	I <-> O CB

6.2.2 Function block



6.2.3 Functionality

Circuit breaker control function intended for circuit breaker control and status information purposes. The functions perform an execution command only if all conditions indicate that a switch operation is allowed.

6.2.4 Principle of operation

The **CB Opn Cmd** output is activated when the open command is given using binary input, via communication or from LHMI. The **CB Cls Cmd** output is activated when the close command is given using binary input, via communication or from LHMI).

The local/remote selection affects circuit breaker control. If local is selected, the opening and closing via communication is disabled and if remote is selected, the opening and closing via LHMI is disabled.

6.2.5 Signals

Table 85: I <-> O CB function input signals

Name	Type	Default	Description
Opn Pos	BOOLEAN	0=False	Signal for open position of apparatus from I/O
Cls Pos	BOOLEAN	0=False	Signal for close position of apparatus from I/O
Block	BOOLEAN	0=False	Block signal for blocking the output signals

Table 86: I <-> O CB function output signals

Name	Type	Description
Opn Cmd	BOOLEAN	CB open command
Cls Cmd	BOOLEAN	CB close command

6.2.6 Setting range of auto reclosing function

Table 83: Setting ranges O -> I function

Parameter	Values (Range)	Default	Description
I <-> O CB Block	0=No 1=Yes	0=No	Block setting for blocking the output signals

Section 7 General functions

7.1 Configurable logical gates

7.1.1 Functionality

Logical gates OR, AND and NOT can be used to form general combinatory expressions with Boolean variables.

The output of the logic gates activates when respective Boolean criteria is fulfilled. OR and AND logic gates have three inputs whereas NOT gate have single input.

7.1.2 Principle of operation

The relay has two instances of OR logic gate, three instance of AND logic gate and four instances of NOT logic gate. The inputs to these logic gates is freely configurable from predefined set of signals. The output of the logic gates can be further configured to connect at Binary outputs, Alarm LEDs, inputs of TON and TOFF timers and for blocking protection functions.

The output of the logic gate cannot be connected to its own input. For example, output of AND2 cannot be connected to any of the inputs of AND2.

The default value for any unconnected input for OR and NOT logic gate is FALSE, whereas it is TRUE for AND logic gate. While configuring NOT logic gate only one signal can be configured at its input, however while configuring OR and AND logic gate it is possible to configure multiple signals at the same input. When such multiple signals are connected to the same input they behave as OR gate at that input. For example, consider the configuration as show in Figure, the behavior of output for AND1 logic gate will be

Output = TRUE if {(I> Start **OR** I>> Start) **AND** BI 1} is satisfied.

Figure 21: Example of multiple input configured to AND Input 1

The logic gates will work even if only single input is connected, in such case output will follow the input. However, when more than one input is connected the logic gates behaves based on Boolean algebra.

It is also possible to register individual events for activation and deactivation of output for these logic gates, however this requires that in configuration for respective logic gates Events are set as “Yes”.

Table 84: Input signals list for logic gates

Signal name	available as Input to gates									
	AND1	AND2	AND3	OR1	OR2	OR3	NOT1	NOT2	NOT3	NOT4
	Protection signals									
All protection start (e.g. I>..)	•	•	•	•	•	•	•	•	•	•
All protection trip (e.g. I>..)	•	•	•	•	•	•	•	•	•	•
3Ith> Block close	•	•	•	•	•	•	•	•	•	•
BF Stage 1	•	•	•	•	•	•	•	•	•	•
BF Stage 2	•	•	•	•	•	•	•	•	•	•
BF Receive Trip	•	•	•	•	•	•	•	•	•	•
O→I Close	•	•	•	•	•	•	•	•	•	•
O→I In Progress	•	•	•	•	•	•	•	•	•	•
O→I Final Trip	•	•	•	•	•	•	•	•	•	•
O→I Blocked	•	•	•	•	•	•	•	•	•	•
TCS Fault	•	•	•	•	•	•	•	•	•	•
	Binary input signals									
Binary Input 1	•	•	•	•	•	•	•	•	•	•
Binary Input 2	•	•	•	•	•	•	•	•	•	•
Binary Input 3	•	•	•	•	•	•	•	•	•	•
Binary Input 4	•	•	•	•	•	•	•	•	•	•

Table 84: Input signals list for logic gates, continue

Signal name	available as Input to gates									
	AND1	AND2	AND3	OR1	OR2	OR3	NOT1	NOT2	NOT3	NOT4
	Control signals									
CB Open Command	•	•	•	•	•	•	•	•	•	•
CB Close Command	•	•	•	•	•	•	•	•	•	•
Unit ready	•	•	•	•	•	•	•	•	•	•
	Logic gates and timer signals									
AND1 Out		•	•	•	•	•	•	•	•	•
AND2 Out	•		•	•	•	•	•	•	•	•
AND3 Out	•	•		•	•	•	•	•	•	•
OR1 Out	•	•	•		•	•	•	•	•	•
OR2 Out	•	•	•	•		•	•	•	•	•
OR3 Out	•	•	•	•	•		•	•	•	•
NOT1 Out	•	•	•	•	•	•		•	•	•
NOT2 Out	•	•	•	•	•	•	•		•	•
NOT3 Out	•	•	•	•	•	•	•	•		•
NOT4 Out	•	•	•	•	•	•	•	•	•	

Table 84: Input signals list for logic gates, continue

Signal name	available as Input to gates									
	AND1	AND2	AND3	OR1	OR2	OR3	NOT1	NOT2	NOT3	NOT4
TON1 Out	•	•	•	•	•	•	•	•	•	•
TON2 Out	•	•	•	•	•	•	•	•	•	•
TON3 Out	•	•	•	•	•	•	•	•	•	•
TON4 Out	•	•	•	•	•	•	•	•	•	•
TOFF1 Out	•	•	•	•	•	•	•	•	•	•
TOFF2 Out	•	•	•	•	•	•	•	•	•	•
Note - • indicates signal available as input, available signals for mapping to gate depends on order code so few signals may not be available if order code does not have that function.										

All four instance of NOT logic gate can be configure from a single HMI screen whereas for OR and AND logic gates separate HMI screens available for different instances. By default none of the logic gates are configured to any signals.

The output of logic gates can be used for blocking protection function. To block a protection function using a particular logic gate one needs to configure that logic gate at Configuration/Blocking setting.

7.1.3 Examples of using logic gates with timers

The relay provides flexibility of configuring predefined set of signals with logic gates and timers to create a signal which can be further used as binary outputs or alarm LEDs or to block any protection function.

Consider an example where user wants to block low set overcurrent protection function (I>), if the binary input 3 AND start from Negative sequence overcurrent protection remains activated for 100ms. The requested logic can be configured as below.

AND1 logic gate and on delay timer TON1 configuration shall be as indicated below:

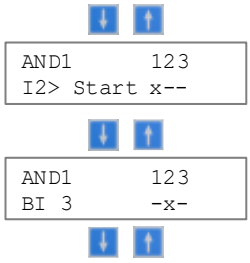


Figure 22: Example: AND1 configuration

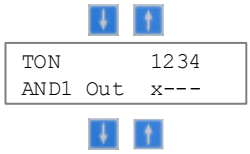


Figure 23: Example: TON1 configuration

TON1 delay can be set as 0.10 s under Configuration -> TON Delay setting.

7.2 On delay timer TON

7.2.1 Functionality

On delay timer TON can be used, for example, for time-delaying the output related to the input signal. The timer has a settable time delay. Once the input is activated, the output is set after the set *TON Delay* time setting has elapsed.

7.2.2 Principle of operation

The relay has four instances of On delay timer TON. The input to these timers is freely configurable from predefined set of signals. The output of the On delay timer TON can be further configured to connect at Binary outputs, Alarm LEDs, inputs of logic gates, inputs of TON and TOFF timers and for blocking protection functions.

However, the output of the delay timer cannot be connected to its own input. For example, output of TON3 cannot be connected to its own input.

The behavior of On delay timer is shown in figure 24.

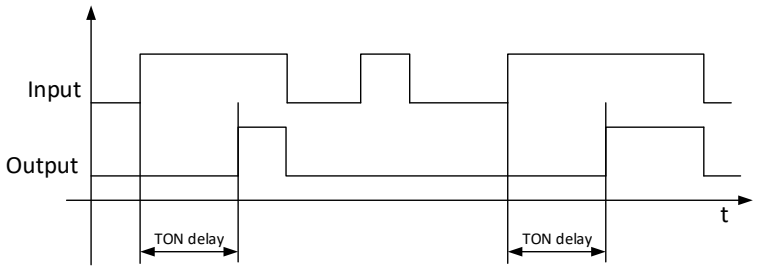


Figure 24 : Behavior of On delay timer TON

It is also possible to register individual events for activation and deactivation of output for these timers, however this requires that in configuration for respective timers Events are set as “Yes”.

Table 85: Input signal list for TON and TOFF timers

Signal name	available as Input to					
	TON1	TON2	TON3	TON4	TOFF1	TOFF2
	Protection signals					
All protection start (e.g. I>..)	•	•	•	•	•	•
All protection trip (e.g. I>..)	•	•	•	•	•	•
3Ith> Alarm	•	•	•	•	•	•
3Ith> Trip	•	•	•	•	•	•
3Ith> Block close	•	•	•	•	•	•
BF Stage 1	•	•	•	•	•	•
BF Stage 2	•	•	•	•	•	•
BF Receive Trip	•	•	•	•	•	•
O→I Close	•	•	•	•	•	•
O→I In Progress	•	•	•	•	•	•
O→I Final Trip	•	•	•	•	•	•
O→I Blocked	•	•	•	•	•	•
TCS fault	•	•	•	•	•	•
	Binary input signals					
Binary Input 1	•	•	•	•	•	•
Binary Input 2	•	•	•	•	•	•
Binary Input 3	•	•	•	•	•	•
Binary Input 4	•	•	•	•	•	•

Table 85: Input signal list for TON and TOFF timers, continue

Signal name	available as Input to					
	TON1	TON2	TON3	TON4	TOFF1	TOFF2
	Control signals					
CB Open Command	•	•	•	•	•	•
CB Close Command	•	•	•	•	•	•
Unit ready	•	•	•	•	•	•
	Logic gates and timer signals					
AND1 Out	•	•	•	•	•	•
AND2 Out	•	•	•	•	•	•
AND3 Out	•	•	•	•	•	•
OR1 Out	•	•	•	•	•	•
OR2 Out	•	•	•	•	•	•
OR3 Out	•	•	•	•	•	•
NOT1 Out	•	•	•	•	•	•
NOT2 Out	•	•	•	•	•	•
NOT3 Out	•	•	•	•	•	•
NOT4 Out	•	•	•	•	•	•
TON1 Out		•	•	•	•	•
TON2 Out	•		•	•	•	•
TON3 Out	•	•		•	•	•
TON4 Out	•	•	•		•	•
TOFF1 Out	•	•	•	•		•
TOFF2 Out	•	•	•	•	•	
Note - • indicates signal available as input, available signals for mapping to gate depends on order code so few signals may not be available if order code does not have that function.						

All four instance of On delay timer TON can be configure from a separate HMI screen. By default no signals are connected to any of the On delay timer. The output of On delay timer TON can be used for blocking protection function. To block a protection function using a particular On delay timer one needs to configure that timer at Configuration.

Table 86: Setting range for On delay timer TON

Parameter	Description	Range	Unit	Step	Default
TON Delay	On delay timer	0.00 … 64.00	s	0.01	0.00

Any input (runtime or configured) that is configured as input to TON module and if the timing of input is less than the TON timer configuration then the input will be ignored by the TON module. For example, Circuit Breaker Open / Close command through LHMI / Modbus command will not work with TON module with delay.

7.3 Off delay timer TOFF

7.3.1 Functionality

The Off delay timer TOFF can be used, for example, for a drop-off-delayed output related to the input signal. The timer has a settable time delay. Once the input is activated, the output is set immediately. When the input is cleared, the output stays on until the time set with *TOFF Delay* time setting has elapsed.

7.3.2 Principle of operation

The relay has two instances of Off delay timer TOFF. The input to these timers is freely configurable from predefined set of signals. The output of the Off delay timer TOFF can be further configured to connect at Binary outputs, Alarm LEDs, inputs of logic gates, inputs of TON and TOFF times and for blocking protection functions.

However the output of the delay timer cannot be connected to its own input. For example, output of TOFF1 cannot be connected to its own input.

The behavior of Off delay timer TOFF is shown in figure 12

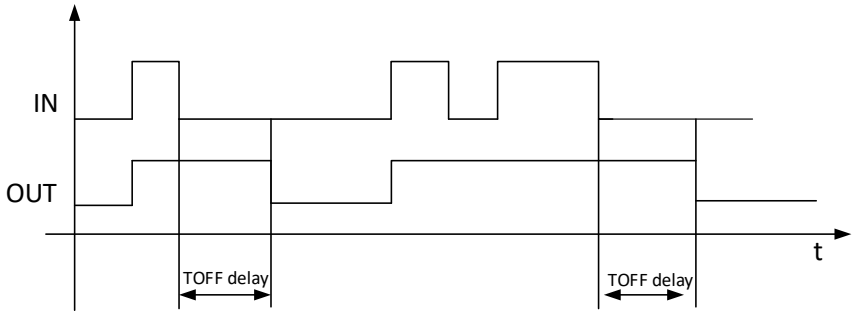


Figure 25: Behavior of Off delay timer TOFF

It is also possible to register individual events for activation and deactivation of output for these timers, however this requires that in configuration for respective timers Events are set as “Yes”.

Both instances of Off delay timer OFF can be configure from a separate HMI screen. By default, no signals are connected to any of the Off delay timer. The output of off delay timer TOFF can be used for blocking protection function. To block a protection function using a particular Off delay timer one needs to configure that timer at Configuration.

