605 series / Relion® Protection and Control

Feeder Protection and Control/ Feeder Protection REF601/REJ601 Application Manual

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Section 1 General

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 IED 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 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

1.4 Document symbol and conventions

This publication includes the following icons that point out safety-related conditions or other important information:

Safety indication symbols

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

Non-observance can result in death, personal injury or substantial property damage

Breaking the sealing tape on the upper handle of the device will result in loss of warranty and proper operation will no longer be guaranteed.

When the plug-in unit has been detached from the case, do not touch the inside of the case. The relay case internals may contain high voltage potential and touching these may cause personal injury.

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

Dangerous voltages can occur on the connectors, even though the auxiliary voltage has been disconnected.

National and local electrical safety regulations must always be followed.

The device contains components which are sensitive to Electrostatic discharge. Unnecessary touching of electronic components must therefore be avoided.

Only a competent electrician is allowed to carry out the electrical installation.

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

Section 2 REF601/REJ601 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. REF601 / REJ601 are the member of ABB's 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.

The common features of REF601 / REJ601includes:

- Compact size and ease of use
- Standard 1A and 5A CT input for phase and earth current measurement
- Earth current measurement internally or externally through CBCT
- Local and remote control of circuit breaker
- Trip Circuit Supervision and relay internal supervision
- Lockout function
- Configurable logic gates and timer
- Faulty phase identification
- 100 event logs with date and time stamping
- Five analogue fault records
- Non-resettable trip counter
- On-line current measurements in primary value
- Comprehensive local HMI
- Universal auxiliary supply
- Optional MODBUS RTU or IEC 60870-5-103 communication
- Non-volatile memory for setting and fault records
- User selectable rated frequency 50 / 60 Hz
- Configurable binary inputs, outputs and alarm LEDs
- Two setting groups

The protection features of REF601/REJ601 includes:

- Three-stage overcurrent protection
- Two-stage earth-fault protection
- Inrush detection for stability during transformer charging
- Thermal overload protection
- Negative sequence overcurrent
- Phase discontinuity / Single phasing protection
- Circuit breaker failure protection
- Multi shot Auto recloser functionality for overhead line

2.2 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

2.3 Operation Functionality

2.3.1 Relay functions

REF601/REJ601 offers pre-configured functionality which facilitates easy and fast commissioning of switchgear. To emphasize the simplicity of relay's usage, only application specific parameters needs to set within the relay's intended area of application.

The relay offers protection, control, measurement and condition monitoring functionality. The table indicates the functions supported by the IED.

Table 1: Relay functions

	Related products		REJ601 / REF601
Functionality	**ANSI**	**IEC**	**E**
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>>>	•
Earth-fault protection, low-set stage	51N	Io>	•
Earth-fault protection, high-set stage	50N	Io>>	•

Table 1: Relay functions, continue

	Related products		REJ601 / REF601
Functionality	**ANSI**	**IEC**	**E**
Protection			
Three phase transformer inrush detector	68	3I2f>	•
Three-phase thermal protection for feeders, cables and distribution transformers	49	3Ith>	•
Phase discontinuity protection / Single phasing protection	46PD	I2/I1>	•
Negative-sequence overcurrent protection	46	I2>	•
Circuit breaker failure protection	51BF/51NBF	3I>/Io>BF	•
Master trip	86	Master Trip	•
Two setting group			•
Control			
Breaker control functionality (Function available in REF601)	I <-> O CB	I <-> O CB	•
Auto-reclosing	79	O -> I	•
Condition monitoring			
Trip circuit supervision	TCM	TCS	•
Measurement			
Three-phase current measurement	3I	3I	•
Residual current measurement	In	Io	•
Negative phase sequence current	I2	I2	•
Thermal level	ϑ	ϑ	•
Operation counter	-	-	•

• = Included

2.3.2 Optional function

The relay supports two optional communication MODBUS RTU on a two wire RS485 interface.

2.3.3 1/5A CT configurability

The relay supports both 1A and 5A primary phase and earth current transformers (CTs). 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.

2.4 Other Functions

2.4.1 Self-Supervision

The IED 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 IED, the green LED ceases to glow and the self-supervision contact opens. Also, all other outputs are released.

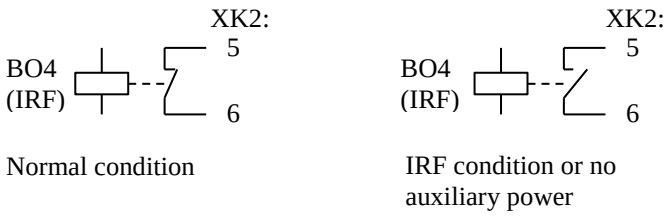


Figure 1: Behavior of contact assigned for Unit ready / IRF

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 IED fault

Table 2: Internal fault indications and fault codes

Internal fault code	Type of fault
IRF 008	Internal supply voltage check
IRF 016	Power on “EEPROM“ check fault
IRF 032	Runtime “EEPROM“ check fault
IRF 064	Gain check fault

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

2.4.2 Fault record and Trip counter

The relay stores records of analog values for last five 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.

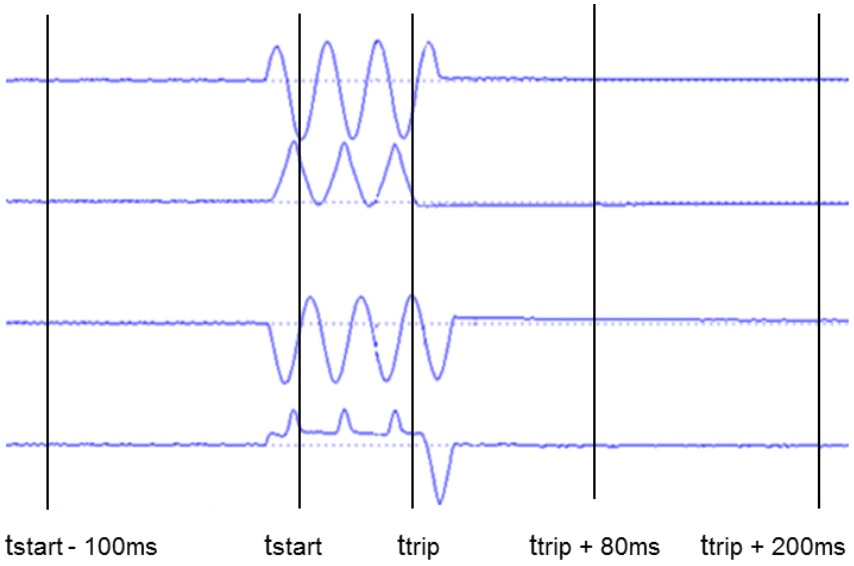


Figure 2: Fault record

These records enable the user to analyze the five 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.

2.4.3 Event Log

To collect sequence-of-events (SoE) information, the relay incorporates a non-volatile memory to store 100 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 activation will be stored as an event. This 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 health shall also record it as an event	TCS fault ↑ TCS fault ↓
3	Setting parameter change	Settings (I>,I>>,I>>>,Io>,Io>> and t>,t>>,t>>>,to>,to>>) alteration will be captured as an event without setting value.	I>, I>>, I>>>, Io>, Io>>, t>, t>>,t>>>, to>, to>>
		Circuit breaker failure protection settings - IBF,I0BF,t Retrip,t Backup	Icbfp,I0cbfp, t Retrip, t Backup
		On change of Count value	Count Value
		Negative sequence setting change - I2> and tI2>	I2>, tI2>
		Phase discontinuity setting change - I2/I1> and tI2/I1>	I2/I1>, tI2/I1>
		Thermal protection setting change- ϑ0,Ib, t↑, t↓s, t↓r, ϑalm, ϑtrip, ϑstrinhibit, ϑEM	ϑ0,Ib, t↑, t↓s, t↓r, ϑalm, ϑtrip, ϑstrinhibit, ϑEM
		Auto resclose function setting change - Mode,CB Ready, Activate t Shot, Pulse tp, cycle t1, cycle t2,cycle t3, cycle t4, Reclaim tr, Block tb	O→I - Mode, CB Ready, Activate t # of Cycle, Pulse tp, cycle t1, cycle t2, cycle t3, cycle t4, Reclaim tr, Block tb
4	Protection start	Start event by I>,I>>, I>>> ,Io> OR Io>> will be captured as individual event for both rising and dropping	Start I> ↑ Start I>> ↑ Start I>>> ↑ Start I0> ↑ Start I0>> ↑ Start I> ↓ Start I>> ↓ Start I>>> ↓ Start I0> ↓ Start I0>> ↓
		On I2> start both rising and falling signal	Start I2> ↑ Start I2> ↓
		On I2/I1> start both rising & falling signal	Start I2/I1> ↑ Start I2/I1> ↓
		On thermal alarm output signal for both rising & falling signal	3Ith> Alarm ↑ 3Ith> Alarm ↓
5	Protection trip	In the event of Tripping, which protection stage (I>, I>>, I>>>, Io> and Io>>) caused trip will be captured as an event information. Event shall be available for both rising & dropping	Trip I> ↑ Trip I>> ↑ Trip I>>> ↑ Trip I0> ↑ Trip I0>> ↑ Trip I> ↓ Trip I>> ↓ Trip I>>> ↓ Trip I0> ↓ Trip I0>> ↓
		On I2> trip both rising & falling signal	Trip I2> ↑ Trip I2> ↓
		On I2/I1> trip both rising & falling signal	Trip I2/I1> ↑ Trip I2/I1> ↓
		On thermal trip output signal for both rising & falling signal	3Ith> Trip ↑ 3Ith> Trip ↓

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

Sr. No.	Event type	Description	Data considered
6	IRF	"IRF" – internal relay fault shall be captured as an event.	IRF codes
7	Breaker open	When breaker open cmd	Breaker Open
8	Breaker close	When breaker close cmd	Breaker Close
9	Remote trip	When remotely trip command issued	Remote Trip
10	Reset	When reset of protection trip, LEDs and screen done	Reset
11	Blocking	When blocking by binary input, And shall have event for both rising & dropping	BI Blocking ↑ BI Blocking ↓
12	Breaker position	When breaker open, close or maintenance position sensed by associated binary input	CB POS CLS ↑ CB POS CLS ↓
			CB POS OPN ↑ CB POS OPN ↓
			CB Maint ↑ CB Maint ↓
13	Logic gates*	When logic gates ANDx, ORx & NOTx output activates and deactivates	ANDx ↑ ORx ↑ NOTx ↑ ANDx ↓ ORx ↓ NOTx ↓
14	Timers*	When timer TON & TOFF output activates and deactivates	TONx ↑ TOFFx ↑ TONx ↓ TOFFx ↓
15	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
16	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
17	Hardware test	When in test menu, initiate hardware test	Hardware Test
18	Binary output test	When in test menu , initiate binary output test	BO Test
19	Functional test	When in test menu, initiate protection function test	Functional Test
20	Power Off	When binary input is mapped to register power off situation & power supply to IED goes OFF.	Power Off
21	Breaker Failure Stage 1, 2 output	On breaker failure receive stage 1 output	BF Stage1 ↑ BF Stage2 ↑ BF Stage1 ↓ BF Stage2 ↓
22	Breaker Failure receive trip output	On breaker failure receive trip output	BF RecTrip BO↑ BF RecTrip BO↓
23	Breaker Failure receive trip Acceptance	On Acceptance of BF RecTrip input	BF RecTrip Acp ↑

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

Sr. No.	Event type	Description	Data considered
24	Setting group change	On change of setting group from one to another	Setting SG Edt. Setting SG No. Setting SG Act.
25	Thermal reset	On reset of thermal function either from BI, LHMI or communication.	3Ith> Reset
26	Thermal block breaker close	On breaker close blocking output signal for both rising & falling signal	3Ith> Blk Cls ↑ 3Ith> Blk Cls ↓
		On breaker close blocking output signal for both rising & falling signal due to cumulative startup protection	I2tn< BlkCl ↑ I2tn< BlkCl ↓
27	O→I close	On O→I close output	O→I close 1 ↑ O→I close 2 ↑ O→I close 3 ↑ O→I close 4 ↑
28	O→I FinalTr	On O→I final trip output	O→I FinalTr ↑
29	O→I Blocked	On O→I blocked output	O→I Blocked ↑ O→I Blocked ↓
30	O→I Stopped	On O→I stopped internal signal generated	O→I Stopped ↑
31	O→I Started	On O→I started internal signal generated	O→I Started ↑
32	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 ↓
33	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 ↓
34	Setting parameter change	OPTS parameter change – value	OPTS - value
35	Start	An event for general start will be capture for both rising and falling which will be from any of start of I>,I>>, I>>> ,Io> ,Io>>, I2>, I2/I1>	Start ↑ Start ↓
36	Trip	An event for general trip will be capture for both rising and falling which will be from any of trip of I>,I>>, I>>> ,Io> ,Io>>, I2>, I2/I1> and Thermal trip	Trip ↑ Trip ↓
37	Factory default	Event for factory default	Factory Default
*Requires that individual logic gates and timer are configured for event registration			

2.4.4 Real Time Clock

IED 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 48 hrs. at ambient temperature when stored energy element is fully charged. Initial time setting is “01/01/2011” and “00:00:00:0000”.

2.4.5 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. With the Ver. 2.2 FP2 REF601 / REJ601 supports two modes for password handling:

1. a combination of different navigation keys (default mode)
2. alphanumeric password

2.4.6 Power-ON sequence

The Power-ON sequence takes around 6 sec.

In case the optional communication on MODBUS RTU is present, the startup time takes around 40 sec.

Section 3 Technical Data

For detailed technical data please refer the product guide.

Section 4 Protection and Control Function

4.1 Three Phase Overcurrent Protection

4.1.1 Functionality

The three-phase overcurrent protections can be used as three phase non-directional overcurrent and short-circuit protection for feeders.

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.

4.1.2 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, 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 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.

4.1.3 Setting range of Three Phase Overcurrent Protection

Table 4: Setting ranges Non-directional overcurrent protection, Low stage 3I>, 51

Description	Value
Setting range of pick-up current I >	0.5...2.50 x In in steps 0.001, infinite
Operate time delay (DT) t >	0.04...64 sec in steps of 0.01
Operating curve type (IDMT)	IEC 60255-3: Normal inverse, Very inverse, Extremely inverse, Long-time inverse ANSI C37.112: Moderate inverse, Normal Inverse, Very inverse, Extremely inverse Special curves: RI inverse
Time multiplier setting k (IDMT)	0.02...1.6, in steps of 0.01
Reset ratio	IDMT : 0.96 and DT : 0.98
Reset time	40 ms
Trig CBFP	Yes / No

Table 5: Setting ranges Non-directional overcurrent protection, High stage 3I>>, 50-1

Description	Value
Setting range of pick-up current I>>	0.5...25 x In in steps 0.001, infinite
Operation mode	Definite time
Operate time delay (DMT) t >>	0.04...64 sec in steps of 0.01
Reset ratio	0.98
Reset time	40 ms
Trig CBFP	Yes / No

Table 6: Setting ranges Non-directional overcurrent protection, Instantaneous stage 3I>>>, 50-2

Description	Value
Setting range of pick-up current I>>>	0.5...25 x In in steps 0.001, infinite
Operation mode	Definite time
Operate time delay (DMT) t >>>	0.03...64 sec in steps of 0.01
Reset ratio	0.98
Reset time	40 ms
Trig CBFP	Yes / No

4.2 Earth Fault Protection

4.2.1 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 stage always operates with the definite time (DT) characteristics.

4.2.2 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> / 51N) and high stage (I0>> / 50N) of earth fault over current functions.

