Relion® 605 series

Feeder Protection REF601
Application Manual

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ABB

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This product complies with the directive of the Council of the European Communities on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive 2004/108/EC) and concerning electrical equipment for use within specified voltage limits (Low-voltage directive 2006/95/EC). This conformity is the result of tests conducted by ABB in accordance with the product standards EN 50263 and EN 60255-26 for the EMC directive, and with the product standards EN 60255-1 and EN 60255-27 for the low voltage directive. The IED is designed in accordance with the international standards of the IEC 60255 series.

Table of Contents

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. Instructions on how to operate the IED during normal service once it has been commissioned and it can be used to find out how to handle disturbances or how to 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 / 20.03.2009	1.0	First release
B / 21.08.2009	1.0	Content updated
C / 30.09.2010	1.0 SP1	Service pack released
D / 04.04.2012	2.0	Content updated to correspond to the product version

1.4 Document symbol and conventions

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

	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.
	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.

Section 2 REF601 overview

2.1 Overview

REF601 is a dedicated feeder protection relay, intended for the protection and control of utility substations and industrial power systems. The relay is compatible with the Rogowski coil sensor for current measurement. The feeder protection relay REF601 is designed to unleash the advantages of current sensors for protection and control in medium voltage applications.

The REF601 features compact size and ease of use. The features include:

- Sensor input for phase current measurement
- Earth current measurement internally or externally through CBCT
- Three-stage overcurrent protection
- Two-stage earth-fault protection
- Inrush detection for stability during transformer charging
- Local and remote control of circuit breaker
- Trip Circuit Supervision
- Lockout function
- 100 event logs
- Two analogue fault records
- Non-resettable trip counter
- On-line current measurements in primary value
- Comprehensive local HMI
- Universal auxiliary supply
- Compact design suitable for circuit breaker or panel mounting
- Optional MODBUS RTU communication
- Non-volatile memory for setting and fault records
- Self-supervision
- User selectable rated frequency 50 / 60 Hz

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

2.3 Operation Functionality

2.3.1 Relay functions

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

The settings can be changed by LHMI (local human-machin interface) or through optional communication interface MODBUS master with setting capability.

The relay offers protection, control, measurement and condition monitoring functionality.

The table indicates the Functions supported by the IED

Table 1: Relay functions

Function	IEC	ANSI
Protection		
Non Directional Over-current, Low set	3I>	51
Non Directional Over-current, High set	3I>>	50-1
Non Directional Over-current, Very High set	3I>>>	50-2
Non Directional Earth-fault, Low-set	I0>	51N
Non Directional Earth-fault, High-set	I0>>	50N
3-phase Transformer Inrush detector	$3I_{2f}$>	68
Control		
Circuit-breaker control	I <-> O CB	I <-> O CB
Condition monitoring		
Trip circuit supervision	TCS	TCM
Measurement		
Three-phase current measurement	3I	3I
Residual current measurement	Io	In

2.3.2 Optional function

- Communication on MODBUS RTU Protocol

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 an existing fault via the LHMI.

When in an IED internal fault is detected, the green Ready LED ceases to glow and the self-supervision output contact is activated. Internal fault indications have the highest priority on the LHMI. None of the other LHMI indications can override the internal fault indication. An indication about the fault is also shown as a message on the LHMI. The text IRF with an additional text message, a code is shown to indicate the fault type.

The user can try to eliminate the fault by restarting the IED. If the fault is still found, the IED stays in internal fault mode. All other output contacts are released and locked for the internal fault.

The self-supervision signal output operates on the closed circuit principle. Under normal conditions the relay is energized and the contact gap 5-6 in connector XK2 is closed. If the auxiliary power supply fail or an internal fault is detected, the contact gap 5-6 is opened.

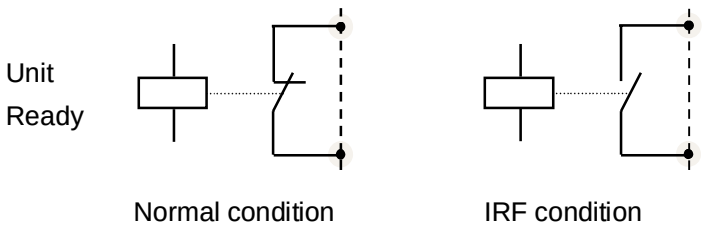


Figure 1: Unit ready contact operation

The internal fault code indicates the type of internal IED fault

Table 1: 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

2.4.2 Recorded data & Trip counter

The relay stores records of analog values for last two trip events in non-volatile memory. The fault recording is triggered by the trip signal of protection function. A sample of analog value is recorded for every power frequency cycle. Fifteen such samples are recorded, five before the trip and ten after the trip event. These records enable the user to analyze the two most recent power system events. Each record includes the current values for three phases and earth current. The oldest recording is lost when a new fault recording is made.

The relay records the number of phase and earth fault trip events into dedicated trip counters. These trip counters cannot be reset by the user and are stored in nonvolatile memory. The recorded information is store in non-volatile memory and can be accessed locally via the user interface on the relay front panel and can be uploaded for subsequent fault analysis.

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 time stamping. The event logs are stored sequentially, the most recent being first and so on. The non-volatile memory retains its data also in case the of loss of auxiliary supply to relay.

The event log facilitates detailed pre- and post-fault analysis of feeder faults. The SoE information can be accessed locally via the user interface on the relay front panel or remotely via the communication interface of the relay.

Table 2: 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 & there is not internal relay fault	Unit Ready
2	Trip circuit supervision	When trip circuit becomes faulty, an event of trip circuit faulty will be recorded.	TCS faulty
3	Setting parameter change	Settings (I>,I>>,I>>>,Io>,Io>> & t>,t>>,t>>>,to>,to>>) alteration will be captured as an event without setting value.	Any from – I>, I>>, I>>>, Io>, Io>>, t>, t>>,t>>>, to>, to>>
4	Protection start	Start event by I>,I>> or I>>> will be captured as single event i.e. Phase start Start event by Io> IR Io>> will be stored as single event i.e. Earth start.	Phase start or Earth start
5	Protection trip	In the event of Tripping, which protection stage (I>, I>>, I>>>, Io> & Io>>) caused trip will be captured as an event information.	Any from – I>, I>>, I>>>, Io>, Io>>
6	IRF	“IRF” – internal relay fault shall be captured as an event.	IRF codes
7	Breaker open	When breaker open command issued	Breaker Open
8	Breaker close	When breaker close command issued	Breaker Close
9	Remote trip	When remotely trip command issued	Remote Trip
10	Reset	When reset of LEDs & screen done	Reset

2.4.4 Real Time Clock

IED comes with a feature of real time clock with user settable date & time. Date can be set in “DD/MM/YY” format & time can be set in “HH:MM:SEC:mSEC” format. RTC is used for time stamping event logs.

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. The password is a combination of different navigation keys.

2.4.6 Power-ON sequence

At Power-ON, controller starts with reading all configuration parameters from nonvolatile memory and validates them. The configurations parameters mainly are relay setting parameters, records & calibration constants. This process will take around 6 sec. Once relay is configured and ready for operation, it will operate unit ready LED & contact. Now the relay is ready and all protections functions are in operational.

In case there is optional communication on MODBUS is present, then even after getting unit ready, relay will in background replicate the content of non-volatile memory of Base module with communication module which will take around @40 sec. After power on , replication of latest information on EEPROM with communication module will be initiated, which will take around 15sec. However, in case during this replication process user initiate menu navigation, the replication will be delayed till return back to default state.

Section 3 Technical Data

3.1 Dimensions

Table 3: Dimensions of relay

Description	Value	
Width	frame	130.0 mm
	case	121.5 mm
Height	frame	160.0 mm
	case	151.5 mm
Depth	case	102.0 mm (92 + 10 mm)
Weight	Relay	1.2 kg

3.2 Power Supply

Table 4: Power supply

Description	Value
Uaux nominal	24...240 V AC, 50 and 60 Hz
	24...240 V DC
Uaux variation	85...110% of Uaux (20.4...264 V AC)
	70...120% of Uaux (16.8...288 V DC)
Burden of auxiliary voltage supply under quiescent (Pq) / operating condition	< 12.0 VA
Ripple in the DC auxiliary voltage	Max 12% of the DC value (at frequency of 100 Hz)
Maximum interruption time in the auxiliary DC voltage without resetting the relay	50 ms at Uaux rated

3.3 Energizing inputs

Table 5: Energizing inputs

Description		Value
Rated frequency		50/60 Hz ± 5 Hz
Phase sensor inputs	Input type	Rogowski coil sensor
	Rated transformation ratio, Kra	250A / 0.15V at 50Hz 250A / 0.18V at 60Hz
	Linear current meas. range	4 A - 25 kA

Description		Value
Earth current input	Input type	Current Transformer
	Rated current, In	1 A
	Linear current meas. range	0.5 – 12.5 x In
	Thermal withstand capability: • Continuously • For 1 sec	 4 A 100 A
	Dynamic current withstand: • Half-wave value	250 A
	Input impedance	< 100 m Ω

3.4 Binary inputs

Table 6: Binary inputs

Description	Value
Rated voltage	24...240 V AC / DC
Operating range	85...110% of Uaux for AC 70...120% of Uaux for DC
Current drain	2...20 mA
Power consumption/input	< 0.5 W
Input sensing time	100 ms

3.5 Binary outputs

Table 7: Single pole output contact (Trip1)

Description	Value
Rated voltage	240 V AC / DC
Continuous contact carry	8 A
Make and carry for 3.0 s	15 A
Make and carry 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R < 40 ms, at 35 / 220 V DC	5 A / 0.2 A
Minimum contact load	100 mA at 24 V AC / DC
Pulse duration of contact operation	200 msec

Table 8: Double pole output contact (Trip2)

Description	Value
Rated voltage	240 V AC / DC
Continuous contact carry	8 A
Make and carry for 3.0 s	15 A
Make and carry 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R < 40 ms, at 48 /110/ 220 V DC (two contacts connected in series)	5 A / 3 A / 1 A
Minimum contact load	100 mA at 24 V AC / DC
Trip-circuit supervision (TCS): • Control voltage range • Current drain through the supervision circuit • Minimum voltage over the TCS contact	 48...250 V AC/DC ~ 1.5 mA 20V AC / DC (15...20 V)

Table 9: Signal output contact (O/C, E/F, Unit ready, Breaker close)

Description	Value
Rated voltage	240 V AC / DC
Continuous contact carry	6 A
Make and carry for 3.0 s	8 A
Make and carry 0.5 s	10 A
Breaking capacity when the control-circuit time constant L/R<40 ms at 35/ 220 V DC	4 A / 0.15 A
Minimum contact load	100 mA at 24 V AC / DC

3.6 Protection function

3.6.1 Low set three-phase non-directional overcurrent protection, stage I> / 51

Table 10: Settings of Low-set overcurrent protection stage

Description	Value
Setting range of pick-up current 'I >'	0.2...1.0 x In in steps 0.025, infinite

Description	Value
Operation accuracy	± 5.0% of set value
Operate time delay (DMT) 't >'	0.1...1.6 sec in steps of 0.1 for B=1 0.5...8.0 sec in steps of 0.5 for B=5
Operation time accuracy	± 5.0% of set value or ± 30 msec
Operating curve type	IEC 60255-3: Normal inverse, Very inverse, Extremely inverse, Long-time inverse Special curves: RI inverse
Time multiplier setting 'k'	0.1...1.6, in steps of 0.1
Operation time accuracy IEC characteristics RI characteristics	 class E(5) or ± 30 msec ± 5.0% of set value or ± 30 msec
Reset ratio	IDMT : 0.96 and DT : 0.98