Table 87: Setting range for Off delay timer TOFF

Parameter	Description	Range	Unit	Step	Default
TOFF Delay	Off delay timer	0.00 … 64.00	s	0.01	0.00

7.4 Fault identification

7.4.1 Functionality

The fault identification function identifies that in which phase fault has occurred when phase overcurrent protection function (I>, I>> or I>>>) operates.

7.4.2 Principle of operation

The relay indicates in which phase(s) fault has occurred when phase overcurrent protection function operates. The individual phase fault identification can be made available over alarm LEDs and Binary outputs. It is also possible to identify multiphase faults. Events will get registered for the phase in which fault has been identified.

7.5 Configurable Binary Outputs

The relay has total six output contacts, two power contact and four signaling contacts. Except BO4 (reserved to IRF signaling purpose), remaining can be individually configured as either Inverted or Non-Inverted and also can be configure for following different operating modes:

1. **Pulse mode (P)**: In pulse mode, the binary output activates for a fixed duration of 200 ms when triggered.
2. **Self-reset mode (S):** In self-reset mode, the binary output follows the behavior of the triggering signal. The output remains in active state till trigger persists.
3. **Hold mode (H)**: Once output is activated, it will remain active even if trigger signal drops.

   Output can be reset by all possible reset input triggers
   - a local HMI by reset key combination
   - b Reset binary input
   - c Reset command from optional communication module via MODBUS RTU.
4. **Lockout mode (L)**: Once output is activated, it will remain active even if trigger signal drop.

Output can be reset only by

a Local HMI by reset key combination and
b Reset binary input.

All above mode also supports Inverted (I) operation.

Operating mode for binary output BO4 is fixed to “Non – inverted Self-Reset Mode.”

By default all binary outputs are NO (Normally Open).

During non-availability of power, binary output configured as Inverted will open and its status will be restored only after availability of power.

All binary outputs except BO4 can be triggered by different protection and control signals. It is possible to map same signal to trigger more than one binary output. The signals available for triggering binary outputs are as follows:

- Individual start of protection functions I>, I>>, I>>>, Io>, Io>> and Io>>>
- Individual trip of protection functions I>, I>>, I>>>, Io>, Io>> and Io>>>
- External trip (open) command available at binary input (configured for Breaker command operation) as well command available from MODBUS / IEC_103 or Front HMI
- External close command available at binary input (configured for Breaker command operation) as well command available from MODBUS / IEC_103 or Front HMI
- External user defined Signal 1 to Signal 3 available at binary input (configured via binary input menu)

Apart from above signals, the UNIT READY status is fixed configured at BO4 and cannot be changed. No other signals can be configured at BO4.

Table 88: Trip and signalling contacts

Binary output	Default configuration
BO1	Default as Trip1 contact for O/C and E/F. Under relay healthy condition, this contact will remain open. In the event of trip/breaker open command, it will close.
BO2	Default as Trip2 contact for breaker open output. In the event of fault (O/C and E/F) / breaker open command, it will close

Table 88: Trip and signalling contacts, continue

Binary output	Default configuration
BO3	Default as contact for Breaker close command. This contact will close, when breaker close command is received either from relay HMI or through communication.
BO4	Non-configurable signaling contact for Unit ready / internal relay fault indication. Under relay healthy condition this will be in close condition. During internal fault this will open
BO5	Default as signaling contact over current trip. In the event of phase faults (I>, I>> and I >>>) it will close and remain latched
BO6	Default as signaling contact earth fault trip. In the event of earth faults (Io>, Io>> and Io>>> it will close and remain latched

7.6 Configurable LED

The relay has total eight LED's for user defined signaling. These can be configured with the same signals as the binary output contacts. They can be individually configured for following different operating modes:

1. **Self-reset mode (S):** In self-reset mode, the LED follows the behavior of the triggering signal. The LED remains in active state till trigger persists.

2. **Hold mode (H)**: Once LED is activated, it will remain active even if trigger signal drops.

   LED can be reset by all possible reset input triggers

   a local HMI by reset key combination
   b Reset binary input
   c Reset command from optional communication module

All eight-user defined LED's can be triggered by different protection and control signals.

Default configuration of the programmable LEDs is indicated in Table 89.

Table 89: Programmable LEDs default configuration

LED	REJ601/REF601 B-C-D	REF601_F	REM601_B,C & F
LED1	Trip Ip	Trip Ip	Trip Ip
LED2	Trip Io	Trip Io	Trip Io
LED3	TCS Fault	Trip 3Ith>	Trip 3Ith>
LED4	Spare	Trip I2>, I2/I1>	Trip I2t n<
LED5	Spare	Trip 3I>/IoBF	Trip I2>,I2/I1>,I2R>
LED6	Spare	CB Mont. Alarm	Restart Inhbt.
LED7	Spare	TCS Fault	TCS Fault
LED8	Spare	Spare	Spare

Table 89: Configuration of LED indications for fixed LEDs

LED	Default configuration
Ready (Green)	LED indicates that relay has no internal fault and is powered up for desired functionality. It glows after internal health check after power on and continue to glow until power goes off or there is internal fault in the relay
Start (Yellow)	Start LED for any protection function start
Trip (Red)	Common trip LED for overcurrent and earth fault trip indication

7.7 Configurable Binary Inputs

The relay has four binary inputs BI1 to BI4. Each binary input can be configured individually and supports various features. Binary input BI1 is fixed for blocking operation, whereas BI2 to BI4 are used for other than blocking operation. However, for binary input BI2 to BI4, user at a time can configure one operation per binary input i.e., once any of the binary input BI2 to BI4 is configured for a particular operation, it is not available for other operation.

1. Blocking: Binary input BI1 is dedicate for blocking protection and control function. User depending on his need can configure this binary input to block individual protection functions viz., I>, I>>, I>>>, Io>, Io>> and Io>>> as well as to block breaker opening and closing command and trip circuit supervision e.g. with open circuit breaker position.

The function configured for blocking will remain in block state until BI1 is active.

BI1 configured to block breaker opening and closing command will block command received from local HMI or MODBUS or binary input.

2. Circuit Breaker Status: Binary inputs BI2 to BI4 can be configured to indicate the status of circuit breaker i.e. breaker open or breaker close or breaker in maintenance. The available status information is sent to MODBUS communication.

3. Circuit Breaker Command: Binary inputs BI2 to BI4 can be configured to provide external (remote) breaker open or breaker close command.

   For routing circuit breaker opening or closing command from binary input, it is necessary that user also configures binary output to receive respective command.

4. Reset: Binary input BI2 to BI4 can be configured for reset operation. When the rising edge is detected, the relay resets all the protection and control functions (all internal timers are reset). It also resets the Start, Trip, Trip Ip, Trip Io and de-latches the binary output.

5. Trip Circuit Supervision: Binary input BI2 is used to receive the invalidity of trip circuit. No other binary input can be used for this purpose.

6. To the Binary input BI2 to BI4 also user defined signals could be configured, called Signal 1 to Signal 3. This Signals can be routed / connected in the binary output configuration menu directly to binary output contacts and additionally in the LED configuration menu to 8 LED's.

All binary inputs BI1 to BI4 also support Inverted (I) operation.

Table 90: Binary inputs

Binary input	Default configuration
BI1	Default configured as UNBLOCK
BI2	Default configured as TCS
BI3	Default configured as external trip command to breaker
BI4	Default configured as reset command for resetting indications and contacts

7.8 Breaker control and Trip command operation

Relay supports breaker control operation. The control operation can be done from control push-buttons provided on relay front, from remote via communication or from signals wired to relay binary inputs duly configured for control operation.

Section 8 Use of LHMI

8.1 Overview

Figure 26: Local HMI of relay

The local HMI of the relay contains following elements:

- LED indicators
- LCD display
- Navigation buttons / keys

The LHMI is used for setting, monitoring and controlling.

8.1.1 LED's

LED's displays following information respective status

Ready:	Green LED	
Start:	Yellow LED	Glows after any start of a protection function
Trip:	Red LED	Glows after any trip of protection function
LED 1…8	Red LED	Glows as per functionality configured

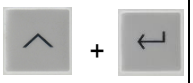
8.1.2 LCD display

The relay has an integrated 128x64 LCD display and 3×3 matrix keypad which supports English, Chinese, German, French, Italian, Spanish, Portuguese and Turkish languages.

8.1.3 Navigation

The LHMI keypad consists of push buttons which are used to navigate in different views or menus. With control push buttons the open or close commands can be given to breaker. The push buttons are also used to acknowledge alarms, reset indications and reset of lockout functions.

Table 91: LHMI push buttons

Key Picture	Key Name	Description
	Up	Used for incrementing of parameter value while editing, or provides up level selection of menu item.
	Down	Used for decrementing of parameter value while editing, or provides down level selection of menu item.
	Back	Used for going to higher level of menu item from its lower level submenu.
	Next	Used for going to lower level submenu from higher level menu.
	Enter	Used for saving of edited parameter value.
	Escape/Cancel	a) Used for discarding changed parameter value in edit mode b) Used for going back to main menu from any level of menu navigation. 2nd pressing “ESC” will lead to default view.
	Reset	Press key combination Up and Enter key together to reset the relay from LHMI as well to reset trip LEDs
	Edit	Press key Enter to edit the relay parameter from LHMI
	Breaker Close	Hotkey for providing Breaker Close command.
	Breaker Open	Hotkey for providing Breaker Open command.

8.1.4 Authorization

To protect the relay from unauthorized access and to maintain the integrity of information, the relay is armed with a three level, role based user authentication system with individual password for operator, engineer and administrator level.

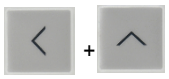
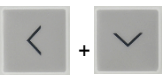
To access the relay by any category of user, supported two different type of password protection as listed below:

- Simple password protection (Default) – Achieve by two key combinations as available in earlier release and earlier. The password shall be set by selecting arrow symbols in password configuration menu.
- Alpha-numeric password protection – Achieve by four letter passwords. The password shall be set in password configuration menu by the allowed character set for password i.e. capital letters from ‘A’ to ‘Z’, number ‘0’ to ‘9’ & underscore ‘_’ as a special character.

Type of password protection shall be distinguished by the way they are set in password configuration menu.

The rights per user category and their default password are listed in following table:

Table 92: User authorization and default password

Sr No.	Features	Operator Level User	Engineer Level User	Admin Level User
1	Menu viewing	Yes	Yes	Yes
2	Protection settings editing	-	Yes	Yes
3	COM Board parameter editing	-	Yes	Yes
4	Perform test	-	Yes	Yes
5	Relay Configuration editing	-	-	Yes
6	Password editing	-	-	Yes
7	Simple password protection: Password key combination (Default combination for simple password method)	Other than Admin/setting	 Back + Up	 Back + Down
8	Alpha numeric password protection:	Other than Admin/setting	Capital letters from ‘A’ to ‘Z’, number ‘0’ to ‘9’ & underscore ‘_’ as a special character	Capital letters from ‘A’ to ‘Z’, number ‘0’ to ‘9’ & underscore ‘_’ as a special character

The selection of user category is done via password at entering the main menu.

At default view, whenever any key is pressed, for 3 second the Configuration status screen appears followed by a password request screen. Password needs to be entered here as indicated in Sr. no. 7 in case it is configured as Simple password and should be as indicated in Sr. no. 8 in case it is configured as alpha-numerical password.

In case of wrong password being entered by the user, automatically the operator user category is selected.

The selected category will pop up for one second before the main menu is shown.

The sequence looks as follow:

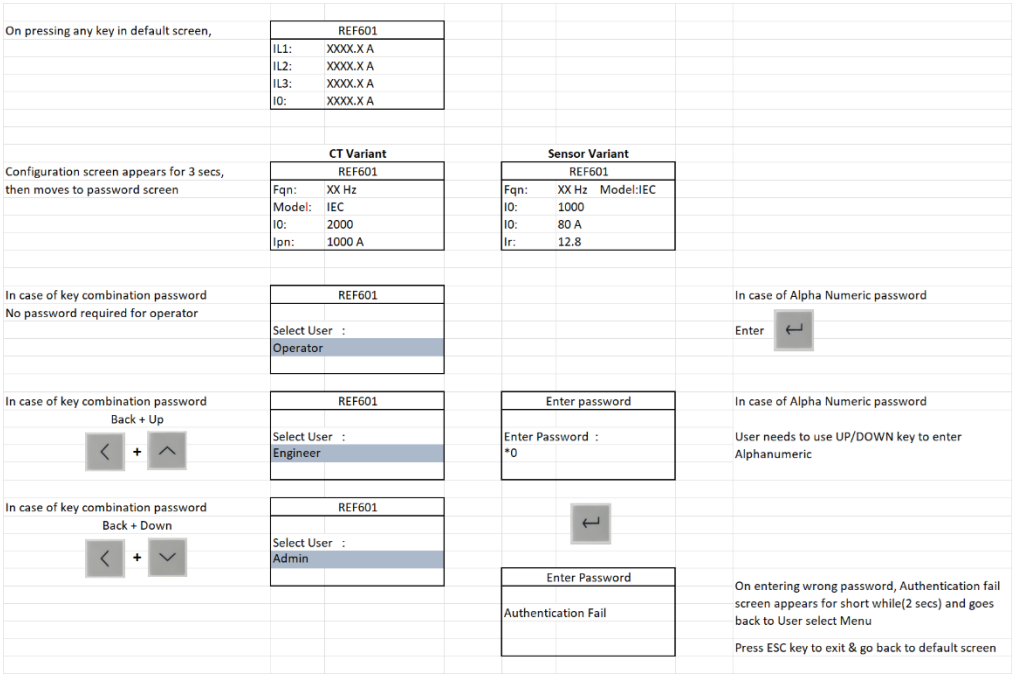


Figure 27: Login process of relay

Password configuration

The password could be changed under the Main Menu -> Authorization. In authorization menu based on the password type, password can be set for both engineer level and admin level. In edit mode, cursor position can be set

by  or  arrow key and allowed password submenu can be selected by  or  arrow key for simple password setting.

