User's manual and Technical description

Feeder Protection Relay

REF601 CEI

ABB

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Guarantee

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Conformity

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 Council 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 a test conducted by ABB in accordance with Article 10 of the directive in agreement with the product standards EN 50263 and EN 60255-26 for the EMC directive, and with the product standards EN 60255-6 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 Introduction

1.1 This manual

This manual contains application and functionality descriptions and connection diagrams, input and output signals, setting parameters and technical data. The manual can be used as a technical reference during the engineering phase, installation and commissioning phase, and during normal service. The manual can also be used when calculating settings. 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 version	Release date	Document history
A	17.03.2009	Document released
B	17.04.2009	Document released
C	21.04.2009	Document released
D	25.05.2009	Document released
E	07.08.2009	Document released
F	30.09.2010	Document released

1.4 Document Symbol and Conventions

1.4.1 Safety information

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.

1.4.2 Functions,codes & Symbols

Protection	IEC code	ANSI code
Three-phase non-directional overcurrent, low-set stage	3I>	51
Three-phase non-directional overcurrent, high-set stage	3I>>	50 / 51
Three-phase non-directional overcurrent, very high-set stage	3I>>>	50 / 51
Non-directional earth-fault, low-set stage	Io>	51N
Non-directional earth-fault, high-set stage	Io>>	50N/51N
Three phase transformer inrush detector	3I2f>	68

Section 2 REF601 CEI overview

2.1 Overview

REF601 is a dedicated feeder protection relay, intended for the protection, measurement and supervision of utility substations and industrial power systems. Engineered from the ground up, the relay is inspired by and is compatible with the Rogowski coil sensor for current measurement. The new feeder protection relay 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

. External CBCT input for earth current

. Three-stage overcurrent protection

. Two-stage earth-fault protection

. Magnetizing inrush detection

. Control of circuit breaker

. Local and remote control

. Five event logs

. Two fault records of analogue value

. Non-resettable trip counter

. On-line measurements

. Comprehensive local HMI

. Universal auxiliary supply rating

. Circuit breaker or panel mounting

. Optional Modbus communication

. Non-volatile memory

. Access control

. Self-supervision

. Built-in test functionality

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

2.3 Operational Functionality

2.3.1 Standard configuration

The IED is available with one standard configuration. The table indicates

the functions supported by the IED

Protection	IEC code	ANSI code
Three-phase non-directional overcurrent, low-set stage	3I>	51
Three-phase non-directional overcurrent, high-set stage	3I>>	50 / 51
Three-phase non-directional overcurrent, very high-set stage	3I>>>	50 / 51
Non-directional earth-fault, low-set stage	Io>	51N
Non-directional earth-fault, high-set stage	Io>>	50N/51N
Three phase transformer inrush detector	3I2f>	68

2.3.2 Optional Function

- **Modbus RTU**

2.4 Basic 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 and the communication.

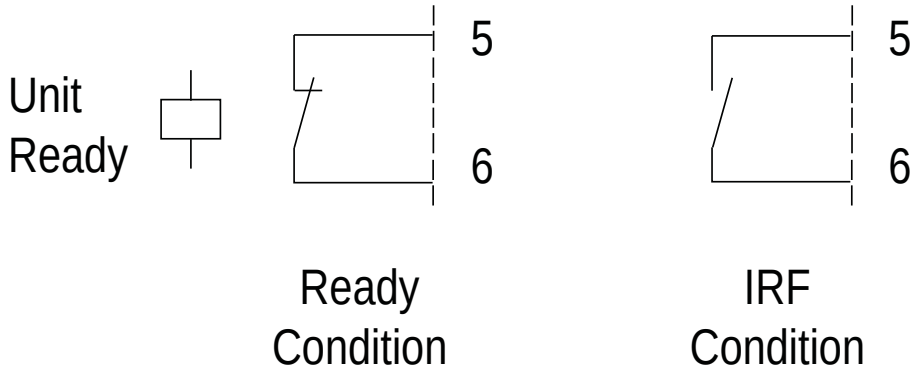
When in an IED internal fault is detected, the green Ready LED ceases to glow and the self-supervision output contact is activated. Internal fault indications have the highest priority on the LHMI. None of the other LHMI indications can override the internal fault indication. An indication about the 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 IED continues to perform internal tests during the fault situation.

If an internal fault disappears, the green Ready LED starts glowing and the IED returns to the normal service state. The fault indication message remains on the LCD until manually cleared.