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

4.2.3 Setting range of Earth fault Overcurrent Protection

Table 7: Setting ranges Non-directional earth fault protection, Low stage Io>, 51N

Description	Value
Nominal value of earth current	1 A or 5A
Setting range of pick-up current Io>	External earth : 0.05...2.0 x In in steps 0.001, infinite Internal earth : 0.5...2.0 x In in steps 0.001, infinite
Operate time delay (DT) to>	0.04...64 sec in steps of 0.01
Operating curve type (IDMT)	IEC 60255-3: Normal inverse, Very inverse, Extremely inverse, Long-time inverse ANSI C37.112: Moderate inverse, Normal Inverse, Very inverse, Extremely inverse Special curves: RI inverse
Time multiplier setting ko (IDMT)	0.02...1.6, in steps of 0.01
Reset ratio	IDMT : 0.96 and DT : 0.98
Reset time	40 ms
Trig CBFP	Yes / No

Table 8: Setting ranges Non-directional earth fault protection, High stage Io>>, 50N

Description	Value
Setting range of pick-up current 'Io>>'	External earth: 0.05...12.5 x In in steps 0.001, infinite Internal earth: 0.5...12.5 x In in steps 0.001, infinite
Operation mode	Definite time
Operate time delay (DMT) 'to >>'	0.04...64 sec in steps of 0.01
Reset ratio	0.98
Reset time	40 ms
Trig CBFP	Yes / No

4.3 Three Phase Inrush Detector

The transformer inrush detection is used to block overcurrent protection during transformer inrush situations in distribution networks.

Transformer inrush detection is based on the ratio of 2^{nd} harmonic current and the fundamental frequency. When an inrush case is detected, the phase overcurrent and earth fault protection functions are immediately blocked.

Table 9: Setting ranges Transformer inrush detector

Description	Value
Inrush threshold value	0.2 … 25 x In
Ratio Setting	30%...50%

4.4 Negative-sequence overcurrent protection

4.4.1 Functionality

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

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.

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

Table 10: Setting ranges Negative sequence overcurrent protection

Parameter	Value (Range)
Start value, 'I2>"	0.1…1.5 x In, in steps of 0.01
Operate delay time, 'tI2>'	0.04 … 300 sec, in steps of 0.1
Block the negative phase sequence protection	0 = No, 1 = Yes
Operation accuracy	± 5.0% of set value
Operation time accuracy	3% of set value or ± 30ms
Reset ratio	0.98

4.5 Phase discontinuity / Single phasing protection

4.5.1 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.

4.5.2 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.

Table 11: Setting ranges Phase discontinuity protection

Parameter	Value (Range)
Start value, 'I2/I1>"	10…100%, in steps of 1%
Operate delay time, 'tI2/I1>'	0.04 … 64 sec, in steps of 0.1
Block the phase discontinuity protection	0 = No, 1 = Yes
Operation accuracy	± 5.0% of set value
Operation time accuracy	3% of set or ± 30 ms
Reset ratio	0.98

4.6 Circuit breaker failure protection

4.6.1 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 settings of the relay.

4.6.2 Principle of Operation

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

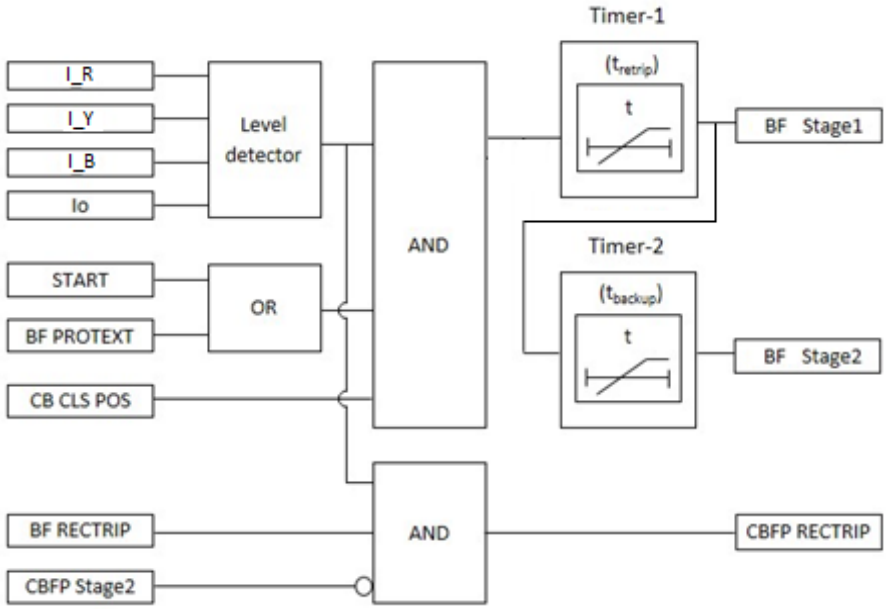


Figure 3: Circuit breaker failure protection functional module diagram

The measured phase currents are compared phasewise to the set I_{CBFP}. Similarly the neutral current is compared to the set I_{oCBFP}. If either of these measured values exceeds the respective setting, the level detector gives permissive to CBFP initiation logic.

The CBFP initiation logic is triggered by the rising edge of the START (from protection function I>, I>>, I>>>, Io> and Io>>) input or by the rising edge of the BF PROTEXT input wired to digital input of relay as external protection trip.

Retrip function

On receipt of trigger signal and reporting of exceeding value of the current by level detector, the CBFP initiation logic activates Timer 1. In case if relay is configured to received CB closed position information at any binary input that information is also used in deciding activation of Timer 1.

Once activated, the timer runs until the set t_{retrip} value has elapsed. The time characteristic for retrip function is according to definite time. When the operation timer has reached the maximum time value, the BF STAGE1 output is activated.

Backup trip function

The Timer 2 for backup trip function activates after timer 1 expires. Once activated, the timer runs until the set t_{backup} value has elapsed. The time

characteristic is according to definite time. When the operation timer has reached the maximum time value, the BF STAGE2 output is activated.

In both retrip as well backup trip conditions, the timer reset immediately when the current value in all three phases decreases below I_{CBFP}, and neutral current decrease below I_{OCBFP}.

However in case where CB closed position information is also used, the timer resets immediately when CB closed position changes to False (i.e. CB opens).

Inter-trip receive function

This block accepts the breaker failure inter trip input from the other IED. The input is accepted on receipt of binary input BF RECTRIP provided its own BF STAGE2 is not active.

The inter-trip logic on acceptance of receipt of binary input will activate binary output BF RECTRIP if the level detector is reporting the exceeding of the value.

The pulse duration of BF STAGE1, BF STAGE2 and BF RECTRIP output is 200ms.

Table 12: Setting ranges Breaker failure protection

Parameter	Value (Range)
Operating phase current, 'ICBFP'	0.2…2.0 x In, in steps of 0.1
Operating neutral current, 'IoCBFP'	0.1…2.0 x In, in steps of 0.1
Time delay for retrip, 'tretrip'	0.06…0.5 sec, in steps of 0.01
Time delay for backup protection, 'tbackup'	0.06…0.5 sec, in steps of 0.01
Block the circuit breaker failure protection	0 = No, 1 = Yes
Operation accuracy	± 10.0% of set value for ICBFP <= 0.5 x In ± 5.0% of set value for ICBFP > 0.5 x In
Operation time accuracy	3% of set value or ± 30ms

4.7 Setting groups

The relay REF601 / REJ601 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 IED 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".

4.8 Auto-reclose function

4.8.1 Functionality

Majority of overhead line faults are transients 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 four programmable auto-reclose cycles and can be set to perform one to four successive auto-reclosures of desired duration.

4.8.2 Principle of operation

Initialization logic

There are two methods by which function can be initialized. The method to be used depends on *O→I start mode* setting. Possible options for this settings are

- Mode 1 = Trip
- Mode 2 = Gen Start & Trip

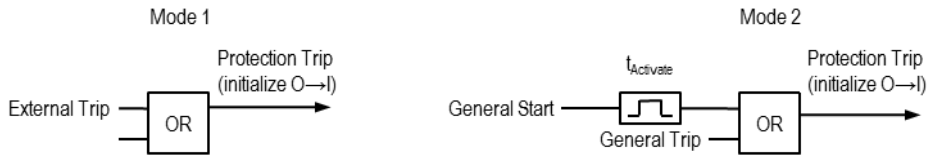


Figure 4: Initiation logic

Mode 1 operation:

The function is initialized on the rising edge of the external trip signal (received via binary input and Modbus, provided they are not blocked).

Remark: However in addition it is required that circuit breaker is in closed position AND auto reclosure is not blocked AND circuit breaker is in ready condition (if *CB ready* setting is selected as O-C-O).

Mode 2 operation:

The function is initialized on rising signal of the general trip signal (which will be an OR of trip of I>, I>>, I>>>, Io>, Io>>, I2>, I2/I1>) if it is received within time set via Activate t of receipt of general start signal (which will be an OR of start of I>, I>>, I>>>, Io>, Io>>, I2>, I2/I1>).

However in addition it is required that circuit breaker is in closed position AND auto reclosure is not blocked AND circuit breaker is in ready condition (if *CB ready* setting is selected as O-C-O).

The initialization of the auto reclosures function will be registered as an event "O→I Started".

The auto-reclose function can be set off by setting *O→I cycle* to "0".

In case if no binary inputs are configured for indicating circuit breaker position, the setting *O→I cycle* will automatically sets to "0" (Auto Reclose not in use) to avoid any mal-operation.

Auto reclose control

The auto reclose control initiated by above described initiation logic follows following schematic:

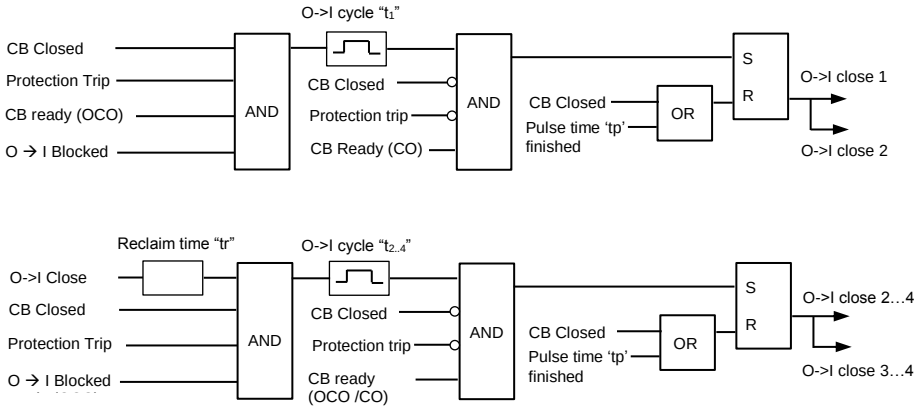


Figure 5: Auto reclose control

O→I cycle 2 … 4 are initiated with a protection trip signal according the selected initiation logic during the set reclaim time t_r. which is started by close command of the previous O→I cycle. For the start of O→I cycle 2 … 4 the CB ready signal is not considered.

The auto reclose cycle could get interrupted respective aborted by the signal O→I blocked and result in a final trip:

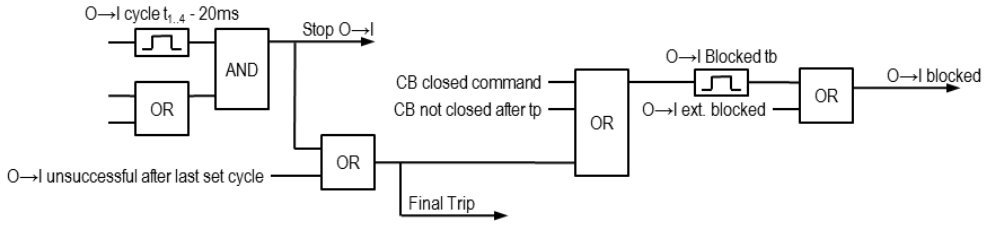


Figure 6: Auto reclose control

If the CB gets closed manually, the auto reclose function is blocked for the time t_b.

In case if no binary inputs are configured for indicating circuit breaker position, the setting *O→I cycle* will automatically sets to "0" (Auto Reclose not in use) to avoid any mal-operation.

4.8.2.1 Setting range for Auto-reclose function

Table 13: Setting ranges for Auto-reclose function I <-> O, 79

Parameter	Description	Range	Unit	Step	Default
O→I start mode	Auto reclose initialization mode	1 = Select Trip 2 = Gen Start & Trip		1	1
CB ready	Type of CB ready signal available	1 = OCO 2 = CO		1	1
# of cycle	Number of Auto reclose cycles (0 = Auto-reclose not in use)	0 … 4		1	1
Activate t	Time between General Start and General Trip for activation of O→I in Mode 2	0.1 … 5	s	0.1	0.8
Pulse tp	Auto reclose pulse time	0.2 … 20.0 [s]	s	0.1	0.2
Cycle t1	Dead time for first auto reclose cycle	0.20 … 300.00 [s]	s	0.01	0.5
Cycle t2	Dead time for second auto reclose cycle	0.20 … 300.00	s	0.01	0.5
Cycle t3	Dead time for third auto reclose cycle	0.20 … 300.00	s	0.01	0.5
Cycle t4	Dead time for fourth auto reclose cycle	0.20 … 300.00	s	0.01	0.5
Reclaim tr	Reclaim time	1 … 300	s	1	1
Block tb	Auto reclosure block time.	1 … 300	s	1	5

4.8.2.2 Configurable inputs to Auto-reclose function

Table 14: Configurable inputs to Auto-reclose function I <-> O, 79

Name	Type	Description
CB CLOS POS	BOOL	Circuit breaker closed position information
EXT TRIP	BOOL	External trip input
CB READY	BOOL	Circuit breaker ready information

4.8.2.3 Configurable outputs of Auto-reclose function

Table 15: Configurable Outputs to Auto-reclose function I <-> O, 79

Name	Type	Description
O→I CLOSE	BOOL	Closing command from auto reclosure
O→I IN PROGRESS	BOOL	Reclosing cycle in progress, activated during reclose time
FINAL TRIP	BOOL	Final trip from auto reclosure
O→I BLOCKED	BOOL	Auto reclosure blocked

4.9 Thermal overload protection

4.9.1 Functionality

The thermal overload protection protects the apparatus from overheating, which causes the premature insulation failures. The function models the thermal behavior of apparatus on the basis of the measured load current and disconnects the apparatus when stored thermal energy has reached the level of set value.

The maximum permanently stored energy at maximum load current is defined as 100%. Additionally the user can set an alarm level ϑ_{alm} to indicate the potential risk.

4.9.2 Principle of operation

The function use for the calculation of the function the highest load current of the three phases.

Thermal model:

The thermal model can be divided into three conditions:

1. warming of apparatus – (diabatic behavior or adiabatic behavior),
2. no change in thermal image
3. Cooling of the apparatus.

1. Warming of the protected object:

Warming of the protected object can be segregated into two types, diabatic and adiabatic behavior. In diabatic behavior, the protected object have a heat dissipation with the environment during warming itself due to the load current.

For current greater than twice the base current I_b (also known as rated current or full load current) the behavior is classified as adiabatic, this means, that the heat exchange with the environment during warming is considerable small related to the heating.

Warming is defined as:

$$\vartheta_0 < \left(\frac{I}{I_b}\right)^2 * 100[\%]$$

ϑ_0 = present value of thermal image

I = maximum value of measured phase currents

I_b = base current (rated current/full load current defined by setting).

Thermal characteristic warming condition at diabatic behavior:

$$\vartheta_1 = \vartheta_0 + \left(\left(\frac{I}{I_b}\right)^2 - \vartheta_0\right) * \left(1 - e^{-\left(\frac{\Delta t}{\tau\uparrow}\right)}\right)$$

ϑ_1 = new value of thermal image

ϑ_0 = present value of thermal image

I = maximum value of measured phase currents

I_b = base current (rated current/full load current defined by setting).

Δt = time interval between ϑ_0 and ϑ_1

$\tau\uparrow$ = Heating time constant

Thermal characteristic warming condition at adiabatic behavior:

$$\vartheta_1 = \vartheta_0 + \left(\frac{I}{I_b}\right)^2 * \left(\frac{\Delta t}{\tau_\uparrow}\right)$$

The value of ϑ_0 at the start of the function (i.e. at power on of the IED is defined by a setting

2. Constant thermal image of protected object:

During this condition, the dissipated heat is equal to heat generated by the current flowing through the protected object.

The thermal model for this conditions is as follow:

$$\vartheta_1 = \vartheta_0$$

whereas:

$$\vartheta_0 = \left(\frac{I}{I_b}\right)^2 * 100[\%]$$

ϑ_1 = new value of thermal image

ϑ_0 = present value of thermal image

I = maximum value of measured phase currents

I_b = base current (rated current/full load current defined by setting).

3. Cooling of protected object:

When the current reduces compared to previous condition it results into cooling of an apparatus.