For alpha-numeric type, password can be set for both engineer level and admin level. In edit mode, cursor position can be set by LEFT or RIGHT arrow key and allowed password character can be entered using UP or DOWN key. Finally, by ENTER key and commit the change, new

password can be set. The alpha-numeric password editing is shown in figure 28.

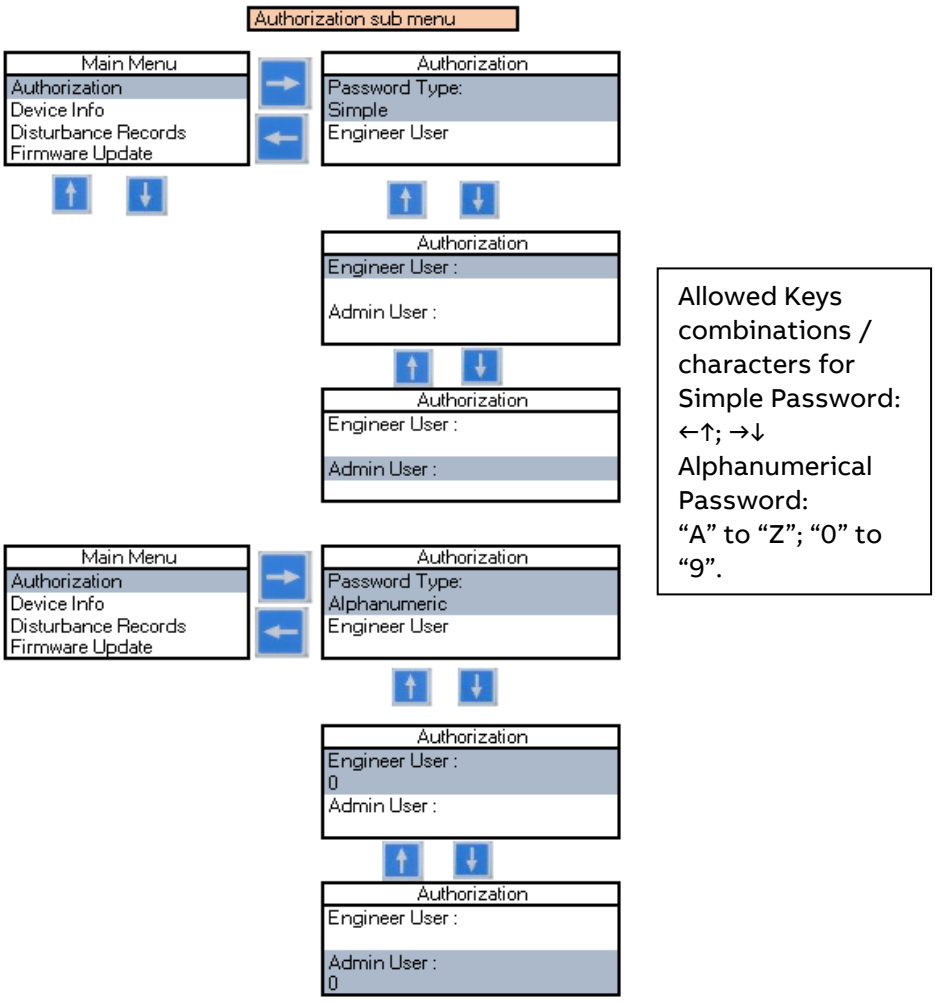


Figure 28: Password configuration in relay

8.1.5 Configuration status

At default view, whenever any key is pressed, for 3 second the Configuration status screen appears followed by a password request screen. The default screen is indicated in figure 29.

REF601	
Fqn:	XX Hz
Mode:	IEC
I0:	20.0
Ipn:	20.0 A

Figure 29: Configuration status display screen

Configuration status screen (3 sec)

1. Frequency: 50 or 60 Hz
2. Mode: Selected standard (IEC, ANSI, CN, CEI)
3. I0: 20..9999 (Primary current of external earth CT)
4. Ipn: 20..9999 (Primary current of phase CT)

8.2 LHMI menu navigation

8.2.1 Default screen

The default view of the relay displays the largest phase current and earth current which is indicated in Fig. 30. The relay returns to default screen after 3 minutes if no key is pressed.

Current values are displayed in this view for IL1, IL2, IL3 phase currents and earth current in “A”.

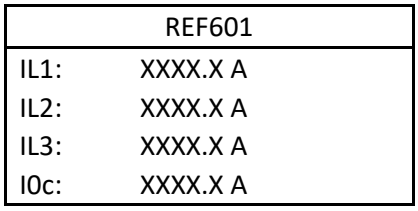


Figure 30: Default screen of relay

8.2.2 Main menu

The main menu appears after entering the password with the user rights depended on the entered password. Following view shows the main menu of the relay.

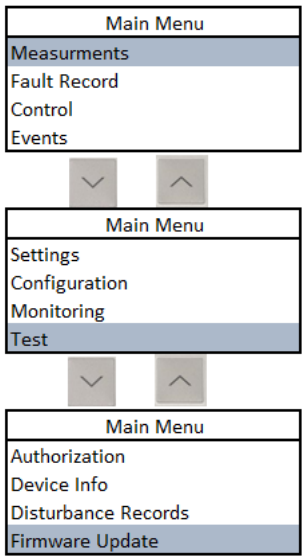


Figure 31: Main menu of relay

8.2.3 Menu – Measurement

Submenu Measurement shows analogue input values as primary or as secondary values according to primary and secondary current of current transformer selected in the submenu configuration – settings.

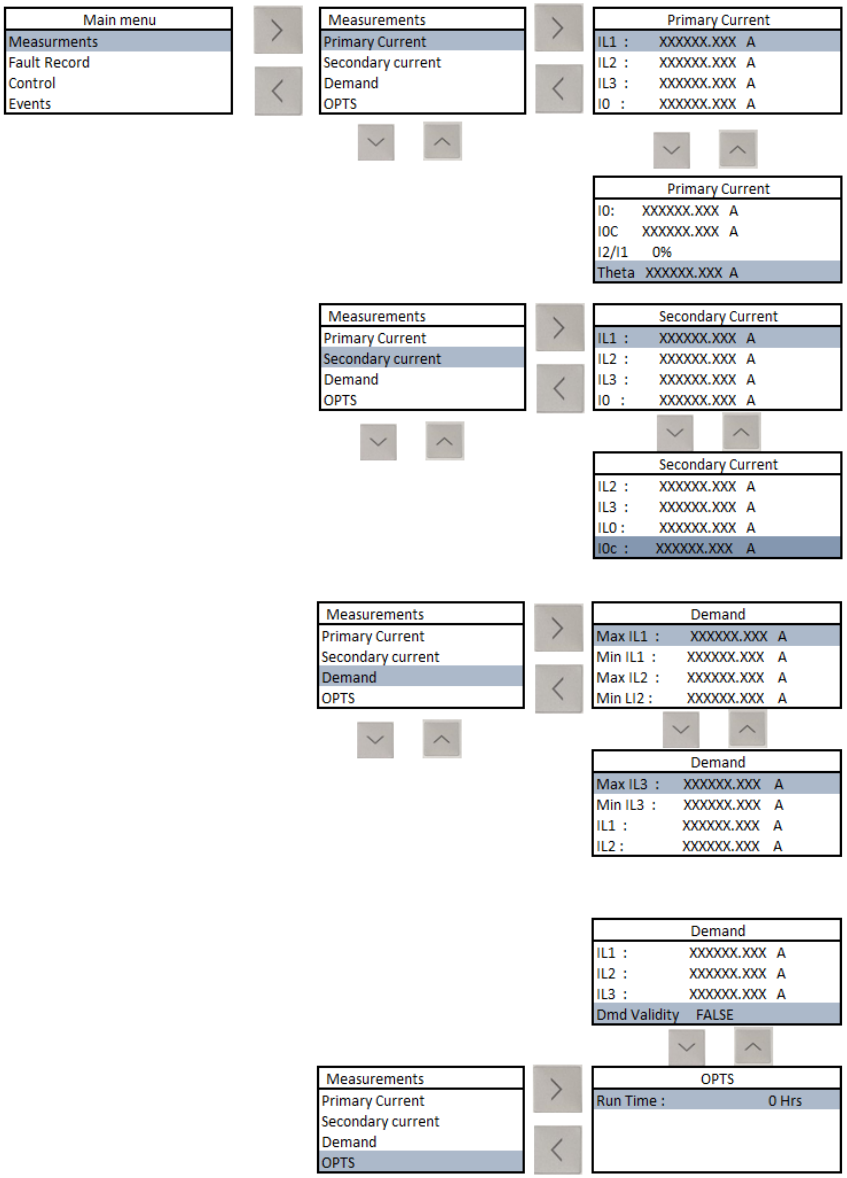


Figure 32: Measurement menu of relay

8.2.4 Menu – Fault record

Submenu fault record shows under recorded current the fault records for the last twenty protection trips and the values for trip counters segregated in phase fault trips and earth fault trips.

For viewing the user should follow the figure 33.

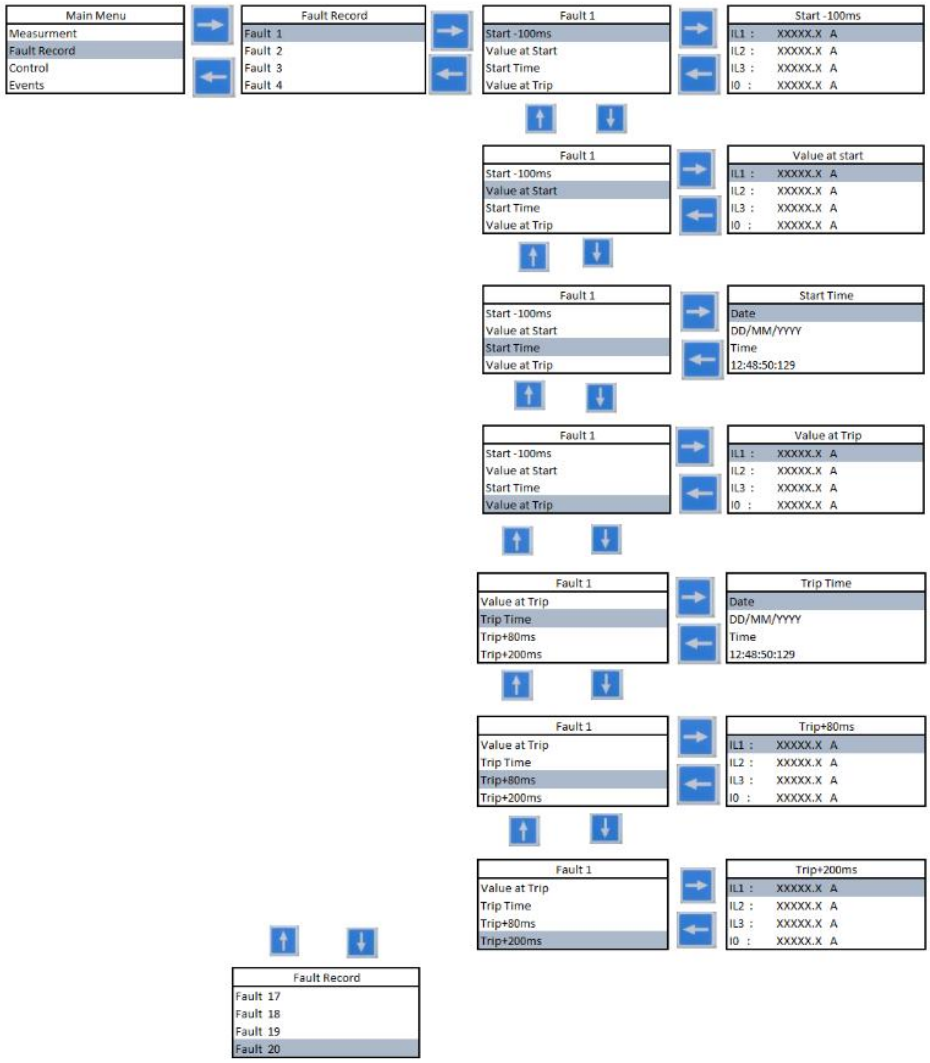


Figure 33: Fault record data menu of relay

8.2.5 Menu - Events

Submenu Events shows events 1 – 100 in internal events and events 1 – 250 in external events with details in respective submenu.

Event 1 will always contain data of most recent event and event 250 (external) and event 100 (internal) would be the oldest.

The event menu can be access as indicated in figure 34.

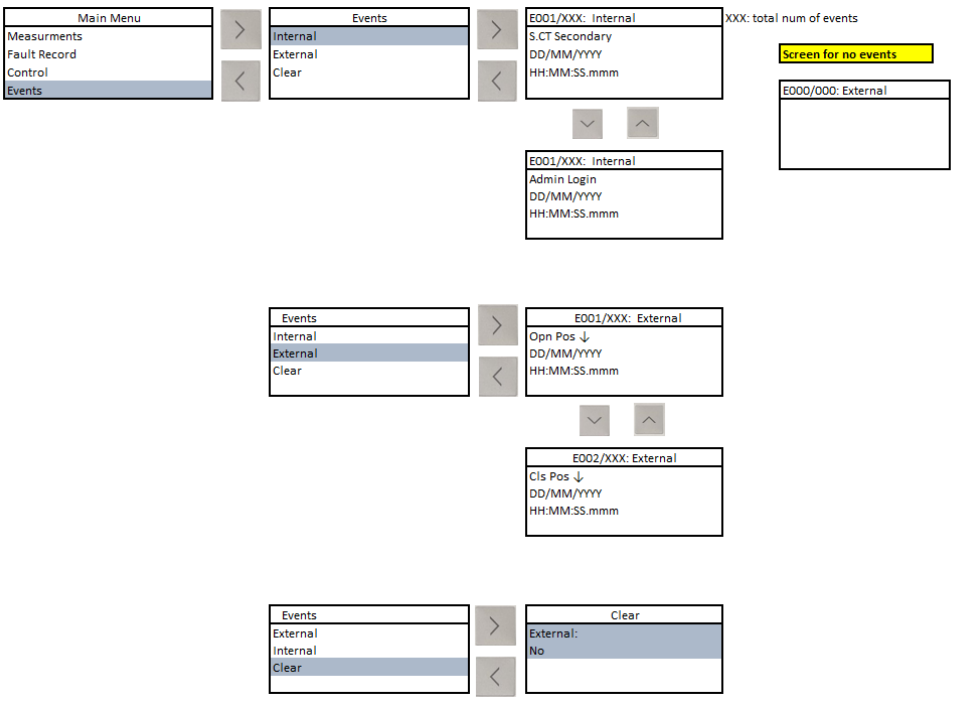


Figure 34: Event menu of relay

8.2.6 Menu – Setting

Submenu Settings and respective submenus shows and allows depending on the user right to change all protection parameters and communication parameters.