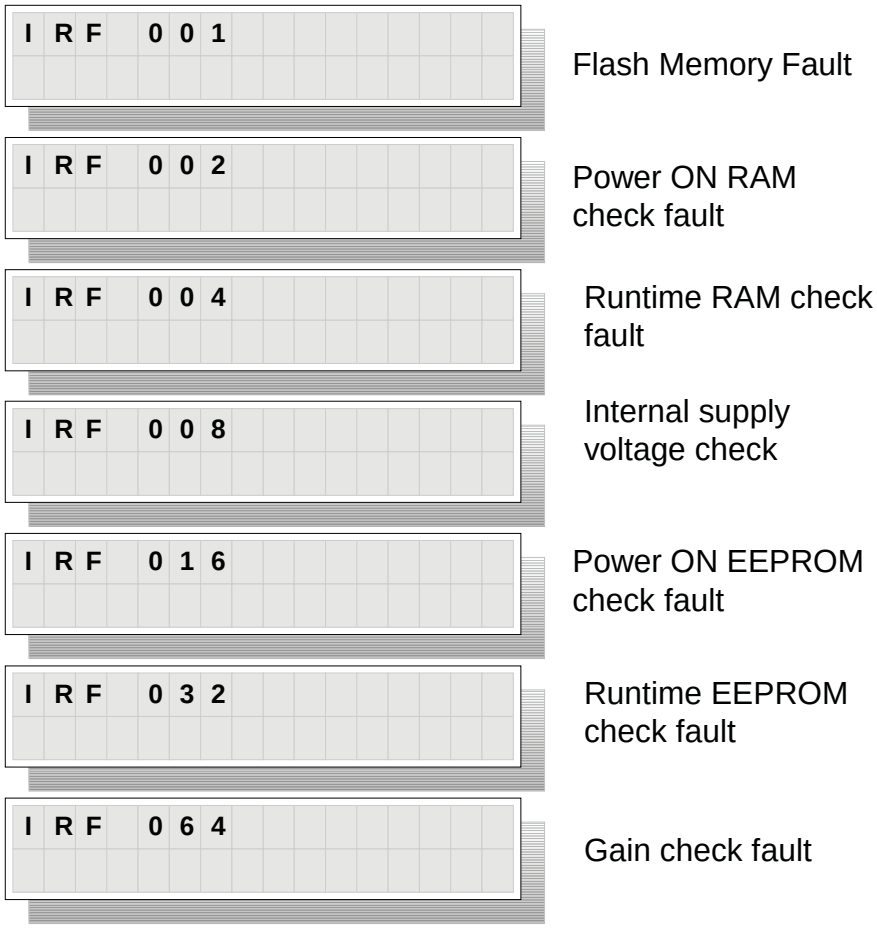
The self-supervision signal output operates on the closed circuit principle. Under normal conditions the relay is energized and the contact gap 5-6 in connector XK2 is closed. If the auxiliary power supply fail or an internal fault is detected, the contact gap 5-6 is opened.

Fig. 1 – Output Contact



The internal fault code indicates the type of internal IED fault. When a fault appears, document the code and state it when ordering the service.

Fig. 2 – Internal fault indication and codes



2.4.2 Recorded data & Trip counter

The relay stores records of analog values for 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 can not be reset by the user and are stored in non-volatile 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 five event logs. Each event log includes a snapshot of Analog values, Protection operation status, Binary I/O status and Relay fault code. 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 relay temporarily loses its auxiliary supply.

The event log facilitates detailed pre- and post-fault analysis of feeder faults and disturbances. 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.

2.4.4 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 and administrator level. The password is a combination of different navigation keys.

2.5 Power Supply

To be able to operate the relay needs a secured auxiliary voltage supply. The power supply module forms the voltages required by the protection relay module and the auxiliary relays.