Cooling condition is defined when:

$$\vartheta_0 > \left(\frac{I}{I_b}\right)^2 * 100[\%]$$

The thermal model used during cooling condition for standing objects (cable / transformer / standing motor) is:

$$\vartheta_1 = \left(\frac{I}{I_b}\right)^2 + \left(\vartheta_0 - \left(\frac{I}{I_b}\right)^2\right) * e^{-\left(\frac{\Delta t}{\tau_{\downarrow s}}\right)}$$

ϑ_1 = new value of thermal image

ϑ_0 = present value of thermal image

I = maximum value of measured phase currents

I_b = base current (rated current/full load current defined by setting).

Δt = time interval between ϑ_0 and ϑ_1

$\tau_{\downarrow s}$ = Cooling time constant of standing objects

Block closing of CB

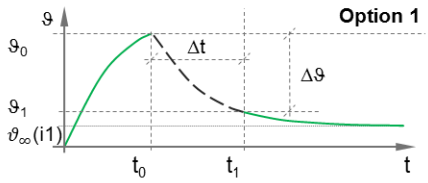
To prevent overheating of hotspots within a motor during startup, the restart could be blocked if the actual thermal image is above by the setting of $\vartheta_{startinhibit}$. During this condition the output to block closing of the CB (BLK_CLOSE) is activated.

When BLK_CLOSE is active closing of CB is not allowed by any means (i.e. communication or HMI or binary input). The activation and deactivation of BLK_CLOSE will be recorded as an event.

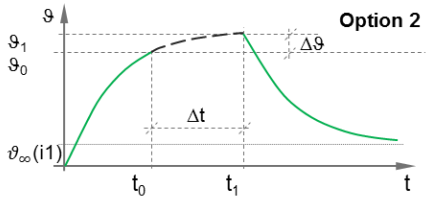
Behavior of thermal image during power down condition of IED:

Condition arises where in the power supplied to the IED is interrupted. The user could select four different behaviors / options to calculate the thermal level when the power is restored. These options are selectable by the setting Mode $\vartheta_{powerOFF}$.

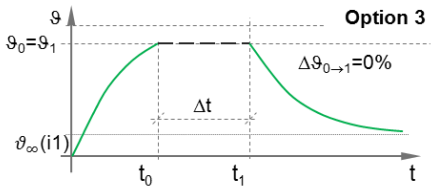
The thermal image along with time is stored every 60 sec. (and for option 1 also the actual maximum phase current).



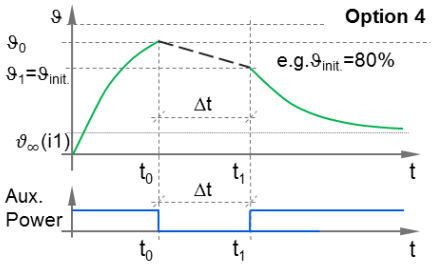
Option 1: When the power is restored after Δt, the new value of current after power on will be considered (which can be more or less compared to when power was interrupted) to calculate new value of thermal image for Δt.



Option 2. When the power is restored after Δt, the new value of thermal image is calculated for Δt considering that the current has remained constant at the value when the power was interrupted.



Option 3: Power interruption of the IED assumes no change of thermal image during interruption period.



Option 4: Power interruption of the IED resets the thermal image to the set value defined by setting ϑ_0.

Figure 7: Behavior of thermal image during power down condition

4.9.2.1 Setting range for thermal overload protection

Table 16: Setting range for thermal overload protection 3Ith, 49

Parameter	Description	Range	Unit	Step	Default
ϑ_0	Initial thermal level of the apparatus	0…100	%	1	80
I_b	Reference current leading to thermal calculation	0.1 … 1.5	xIn	0.1	1.0
$\tau_{\uparrow}$	Heating time constant	1 … 300	min	1	45
$\tau_{\downarrow s}$	Cooling time constant	1 … 300	min	1	45
ϑ_{alm}	Alarm value	50 … 200	%	1	121
ϑ_{trip}	Operate value	50 … 200	%	1	144
$\vartheta_{startinhibit}$	Start inhibit value	50 … 200	%	1	105
ϑ_{EM}	Percentage by which ϑ_{trip} will be increased in emergency mode	10… 100	%	1	50
Mode $\vartheta_{powerOFF}$	Options for calculating thermal value during power interruption	1…4	-	1	4

4.9.2.2 Configurable inputs to thermal overload protection

Table 17: Configurable inputs to thermal overload protection 3Ith, 49

Name	Type	Description
RESET	BOOL	Reset protection
BLOCK	BOOL	Block protection

4.9.2.3 Configurable outputs of thermal overload protection

Table 18: Configurable inputs to thermal overload protection 3Ith, 49

Name	Type	Description
ALARM	BOOL	Alarm
OPERATE	BOOL	Operate
Θ	REAL	Value of thermal image

4.10 Configurable logic gates

4.10.1 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.

4.10.2 Principle of operation

REF/REJ 601 2.2FP2 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.

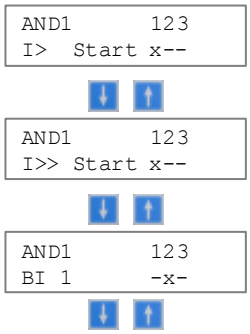


Figure 8: Example of multiple input configured to AND Input 1

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 19: Input signals list for logic gates

Signal name	Available as Input to									
	AND1	AND2	AND3	OR1	OR2	OR3	NOT1	NOT2	NOT3	NOT4
	Protection signals									
I> Start	•	•	•	•	•	•	•	•	•	•
I> Trip	•	•	•	•	•	•	•	•	•	•
I>> Start	•	•	•	•	•	•	•	•	•	•
I>> Trip	•	•	•	•	•	•	•	•	•	•
I>>> Start	•	•	•	•	•	•	•	•	•	•
I>>> Trip	•	•	•	•	•	•	•	•	•	•
I0> Start	•	•	•	•	•	•	•	•	•	•
I0> Trip	•	•	•	•	•	•	•	•	•	•
I0>> Start	•	•	•	•	•	•	•	•	•	•
I0>> Trip	•	•	•	•	•	•	•	•	•	•
3Ith> Alarm	•	•	•	•	•	•	•	•	•	•
3Ith> Trip	•	•	•	•	•	•	•	•	•	•
3Ith> Block close	•	•	•	•	•	•	•	•	•	•
I2/I1> Start	•	•	•	•	•	•	•	•	•	•
I2/I1> Trip	•	•	•	•	•	•	•	•	•	•
I2> Start	•	•	•	•	•	•	•	•	•	•
I2> Trip	•	•	•	•	•	•	•	•	•	•
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	•	•	•	•	•	•	•	•	•	•
	Control signals									
CB Open Command	•	•	•	•	•	•	•	•	•	•
CB Close Command	•	•	•	•	•	•	•	•	•	•
Unit ready	•	•	•	•	•	•	•	•	•	•

Table 19: Input signals list for logic gates, continue

	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 particular 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 gates one needs to configure that logic gate at Configuration/Blocking setting.

4.10.3 Examples of using logic gates with timers

REF/REJ 601 2.2FP2 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 configuration:

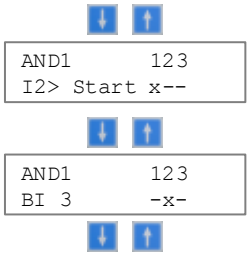


Figure 9: Example: AND1 configuration

On delay timer TON1 configuration:

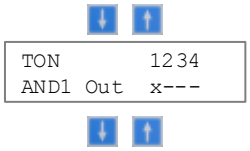


Figure 10: Example: TON1 configuration

Also TON1 delay to be set as 0.10 s under Configuration/TON Delay setting.

4.11 On delay timer TON

4.11.1 Functionality

The 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.

4.11.2 Principle of operation

REF/REJ 601 2.2FP2 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 11.

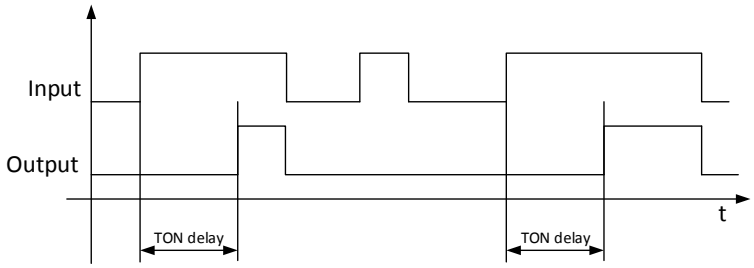


Figure 11 : Behavior of On delay timer TON

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 20 Input signal list for TON and TOFF timers

Signal name	Available as Input to					
	TON1	TON2	TON3	TON4	TOFF1	TOFF2
	Protection signals					
I> Start	•	•	•	•	•	•
I> Trip	•	•	•	•	•	•
I>> Start	•	•	•	•	•	•
I>> Trip	•	•	•	•	•	•
I>>> Start	•	•	•	•	•	•
I>>> Trip	•	•	•	•	•	•
I0> Start	•	•	•	•	•	•
I0> Trip	•	•	•	•	•	•
I0>> Start	•	•	•	•	•	•
I0>> Trip	•	•	•	•	•	•
3Ith> Alarm	•	•	•	•	•	•
3Ith> Trip	•	•	•	•	•	•
3Ith> Block close	•	•	•	•	•	•
I2/I1> Start	•	•	•	•	•	•
I2/I1> Trip	•	•	•	•	•	•
I2> Start	•	•	•	•	•	•
I2> Trip	•	•	•	•	•	•
BF Stage 1	•	•	•	•	•	•
BF Stage 2	•	•	•	•	•	•
BF Receive Trip	•	•	•	•	•	•
O→I Close	•	•	•	•	•	•
O→I In Progress	•	•	•	•	•	•
O→I Final Trip	•	•	•	•	•	•
O→I Blocked	•	•	•	•	•	•

Table 20 Input signal list for TON and TOFF timers, continue

Signal name	Available as Input to					
	TON1	TON2	TON3	TON4	TOFF1	TOFF2
TCS Fault	•	•	•	•	•	•
	Binary input signals					
Binary Input 1	•	•	•	•	•	•
Binary Input 2	•	•	•	•	•	•
Binary Input 3	•	•	•	•	•	•
Binary Input 4	•	•	•	•	•	•
	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 particular function.

All four instance of On delay timer TON can be configure from a single 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/Blocking setting.

Table 21: 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.

4.12 Off delay timer TOFF

4.12.1 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.

4.12.2 Principle of operation

REF/REJ 601 2.2FP2 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

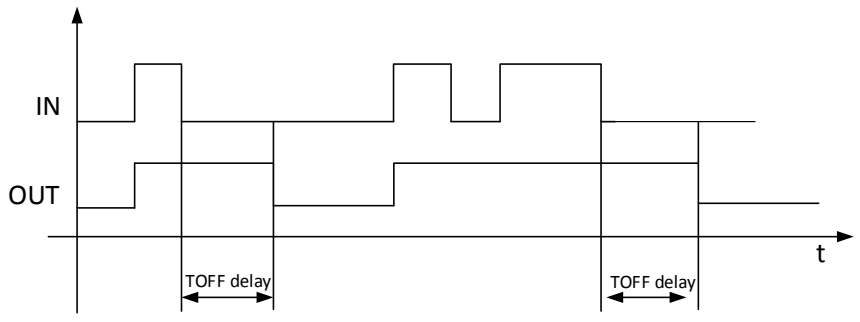


Figure 12: Behavior of Off delay timer TOFF

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 single 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/Blocking setting.

Table 22: 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

4.13 Fault identification

4.13.1 Functionality

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

4.13.2 Principle of operation

REF/REJ 601 2.2FP2 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. The information can also be used with logic gates and TON & TOFF timers. It is also possible to identify multiphase faults. Events will get registered for the phase in which fault has been identified.

4.14 Protection characteristics

4.14.1 Time / Current characteristics

Relay offers three-stage overcurrent and two 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 ANSI C37.xxx standard namely moderate inverse, normal inverse, very inverse, extremely inverse and one special curve, named RI type curve along with DT characteristics.

4.14.2 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 23: 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

4.14.3 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 24: 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

4.14.4 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:

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

Where,

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

4.15 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.

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> and Io>>
- Individual trip of protection functions I>, I>>, I>>>, 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 25: Trip and signaling 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
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> and Io>> it will close and remain latched

4.16 Configurable LED

The relay has total five LED's for user defined signaling. The 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 via MODBUS.

All five user defined LED's 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> and Io>>
- Individual trip of protection functions I>, I>>, I>>>, Io> and Io>>
- External user defined Signal 1 to Signal 3 available at binary input (configured via binary input menu)

Table 26: LED indications (on relay front))

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
LED 1 (RED)	User configured: Default: Trip Ip => Trip overcurrent faults (I>, I>> and I>>>)
LED 2 (RED)	User configured: Default: Trip Io => Trip earth faults (Io> and Io>>)
LED 3 (RED)	User configured: Default: TCS Fault => trip circuit has failure
LED 4 (RED)	User configured: Default: Spare (not configured)
LED 5 (RED)	User configured: Default: Spare (not configured)

4.17 Configurable Binary Inputs

The IED 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> 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 IED 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 5 LED’s.

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

Table 27: 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

4.18 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 MODBUS communication or from signals wired to relay binary inputs duly configured for control operation.

4.19 Trip Circuit Supervision

Application

The Trip Circuit Supervision TCS 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.

It is possible to enable/disable TCS functionality through configuration parameter. For the TCS functionality the BI2 need to be connected in parallel to the trip output BO2 as shown in the figure below. Additionally the BI2 need to be configured for the TCS functionally.

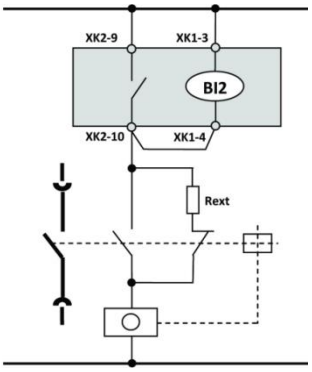


Figure 13: Application diagram of TCS function

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 28: 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 AC/DC 60 V AC/DC 110 V AC/DC 220 V AC/DC	Recommended shunt resistor Rext 1.2 kΩ, 5 W 5.6 kΩ, 5 W 22 kΩ, 5 W 33 kΩ, 5 W

Whenever TCS functionality is enabled, it is recommended to connect R_{ext}. Otherwise, TCS sees a faulty trip circuit in open circuit breaker position.

Table 29: TCS functionality parameters and selection range

Name	Value (Range)	Unit	Step	Default	Description
Operate delay time	1…10	Sec	1	1	Settable
	10…300	Sec	1		
Reset delay time	0.5	Sec	---	0.5	Fixed

Section 5 Use of LHMI

5.1 Overview

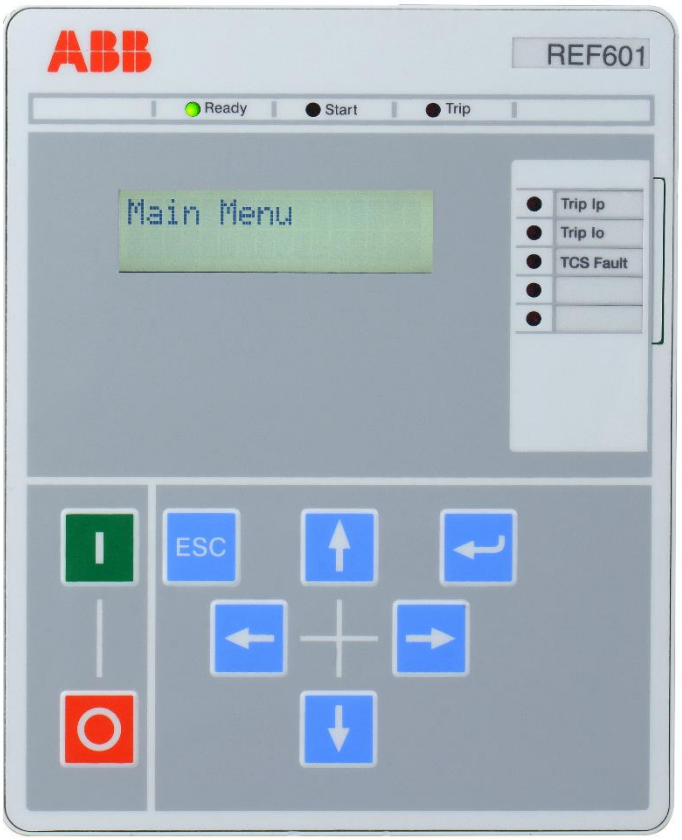


Figure 14: Local HMI of relay REF601 / REJ601

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.