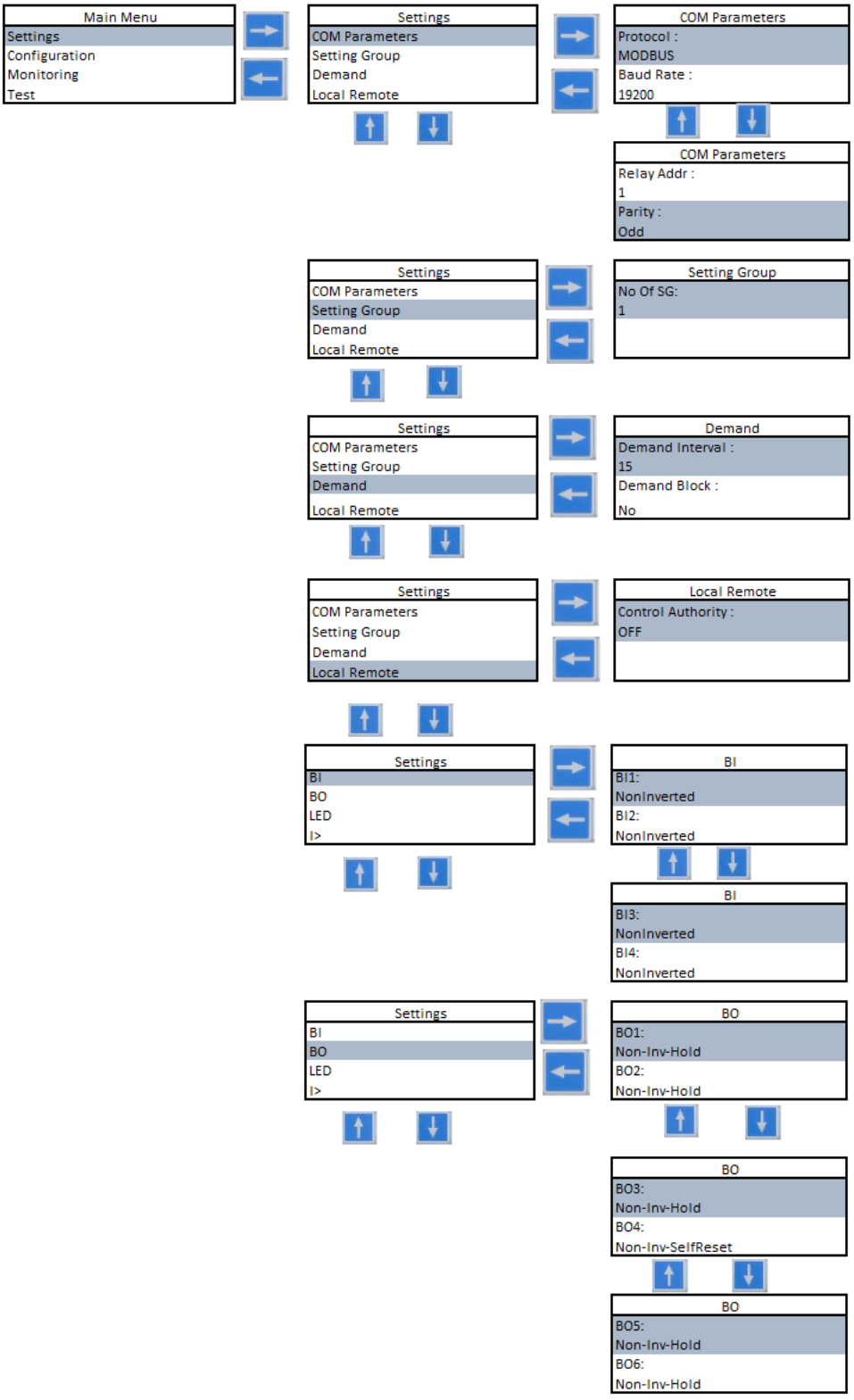
Remark:

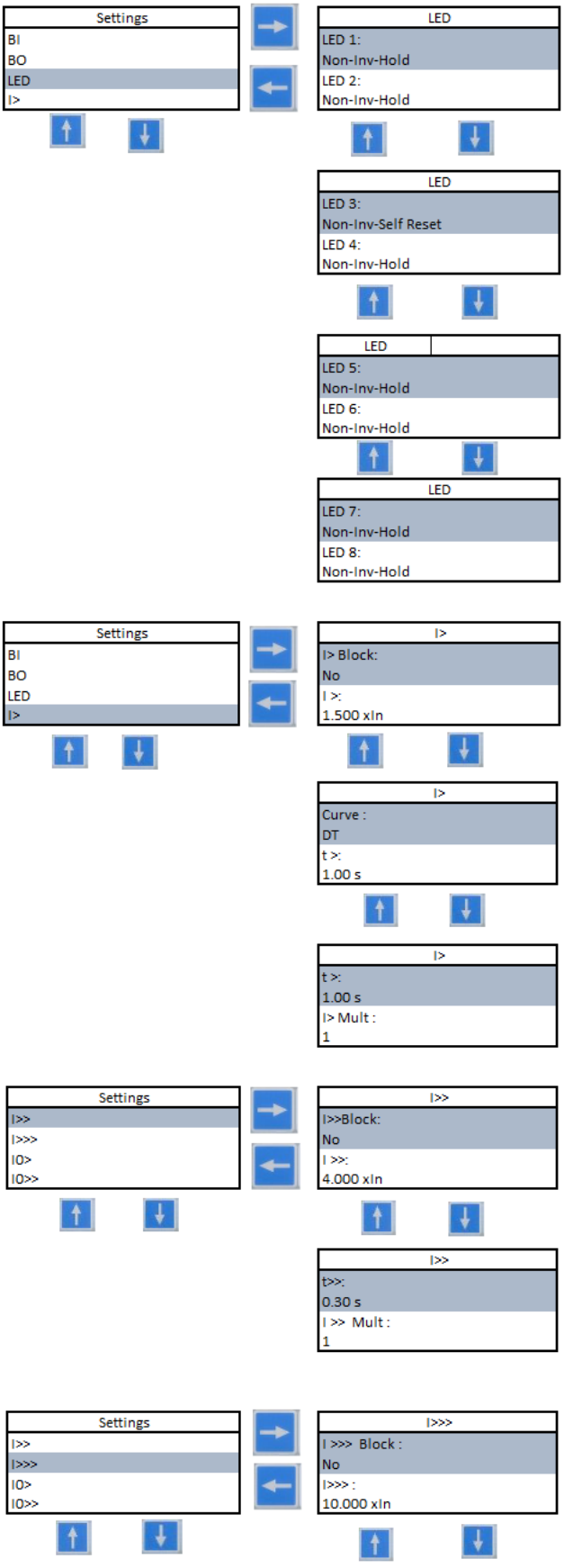
- To modify settings needs user rights of Setting or Admin user
- To modify selected setting start with key 
- To save changed setting with key 
- To discard and exit a modified setting with key 

- View of time parameters of I> and I0> (k / t> respective k/t0>) are depending on the selection of the curve selection of its function.

If COM Admin Level is YES, then relay configuration parameter is allowed to change through MODBUS RTU.

Following menu structure is used to navigate to the respective settings:




Settings
BI
BO
LED
I>
LED
LED 1:
Non-Inv-Hold
LED 2:
Non-Inv-Hold
LED
LED 3:
Non-Inv-Self Reset
LED 4:
Non-Inv-Hold
LED
LED 5:
Non-Inv-Hold
LED 6:
Non-Inv-Hold
LED
LED 7:
Non-Inv-Hold
LED 8:
Non-Inv-Hold
Settings
BI
BO
LED
I>
I>
I> Block:
No
I >:
1.500 xIn
I>
Curve :
DT
t >:
1.00 s
I>
t >:
1.00 s
I> Mult :
1
Settings
I>>
I>>>
I0>
I0>>
I>>
I>>Block:
No
I >>:
4.000 xIn
I>>
t>>:
0.30 s
I >> Mult :
1
Settings
I>>
I>>>
I0>
I0>>
I>>>
I >>> Block :
No
I>>> :
10.000 xIn

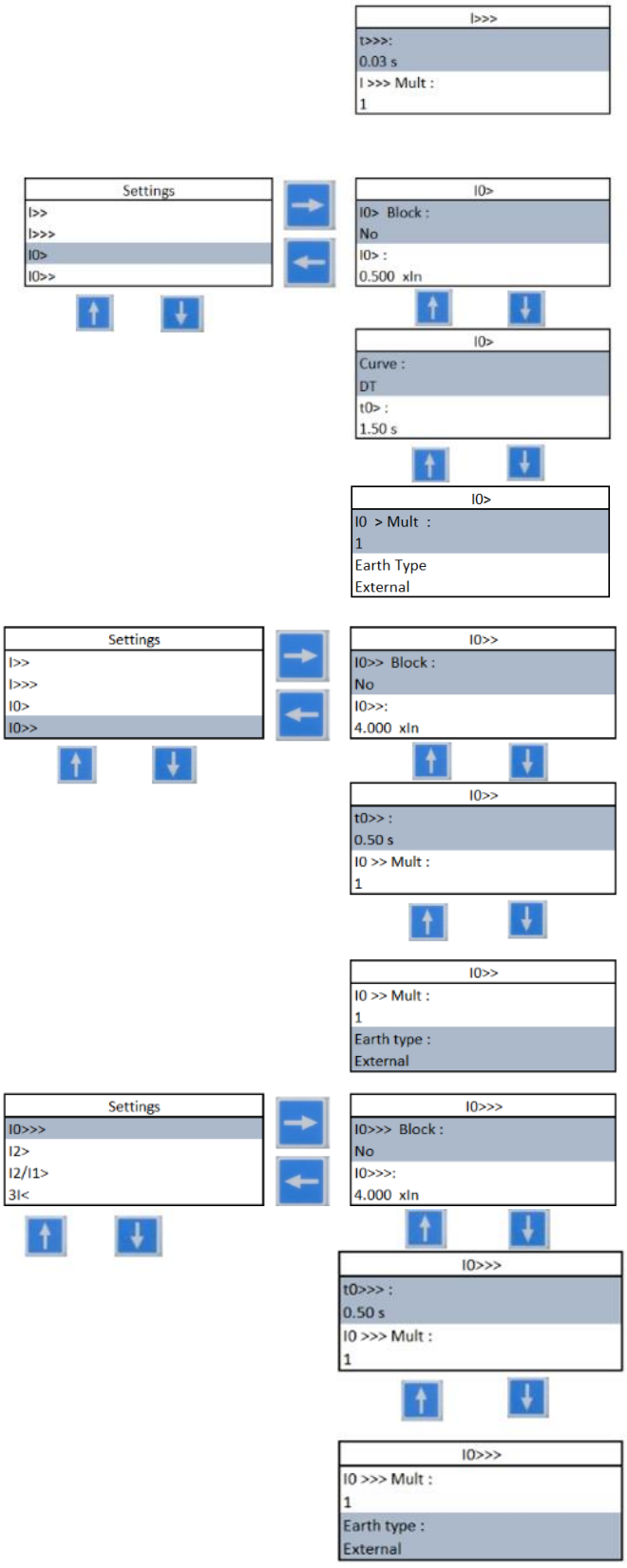


Figure 35: Setting menu of relay

For other protection settings menu please refer detailed menu navigation document.