3.6.2 High set three-phase non-directional overcurrent protection, stage I>> / 50-1

Table 11: Settings of High-set overcurrent protection stage

Description	Value
Setting range of pick-up current 'I>>'	1.0...2.75 x In in steps 0.25, infinite
Operation accuracy	± 5.0% of set value
Operation mode	Definite time
Operate time delay (DMT) 't >>'	0.1...0.45 sec in steps of 0.05
Operation time accuracy	± 5.0% of set value or ± 30 msec
Reset ratio	0.98

3.6.3 Very high set three-phase non-directional overcurrent protection, stage I>>> / 50-2

Table 12: Settings of Very high-set overcurrent protection stage

Description	Value
Setting range of pick-up current 'I>>>'	2.0...15.0 x In in steps 1.0, infinite
Operation accuracy	± 5.0% of set value
Operation mode	Instantaneous
Operate time 't >>>'	0.05 sec
Operation time accuracy	± 15 msec
Reset ratio	0.98

3.6.4 Low set non-directional earth-fault protection, stage Io> / 51N

Table 13: Settings of Low-set earth-fault protection stage

Description	Value
Nominal value of earth current	1 A
Measurement range	0.05...5 x In
Setting range of pick-up current 'Io>'	External earth measurement : 0.05...1.0 x In in steps 0.05, infinite Internal earth measurement : 0.2...1.0 x In in steps 0.05, infinite
Operation accuracy	External earth measurement : ± 5.0% of set value Internal earth measurement : ± 15.0% of set value
Operate time delay (DMT) 'to>'	0.1...1.6 sec in steps of 0.1 for B=1 0.5...8.0 sec in steps of 0.5 for B=5
Operation time accuracy	External earth measurement : ± 5.0% of set value or ± 30 msec Internal earth measurement : ± 10.0% of set value or ± 30 msec

Description	Value
Operating curve type	IEC 60255-3: Normal inverse, Very inverse, Extremely inverse, Long-time inverse Special curves: RI inverse
Time multiplier setting 'k'	0.1...1.6, in steps of 0.1
Operation time accuracy IEC characteristics RI characteristics IEC characteristics RI characteristics	 External earth measurement : class E(5) or ± 30 msec External earth measurement : class E(7.5) or ± 30 msec Internal earth measurement : ± 5.0% of set value or ± 30 msec Internal earth measurement : ± 10.0% of set value or ± 30 msec
Reset ratio	IDMT : 0.96 and DT : 0.98

3.6.5 High set non-directional earth-fault protection, stage Io>> / 50N

Table 14: Settings of High-set earth-fault protection stage

Description	Value
Setting range of pick-up current 'Io>>'	0.5...4.0 x In in steps 0.25, infinite
Operation accuracy	External earth measurement : ± 5.0% of set value Internal earth measurement : ± 15.0% of set value
Operation mode	Definite time
Operate time delay (DMT) 'to >>'	0.00...0.75 sec in steps of 0.05
Operation time accuracy	External earth measurement : ± 5.0% of set value or ± 30 msec Internal earth measurement : ± 10.0% of set value or ± 30 msec For setting 0.00 msec : 45 msec
Reset ratio	0.98

3.6.6 Transformer inrush detector

Table 15: Settings of transformer inrush detector function

Description	Value
Inrush threshold value	0.2...20 x In
Ratio Setting	30%...50%

3.7 Degree of protection of flush-mounted relay

Table 16: Degree of protection

Description	Value
Front side	IP 43
Sides with connection terminal	IP 20

3.8 Environmental conditions

Table 17: Environmental conditions

Description	Value
Operating temperature range	-25...+55ºC
Short-time service temperature range	-25...+70ºC (<16 h)
Relative humidity	< 93%, non-condensing
Atmospheric pressure	86...106 kPa
Altitude	up to 2000 m
Transport and storage temperature range	-40...+85ºC

3.9 Product safety

Table 18: Product safety

Description	Type test value
LV directive	2006/95/IEC
Standard	EN 60255-27 (2005) EN 60255-1 (2009)

3.10 EMC compliance

Table 19: EMC compliance details

Description	Type test value
EMC directive	2004/108/EC
Standard	EN 50263 (2000) EN 60255-26 (2007)

3.11 RoHS compliance

Table 20: RoHS compliance details

Description
Complies with RoHS directive 2002 / 95 / IEC

3.12 Data communication (Optional)

Table 21: Data communication details

Description	Value
Protocol	MODBUS RTU
Communication port	RS485, 2 wire

Section 4 Protection Function

4.1 Three Phase Current Protection

4.1.1 Functionality

The three-phase overcurrent protections is used as single-phase, two-phase or three phase non-directional overcurrent and short-circuit protection for feeders.

The function starts when the current exceeds the set limit. The operate time characteristics for low stage is both DMT and IDMT and high stage is definite time (DT) definite minimum. The instantaneous stage always operates with the DT characteristic.

In the DT mode, the function operates after a predefined operate time and resets when the fault current disappears. The IDMT mode provides current-dependent timer characteristics.

4.1.2 Principle of Operation

The three-phase overcurrent unit continuously measures the phase currents of the protected object. On detection of a fault the relay starts, trips the circuit breaker, , records fault data etc. in accordance with the application.

REF601 has overcurrent protection with low set, high set and very high set module.

The product support both DMT and IDMT times in low set (I>) while high set (I>>) and Very high set (I>>>) supports to DMT timings. As the fault current exceeds the set value, trip time counting is started and start LED on front panel of relay glows ON. If fault current falls down below the drop-off value of set current for 40 ms before trip time gets complete, start LED will be turned off and trip count will become zero. Trip time will start from zero for next time when the fault current exceeds the set value again. After a healthy trip, Start LED will be turned off and again if fault current exceeds threshold, start LED will be turned ON again.

In case of healthy trip, after trip time get elapsed relay generates the trip command which operates the Trip relay contacts as per user selected configuration. Two LED indications on front plate of relay i.e. Trip (common trip indication) and Trip Ip and one signaling contact (XK2.3 – XK2.4) will also be activated for user as Trip indication.

4.2 Earth Fault Protection

4.2.1 Functionality

The earth-fault function is used as non-directional earth-fault protection for feeders. The function starts and operates when the set current exceeds the set limit.

The relay can measure earth current by internal calculation (IEC variant only) and also by external core balance current transformer input. Separate earth fault input is available in relay which can be connected to core-balance current transformer of 1A secondary.

The operate time characteristic for low stage has both DT and IDMT and high stage has only definite time (DT) .. In the DT mode, the function operates after a predefined operate time and resets when the fault current disappears.

4.2.2 Principle of Operation

REF601 has earth fault protection with low set and high set module. Earth fault modules operate the protection as soon as fault current exceeds the set value of current. It supports both DMT and IDMT timing while highset supports to DMT timings.

As the fault current exceeds the set value, trip time counting is started and start LED on front panel of relay glows ON. If fault current falls down below the drop-off value of set current for 40 ms before trip time gets complete, start LED will be turned off and trip count will become zero. Trip time will start from zero next time when the fault current exceeds the set value again. After a healthy trip, Start LED will be turned off and again if fault current exceeds threshold, start LED will be turned ON again.

In case of healthy fault generation, after trip time get elapsed relay generates the trip command which operates the Trip relay contacts as per user selected configuration. Two LED indications on front plate of relay i.e. Trip (common trip indication) and Trip Io and one signaling contact (XK2.1 –XK2.2) will also be generated for user as Trip indication.

4.3 Three Phase Inrush Detector

The transformer inrush detection is used to coordinate transformer inrush situations in distribution networks.

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

The operate time characteristic for the function is of definite time (DT) type. When applying overcurrent protection to the MV side of the power transformer, it is necessary that the protection system remains inoperative during transformer energization, when a large primary current flows for a short period during switch on. The REF601employs the most proven technique of blocking based on measured value of second harmonic content to make the protection immune to magnetizing inrush.

4.4 Lockout function

This function will be used as a trip command triggers handler. The feature of this function influences the trip signal behavior. It is be possible to select different modes & accordingly trip signal behavior can be changed.

Operate: The different possible triggers which finally get converted to issue trip will be given to Operate i/p of the function.

Block: If YES, Trip contacts associated with the output of the function will be blocked & hence NO TRIP will be issued. & if NO, output trip will be according to mode selected.

Reset: I/P to function will reset the output, only when lockout or Latch mode is selected.

Mode: I/P to function will have three different modes as follows:

1. **SELF RESET:** Trip output will remain active till fault persists with minimum self reset time of 200 msec. By term minimum reset time it means that once trip output issued will be for min. 200 msec. or till fault persists whichever is greater.
2. **LATCH**: Once Trip is issued will remain even if fault doesn't persists. Output trip can be reset by all possible reset input triggers i.e. a) local HMI by reset key combination b) Reset binary input c) Reset command from optional communication module via MODBUS.
3. **LOCKOUT**: Once Trip is issued will remain even if fault doesn't persists. Output trip can be reset by following two possible reset input triggers i.e. a) local HMI by reset key combination b) Reset binary input.

Default will be **SELF RESET** mode.

Output: An o/p of function handles only associated trip contact

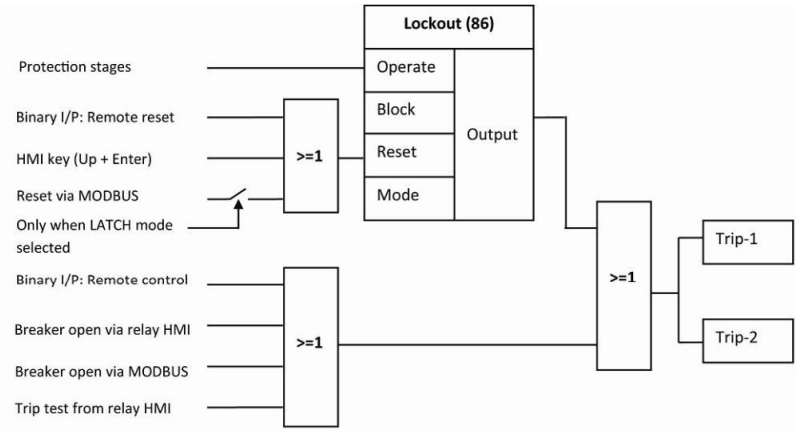


Figure 2: Trip lockout function operation

4.5 Outputs & Inputs

The relay has pre-defined output contacts. The REF601 has trip / breaker open command output NO contact and additional NC trip output command which are activated for minimum 200 msec or till the fault persists. The relay has 2 nos. signaling contacts for over current trip and earth fault trip indication. Relay has 1 no. signaling contact for unit ready indication.

The relay has 2 nos. binary input with wide aux. voltage band of 24V-240V AC/DC for remote trip and remote reset. Applying a valid voltage input to remote trip input, it will generate a trip command directly irrespective of current flowing in system. While activation of reset input, will reset all the protection indications to normal state. Relay indications include protection start, protection trip, phase fault trip Ip,Earth fault trip Io and relay ready / IRF LED's. and also will reset all internal protection trip timers.

4.6 Breaker control & Trip command operation

REF601 supports the breaker control operation. The control operation can be done from additional control push-buttons provided on relay front or from remote through using MODBUS communication. The close / trip control command to the breaker will be generated by respective output contacts.