5.1.1 LED's

LED's displays following information respective status

Ready:	Green LED	
Start:	Yellow LED	lights after any start of a protection function
Trip:	Red LED	lights after any trip of protection function
LED 1…5	Red LED	functionality as configured

5.1.2 LCD display

The LHMI includes a 2 x 16 character LCD display which supports English and Chinese characters.

5.1.3 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 30: 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.

5.1.4 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 release 2.2 and earlier. The password shall be set by selecting arrow symbols in password configuration menu.
- Alpha-numeric password protection – Achieve by four letter password. 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 31: 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.

Sequence looks as follow:

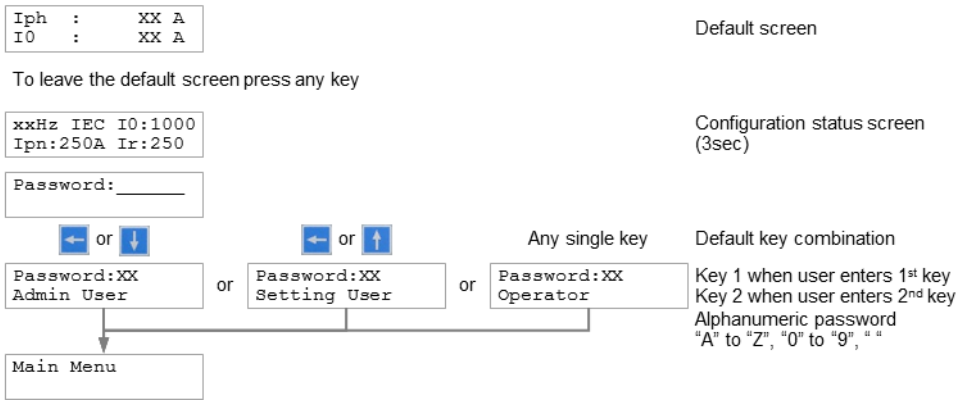


Figure 15: Login process of relay REF601 / REJ601

Password configuration

The password could be changed under the Main Menu -> Access Level.

In access level menu, password can be set for both setting & admin level. In edit mode, cursor position can be set by ← or ← arrow key and allowed password symbol can be selected by ↑ or ↓ arrow key. Finally by ENTER key password can be set.

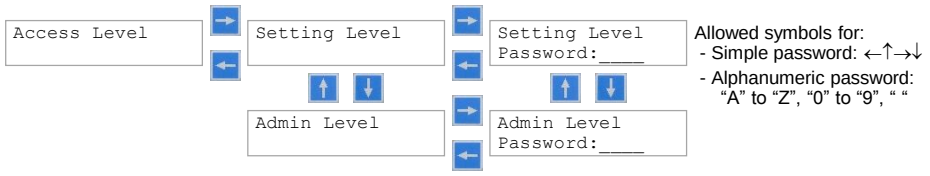


Figure 16: Password configuration in relay

5.1.5 Configuration status

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

Following figure shows configuration status screen:

Figure 17: Configuration status display screen

Configuration status screen (3 sec)

1. Frequency: 50 or 60 Hz
2. I0: 20..9999 (Primary current of external earth CT)
3. Ipn: 20..9999 (Primary current of phase CT)

5.2 LHMI menu navigation

5.2.1 Default screen

The default view of the relay displays the largest phase current and earth current which is indicated in Fig. 10. The relay returns to default screen after 5 minutes if no key is pressed.

Current values are displayed in this view for phase current and earth current in “A” as shown in following figure.

Figure 18: Default screen of relay REF601 / REJ601

5.2.2 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.

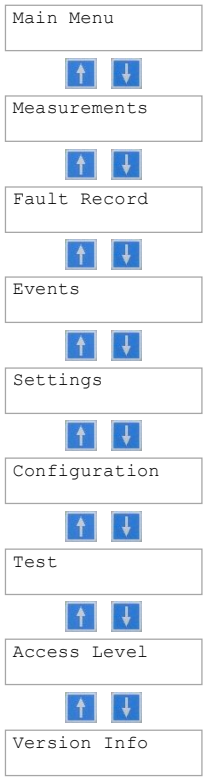


Figure 19: Main menu of relay REF601 / REJ601

5.2.3 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. Also it shows binary input and output status at the relay terminal.

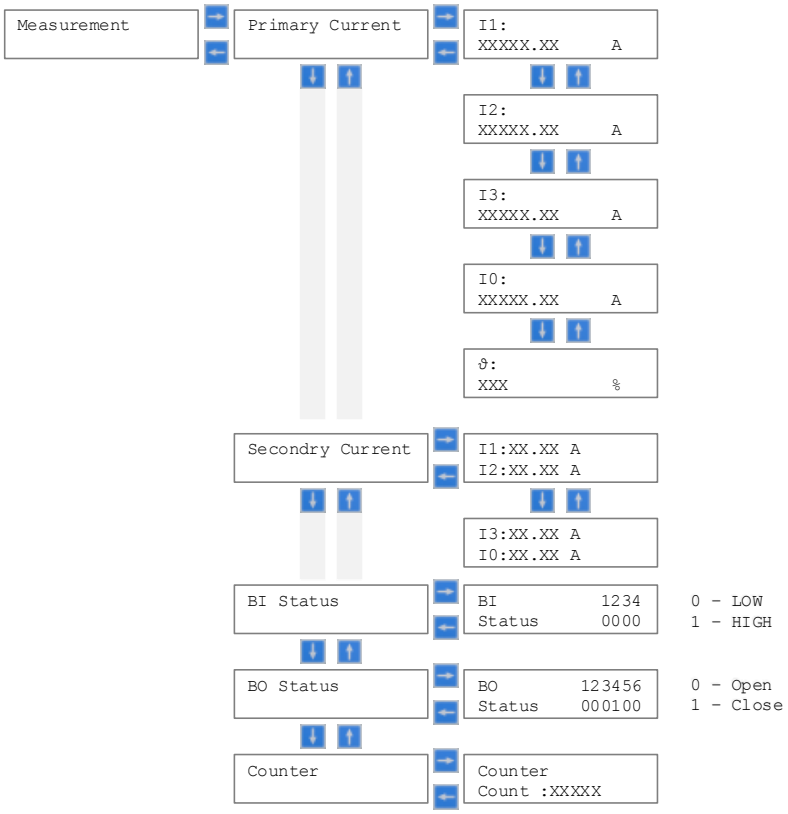


Figure 20: Measurement menu of relay REF601 / REJ601

5.2.4 Menu – Fault record

Submenu Fault record shows under Recorded Current the fault records for the last five 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 below.

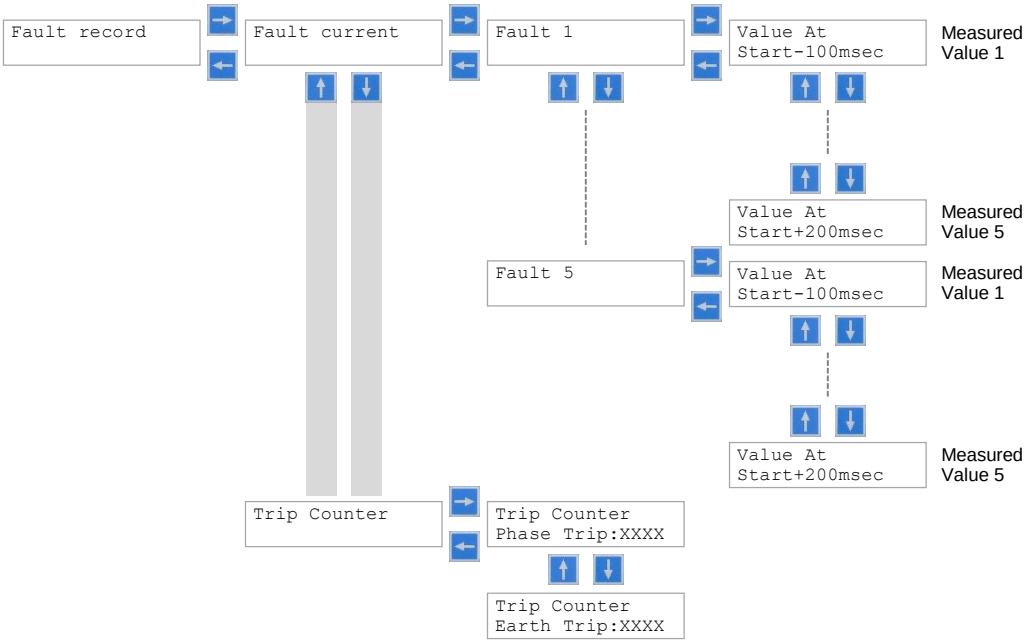


Figure 21: Fault record data menu of relay REF601 / REJ601

5.2.5 Menu - Events

Submenu Events shows events 1 – 100 with details in respective submenu.

Event 1 will always contain data of most recent event and event 100 would be the oldest.

The event menu can be access as below.

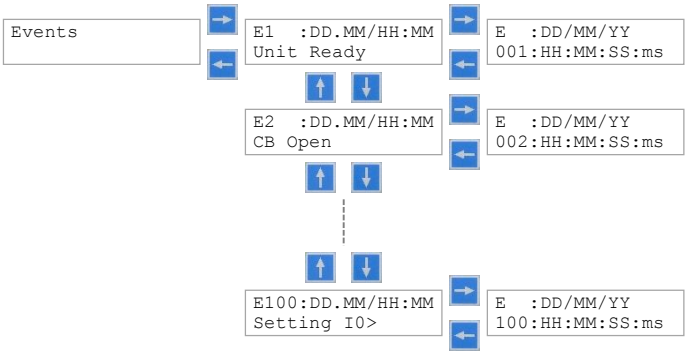


Figure 22: Event menu of relay REF601 / REJ601

5.2.6 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 IED configuration parameter is allowed to change through MODBUS

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

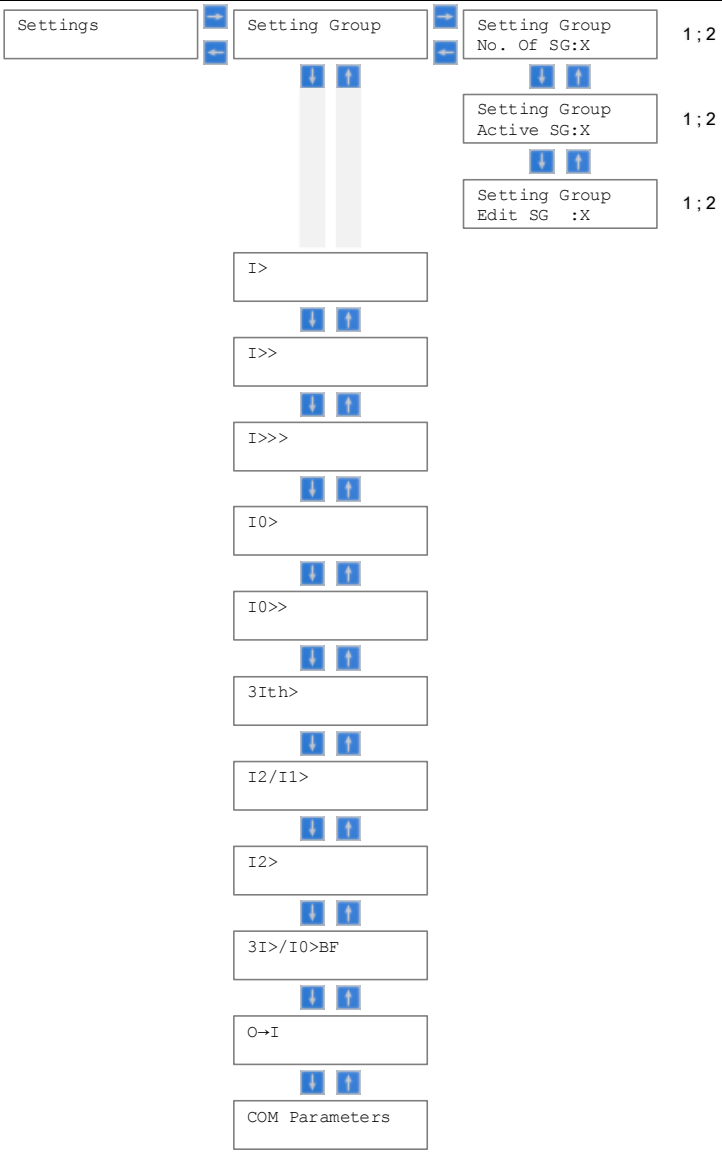


Figure 23: Setting menu of relay REF601 / REJ601

5.2.7 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
- 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:

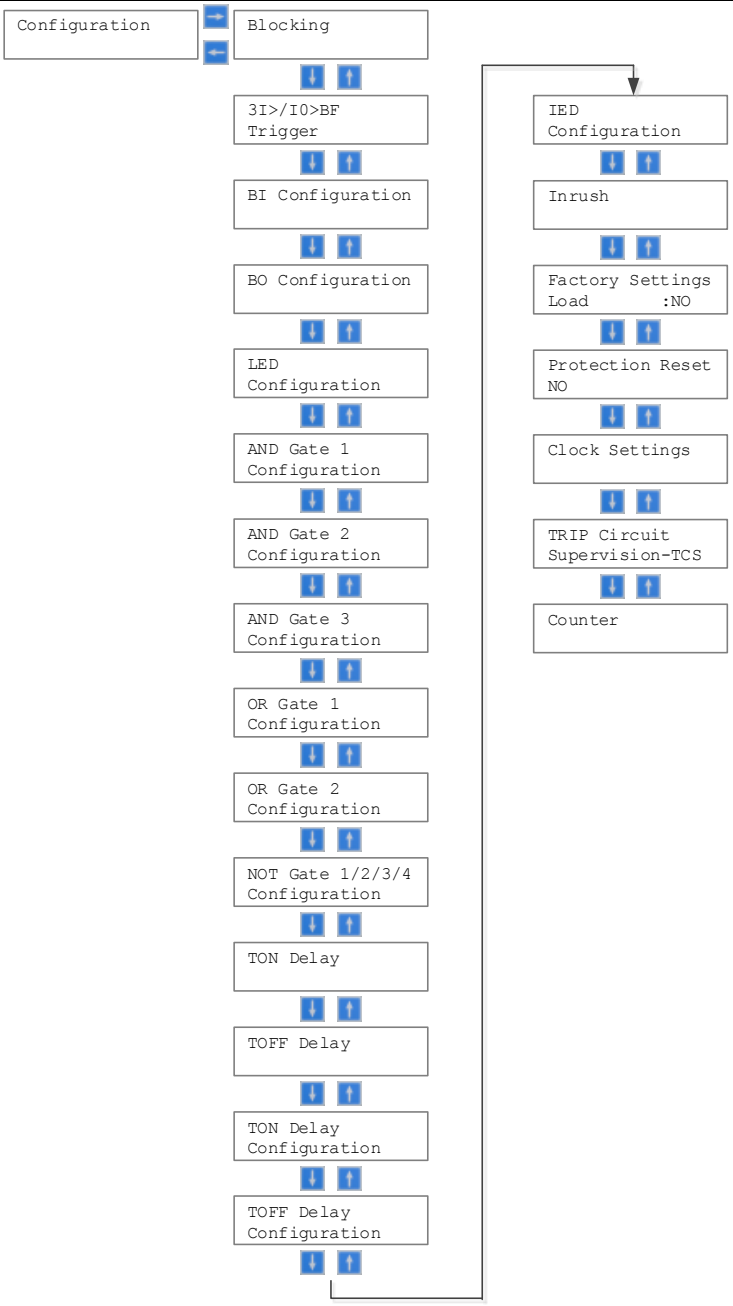


Figure 24: Configuration menu of relay REF601 / REJ601 with its submenu

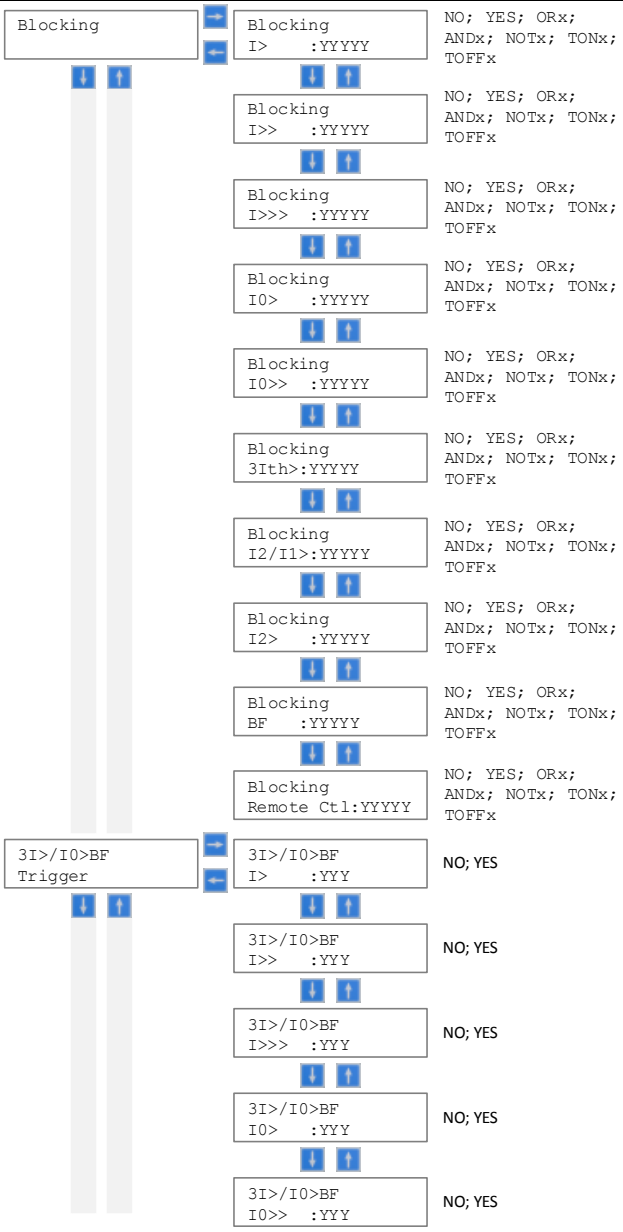


Figure 24: Configuration menu of relay REF601 / REJ601 with its submenu, continue