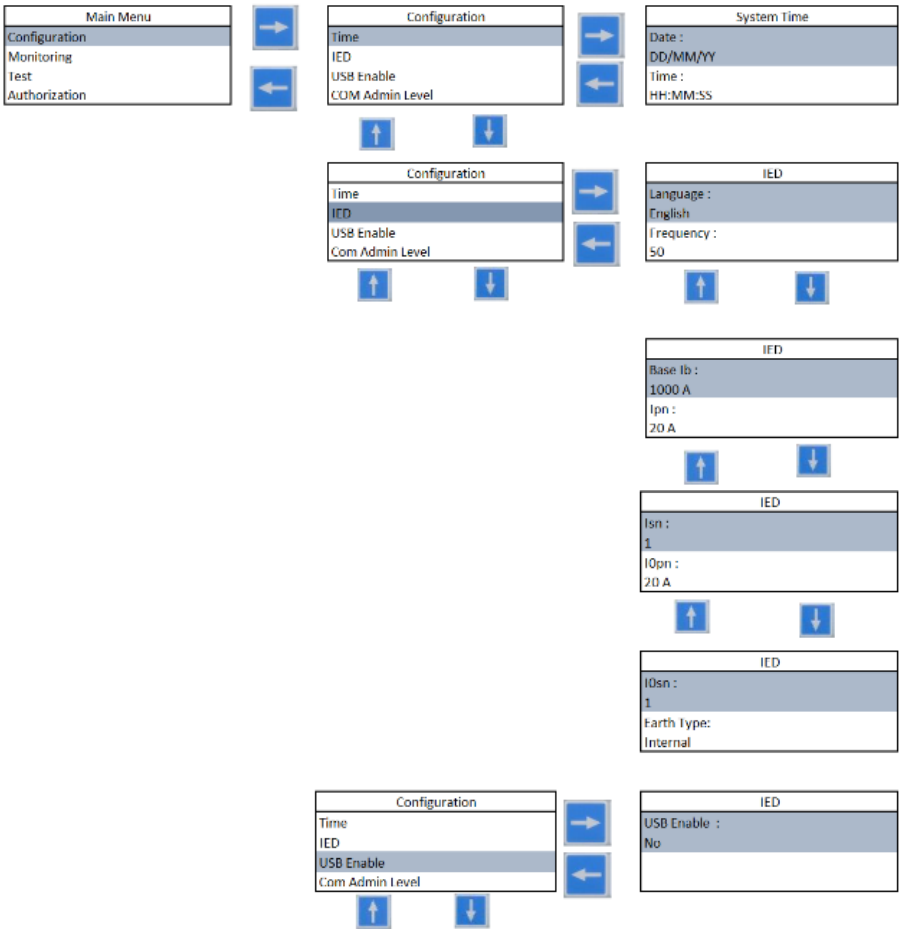
8.2.7 Menu – Configuration

- Submenu Configuration and respective submenus shows and allows depending on the user right to change
- Blocking of particular protection stage or remote trip activation
- Relay configuration settings like earth current calculation method
- Inrush protection related settings
- BI, BO, LED, logic gates and function to functions configurations
- Selection for loading factory settings (protection parameters only)

Remark:

- To modify configuration settings needs user rights of Admin user.
- To modify selected setting start with key 
- To save changed setting with key 
- To discard and exit a modified setting with key 

Following menu structure is used to navigate to the respective configuration settings:



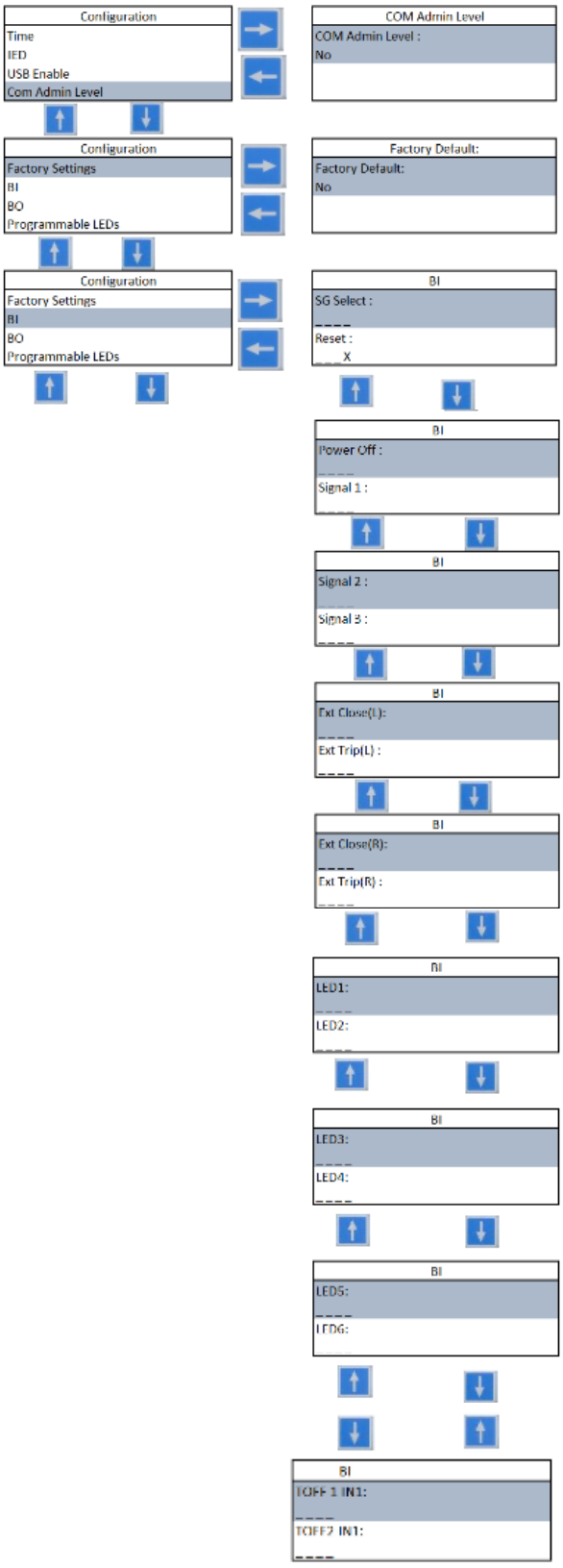


Figure 36: Configuration menu of relay with its submenu

For other configuration settings please refer detailed menu navigation document.

8.2.8 Menu – Test

Submenu Test and respective submenus shows and allows depending on the user right to perform several kinds of tests to verify the relay functionality:

- **Test Mode:** Test Mode feature that allows activation and deactivation of test mode.
- **Hardware:** Enables Internal Hardware Tests, which includes LCD check, Keyboard check and LEDs check. User can initiate checks using interactive menu selection. Enables testing of all output contact to test the complete external circuit initiated by the output contact. Once test BO is selected, output will be operated for around 2 secs. Once LED test is selected, three rounds of LED toggling checks will be performed.
- **Functional:** Enables each protection function tests by loading fixed analog values for five seconds and ignoring actual analog inputs. User can test all protection stages and accordingly its relay configuration by having a simulated analog value for 5 seconds.

The details of functions available in test mode are described as under the respective section.

Remark: To modify settings needs user rights of Engineer or Admin user.

Following menu structure is used to navigate to the respective test settings:

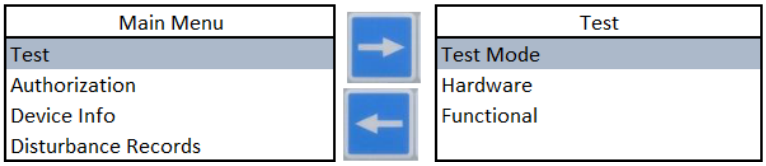


Figure 37: Test menu of relay with its submenu

8.2.8.1 Sub Menu – Test mode

Test mode function is used for activation and deactivation

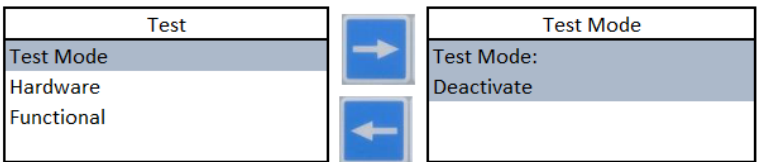


Figure 38: Test mode menu of relay

8.2.8.2 Sub Menu – Hardware

Following functionalities can be tested through this menu

- LCD Test
- Keyboard Test
- LED Test
- BO Test

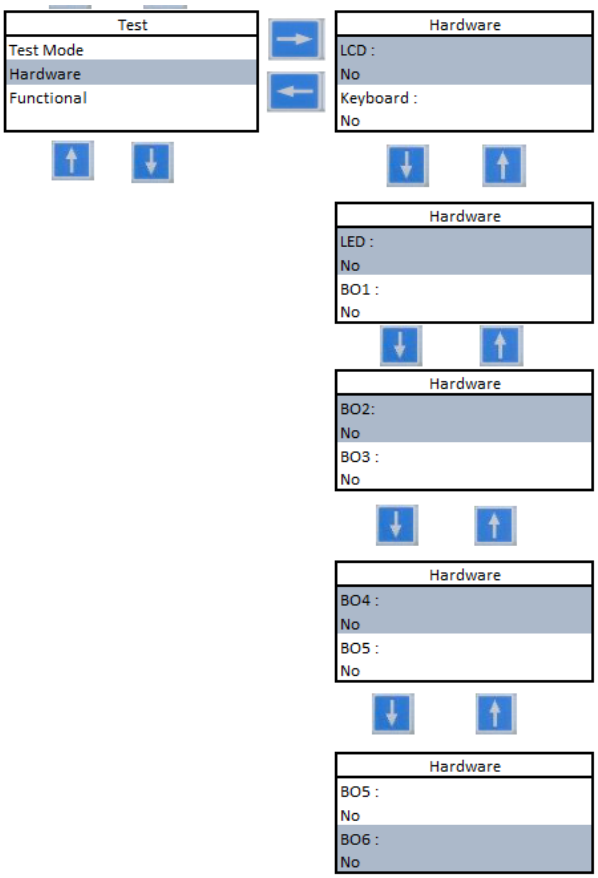


Figure 39: Hardware test menu of relay

During each hardware test wherever confirmation from user is asked to continue test sequence, if no selection from user, automatically after 5 sec timeout test sequence will move to next screen.

8.2.8.3 Menu – Functional

Submenu functional test allows performing simulation of each protection function by giving a test current to the selected protection function.

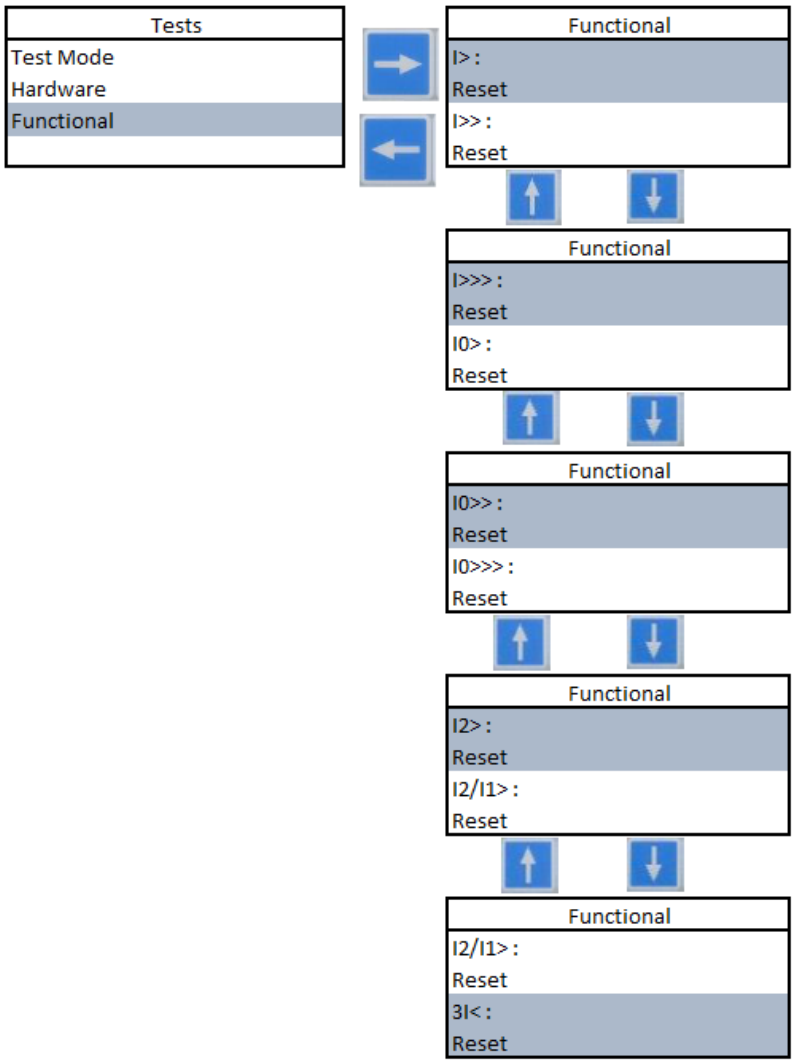


Figure 40: Functional test menu of relay with its submenu

During functional test it is possible to activate the protection start and protection trip, the same can be deactivated after test.

8.2.9 Menu - Authorization

This menu provides the password change facility for the different access levels. Only Admin can change the password of the other authorization level. Activate enter menu for a particular user and edit field, then user can then enter new password and commit the data to save the new password. Changing passwords for both types i.e. simple and alpha-numeric is supported. The default mode of password will be simple type i.e key combinations. Only two key combinations can be used for password entry/selection.

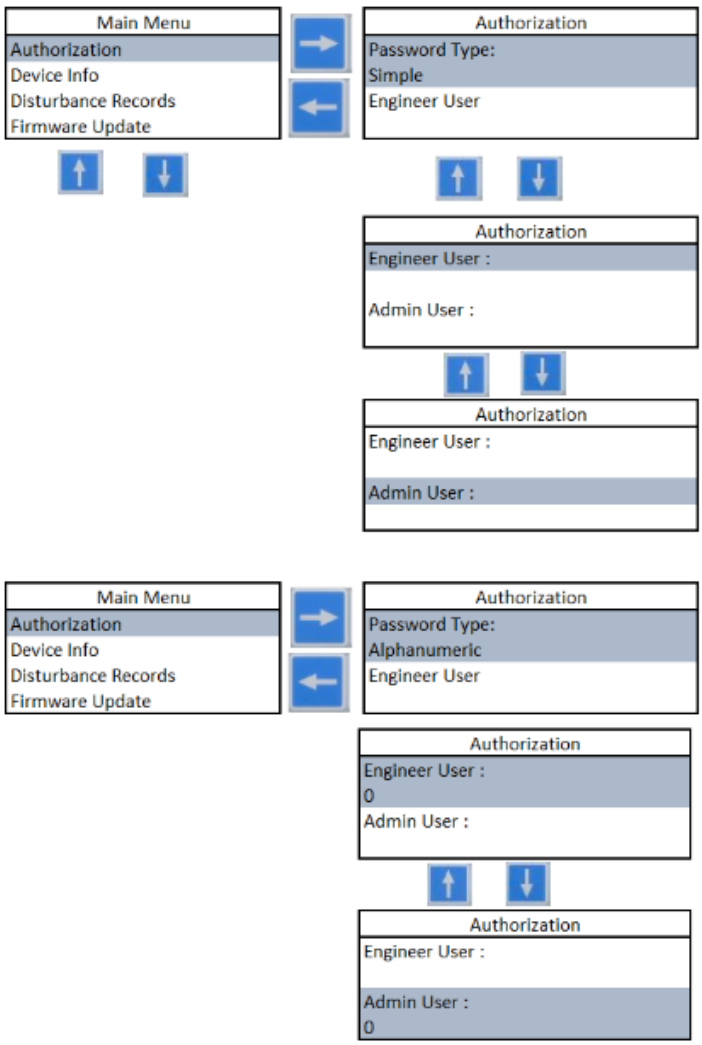


Figure 41: Authorisation menu

8.2.10 Menu - Device information

This menu provides information regarding the product name selected, software version and sub version, application configuration, model name, relay order code and serial number being presently configured into the product.