REF601 generates the trip in case of remote trip command, protection trip or breaker open command and in case of protection trip, breaker control operation will be according to mode of lockout 86 as shown in figure below,

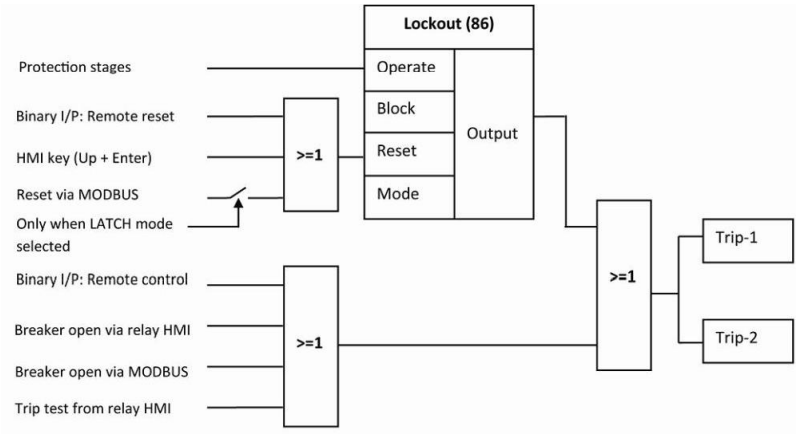


Figure 3: Various trip arrangement available in feeder protection relay REF601

Relay trip command operates the potential free contact from CLOSE position to OPEN for minimum for 200msec, in case of valid trip condition. The complete sequence of Trip operation is shown on next page considering case of self reset mode.

At Power-ON, relay will perform internal health check and then change the ready contact to CLOSE. In case of healthy trip (After set time), this CLOSE contacts will changeover to OPEN (till the fault persist) and again will become CLOSE. Trip indications are still ON and they reset only with valid reset command. In case of Power-OFF without reset command, at next power-on, trip signaling will get restored. In case of power OFF condition and internal relay fault condition, trip contact will be in open condition.

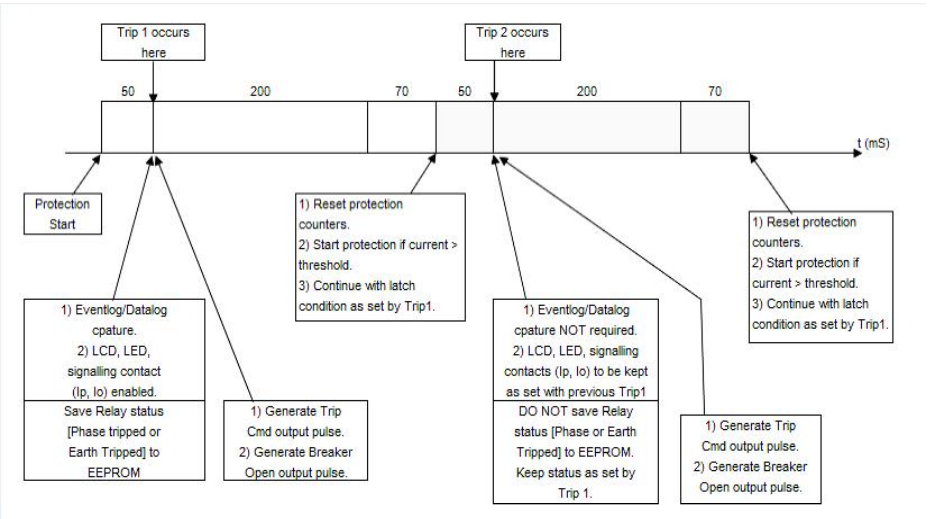


Figure 4: Trip contact management

Note: The set trip time is taken as 50ms for illustrative purposes. In case of fault current persist for longer duration; repeated trip command (200mS pulses) will be generated

External control command inputs (Remote open and Reset input)

REF601 supports the external control command voltage inputs too, with wide voltage band of 24V-240V AC/DC input.

Applying a valid voltage input (appropriate input for at least 100ms) to “Breaker open” input terminals (XK1.3 – XK1.4), will generate a trip command directly irrespective of current flowing in system. It also generations “breaker open” output (XK2.9 – XK2.10) i.e. contacts becomes NC for 200mSec. While by applying the proper voltage input to “Breaker close” input terminals (XK1.1–XK1.2) will generates “breaker close” output (XK2.7 – XK2.8) i.e. contacts becomes close for 200mSec.The difference between Remote opening command and Breaker open is that Remote opening function can be blocked, moreover when remote opening is activated the message “Remote Trip Activated” is displayed on the LCD.

Breaker control command inputs

REF601 supports the Breaker control command given by push buttons or via MODBUS communication.

Valid “Breaker OPEN” command will generate a trip (Activation of Trip1 and Trip2 contact for 200mSec) directly irrespective of current flowing in system.

Valid “Breaker CLOSE” command activate “breaker close” output (XK2.7 – XK2.8) i.e. contacts becomes close for 200mSec.

4.7 Trip Circuit Supervision

It will be possible to enable/disable TCS functionality through menu navigation or through comm. Interface over MODBUS.

TCS status:
This module receives the trip circuit status from the hardware. TCS circuit measures the voltage across “TRIP 2” (BO) contacts. If the voltage goes below the threshold value, it activates the timer.

Timer:
Once activated, the timer runs until the set value of *Operate delay time* has elapsed. The time characteristic is according to DT. When the operation timer has reached the maximum time value, the LED/LCD indication is activated. If a drop-off situation occurs during the operate time up counting, the operation timer will be frozen and the fixed 0.5 Sec reset timer will be activated. After that time, the operation timer will get reset. In case when Trip2 contact is in operation, the operate delay time counter is frozen & TCS LED will retain the last status.

BLOCK:
The BLOCK input can be controlled with an internal signal of the relay program. The activation of the BLOCK input freezes the Timer and so prevents the LED/LCD indication to be activated, even in a condition, when fault has been detected in Trip circuit.

Application
TCS detects faults in the electrical 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. When the circuit breaker is open, TCS can measure the voltage across the trip contact through R_{ext} (external shunt resistance shown in below figure) and trip coil. When the circuit breaker is close, TCS can measure the voltage across the trip contact through CB internal contact and trip coil. Below table shows the specification for the TCS circuit.

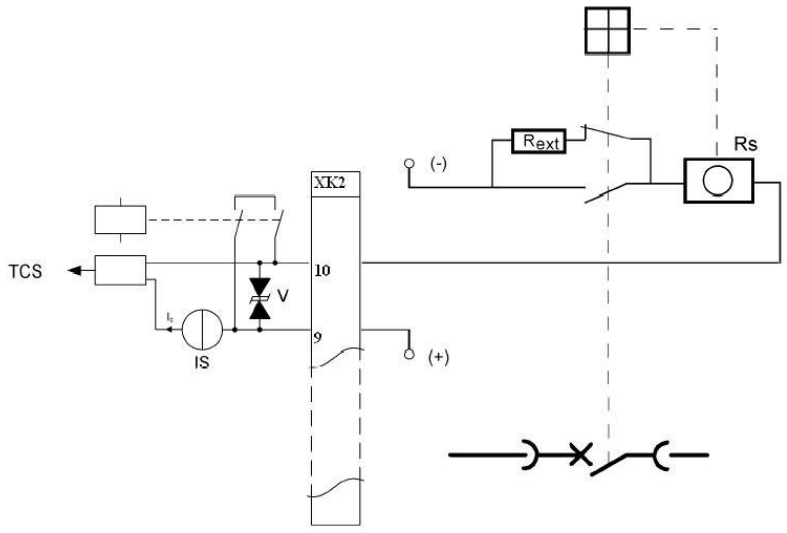


Figure 5: Application diagram of TCS function

Table 22: TCS functionality specification

Description	Value
Auxiliary voltage range	48-250V AC/DC
Current drain through the supervision circuit	~1.5 mA
Minimum voltage over the TCS contact	20 V AC/DC
Operating voltage Vaux 48 V DC 60 V DC 110 V DC 220 V DC	Recommended shunt resistor R_{ext} 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 must to connect R_{ext}. Otherwise, when the circuit breaker is in the open position, TCS sees the situation as a faulty circuit. The external shunt resistance should be not too high a resistance causes too high a voltage drop, jeopardizing the requirement, recommended shunt resistor values shown in above table, the auxiliary voltage must be higher or equal to 48V and voltage across Trip2 contact must be at least 20V AC/DC.

Table 23: 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	10		
Reset delay time	0.5	Sec	---	0.5	Fixed

4.8 Signal Diagram

The figure below schematically illustrates the analogue input, binary input / output and LED indications.

Note: Diagram to be updated directly in final user manual.

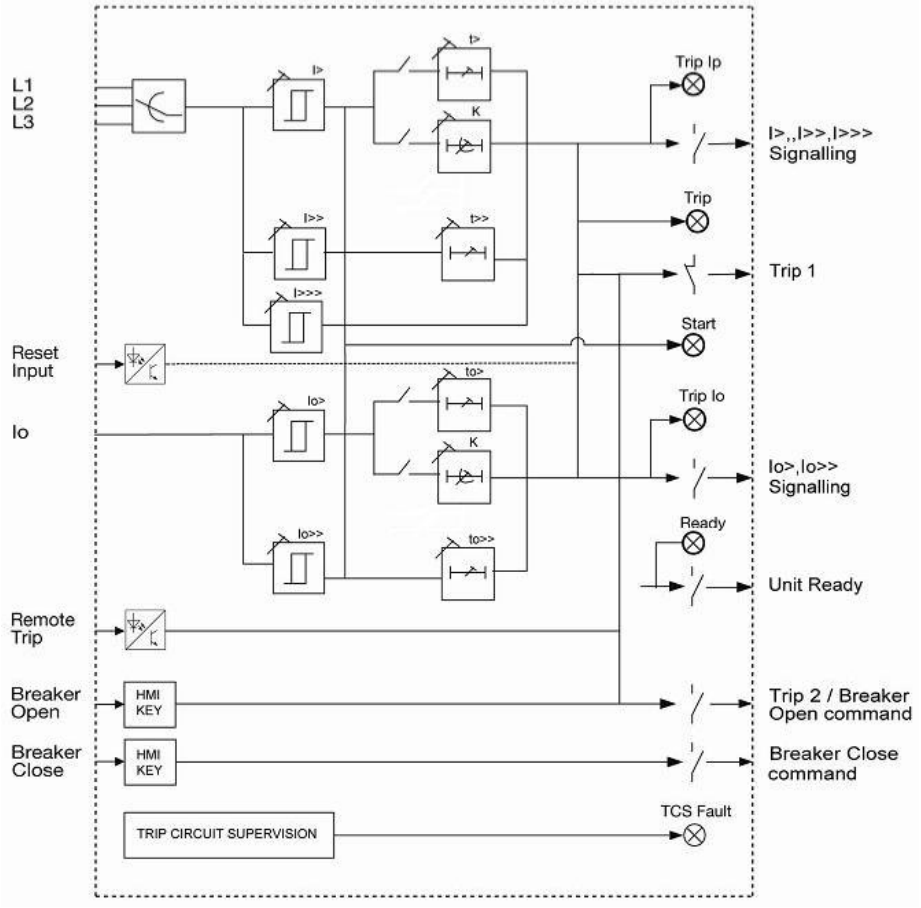


Figure 6: Signal diagram of relay REF601

Table 24: Analogue inputs

L1, L2, L3	Energizing sensor input for phase L1, L2, L3
Io	Earth current input 1A through CBCT for external earth measurement

Table 25: Binary input:

Remote Trip	Remote trip command to breaker
Remote reset	Remote reset command for resetting indications and contacts

Table 26: LED indications (on relay front))

Trip (RED)	Common trip LED for overcurrent and earth fault trip indication
Trip Ip (RED)	Trip LED for overcurrent faults (I>, I>> and I>>>)
Trip Io (RED)	Trip LED for earth faults (Io> and Io>>)
Start (Yellow)	Start LED for any protection function start
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
TCS Fault	LED indicates that trip circuit has failure

Table 27: Trip and signaling contacts

Trip 1	Trip contact for O/C and E/F. Under relay healthy condition, this contact will remain closed. In the event of trip, it will open.
O/C Trip Signal	Signaling contact over current trip. In the event of phase faults (I>, I>> and I >>>) it will close.
E/F Trip Signal	Signaling contact earth fault trip. In the event of phase faults (Io> and Io>> it will close.
Unit ready / IRF	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
Trip 2 / Breaker Open	Contact for breaker trip output. In the event of fault (O/C and E/F) this will close and extend trip command to breaker
Breaker Close	Contact for Breaker close command. This contact will close, when breaker close command is received either from relay HMI or through communication.