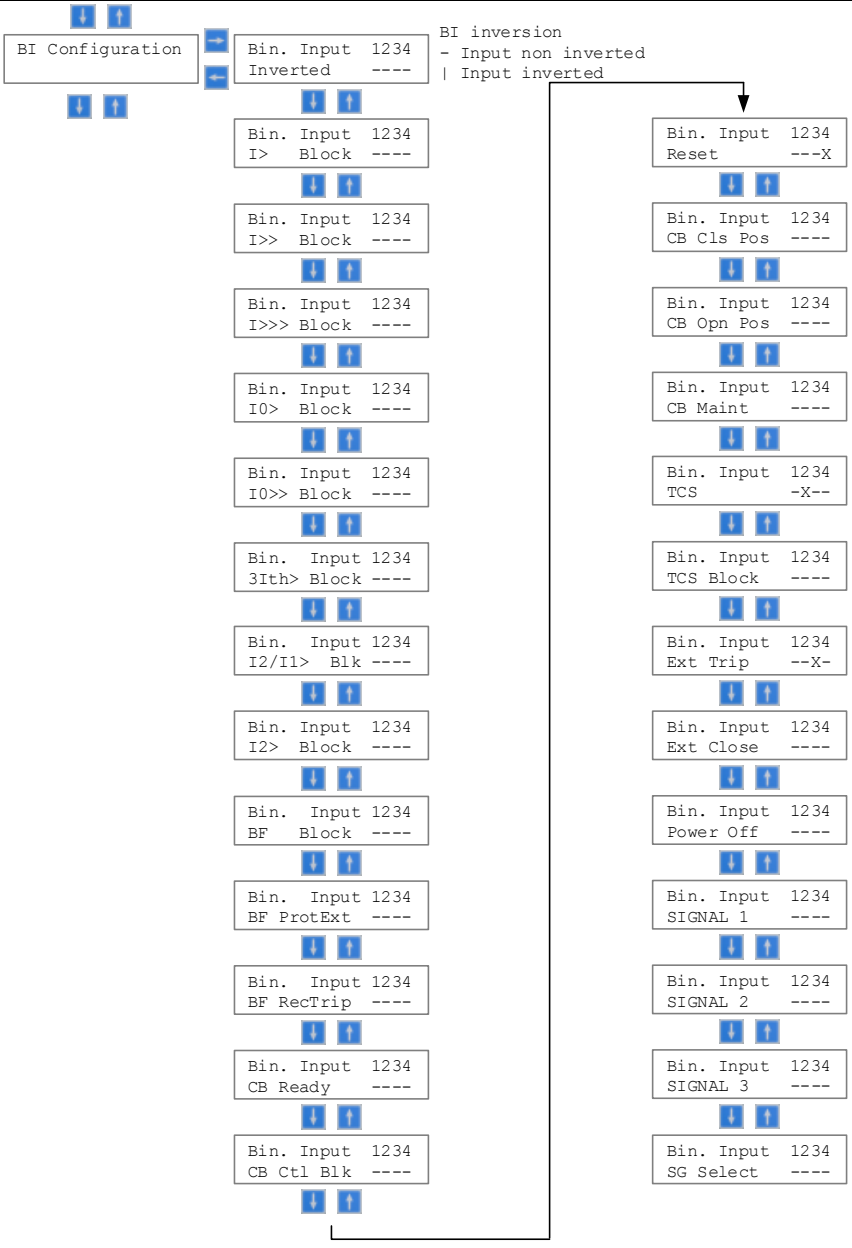


Figure 24: Configuration menu of relay REF601 / REJ601 with its submenu, continue

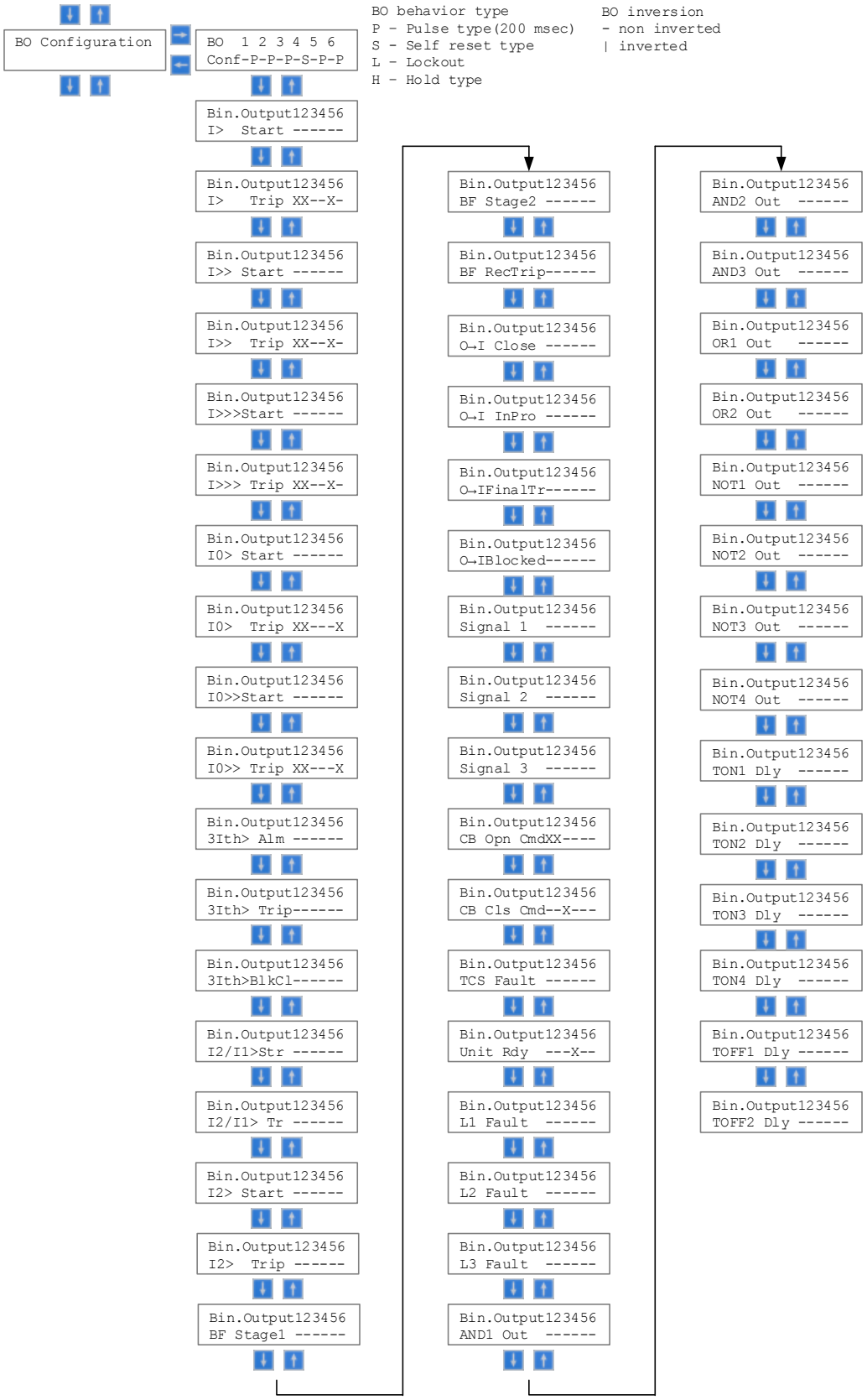


Figure 24: Configuration menu of relay REF601 / REJ601 with its submenu, continue

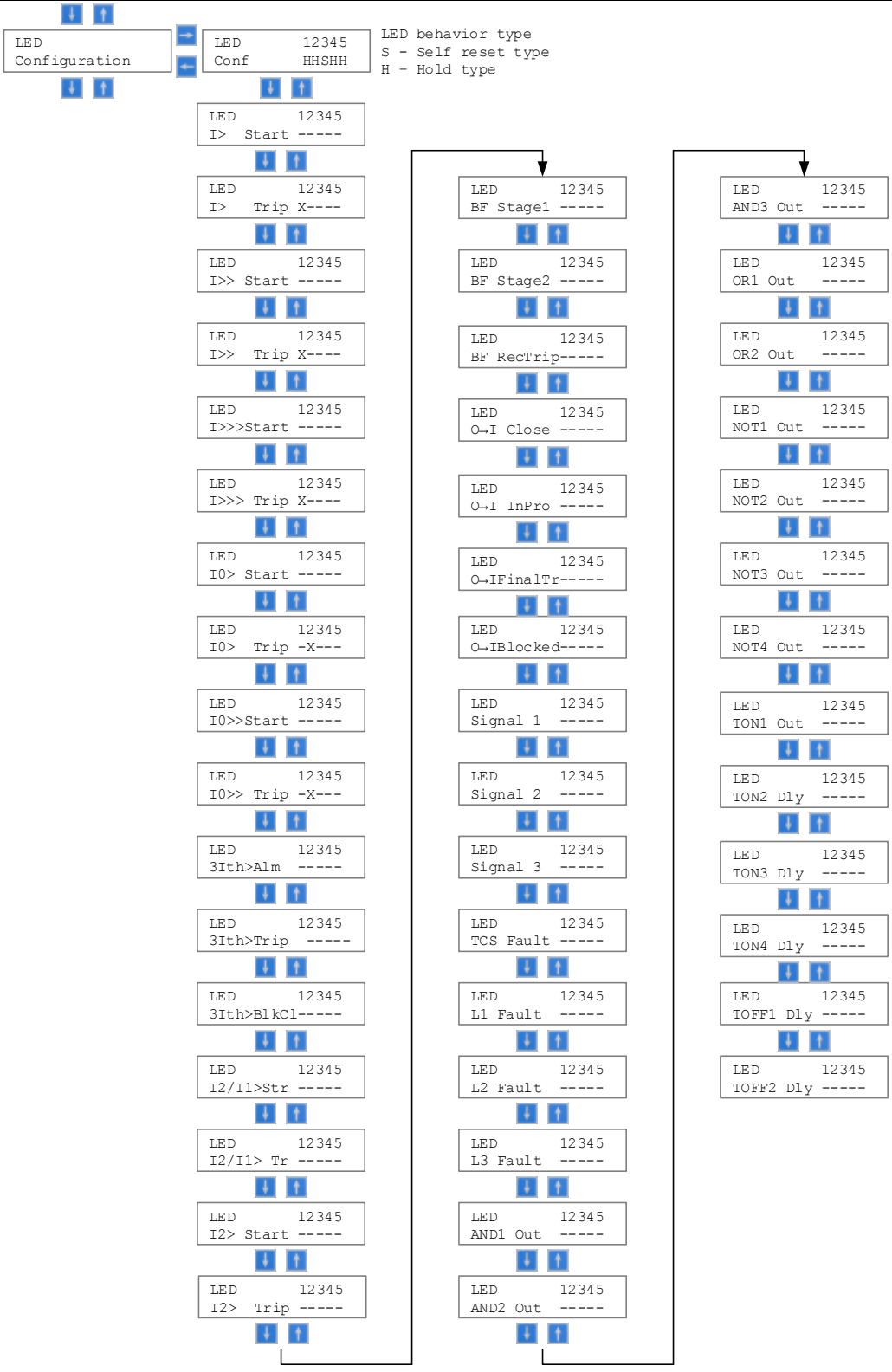


Figure 24: Configuration menu of relay REF601 / REJ601 with its submenu, continue

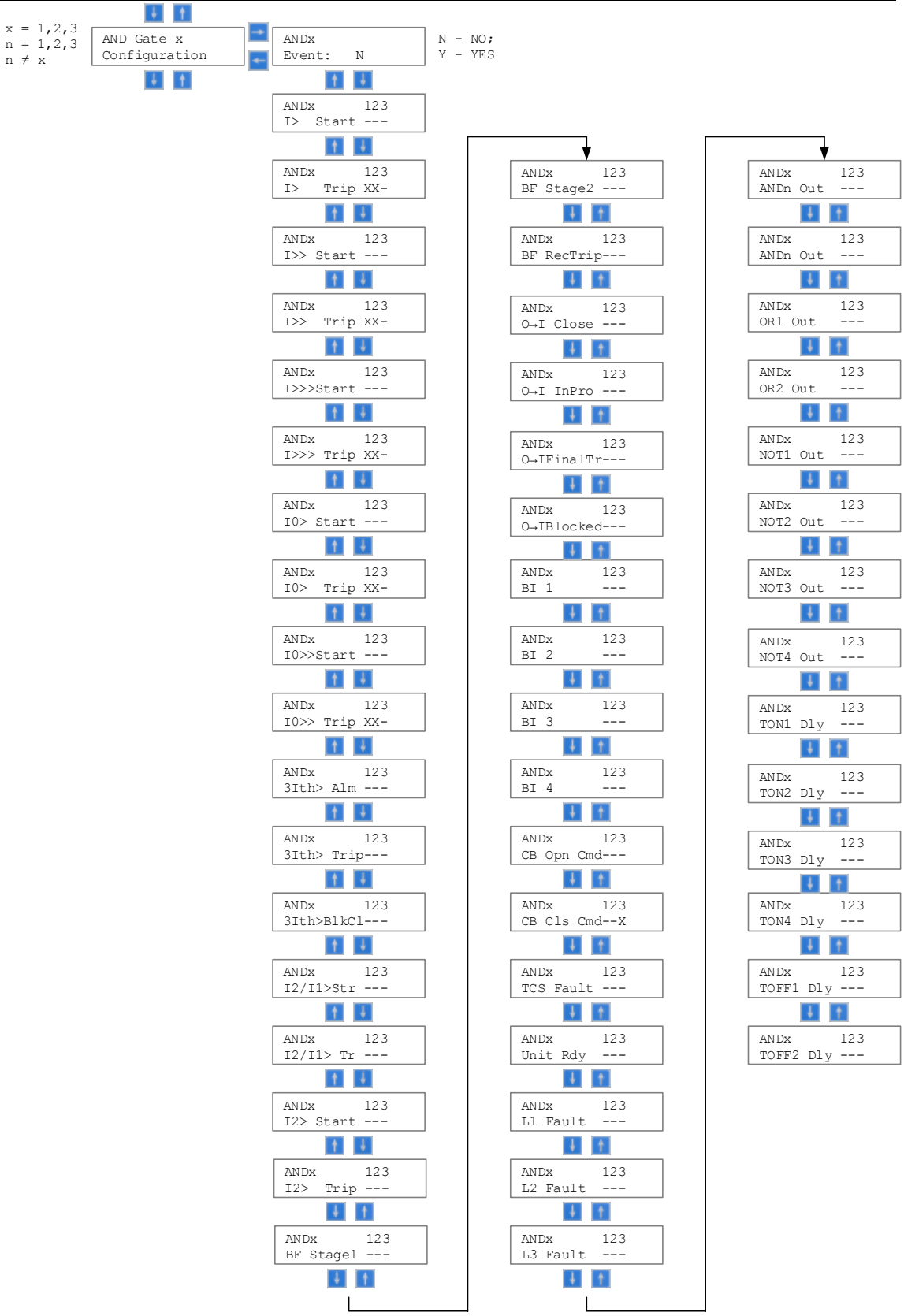


Figure 24: Configuration menu of relay REF601 / REJ601 with its submenu, continue