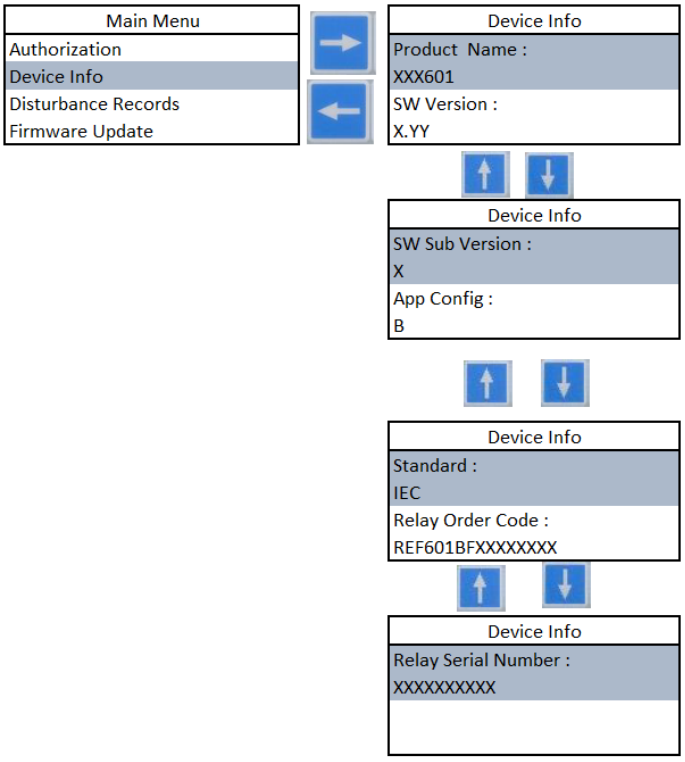


Figure 42: Version information menu

Section 9 Installation

9.1 Unpacking and inspecting the device

REF601 / REJ601/ REM601 products, although of robust construction, require careful handling prior to installation on site. The delivered products should always be examined to ensure that no damage has been sustained during transit.

Remove transport packing carefully without force. Appropriate tools need to be used.

Check the relay for transport damages. If the product has been damaged, a claim should be made to the transport contractor and the local representative of ABB should be promptly notified. Compare the type designation of the product with the ordering information to verify that you have received the right product.

Electrostatic discharge (ESD): The products contain components that are sensitive to electrostatic discharge. The electronic circuits are well protected by the relay case and therefore the relay casing should not to be removed.

9.2 Storage

On receipt, the apparatus must be carefully unpacked and checked as described under chapter 6.1. Should installation not be carried out immediately, the apparatus must be repacked using the original packing material. Should the original packing material no longer be available, store the apparatus in a dry, dust-free, covered area which is non-corrosive and has a temperature of between – 40 °C and + 85 °C.

9.3 Checking environmental condition and mounting space

The mechanical and electrical environmental conditions at the installation site must be within the limits described in the technical data.

- Avoid installation in dusty, damp places.
- Avoid places susceptible to rapid temperature variations, powerful vibrations and shocks, surge voltages of high amplitude and fast rise time, strong induced magnetic fields or similar extreme conditions.
- Check that sufficient space is available for wiring and mounting the relay.
- To allow access for maintenance and future modifications a sufficient space is needed in front and at side of the relay.
- Suitably qualified personnel with adequate knowledge of the apparatus must carry out all the installation operations.

- The relay should be disconnected before carrying out any work on relay.
- While communicating with Serial RS-485 port on the rear of the relay - ensure that the RS-485 to USB converters used are having proper Earthing. If this is not taken care, it may lead to detection of unexpected current.

9.4 Relay wiring

The connection wiring to the relay should be made by using single strand wire or stranded wire with the use of insulated crimp terminal to maintain the insulation requirements. The wire with below indicated cross-section should be used for control wiring:

- 0.2 - 2.5 mm^2 finely stranded
- 0.2 - 2.5 mm^2 single-core
- 2 x 0.2 – 1.0 mm^2

For short circuit terminals for conventional CT the wire with below indicated cross-section should be used for wiring:

- 0.5 – 6.0 mm^2 finely stranded
- 0.5 – 6.0 mm^2 single-core
- 2 x 0.5 - 2.5 mm^2

9.5 Relay mounting and dimensions

All the mounting elements are integrated in the relay. The relay has been equipped with in-build press fit mechanism.

The space requirement of mounting:

Overall dimensions (H x W x D)	: 160 x 130 x 151.5 mm
Cutout dimensions (H x W)	: 151.5 ± 0.5 x 121.5 ± 0.5 mm
Depth behind the panel	: 151.5 mm
Weight	: 1.43 kg

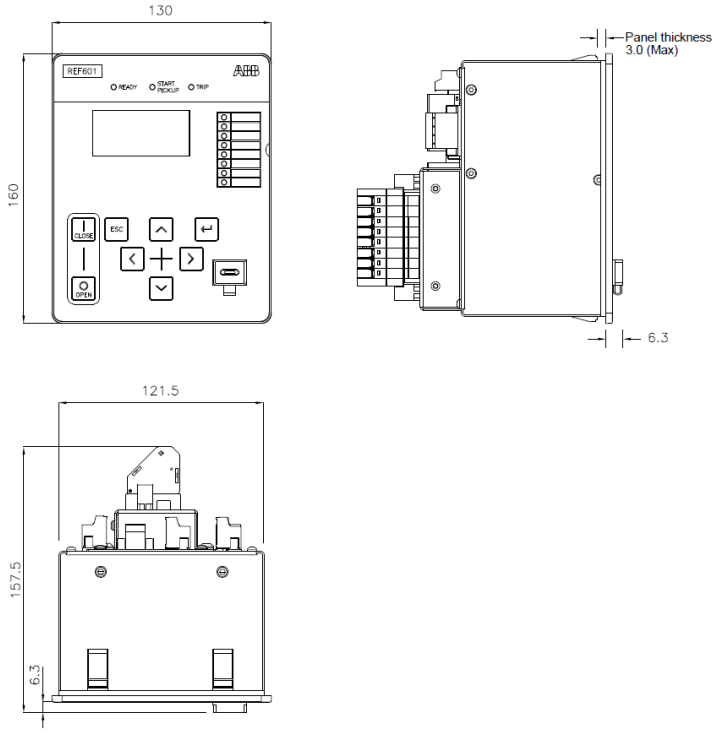


Figure 33: Overall mounting dimension relay with CT version

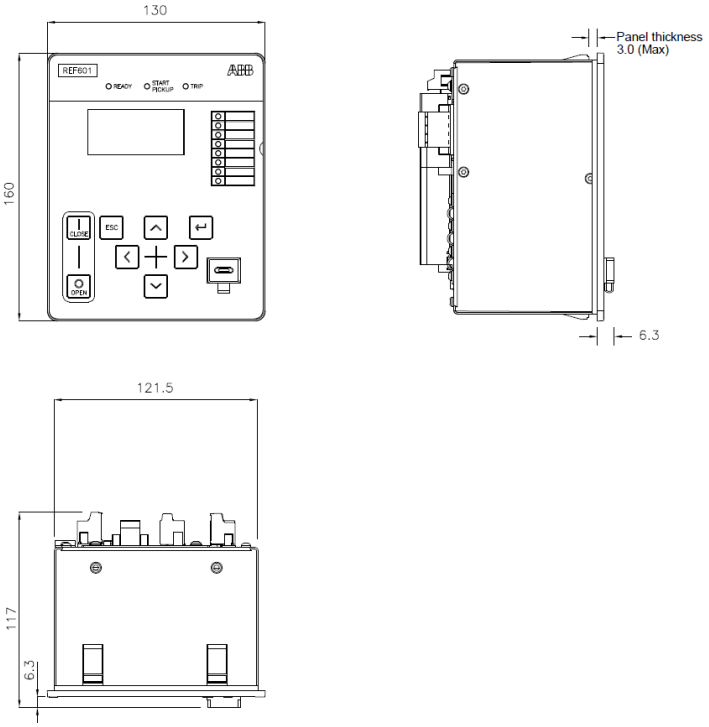


Figure 34: Overall mounting dimension relay with sensor version

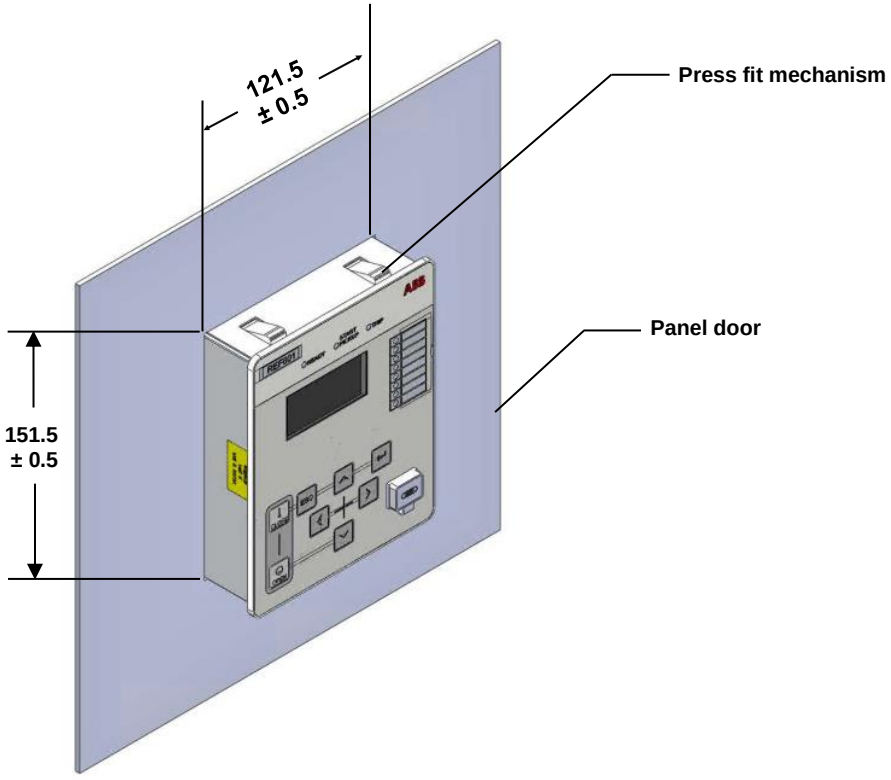


Figure 35: Panel mounting details relay

9.6 Terminal diagram

Relay terminal / connection diagram shall be as the relay.

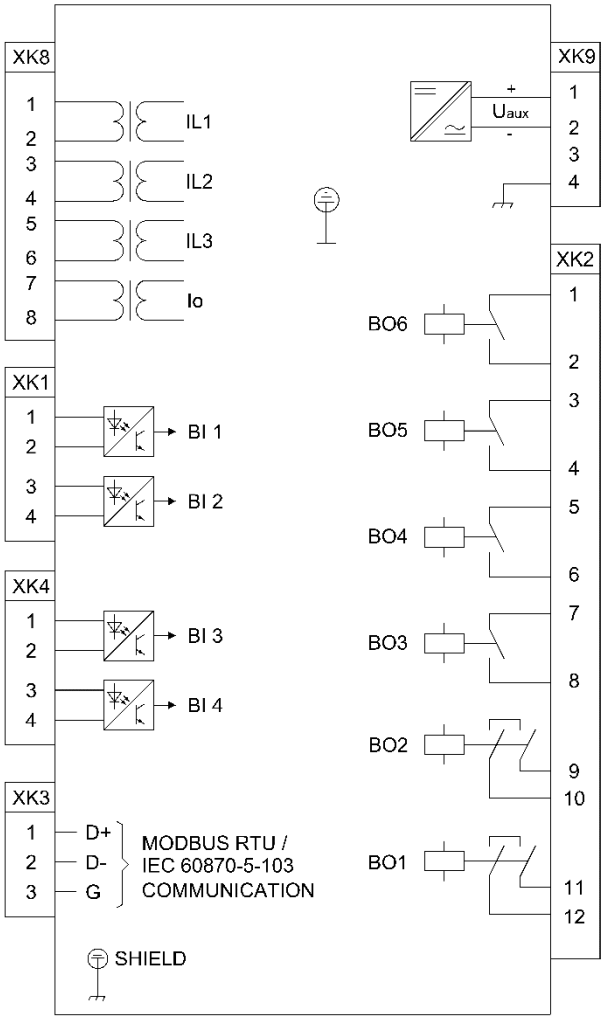


Figure 36: Connection diagram of CT version relay

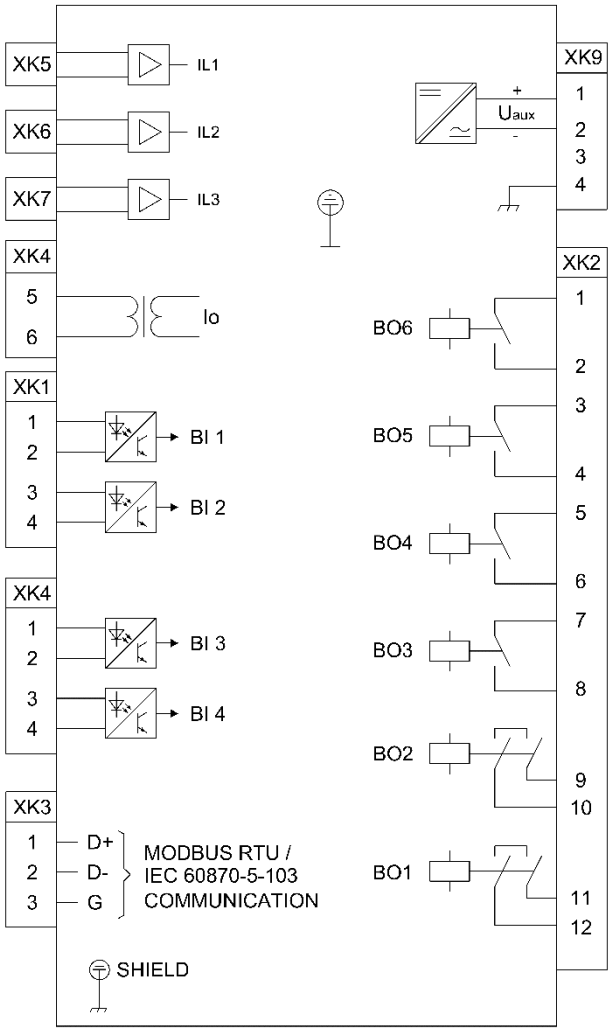


Figure 37: Connection diagram of sensor version relay

9.7 Relay ordering information

The relay type and serial number label identifies the protection relay. An order number label is placed on the side of the relay. The order number consists of a string of codes generated from the hardware and software modules of the relay. The serial number and order number label is placed on side of relay.