The signaling contacts can be reset to normal default conditions by proper reset command. Reset command can be given by push buttons or by binary input or through communication interface.

4.9 Protection characteristics

4.9.1 Time / Current characteristics

REF601 offers three-stage overcurrent and two stage earth-fault protection functions. The low-set stage of overcurrent protection & earth-fault protection are equipped with standard Inverse-definite Minimum Time (IDMT) characteristics – (Normal Inverse (NI), Extreme Inverse (EI), Long Inverse (LI), & Very Inverse (VI)) and also has a definite minimum

time (DMT). Characteristics for better co-ordination with rest of the network. Additionally special characteristic curve i.e. Belgium RI & DT=5 are also provided. The high-set and very high-set stages for over current protection and high stage earth fault protection come with DMT 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 seven time/current curve sets – four according to the BS 142 and IEC 60255 standards namely normal inverse, very inverse, extremely inverse and longtime inverse and one special curve, named RI type curve.

4.9.2 IEC 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 28: Values of constant α and β

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

4.9.3 RI type characteristic

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

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

Where,

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

$\alpha = 0.339$

$\beta = 0.236$

Section 5 Use of LHMI

5.1 Overview

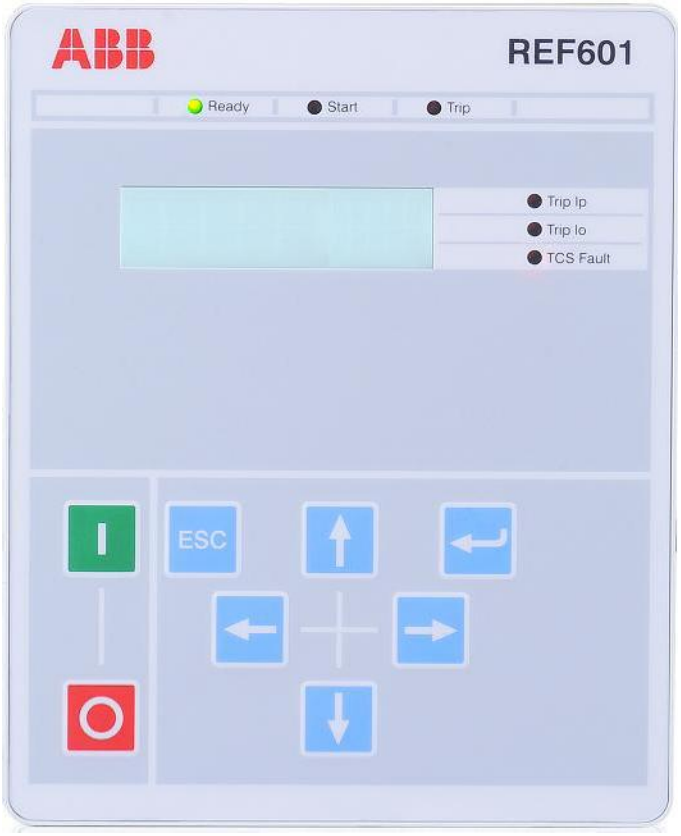


Figure 7: Local HMI of relay REF601

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:	Red LED	lights after any start of a protection function
Trip:	Red LED	lights after any trip of protection function
Trip Ip	Red LED	lights after trip of phase overcurrent function
Trip Io	Red LED	lights after trip of neutral overcurrent function
TCS Fault	Red LED	lights at detected failure of trip circuit

For reset of LED's use key combination 

5.1.2 LCD display

The LHMI includes 2 x 16 character LCD display. The measurement, recorded data, events, settings etc. can be viewed in the display.

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 29: 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.

Key Picture	Key Name	Description
	Escape/ Cancel	Used for discarding changed parameter value in edit mode, or for going back to main menu from any level of menu navigation.
	Reset	Press key combination Up & Enter key together to reset the relay from LHMI
	Edit	Press key combination Enter & Escape key together to edit the relay parameter from LHMI
	Breaker Close	Hotkey for providing Breaker Close command.
	Breaker Open	Hotkey for providing Breaker Open command.

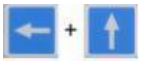
5.1.4 Authorization

Within REF601 three user categories with predefined user rights are provided.

During access of the main menu the selection of user category is handled with an own password (two key combinations).

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

Table 30: User authorization and default password

Sr No.	Features	Operator Level User	Setting 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	Password key combination (Default combination)	Other than Admin/setting	 Back + Up	 Back + Down

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

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 the combination of two keys. 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:

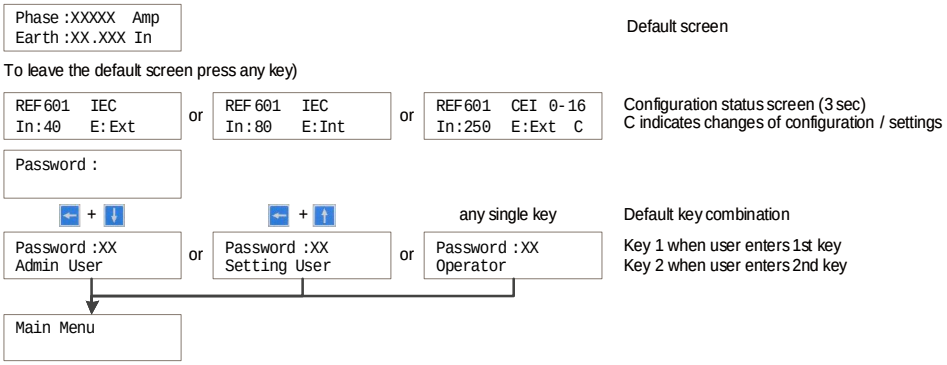


Figure 8: Login process of relay REF601

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 for various possible combinations.

Figure 9: Configuration status display screen

As an indication that settings parameters have been changed and the unit is working on new set of parameters, ‘C’ is displayed at the last column of second line of display as shown above. This is displayed only once when user presses any key when in default screen mode if settings gets changed before that, either by user through menu navigation, by communication module or by Configuration Tool.

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 60 seconds if no key is pressed.

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

Figure 10: Default screen of relay REF601

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.

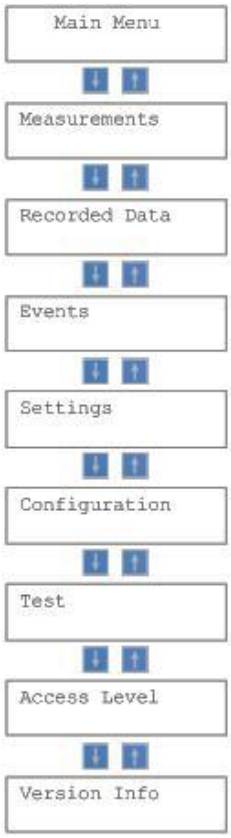


Figure 11: Main menu of relay REF601

5.2.3 Menu – Measurement

Submenu Measurement shows analogue input values as primary or as nominal values, whereas the nominal value for phase currents is the value for the sensor input selected in the submenu configuration – settings – nominal value.

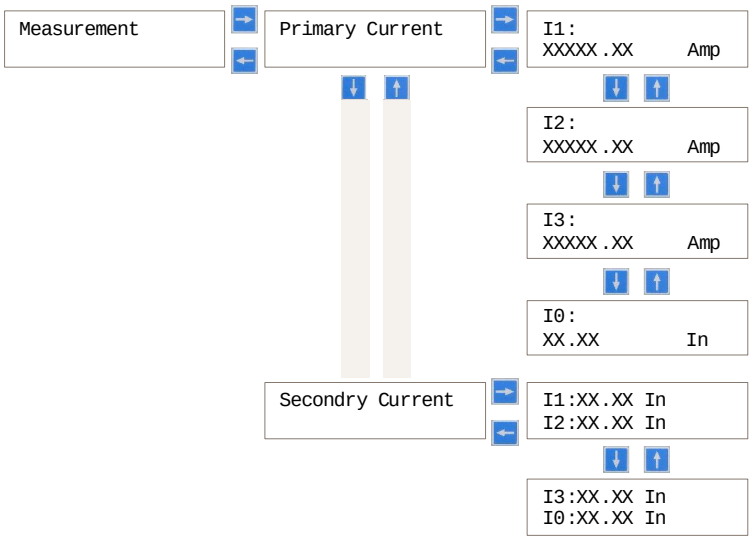


Figure 12: Measurement menu of relay REF601

5.2.4 Menu – Recorded data

Submenu Recording Data shows under Recorded Current the fault records for the last two 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.

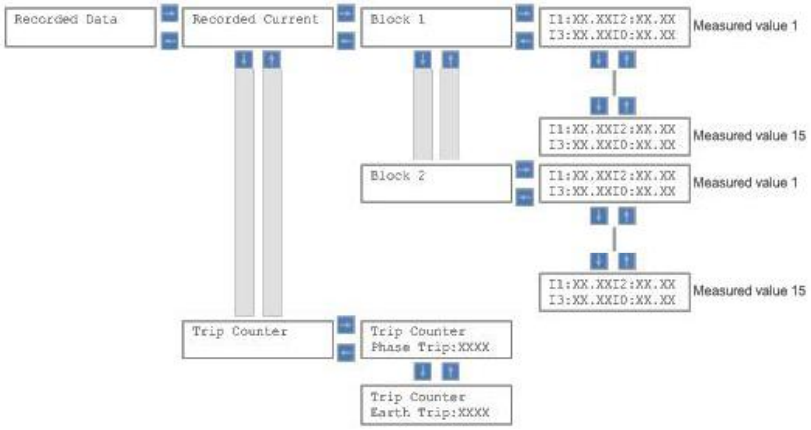


Figure 13: Recorded data menu of relay REF601

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.

For viewing the user should follow the figure below.