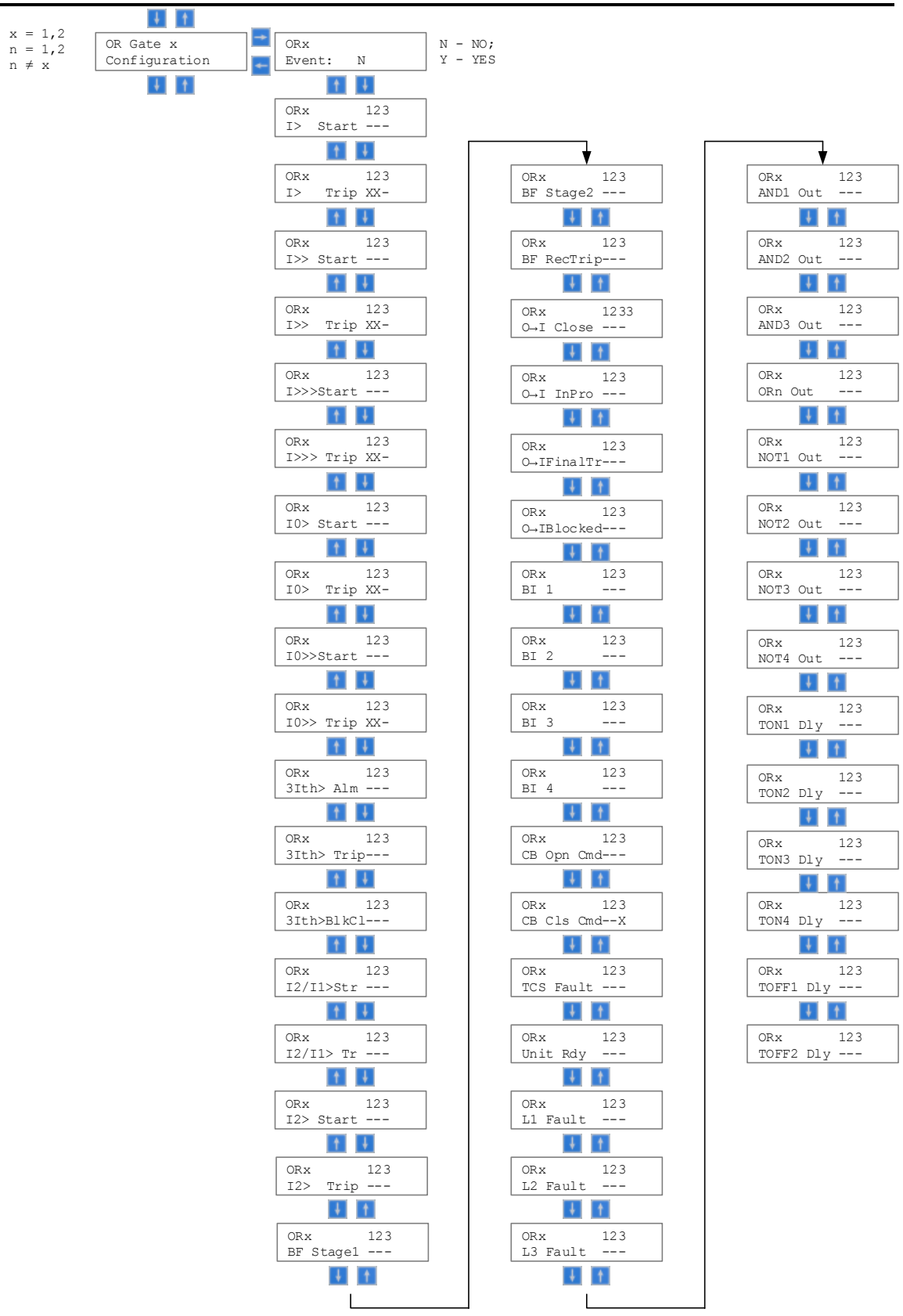


Figure 24: Configuration menu of relay REF601 / REJ601 with its submenu, continue

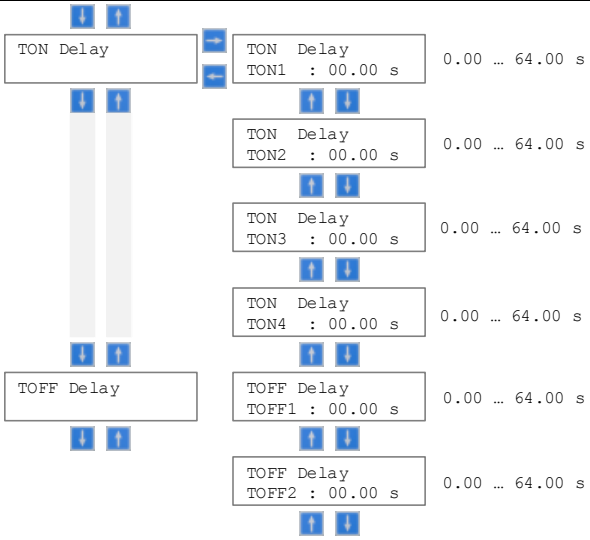


Figure 24: Configuration menu of relay REF601 / REJ601 with its submenu, continue

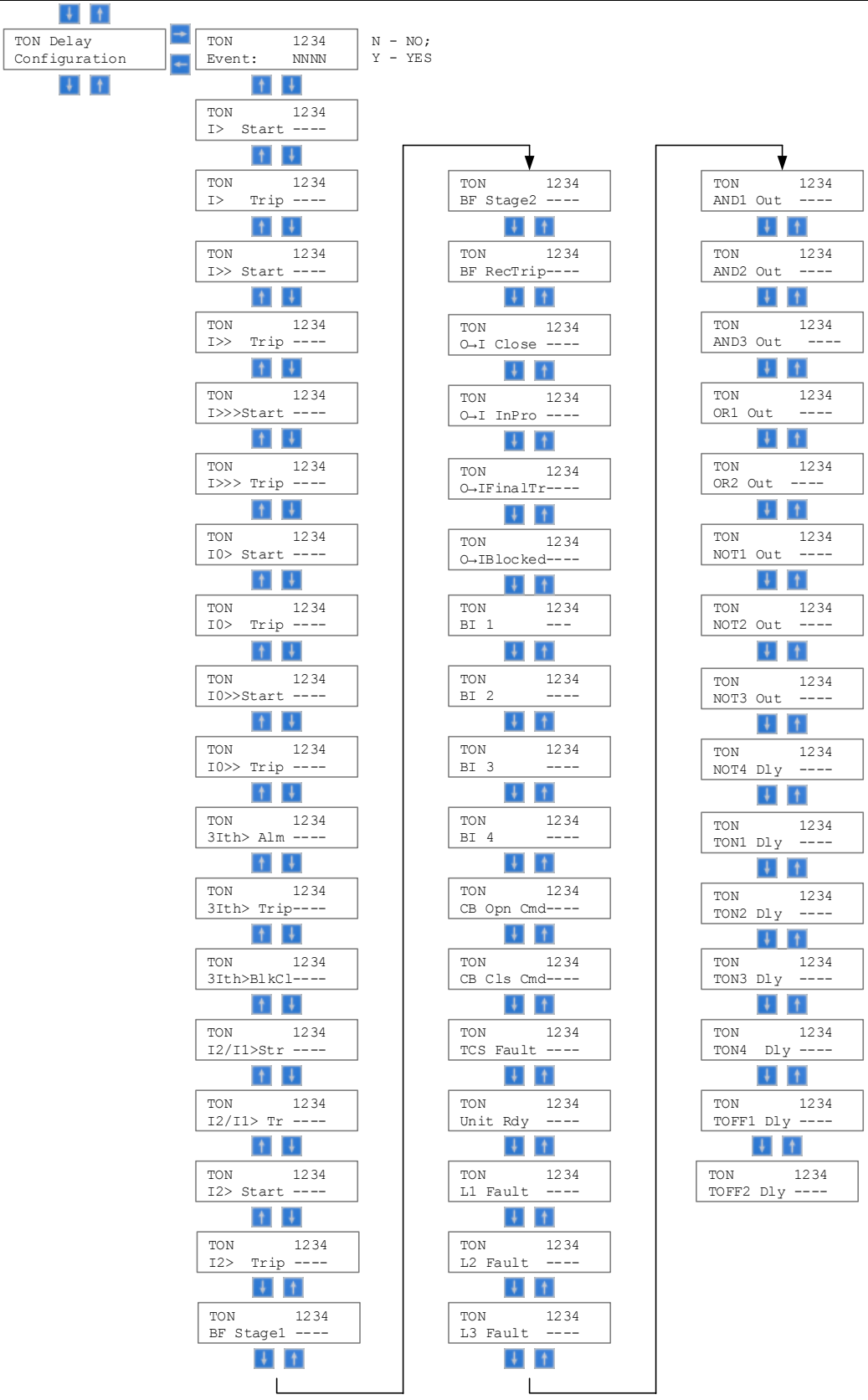


Figure 24: Configuration menu of relay REF601 / REJ601 with its submenu, continue

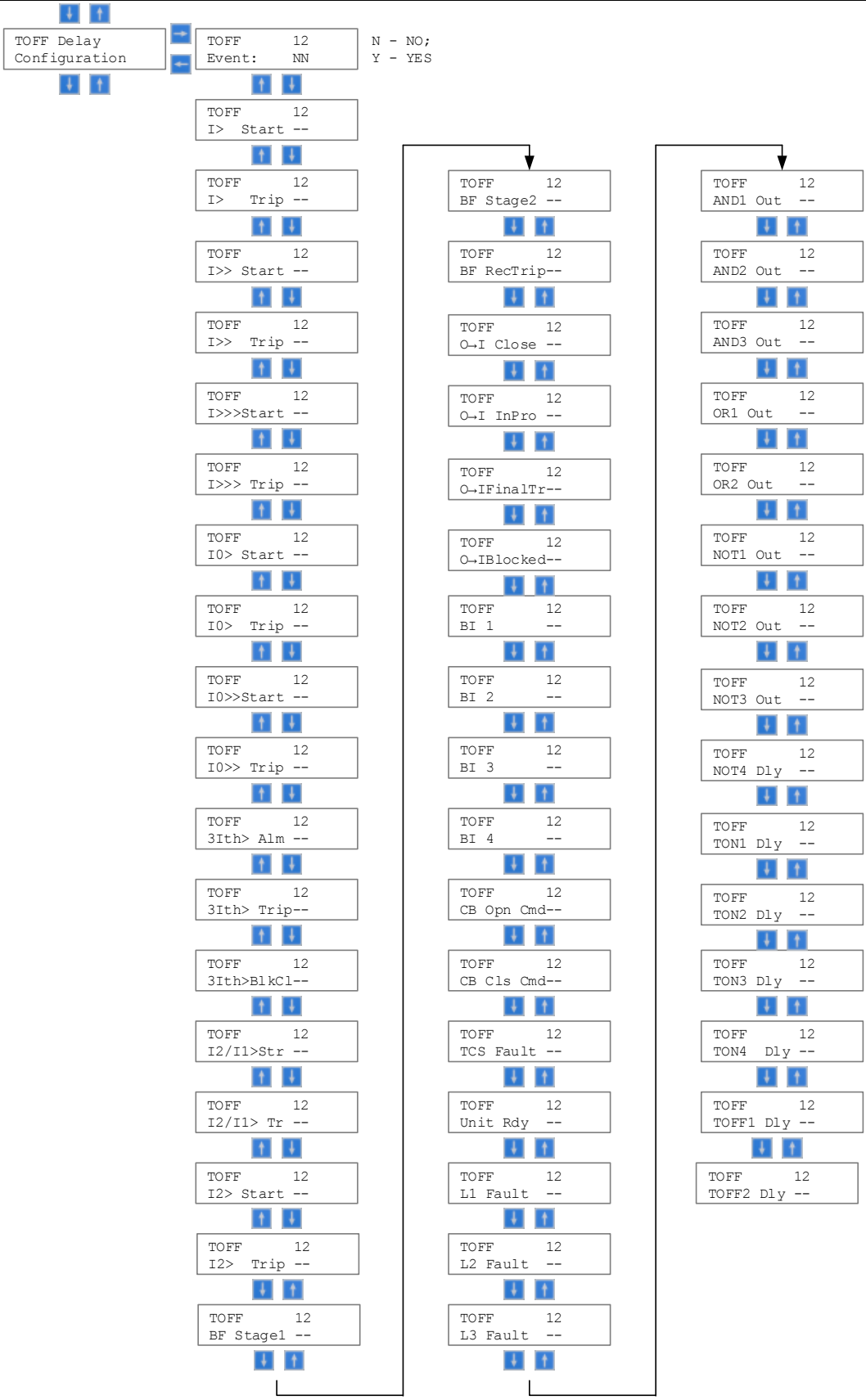


Figure 24: Configuration menu of relay REF601 / REJ601 with its submenu, continue

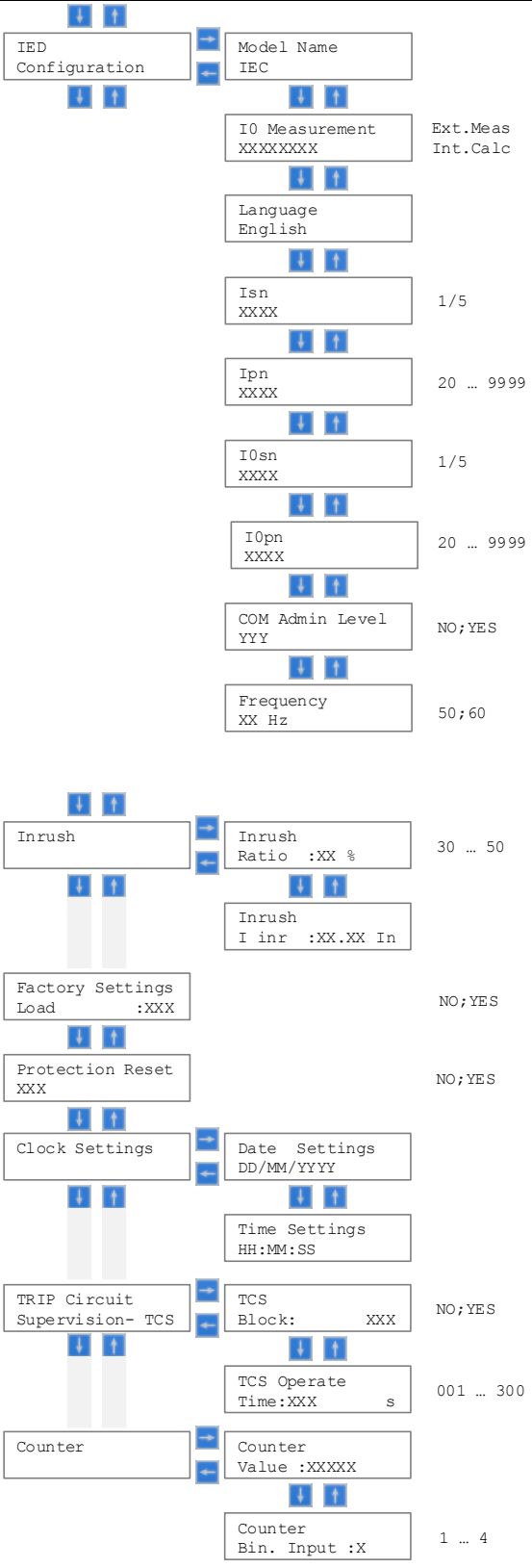


Figure 24: Configuration menu of relay REF601 / REJ601 with its submenu

5.2.8 Menu – Test

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

Test -> Hardware: Enables Internal Hardware Tests, which includes LCD check, Keyboard check and LEDs check. User can skip particular checks using interactive menu selection.