Example code		REF601	B	F4	46	D	B	1	N	K
#	**Description**									
1	**Relay type**									
	Feeder protection with control	**REF601**								
	Feeder protection	REJ601								
2	**Standard**									
	ANSI	A								
	IEC	**B**								
	Chinese	C								
	CEI	J								
3,4	**Analog input / output**									
	3 sensor and ground current input	A4								
	Phase and Earth current input – 1 & 5A	**F4**								
5,6	**Binary input / output**									
	4 BI + 6 BO	**46**								
7	**Serial communication**									
	MODBUS RTU and IEC60870-5-103 with RS485 two wire	**D**								
	None	N								
8	**Application configuration**									
	Configuration B	B								
	Configuration C	C								
	Configuration D	D								
	Configuration F	**F**								
9	**Power supply**									
	24...240V AC / DC	**1**								
10	**Configuration**									
	Disconnecting Ring lug terminals with CT shorting	B								
	Disconnecting Screw terminals with CT shorting	**N**								
11	**Version**									
	Product version 2.5	K								

Digit (#)	**1-6**	**7**	**8 9**	**10 11**	**12**	**13**	**14**	**15**	**16**
Code									

Figure 36: Ordering information of relay REF601 / REJ601

Example code		REM601	B	F4	46	D	B	1	N	K
#	Description									
1	**Relay type**									
	Motor protection with control	**REM601**								
	Motor protection	REM601								
2	**Standard**									
	ANSI	A								
	IEC	**B**								
	Chinese	C								
3,4	**Analog input / output**									
	3 sensor and ground current input	A4								
	Phase and Earth current input – 1 & 5A	**F4**								
5,6	**Binary input / output**									
	4 BI + 6 BO	**46**								
7	**Serial communication**									
	MODBUS RTU and IEC60870-5-103 with RS485 two wire	**D**								
	None	N								
8	**Application configuration**									
	Configuration B	B								
	Configuration C	C								
	Configuration F	**F**								
9	**Power supply**									
	24...240V AC / DC	**1**								
10	**Configuration**									
	Disconnecting Ring lug terminals with CT shorting	B								
	Disconnecting Screw terminals with CT shorting	**N**								
11	**Version**									
	Product version 2.5	K								

Digit (#)	1-6	7	8 9	10 11	12	13	14	15	16
Code									

Figure 37: Ordering information of relay REM601

9.8 Accessories and ordering data

Table 93: Relay accessories and ordering data

Item	Order number
RE_601 communication card	CIM601BNNNNBANXH

9.9 Earthing of relay

The earth lead must be at least 6.0 mm2. If the length of the earth lead is long, the cross section of the wire must be increased.

To improve the immunity against high frequency distortion it is recommended to use flat braided copper wire as the earth lead.

To connect a separate earth protection lead:

1. Loosen the protective earth screw to connect a separate earth protection lead.

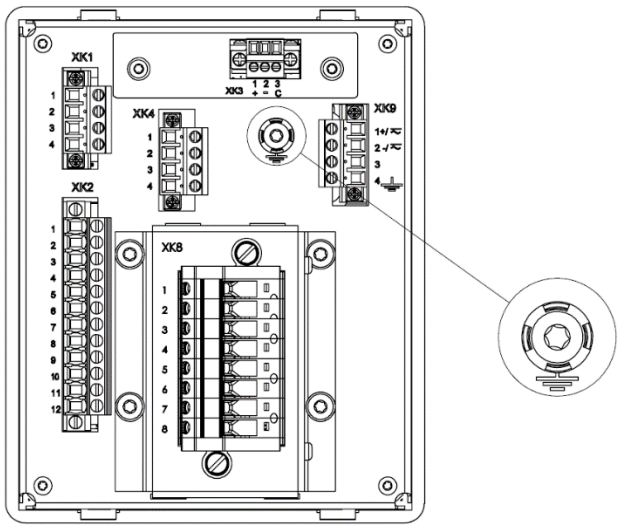


Figure 38: Location of protective earth screw

The earth lead should be as short as possible but notice that extra length is required for door mounting.

Each relay must have its own earth lead connected to the earth circuit connector.

2. Connect the earth lead to the earth bar. Use either stripped wire screwed between a washer cup and the protective earth screw or a ring-lug.

   Select a suitable ring-lug to fit under the M4 screw.

3. Tighten the protective earth screw.
4. Support the earth lead so that it cannot break or weaken.
   Be aware of the mechanical, chemical and electrochemical environment

Section 10 PCM600 connectivity

Protection and Control IED Manager PCM600 offers functionality of relay configuration and monitor the devices. It is also used for fault data upload from the relay for necessary analysis purpose.

The PCM600 in combination with the relay-specific connectivity package provides the seamless access to the relay. The relay connectivity package is a collection of software and specific relay information which enables system products and tools to connect and interact with the protection relay. The connectivity packages reduce the risk of errors in system integration, minimizing device configuration and setup times.

10.1 PCM600 and relay connectivity package version

The supported version of PCM600 and connectivity package shall be as indicated Table 94.

Table 94: Supported tool information

Item	Version details
PCM600	2.13 Hotfix 20240725 or later
Relay connectivity package	2.5 or later

10.2 Supported functions by PCM600 software

The details of the supported functions by PCM600 software are as indicated in Table 95.

Table 95: Supported functions by PCM600

Function	PCM600
Relay parameter setting	•
Saving of relay parameter settings in the relay	•
Signal monitoring	•
Disturbance recorder handling	•
Alarm LED viewing	•
Access control management	•
Relay signal configuration (Signal Matrix)	•
Saving of relay parameter settings in the tool	•
XRIO parameter export/import	•
Event viewing	•
Saving of event data on the user's PC	•

10.3 Communication of relay to PCM600 software

10.3.1 Setting up communication

The relay can be configured from front USB port or rear port. The steps for relay configuration from the front port shall be as indicated below:

- On the LHMI, set the USB Enable parameter to "True" via Configuration for communicating with USB from PCM600 tool.
- Ensure only one relay is connected to the PC via USB when connected to the front port.
- Ensure the drive is available in the PC after USB connection with the relay.
- Front port (USB) can be configured in PCM600 Tool wizard page.
- User can select Front Port(USB) or Rear Port(RS485) option in PCM600 Tool wizard page.
- Communication port can be selected from PCM600 wizard page and provide the slave address for communication with relay.

Right-click on the IED and select Communication Port to activate a respective communication Port either Front or Rear port.

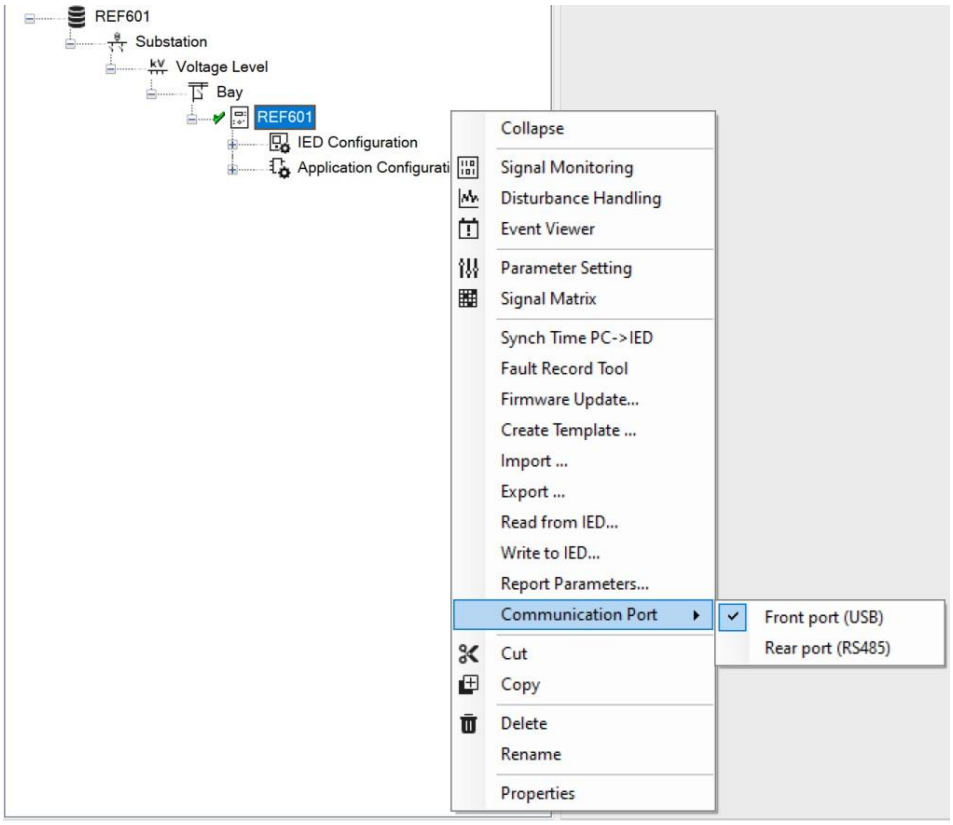


Figure 39: PCM600 connectivity

The selected communication port is displayed next to selected port on the Object Properties window.

Write operation requires relay to be in **Admin** mode, whereas Read operation works in any mode.

If both rear port and front port connected to relay then rear port communication takes the priority.

10.3.2 Disturbance handling tool

PCM 600 DHT (Disturbance Handling Tool) will support through Front Port or Rear Port communication of the relay. The DHT will support the read of disturbance records. The disturbance record COMTRADE file can read from relay through disturbance handling (DHT) PCM600 Tool. The recording information (.CFG file and . DAT) files can be read from relay. There is provision to read one record or all records at a time from relay.

Manual DR tiggering is not supported in PCM600 DHT Tool

Selected disturbance recording delete is not supported in PCM600 DHT Tool.

It is recommanded to Read the individual DR from the DHT tool after reading the "read record information" from the IED. Reading all or multiple DR's will take more time and PCM may become unresponsive for certain time. This is applicable for both rear and front USB communication.

10.3.3 Fault recorder tool

PCM 600 fault recorder tool will support the reading fault records from the relay.

In PCM600, right-click on the relay instance and select Fault Record Tool.

Select records number (e.g. 1 Fault Record or 10 Fault Record or All Fault Records) then user need to click read.

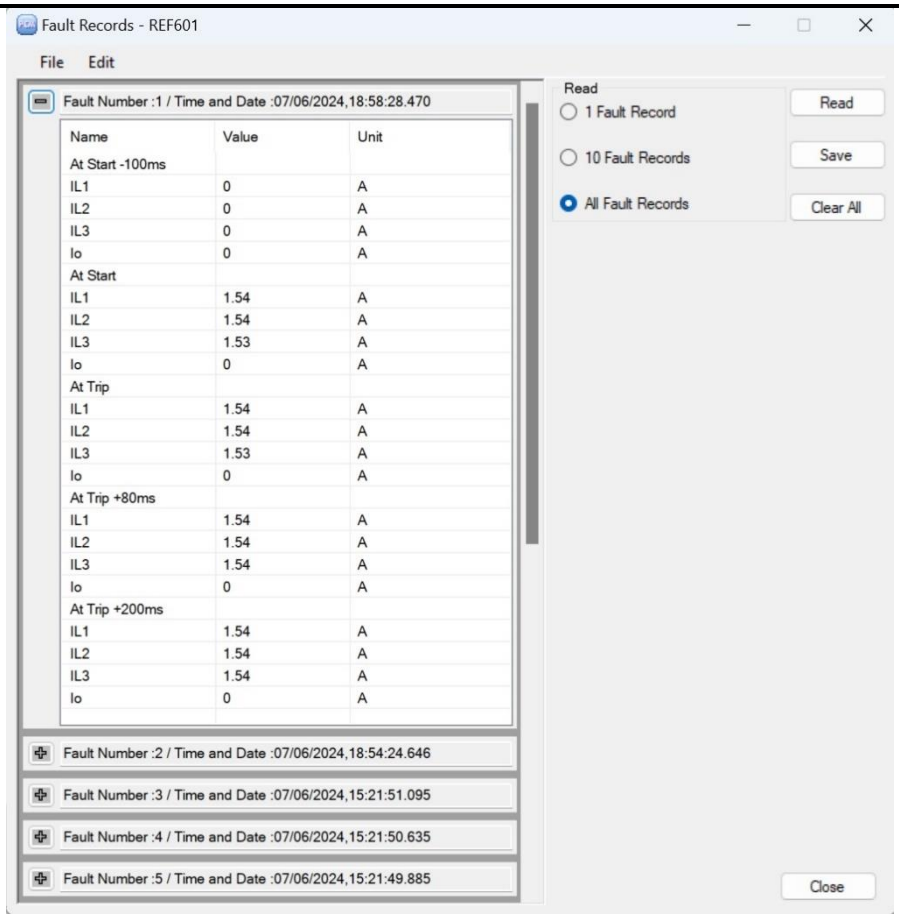


Figure 40: PCM600 Fault record tool

Records loads in PCM600 tool base upon selection if any available in relay.