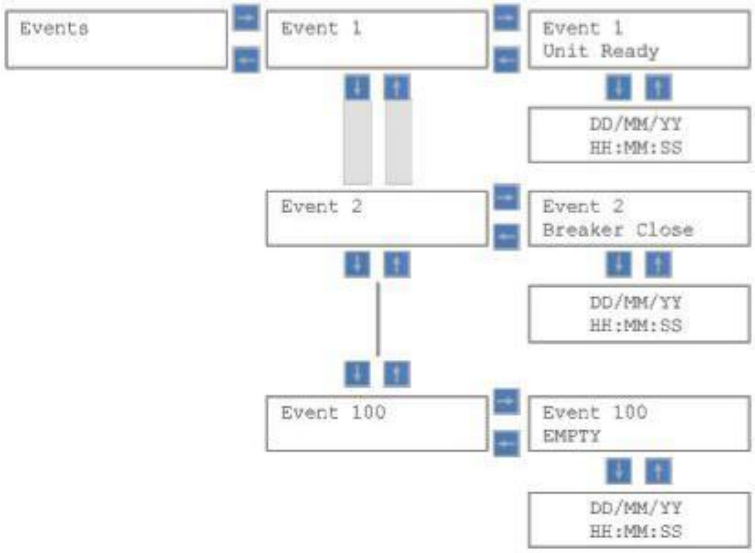


Figure 14: Event menu of relay REF601

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 combination ESC + ↵
- To save changed setting with key ↵.
- To discard and exit a modified setting with key ESC
- 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.

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

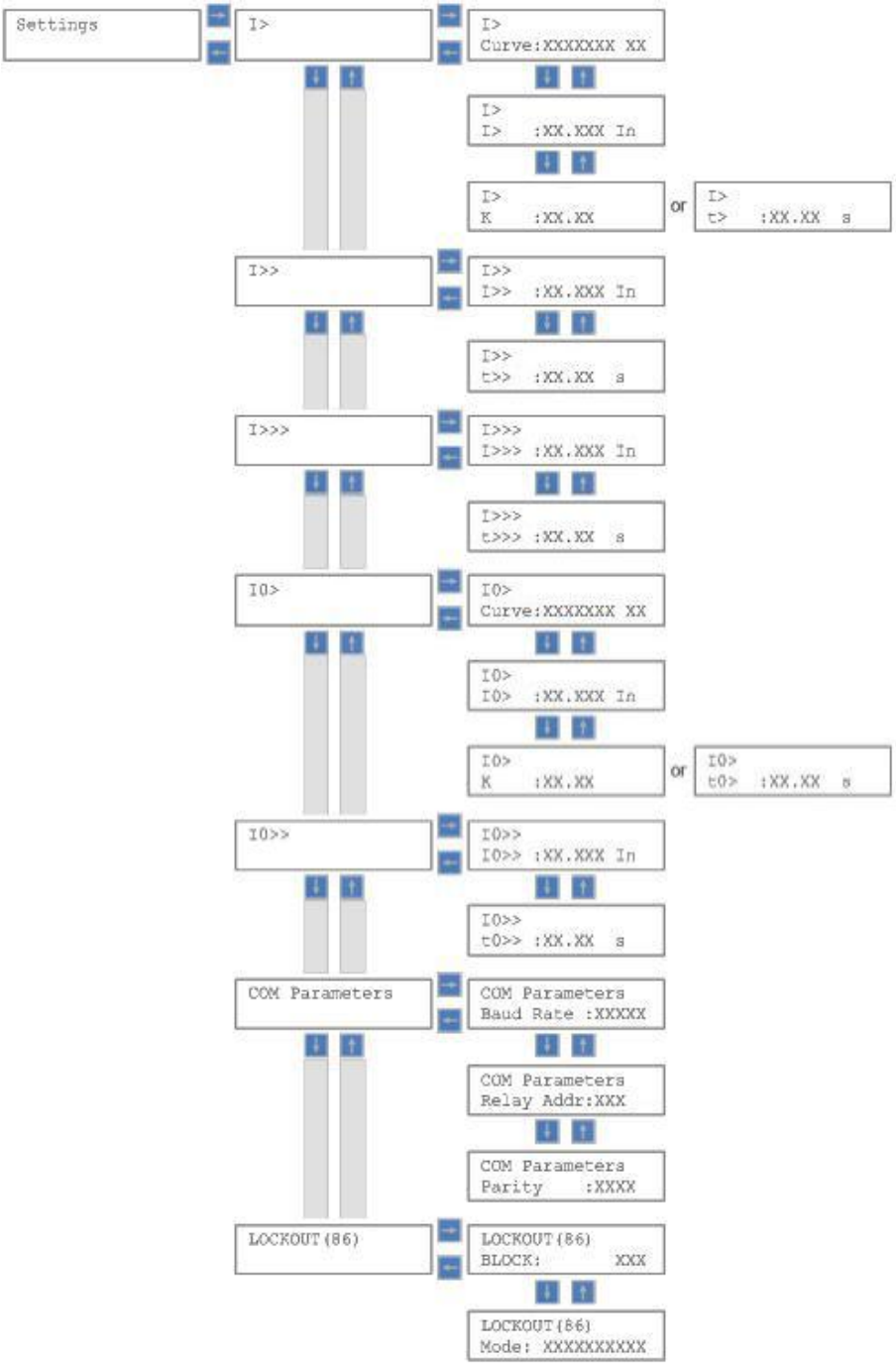


Figure 15: Setting menu of relay REF601 with its submenu

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 sensor type selection & earth current calculation method
- Inrush protection related settings
- Selection for loading factory settings (protection parameters only)

Remark:

- To modify settings needs user rights of Admin user.
- To modify selected setting start with key combination 

- 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:

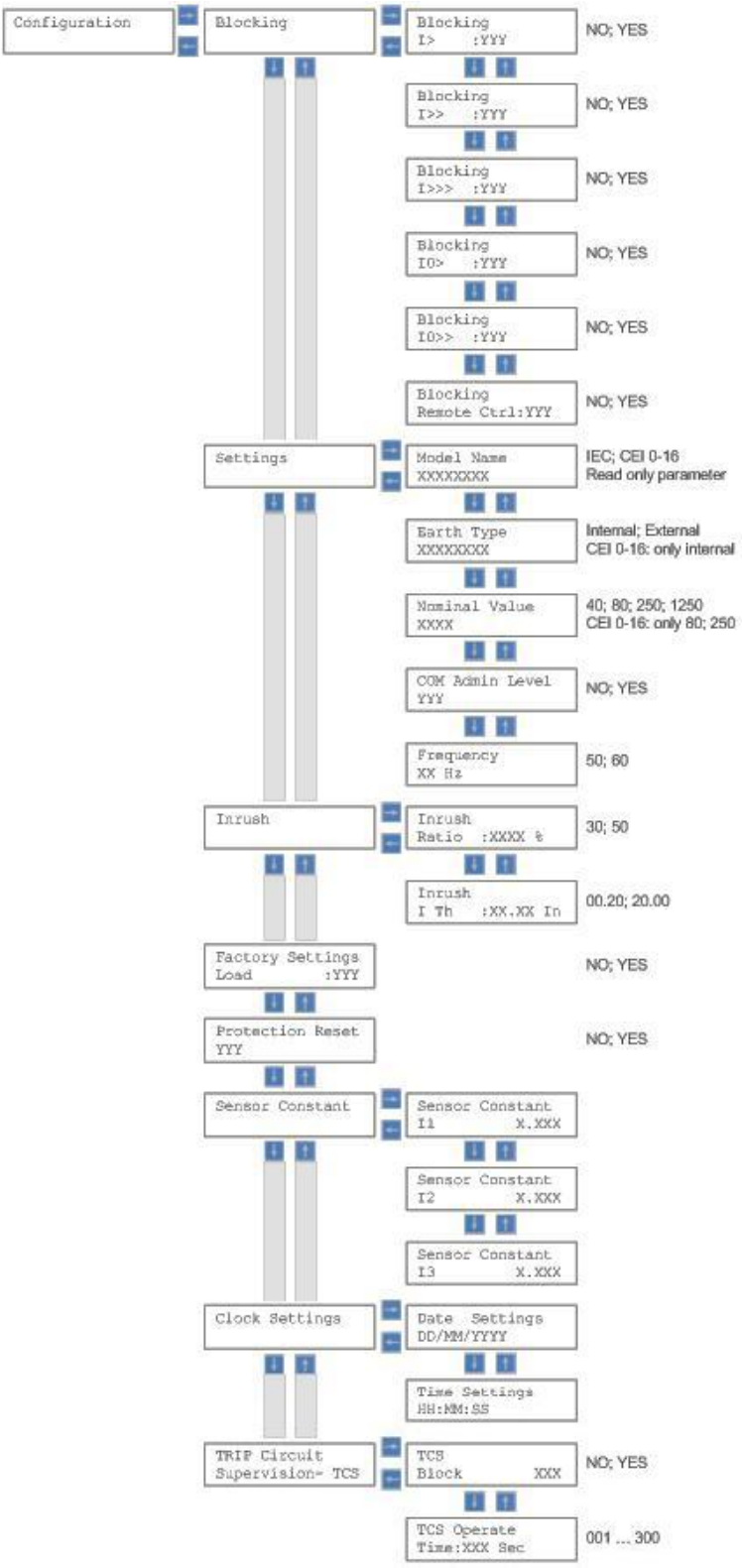


Figure 16: Configuration menu of relay REF601 with its submenu

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, Binary Inputs check, Binary Output check, LEDs check, EEPROM check. User can skip particular checks using interactive menu selection.

Test -> Trip Output: Enables testing of Trip command output and Breaker Open output to ensure proper working of trip signaling chain.

Test -> Functional: Enables protection function tests by loading different preset protection-settings. User can select particular set of protection settings from the list of available group.

Test -> Calibration: Enables Calibration process for current sensors. User can select or skip particular channel's calibration process using interactive menu selection.

Test -> Trip Output: Enables testing of Trip command output and Breaker Open output to ensure proper working of trip signaling chain.

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

Remark:

- To modify settings needs user rights of of Setting or Admin user.