Test -> Binary Output (BO): Enables testing of all output contact to test the complete external circuit initiated by the output contact. Once test BO selected output will be operated for around 2 sec.

Test -> 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 values 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 Setting or Admin user.

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

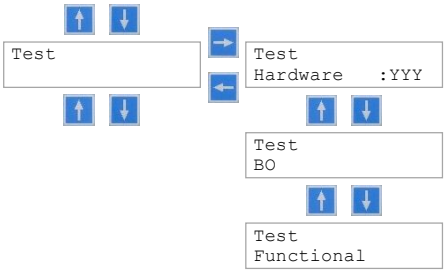


Figure 25: Test menu of relay REF601 / REJ601 with its submenu

5.2.8.1 Menu – Hardware

Following functionalities can be tested through this menu.

- LCD Test
- Keyboard Test
- LED Test

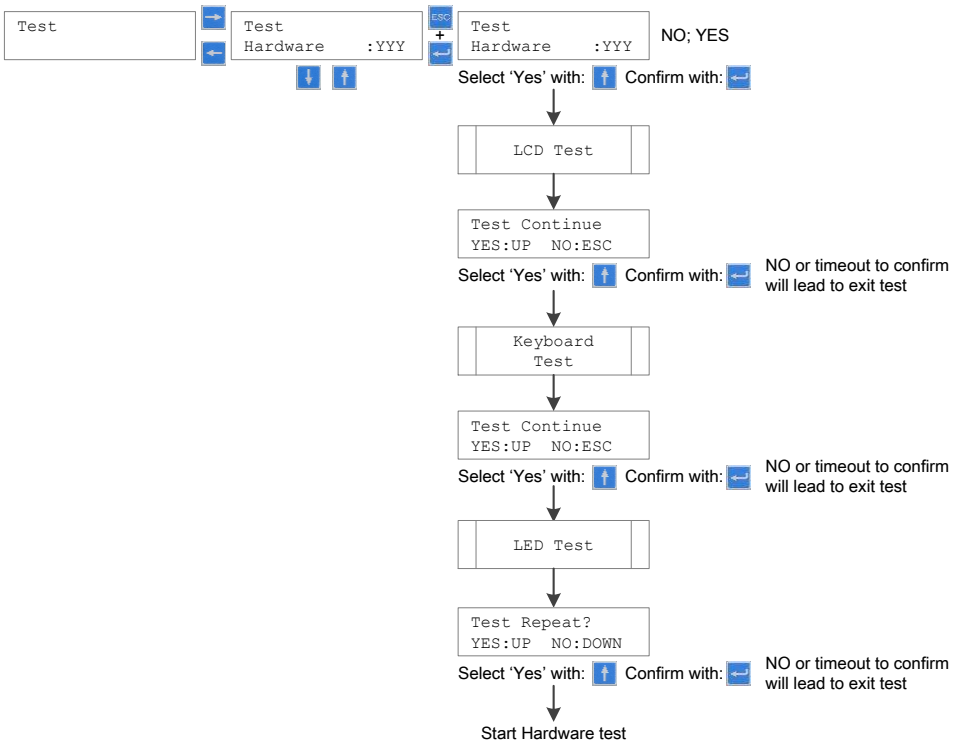


Figure 26: Hardware test menu of relay REF601 / REJ601 with its submenu

During each 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.

Each test procedure provides test result messages and interactive user selections on LCD.

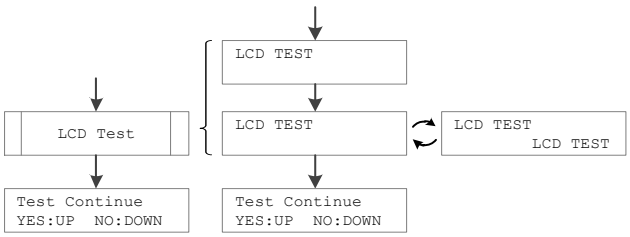


Figure 27: Hardware test menu of relay REF601 / REJ601 with its submenu

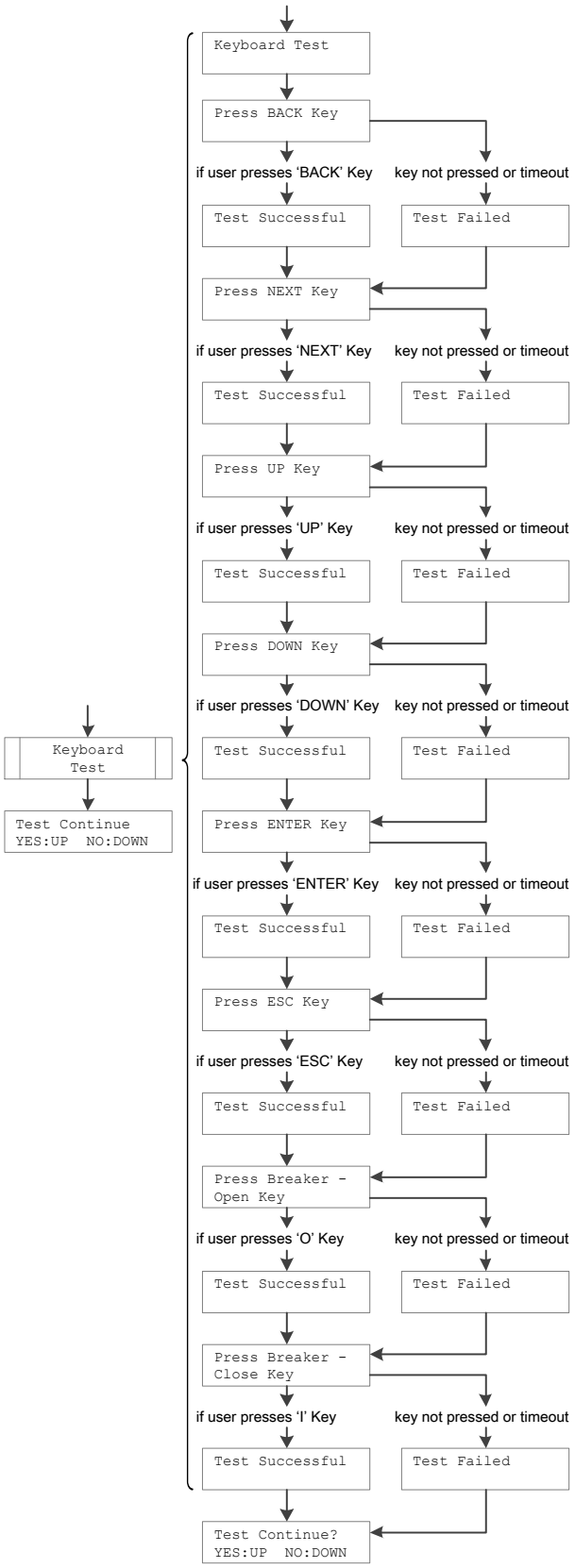


Figure 28: Hardware test menu of relay REF601 / REJ601 with its submenu (Continue)

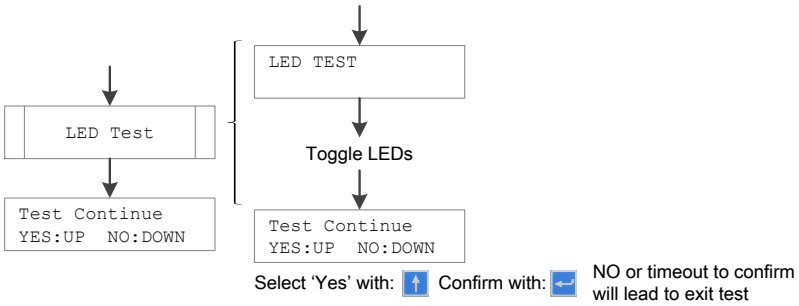


Figure 28: Hardware test menu of relay REF601 / REJ601 with its submenu (Continue)

5.2.8.2 Submenu – Binary output test

Submenu binary output test allows to force a binary output. The forced output operates for a pulse duration of 1 sec.

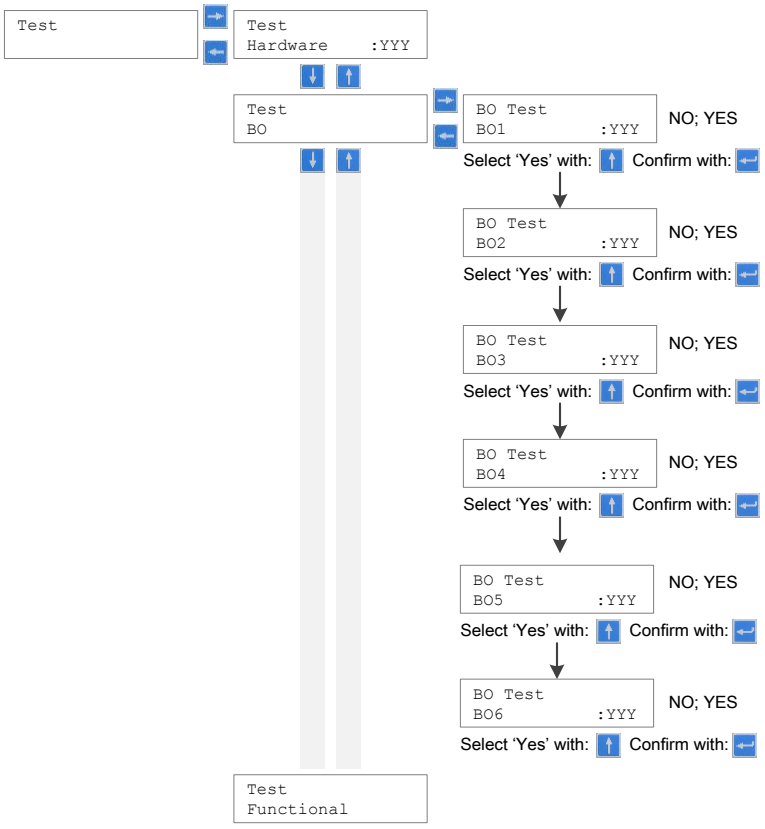


Figure 29: Binary output test menu of relay REF601 / REJ601 with its submenu

5.2.8.3 Submenu – Functional test

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

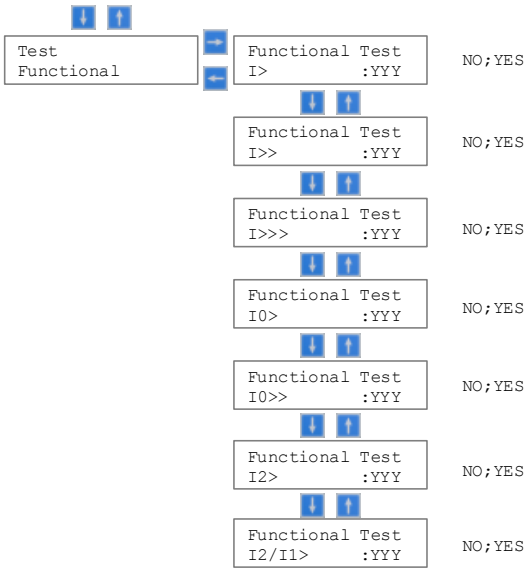


Figure 30: Functional test menu of relay REF601 / REJ601

5.2.9 Access level

This menu provides the password change facility for the different access levels. Only Admin can change the password of the other access levels. Activating edit mode by pressing Enter and Cancel button together can change password. User can then enter new password. Enter button must be pressed before timeout period after changing the password. Password can be of six different combinations of the navigation keys. Each navigation key has its unique ID (1..4) which will be selected as password for the different access levels. Only two key combinations can be used for password entry/selection.

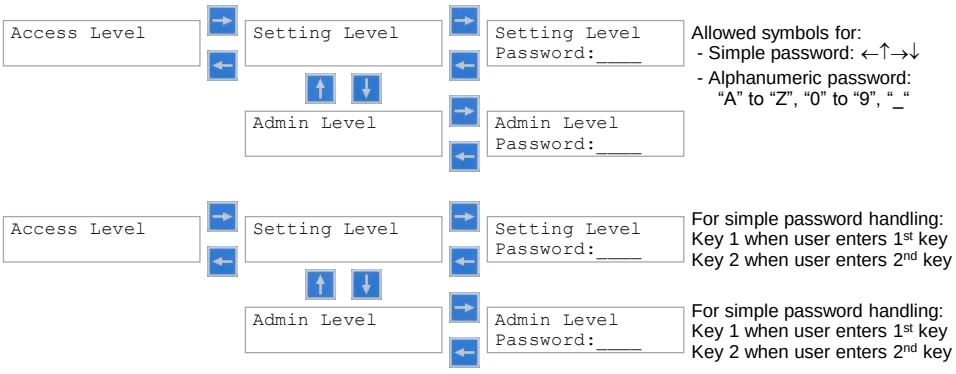


Figure 31: Access level menu

5.2.10 Version information

This menu provides information regarding the Product type selected, Software version being presently loaded into the product, Model name, Nominal current value selected, and the type of trip circuit present.

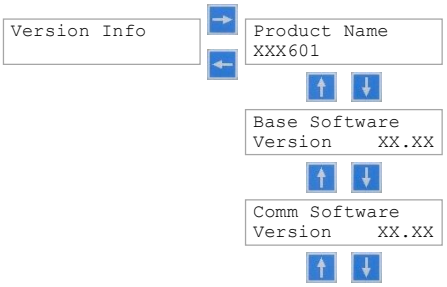


Figure 32: Version information menu

Section 6 Installation

6.1 Unpacking and inspecting the device

REF601 / REJ601 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 needs 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 rear panel may not be removed.

6.2 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.

6.3 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.
- 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.