Detail of fault record can be visible by clicking “+” symbol of record.

Fault record can be saved as txt file.

Local fault record can be deleted from PCM600 tool by clicking “Clear All”.

10.3.4 Event viewer tool

PCM600 Event Viewer Tool can be used to view the internal events and external events.

External events can be process events or system events. Internal events can be security-related events,changes in the protection relay etc.

In PCM600 tool, right-click the relay instance and select Event Viewer.

If default security tab page not selected , select that page, read Internal events through PCM600 Tool by clicking "Read newest event from IED" button

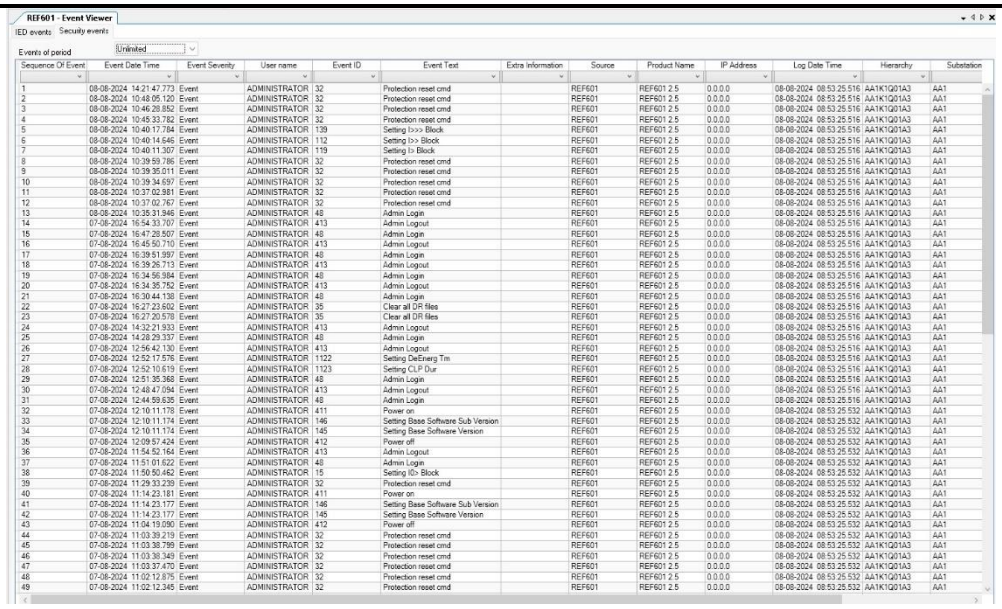


Figure 41: PCM600 Event viewer tool

PCM600 Event Viewer Tool can filter events data. External and Internal events can be exported from PCM600 Events Viewer Tool.

It is recommended to NOT use periodic event read.

10.3.5 Signal monitoring

Signal monitoring tool provides the user with online information about the measured values and displays the status of binary input and output, analog input signals of relay.

Signal value can be read from relay through rear port or front port communication.

There are two types of user interface to view signal monitoring data.

- Overview
- Module view

In the overview interface all monitoring signal with value appears as list view. User can read all monitoring signal details from relay.

In module view interface monitoring signal appears as modular view where each module contains multiple signal details. User can read selected module monitoring signal from relay.

It is recommended to NOT use continuous toggle feature in PCM600 for Signal monitoring tool.

10.3.6 Parameter setting tool

Parameter Setting enables viewing and setting IED parameters offline (stored in the tool) and online (stored in both the tool and the IED). The parameters can be read from the IED to PCM600 or written from PCM600 to the IED while the IED is in service. In addition, the parameters can be exported and imported for test sets in the XRIO format (for example, Omicron Test Universe) or in the CSV format to be easily read and reused.

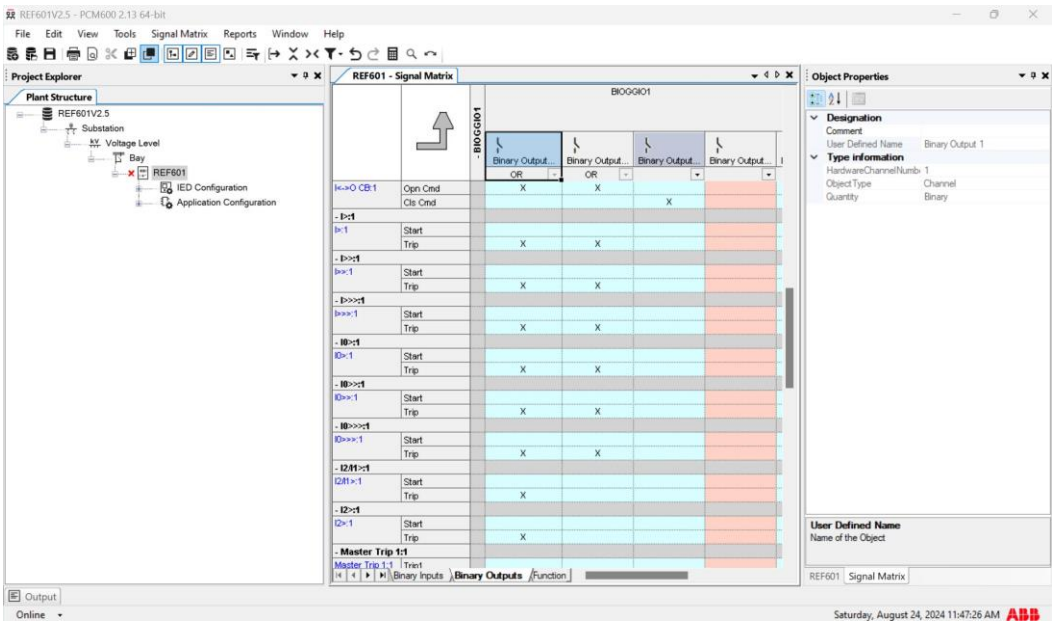


Figure 42: PCM600 parameter setting tool

In PST (Parameter Setting Tool), if parameters settings(.xrio or .csv) are to be imported, then below step needs to be followed.

Customer to use culture where list separator is semicolon ";" or defines that existing culture uses semicolon as list separator in the settings as follow: Region\Additional settings...\List separator.

Section 11 Cyber security deployment guideline

The cyber security deployment guideline describes the process for handling cyber security when communicating with the protection relay. The cyber security deployment guideline provides information on how to secure the system on which the protection relay is installed. The guideline can be used as a technical reference during the engineering phase, installation and commissioning phase, and during normal service.

This guideline is intended for the system engineering, commissioning, operation and maintenance personnel handling cybersecurity during the product lifecycle.

The personnel are expected to have general knowledge about topics related to cybersecurity.

- Protection and control devices, gateways and workstations
- Serial communication RS485 to USB
- Security policies
- Application whitelisting
- Secure remote communication

Encryption Algorithms

A hashed representation of the passwords with SHA 256 is stored in the protection relay within a csv file. These are not accessible from outside via any ports. No passwords are stored in clear text within the protection relay.

User management

Four factory default user accounts have been predefined, each with different rights and default passwords. The roles for these user accounts are the same as the username.

- Operator
- Engineer
- Administrator

The default passwords in the protection relay delivered from the factory can be changed with Administrator user rights only. Relay user passwords can only be changed using the LHMI. There is no user authentication supported by PCM600.

Each protection relay supports three roles each. There is direct mapping of users and their roles. Any user logging into the protection relay from LHMI is authenticated based on the user account information and this user’s rights are defined by the user’s role

Only administrator has the privilege to change passwords and reset passwords of all users to default ones.

Table 96: Default user roles

Role	Description
Operator	Viewing what objects are present in the device. Performing control operations such as opening or closing the circuit breaker, editing setting group and clearing indications
Engineer	Viewing what objects are present in the device. Making parameter setting changes in addition to having almost full access to the data sets and files
Administrator	Superset of all the roles

Loggin In: At default view, whenever any key is pressed, for 3 second the Configuration status screen appears followed by a password request screen for all the above users which can be selected using down key.

Loggin Out: Press ESC key on main menu screen to logout. For no activity logout, device left idle for 3 minutes goes for a logout.

Table 97: Default mapping of the user roles

Username / User rights	Relay LHMI			PCM600			Remote Communication
	Operator	Engineer	Administrator	Operator	Engineer	Administrator	
Menu Viewing (Read only access)	Yes	Yes	Yes	Yes	Yes	Yes	If COM Admin Level is YES, then IED configuration parameter is allowed to change through MODBUS
Selecting remote or local state	-	Yes	Yes	-	Yes	Yes	
Breaker Control	-	Yes	Yes	-	Yes	Yes	
Changing setting group	Yes	Yes	Yes	Yes	Yes	Yes	
Clearing Indications	Yes	Yes	Yes	Yes	Yes	Yes	
Changing settings	-	Yes	Yes	-	Yes	Yes	
Selecting Language	-	Yes	Yes	-	Yes	Yes	
Clearing Event List	-	Yes	Yes	-	Yes	Yes	
Clearing Distrubance Records	-	Yes	Yes	-	Yes	Yes	
Setting the protection relay to test mode	-	Yes	Yes	-	Yes	Yes	
Relay Configuration Editing	-	-	Yes	-	-	Yes	
Changing Password	-	-	Yes	-	-	Yes	
Factory default activation	-	-	Yes	-	-	Yes	

Table 97 describes the default mapping of all the user rights associated with all the roles in the protection relay. This mapping can be modified according to the user requirements

Note: User authorization is set to Simple password mode i.e. Keypad login by default for the LHMI and can be changed via the Authorization menu. Path **Authorization** > **Password Type.**

Changes in user management settings including password change and password reset do not cause the protection relay to reboot and can be done only via the LHMI. The changes are taken into effect immediately after committing the changed settings on the menu root level.

Password policies

Simple passwords key combination, if required can be changed to any of the possible combination. Alphanumeric passwords are settable for the user accounts in all roles only by the admin. Only the following characters are accepted:

- Numbers 0-9
- Letters a-z, A-Z
- Special characters like !"#%&()*+'-./:;<=>?@[]^_`{|}~

There are default password length policies in the protection relay:

- Minimum password length: 4
- Maximum password length: 8
- Minimum uppercase characters: 0
- Minimum numeric characters: 0
- Minimum special characters: 0

The protection relays are delivered from the factory with default passwords. It is recommended to change the default alphanumeric passwords.

Table 98: Predefined users, their passwords and roles

User role	Simple password	Alphanumeric password
OPERATOR	No password / wrong password	0001 / wrong password
ENGINEER		0002
ADMINISTRATOR		0003

Security logging

The protection relay offers a security event-logging functions. Critical system and protection relay security-related events are logged to a separate non-volatile audit trail for the administrator.

Audit trail is a chronological record of system activities that allows the reconstruction and examination of the sequence of system and security-related events and changes in the protection relay. Both security events (100 in number) and process related events (250 in number) can be examined and analyzed in a consistent method with the help of Event List in LHMI and Event Viewer Tool in PCM600. Event list works according to the FIFO principle.

Security events as indicated in Table 99 are supported in relay.

Table 99: Details of the security events

Event	Description
User Login	Successful operator login from LHMI
User Logout	Successful operator logout from LHMI
Admin Login	Successful admin login from LHMI
Admin Logout	Successful admin logout from LHMI
Engineer Login	Successful engineer login from LHMI
Engineer Logout	Successful engineer logout from LHMI
Firmware Update Success	Firmware update is successful
Firmware Update Failure	Firmware update has failed
Setting password type	Password type is updated successfully
Setting control authority	Control Authority for local remote updated successfully
Protection Reset Cmd	Protection Reset executed successfully
Test Mode Activate	Setting test mode on successfully
Test Mode Deactivate	Setting test mode off successfully
Setting Base software version	Base software version updated successfully
Setting Base software sub version	Base software sub version updated successfully
CB Opn Cmd	CB open command executed successfully
CB Cls Cmd	CB close command executed successfully
Setting change	Any common settings updated successfully
Configuration change	Any configuration updated successfully

Restoring factory settings

In case of configuration data loss or any other file system error that prevents the protection relay from working properly, the whole device system parameters can be restored to the original factory state. All default settings stored in the factory are restored. Only the administrator can restore the factory settings.

Select **Main menu** > **Configuration** > **Factory settings> Yes** and press enter to commit. Device goes for a reboot.

Section 12 Applicable standards and regulations

EN 60255-1

EN 60255-26

EN 60255-27

EMC council directive 2004/108/EC EU directive 2002/96/EC/175

IEC 60255

Low-voltage directive 2006/95/EC IEC 61850

BS EN 60255-26: 2013

BS EN 61000-6-2: 2005

BS EN 61000-6-4: 2019

BS EN 60255-1: 2010

BS EN 60255-27: 2014

Section 13 Glossary

CAT 6	A twisted pair cable type designed for high signal integrity
COMTRADE	Common format for transient data exchange for power systems. Defined by the IEEE Standard.
CT	Current transformer
DFT	Discrete Fourier transform
DT	Definite time
EMC	Electromagnetic compatibility
FIFO	First in, first out
HMI	Human-machine interface
IDMT	Inverse definite minimum time
IEC	International Electrotechnical Commission
IED	Intelligent electronic device
IRF	Internal relay fault
LCD	Liquid crystal display
LED	Light-emitting diode
LHMI	Local human-machine interface
Modbus	A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices
MV	Medium voltage
LV	Low voltage
NC	Normally closed
PCM600	Protection and Control IED Manager
RS-485	Serial link according to EIA standard RS485
RTC	Real-time clock
SMT	Signal Matrix tool in PCM600
PST	Parameter setting tool in PCM600
DHT	Disturbance handling tool in PCM600
TCS	Trip-circuit supervision
USB	Universal Serial Bus

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