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

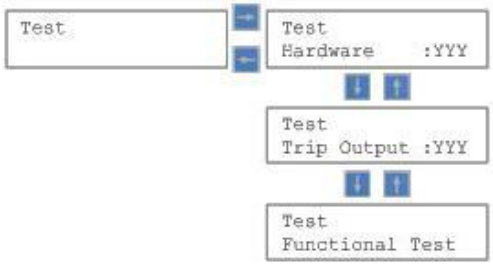


Figure 17: Test menu of relay REF601 with its submenu

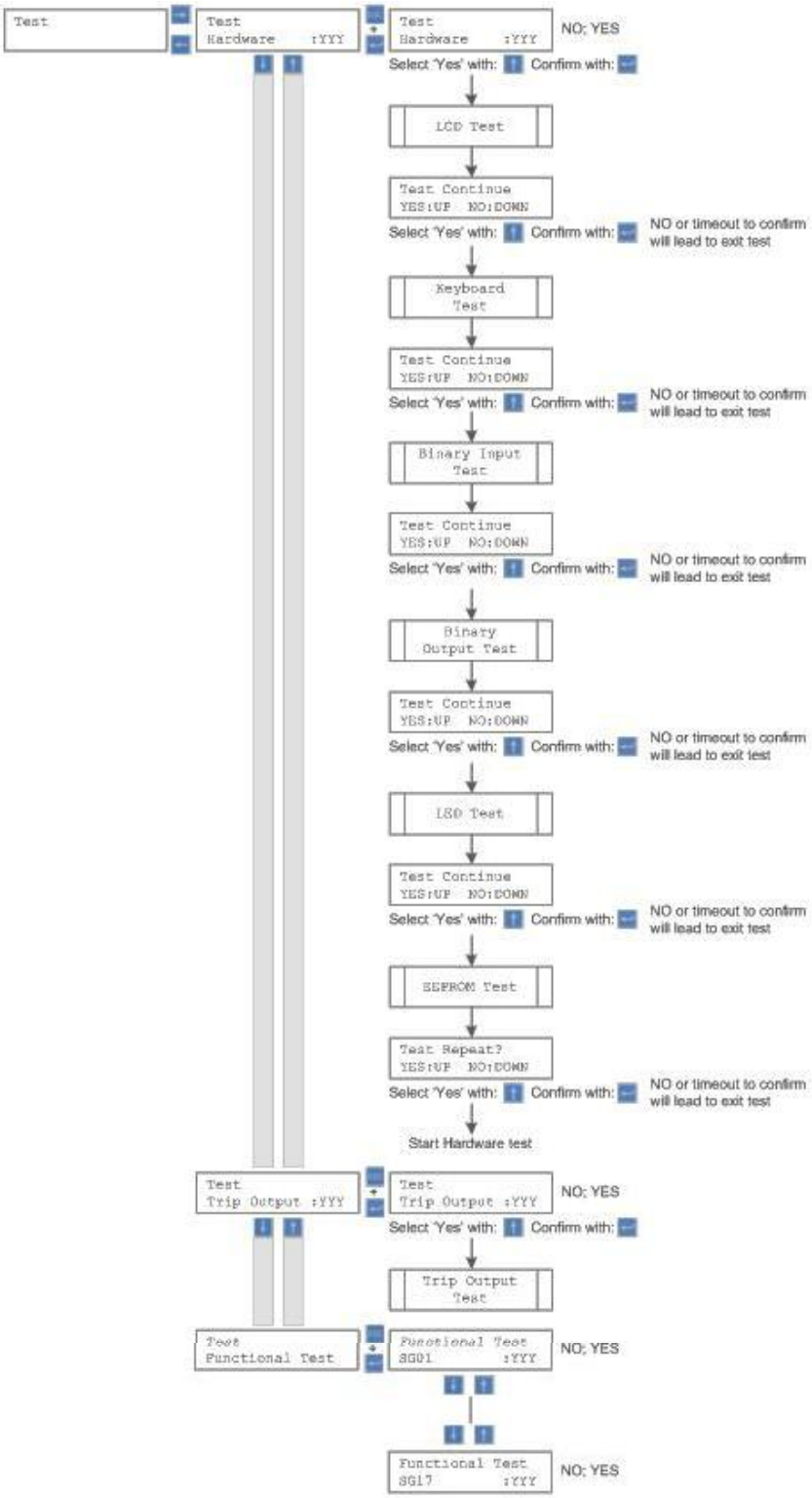


Figure 17: Test menu of relay REF601 with its submenu

5.2.8.1 Menu – Hardware

Following functionalities can be tested through this menu.

- LCD Test
- Keyboard Test
- LED Test
- Binary Inputs Test
- Binary Outputs Test
- Serial EEPROM Test

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.

For binary input tests, timeout between one test to another binary input test is 10 sec. And during binary output test each output will toggle for 100msec ON & 100 msec OFF.

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

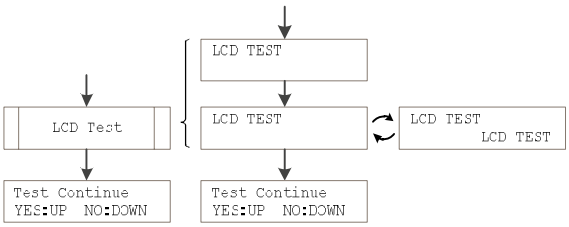


Figure 18: Hardware test menu of relay REF601 with its submenu

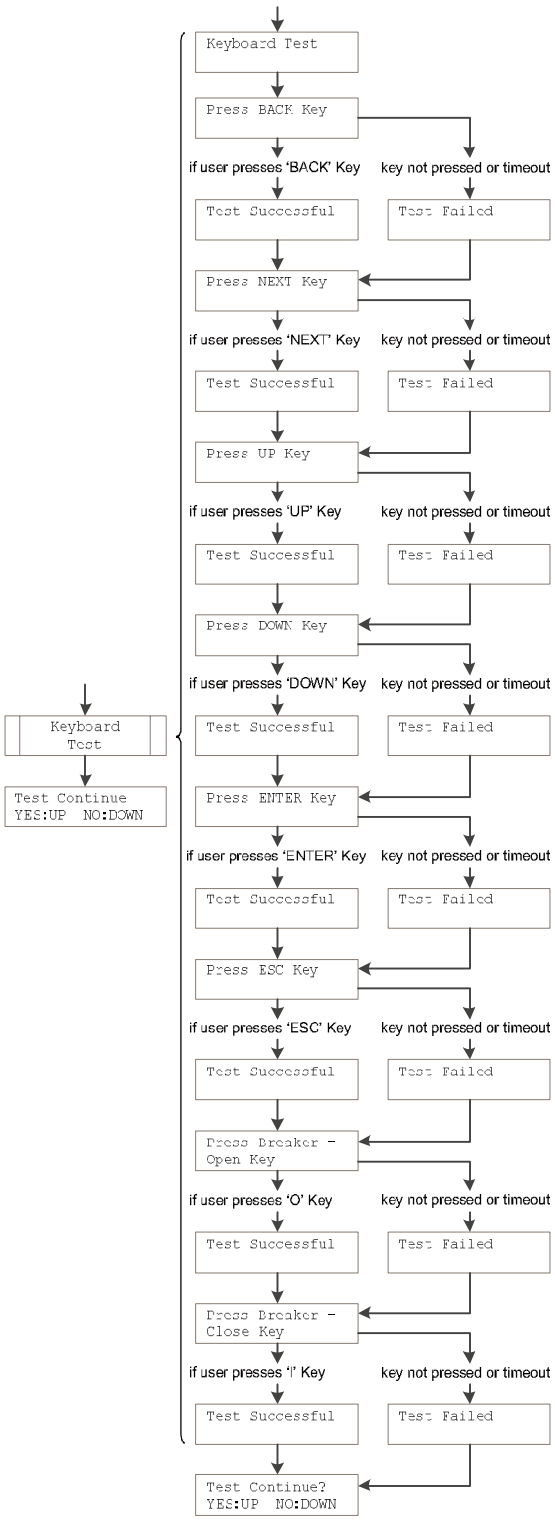


Figure 18: Hardware test menu of relay REF601 with its submenu (Continue)

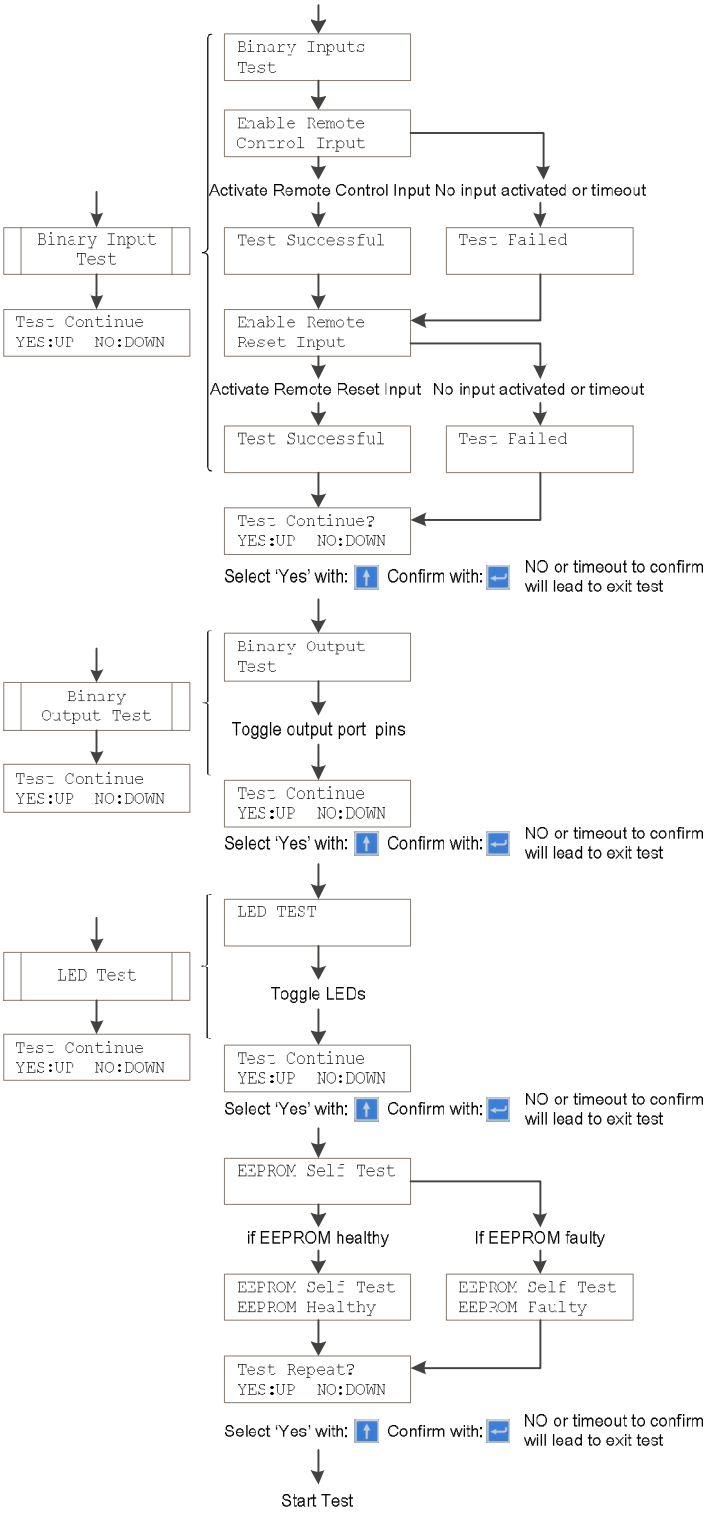


Figure 18: Hardware test menu of relay REF601 with its submenu (Continue)

5.2.8.2 Submenu – Trip output test

Submenu Trip output test allows to force a trip command.

This action is not of latching nature, and lasts only for the specified duration (200msec low pulse in case of Normally Open type trip circuit contacts).

5.2.8.3 Submenu – Functional test

Submenu functional test allows performing injection of protection function with pre-defined settings. The settings follow the protection parameter setting groups SG of the table below.

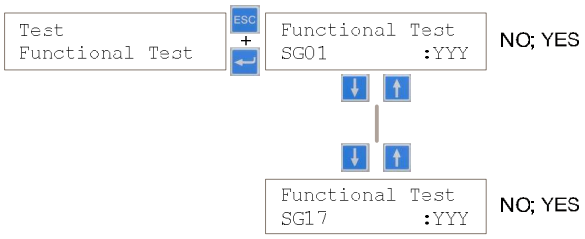


Figure 19: Functional test menu of relay REF601

Table 30: Functional test group parameter values

SG	Test Parameter IEC Model		Test Parameter CEI 0-16	
1	I> = 0.2 In Curve: DT B = 5	t> = 0.5 sec	I> = 0.2 In Curve: VI	K = 0.1
2	I> = 0.2 In Curve: DT B = 5	t> = 8.0 sec	I> = 0.5 In Curve: VI	K = 0.1
3	I> = 1.0 In Curve: DT B = 5	t> = 0.5 sec	I> = 1.2 In Curve: VI	K = 0.1
4	I> = 1.0 In Curve: DT B = 5	t> = 8.0 sec	I>>> = 0.8 In	t>>> = 0.05 sec
5	I>> = 2.75 In	t>> = 0.45 sec	I>>> = 5.0 In	t>>> = 0.05 sec
6	I>>> = 5.0 In		I>>> = 5.0 In	t>>> = 0.2 sec
7	I> = 0.2 In Curve: NI	K = 0.1	I>> = 0.2 In	t>> = 0.05 sec
8	I> = 0.2 In Curve: NI	K = 1.6	I>> = 2.1 In	t>> = 0.3 sec
9	I> = 0.2 In Curve: EI	K = 0.1	I>> = 4.2 In	t>> = 0.5 sec
10	I> = 1.0 In Curve: EI	K = 1.6	I_o> = 0.2 In Curve: DT	t_o> = 0.2 sec
11	I_o> = 0.05 In Curve: DT B = 5	to> = 0.5 sec	I_o> = 0.5 In Curve: DT	t_o> = 0.05 sec

SG	Test Parameter IEC Model		Test Parameter CEI 0-16	
12	I_o> = 1.0 In Curve: DT B = 5	to> = 0.5 sec	I_o> = 0.1 In Curve: DT	t_o> = 0.2 sec
13	I_o>> = 2.0 In	to>> = 0.75 sec	I_o> = 0.025 In Curve: DT	t_o> = 0.05 sec
14	I_o> = 0.05 In Curve: NI	K = 0.1	I_o> = 0.4 In Curve: DT	t_o> = 0.3 sec
15	I_o> = 0.05 In Curve: NI	K = 1.6	I_o>> = 0.25 In	t_o>> = 0.05 sec
16	I_o> = 0.05 In Curve: EI	K = 0.1	I_o>> = 1.0 In	t_o>> = 0.2 sec
17	I_o> = 0.05 In Curve: EI	K = 1.6	I_o>> = 2.0 In	t_o>> = 0.1 sec

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.