6.4 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

6.5 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

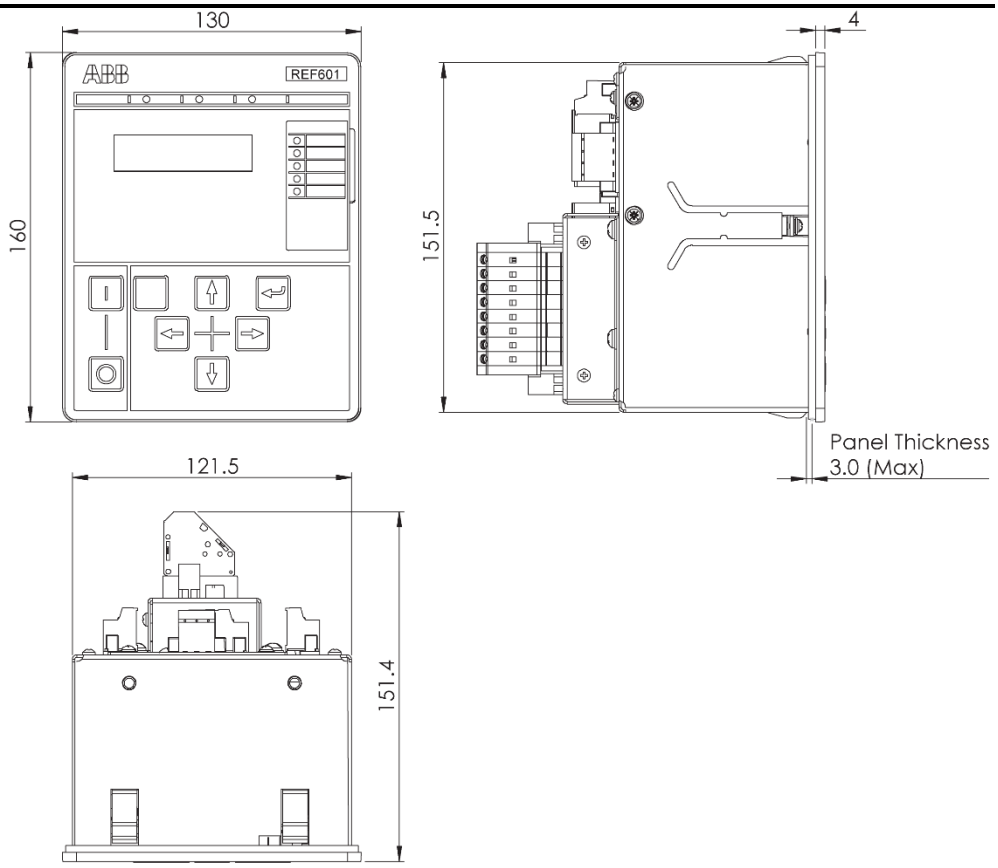


Figure 33: Overall mounting dimension of REF601 / REJ601

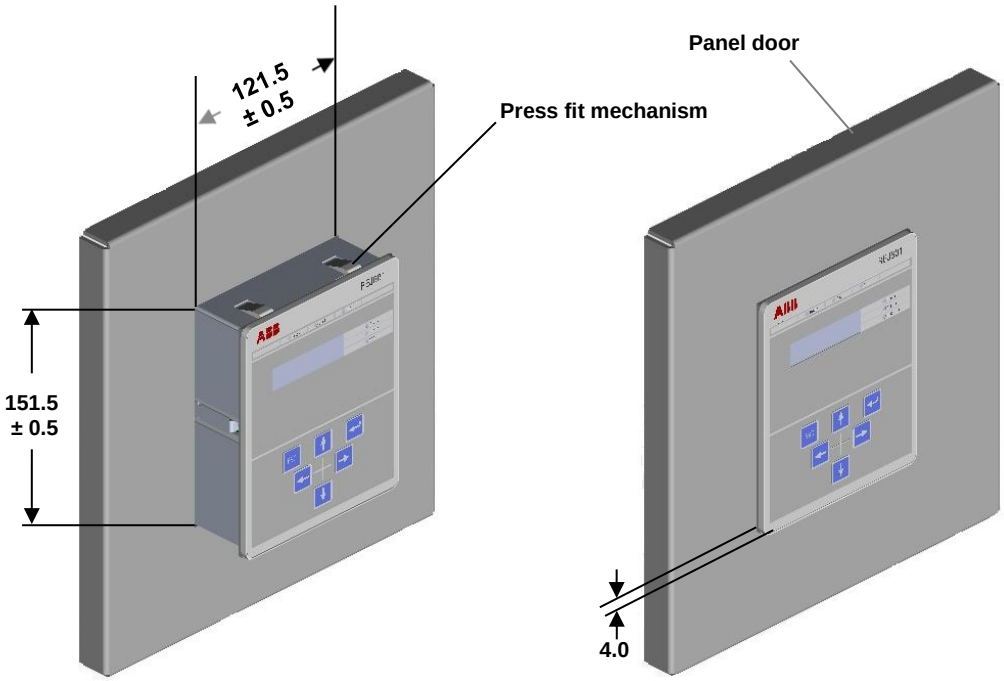


Figure 34: Panel mounting details of REF601 / REJ601

6.6 Terminal diagram

Relay terminal / connection diagram shall be as the relay.

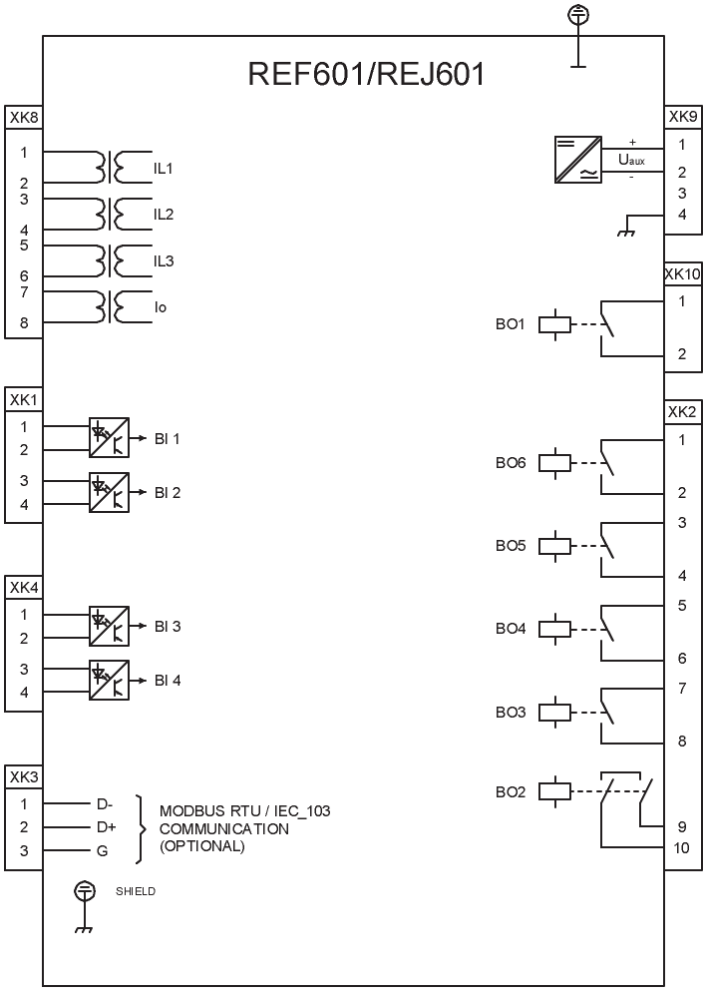


Figure 35: Connection diagram of relay REF601 / REJ601

6.7 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	B	E	1	N	I
#	Description									
1	**Relay type**									
	Feeder protection with control	REF601								
	Feeder protection	REJ601								
2	**Standard**									
	IEC	B								
3,4	**Analog input / output**									
	Phase and Earth current input – 1/5A	F4								
5,6	**Binary input / output**									
	4 BI + 6 BO	46								
7	**Serial communication**									
	MODBUS RTU with RS485 two wire	B								
	None	N								
8	**Application configuration**									
	Configuration 5	E								
9	**Power supply**									
	24...240V AC / DC	1								
10	**Configuration**									
	Ring lug terminals	B								
	Screw terminals	N								
11	**Version**									
	Product version 2.2 FP2	I								

Digit (#)	1	2	3,4	5,6	7	8	9	10	11
Your Order Code									

Figure 36: Ordering information of relay REF601 / REJ601

6.8 Accessories and ordering data

Table 32: REF601 / REJ601 accessories and ordering data

Item	Order number
RE_601 communication card	CIM601BNNNNBANXI

6.9 Setting table

Table 33: Settings

Parameter	Actual value	Default value	Unit	Range	Resolution
3I> / 51					
I>		01.50	In	0.5...2.5; infinite	0.001
t>		01.00	s	0.04…64	0.010
I> Curve		DT	-	DT, IEC NI, IEC VI, IEC LI, IEC EI, RI, ANSI NI, ANSI VI, ANSI MI, ANSI EI,	-
k				0.02 – 1.6	0.010
3I>> / 50-1					
I>>		04.00	In	0.5…25; infinite	0.001
t>>		00.30	s	0.04…64	0.010
3I>>> / 50-2					
I>>>		10.00	In	0.5…25; infinite	0.001
t>>>		00.03	s	0.03…64	0.010
I0> / 51N					
I0>		00.05	In	Ext.: 0.05...2.0; infinite Int.: 0.5…2.0; infinite	0.001
t0>		01.50	s	0.04...64	0.010
I0> Curve		DT	-	DT, IEC NI, IEC VI, IEC LI, IEC EI, RI, ANSI NI, ANSI VI, ANSI MI, ANSI EI,	-
k0				0.02 – 1.6	0.010
I0>> / 50N					
I0>>		04.00	In	Ext.: 0.05…12.5; infinite Int.: 0.5…12.5; infinite	0.001
t0>>		00.05	s	0.04…64	0.010
3I2f> / 68					
Inrush threshold		0.50	In	0.5…25	0.010
Ratio Setting		30%	%	30%...50%,	5%
I2> / 46					
I2>		0.30	In	0.1…1.5	0.010
tI2>		1.00	s	0.04 … 300	0.100
I2/I1> / 46PD					
I2/I1>		015%	In	10…100%	0.010
tI2/I1>		00.10	s	0.04… 64	0.100

Table 33: Settings, continue

Parameter	Actual value	Default value	Unit	Range	Resolution
3Ith> / 49					
ϑ0		080	%	0.0…100%	1%
ϑpowerOFF		4	-	1…4	1
Ib		1.0	In	0.1 … 1.5	0.100
τ↑		045	min	1.0…300	1.000
τ↓s		045	min	1.0…300	1.000
ϑalm		121	%	50…200%,	1%
ϑtrip		144	%	50…200%,	1%
ϑstartinhibit		105	%	50…200%,	1%
3I/IoBF / 51BF/51NBF					
Icbfp		01.1	In	0.2…2.0	0.100
Iocbfp		01.1	In	0.1…2.0	0.100
t Retrip		0.10	s	0.06…0.5	0.010
t Backup		0.12	s	0.06…0.5	0.010
O -> I / 79					
AR start mode		1	-	1 = Trip, 2 = Gen. start and trip	1
CB ready		1	-	1 = OCO, 2 = CO	1
Shot		3	-	0…4	1
Activate t			sec	0.1…5	0.100
Pulse tp			sec	0.2…20	0.100
Cycle t1			sec	0.2…300	0.010
Cycle t2			sec	0.2…300	0.010
Cycle t3			sec	0.2…300	0.010
Cycle t4			sec	0.2…300	0.010
Reclaim tr			sec	1…300	1
Block tb			sec	1…300	1

Table 34: Configuration

Configuration Parameter	Actual value	Default value	Unit	Range	Resolution
Blocking: I> / 51		NO	-	NO; YES; ORx; ANDx; NOTx; TONx; TOFFx	-
Blocking: I>> / 50-1		NO	-	NO; YES; ORx; ANDx; NOTx; TONx; TOFFx	-
Blocking: I>>> / 50-2		NO	-	NO; YES; ORx; ANDx; NOTx; TONx; TOFFx	-
Blocking: Io> / 51N		NO	-	NO; YES; ORx; ANDx; NOTx; TONx; TOFFx	-
Blocking: Io>> / 50N		NO	-	NO; YES; ORx; ANDx; NOTx; TONx; TOFFx	-
Blocking: 3Ith> / 49		NO	-	NO; YES; ORx; ANDx; NOTx; TONx; TOFFx	-
Blocking: I2> / 46		NO	-	NO; YES; ORx; ANDx; NOTx; TONx; TOFFx	-
Blocking: I2/I1> / 46PD		NO	-	NO; YES; ORx; ANDx; NOTx; TONx; TOFFx	-
Blocking: BF		NO	-	NO; YES; ORx; ANDx; NOTx; TONx; TOFFx	-
Blocking: O -> I / 79		NO	-	NO; YES; ORx; ANDx; NOTx; TONx; TOFFx	-
Blocking Remote Ctrl		NO	-	NO; YES; ORx; ANDx; NOTx; TONx; TOFFx	-
Block TCS		NO	-	NO; YES	-
TCS Operate Time		5	sec	1 … 300	1
Earth type / I0 meas.		External		Internal; External	-
CT Ipn		1000	A	20 … 9999	1
CT Isn		1	A	1; 5	-
CT I0pn		1000	A	20 … 9999	1
CT I0sn		1	A	1; 5	-
Frequency		50	Hz	50; 60	-
COM Parameters					
Protocol				MODBUS RTU	
Relay Addr		001	-	MODBUS: 001 … 247	
Comm. Baud Rate		19200	-	MODBUS: 2400; 4800; 9600; 19200; 38400	-
Comm. Parity		Even	-	MODBUS: None; Odd; Even	-
Comm Admin Level		Yes	-	NO; YES	-

Table 35: Binary Input configuration

Binary input / Connected to signal	BI1	BI2	BI3	BI4
Input behavior: inversion	(-)	(-)	(-)	(-)
Block : I> / 51				
Block : I>> / 50-1				
Block : I>>> / 50-2				
Block : Io> / 51N				
Block : Io>> / 50N				
Blocking: 3Ith> / 49				
Blocking: I2> / 46				
Blocking: I2/I1> / 46PD				
Blocking: BF				
Blocking: BF ProtExt				
Blocking: BF RecTrip				
CB Ready				
Block : CB Control				
Reset				(x)
CB Close Position				
CB Open Position				
CB Maintenance (Test)				
TCS		(x)		
TCS Block				
External Trip			(x)	
External Close				
Power off				
Signal 1				
Signal 2				
Signal 3				
SG Select				

Input behavior: "-" = Non inverted, "I" = Inverted
Remark: "(..)" = Default setting

Table 36: Binary Output configuration

Binary output / Signal to activate output	BO1	BO2	BO3	BO4	BO5	BO6
Output behavior: inversion	(-)	(-)	(-)	(-)	(-)	(-)
Output behavior: duration	(P)	(P)	(P)	(S)	(P)	(P)
Start : I> / 51						
Start : I>> / 50-1						
Start : I>>> / 50-2						
Start : Io> / 50N-1						
Start : Io>> / 50N-2						
3Ith > Alm						
3Ith> Blkcl						
I2/I1> Str						
I2> Start						
Trip : I> / 51	(x)	(x)			(x)	
Trip : I>> / 50-1	(x)	(x)			(x)	
Trip : I>>> / 50-2	(x)	(x)			(x)	
Trip : Io> / 51N	(x)	(x)				(x)
Trip : Io> / 50N	(x)	(x)				(x)
3Ith > Trip						
I2/I1> Trip						
I2> Trip						
BF Stage1						
BF Stage2						
BF RecTrip						
O->I Close						
O->I InPro						
O->I FinalTr						
O->I Blocked						
Signal 1						
Signal 2						
Signal 3						
CB Open Command	(x)	(x)				
CB Close Command			(x)			
TCS Fault						
Unit Ready				(x)		
Lx Fault						
ANDx Out						
ORx Out						
NOTx Out						
TONx Dly						
TOFFx Dly						

Output behavior : "-" = Non inverted, "I" = Inverted
Remark : "(..)" = Default setting

Table 37: LED configuration

Configurable LED / Signal to activate output	LED1	LED2	LED3	LED4	LED5
LED behavior: S=Self reset H=Hold	(H)	(H)	(S)	(H)	(H)
Start : I> / 51					
Trip : I> / 51	(x)				
Start : I>> / 50-1					
Trip : I>> / 50-1	(x)				
Start : I>>> / 50-2					
Trip : I>>> / 50-2	(x)				
Start : Io> / 50N-1					
Trip : Io> / 50N-1		(x)			
Start : Io>> / 50N-2					
Trip : Io>> / 50N-2		(x)			
3Ith> Alm					
3Ith> Trip					
3Ith> BlkCl					
I2/I1> Str					
I2/I1> Tr					
I2> Start					
I2> Trip					
BF Stage1					
BF Stage2					
BF RecTrip					
O->I Close					
O->I InPro					
O->I FinalTr					
O->I Blocked					
Signal 1					
Signal 2					
Signal 3					
TCS Fault			(x)		
Lx Fault					
ANDx Out					
ORx Out					
NOTx Out					
TONx Dly					
TOFFx Dly					

6.10 Earthing of relay

6.10.1 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.

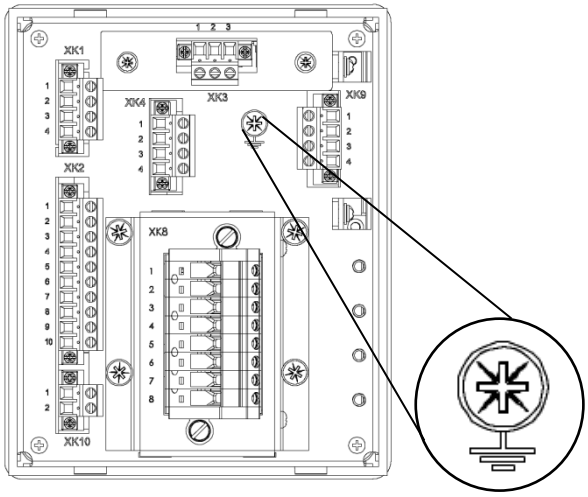


Figure 37: Location of protective earth screw

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

Each IED 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.

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