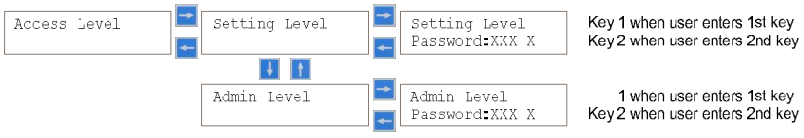


Figure 20: Access level menu

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.

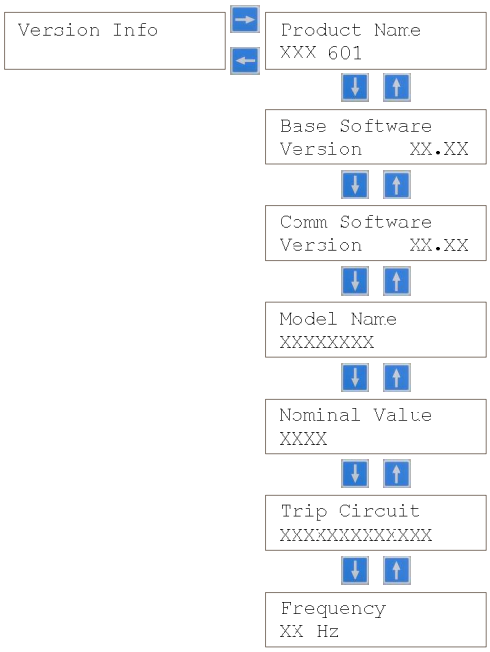


Figure 21: Version information display of relay REF601

Section 6 Installation

6.1 Unpacking and inspecting the device

REF601 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 + 70 °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 wiring:

- 0.2 - 2.5 sq. mm single-core
- 0.2 - 2.5 sq. mm finely stranded

6.5 Relay mounting and dimensions

The relay is available in two mounting version:

- Flush (panel) mounting
- Breaker mounting

The space requirement of mounting:

Overall dimensions (H x W x D)	: 160 x 130 x 102 mm
Cutout dimensions (H x W)	: 151.5 x 121.5 mm
Weight	: 1.2 kg

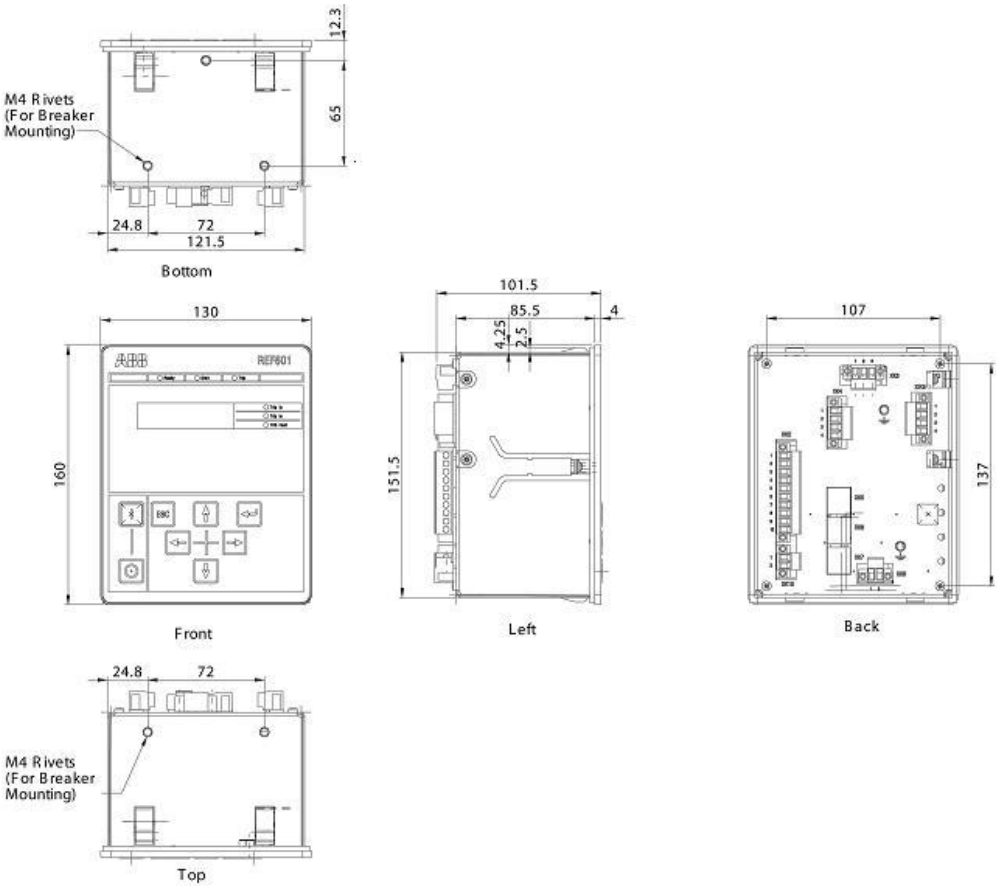


Figure 22: Overall mounting dimension of REF601

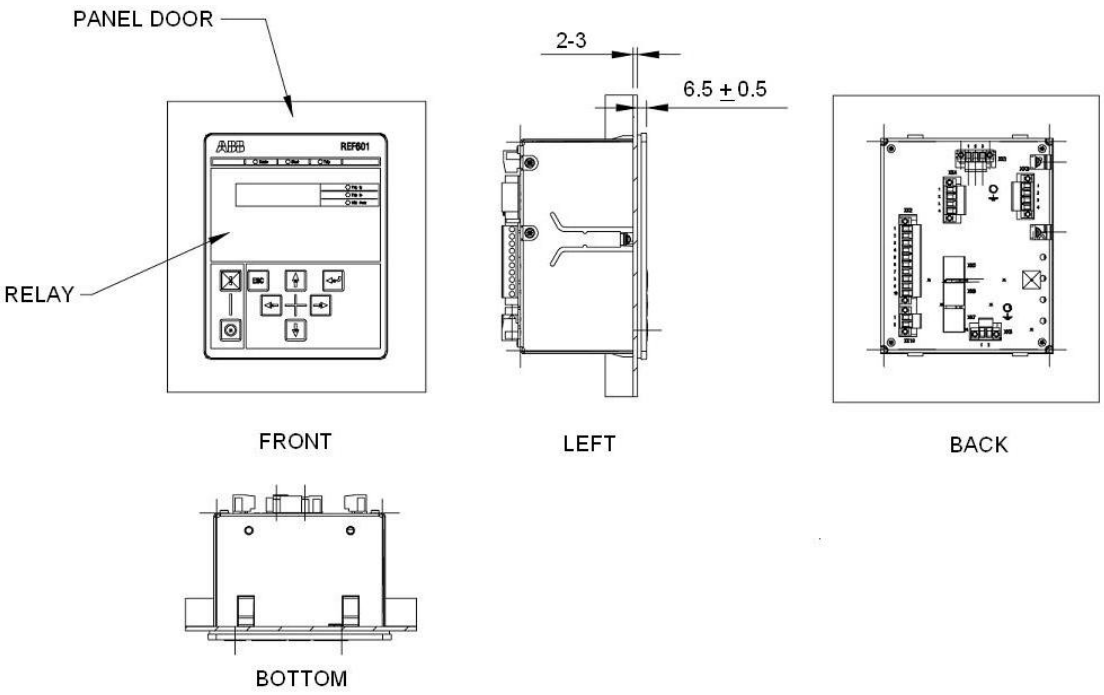


Figure 23: Panel mounting details of REF601

6.6 Relay connection diagram

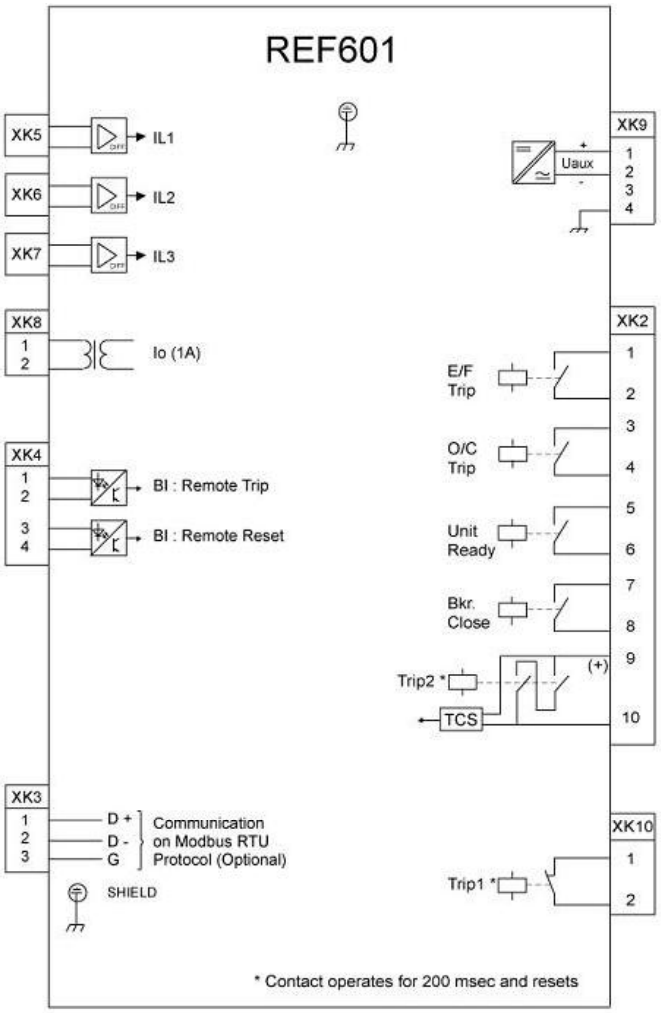


Figure 24: Connection diagram of relay REF601

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.

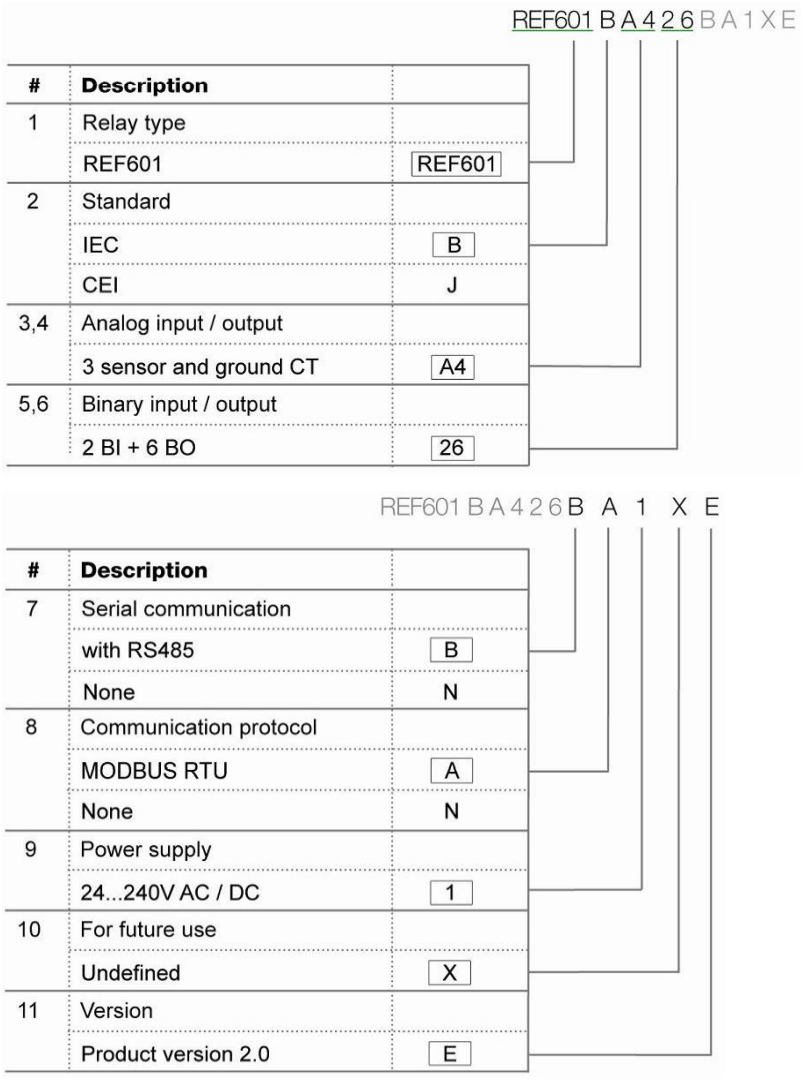


Figure 25: Ordering information of relay REF601

6.8 Accessories and ordering data

Table 31: REF601 accessories and ordering data

Item	Order number
KEVCR for integrated circuit-breakers type VD4/HD4	KEVCR24OC2R0101, 630A
	KEVCR24AC2R0102, 1250A
KECA for other applications where relay is panel mounted For more information please refer to the catalogue reference - no. 1VLC000584.	KECA 250 B1 : 1VL5400052V0101

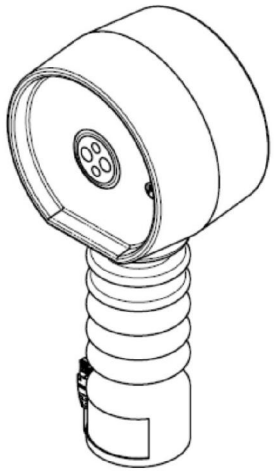


Figure 26: Outline view of KEVCR sensor

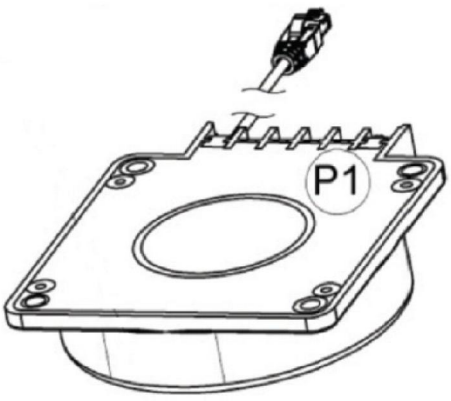
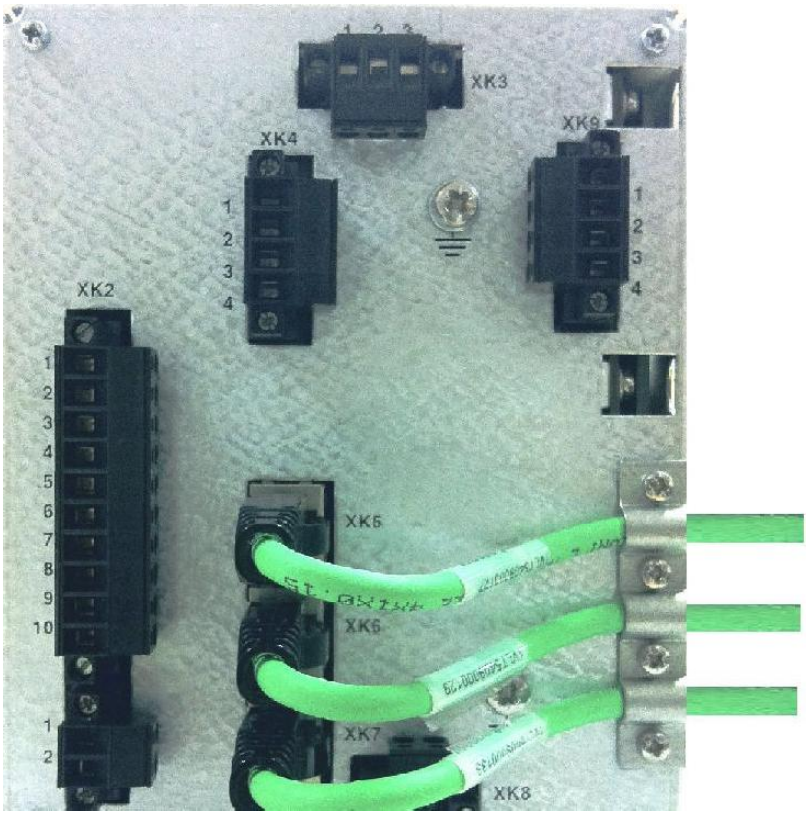


Figure 27: Outline view of KECA sensor

6.9 Bonding of sensor cable shield

6.9.1 Shield connection at relay side

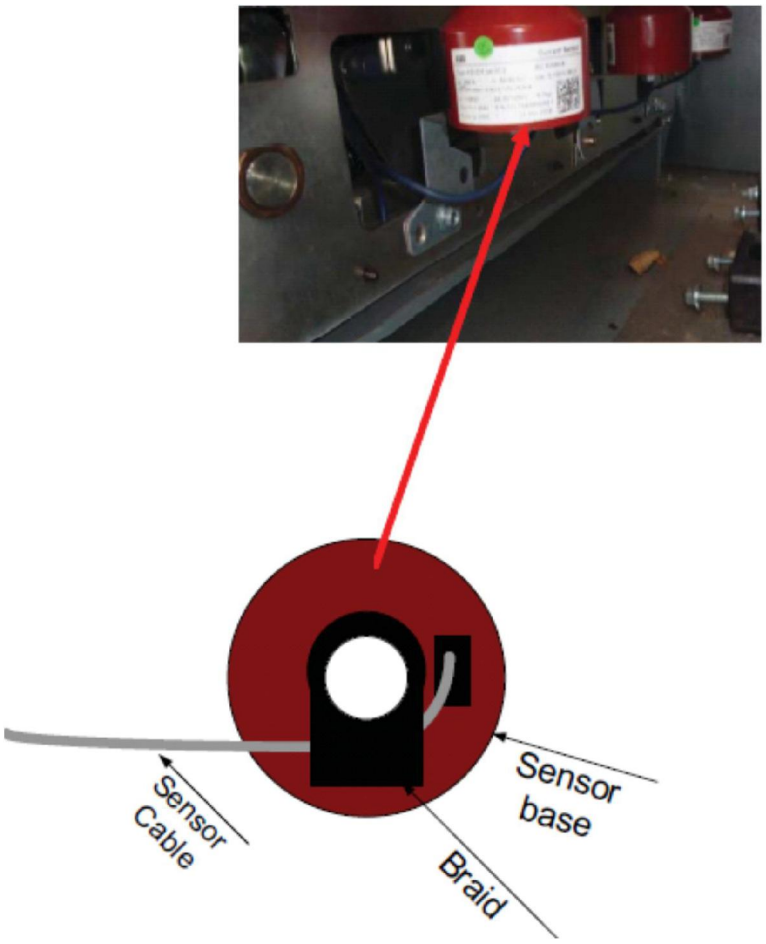
- Remove the isolation of the sensor cable for the specific section at relay side.
- Metal strip to be mounted at the rear of the relay as shown in figure with cables.
- Tighten screws carefully so that the sensor cable should not get damaged due to misalignment
- This shall result in a better connection of the sensor cable shield to the chassis respect to ground.



- In case of breaker mounting metal strip can be mounted at the rear of the relay on metal plate.

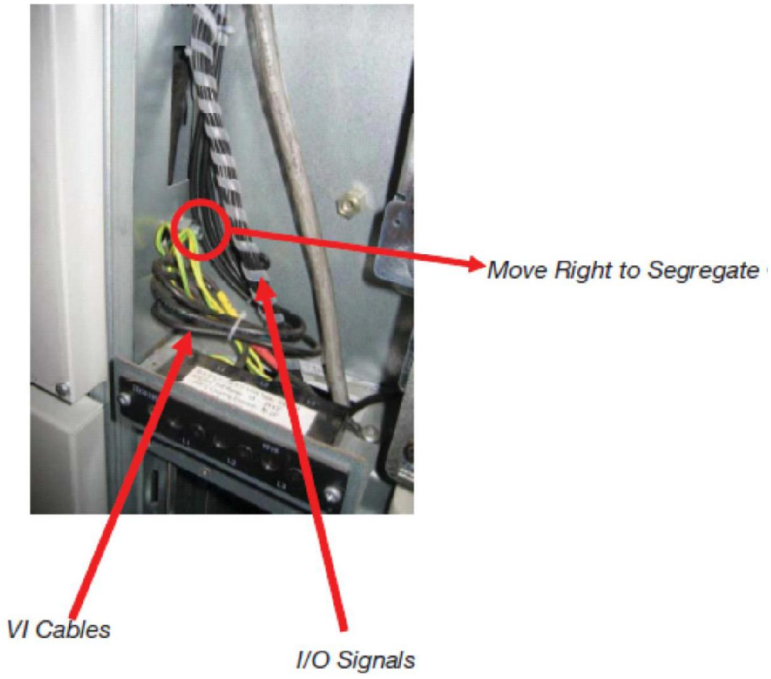
6.9.2 Shield connection at sensor side

- Remove the isolation of the sensor cable for the specific section at sensor side
- Insert into braid, close it and screw it to the mechanical fixation
- The following order of the mechanical parts to be applied:
- Sensor --> Mechanical Fixation --> Braid --> Screw
- This shall result in a short and big area connection of the sensor cable shield to the chassis resp. GND
- The braid shall have a similar or equivalent construction as shown on image (ring type)



6.9.3 Segregation of Voltage Indicator System

- VI Cables to be moved on the right side in case of UniSec switchgear of ABB. See Picture
- A coupling path between cables for I/O , Power Supply and the cables for voltage indicator should be avoided.
- A typical segregation of 40cm shall be considered



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