The power supply board is having universal 24-240V AC / DC input voltage range. It is galvanically isolated switch mode power supply. It is implemented using fly-back topology where output voltages (+12V and -15V) are obtained using an isolation transformer. The output voltages are sensed through optical isolation

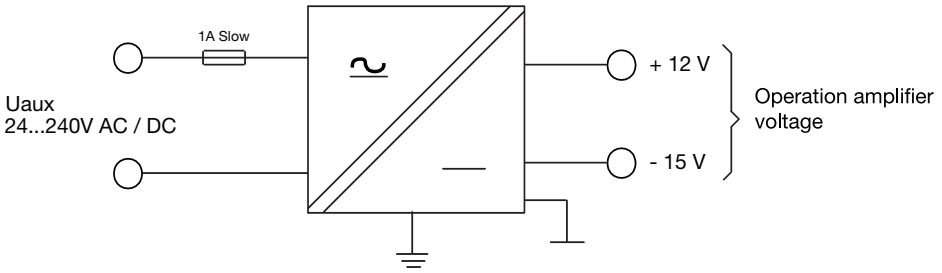


Fig. 3 – Power supply unit input / output of relay REF601

Unit is able to accept a wide voltage range as following:

Description	Range	Tolérance	Frequency	Insulation
Input Voltage Power	24…240Vdc* 24…240Vac	70%…+120% 85%…+110%	 50Hz	Galvanic, 2kV rms

* Ripple up to 12% has to be acceptable to the unit.

Section 3 Technical data

Dimensions

Width	frame case	130.0 mm, 121.5 mm
Height	frame case	160.0 mm, 151.5 mm
Depth	case	92 mm, 101 mm with terminal
Weight	relay	1.2 kg

Power Supply

U_{aux} nominal	24...240 V AC, 50 Hz 24...240 V DC
U_{aux} variation	85...110% of Un (20.4...264 V AC) 70...120% of Un (16.8...288 V DC)
Burden of auxiliary voltage supply under quiescent (Pq)/operating condition	< 5.0 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 U_{aux} rated

Energizing inputs

Rated frequency		50 Hz ± 5 Hz
Phase current inputs	Input type	Rogowski coil sensor
	Nominal primary current In(amp) selection	80A , 250A
	Rated transformation ratio, K_{ra}	250A / 0.15V at 50Hz 250A / 0.18V at 60Hz
	Linear current measurement range	8 A - 25 kA
Earth current input	Input type	Current Transformer
	Rated current, I_n	40 / 1A
	Burden at rated current	< 0.1 VA at 1A
	Linear current measuring range	0.025 x In - 12.5 x In
	Thermal withstand capability: • Continuously • For 1 s	 5 A 100 A
	Dynamic current withstand: • Half-wave value	 250 A

Binary inputs

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

Output relays

Trip1 output (Normally closed contact)	
Rated voltage	240 V AC / DC
Continuous contact carry	8 A at 250V AC
Make and carry for 3.0 s	15 A at 24V DC
Make and carry 0.5 s	30 A at 24V DC
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

Trip2 output (Normally open contact)	
Rated voltage	240 V AC / DC
Continuous carry	6 A at 250V AC
Make and carry for 3.0 s	8 A at 24V DC
Make and carry 0.5 s	10 A at 24V DC
Breaking capacity when the control-circuit time constant L/R<40 ms at 30 / 220 V DC	4 A/0.15 A
Minimum contact load	100 mA at 24 V AC / DC

Signal output (O/C, E/F Trip, Unit ready, Breaker close)	
Rated voltage	240 V AC / DC
Continuous contact carry	6 A at 250V AC
Make and carry for 3.0 s	8 A at 24V DC
Make and carry 0.5 s	10 A at 24V DC
Breaking capacity when the control-circuit time constant L/R<40 ms at 30 / 220 V DC	4 A/0.15 A
Minimum contact load	100 mA at 24 V AC / DC

Protection functions

Three-phase non-directional overcurrent protection

Low-set stage I >	Setting range of pick-up current	0.2...1.2 x In in steps of 0.05, Excludable
	Setting range of time multipler ' k '	0.1...1.6, in steps of 0.1
	Inverse time characteristics	IEC 60255-3: Very inverse,
	Accuracy of pick-up current	NA (Only VI Curve)
	Accuracy of operate time IDMT characteristic	class E(5) or ± 30 msec
	Reset ratio	IDMT : 0.96
High-set stage I >>	Setting range of pick-up current	0.2...5 x In in steps of 0.1, Excludable
	Operation mode	Definite time
	Operate time t >>	0.05...1 sec in steps of 0.05
	Accuracy of pick-up current	± 10% of set value
	Accuracy of operate time	± 5% of set value or ± 30 msec
	Reset ratio	0.98
Very High-set stage I >>>	Setting range of pick-up current	0.8...15 x In in steps of 0.2, Excludable
	Operation mode	Definite time
	Operate time t >>>	0.05...0.2 sec in steps of 0.05
	Accuracy of pick-up current	± 10% of set value
	Accuracy of operate time	± 5% of set value or ± 30 msec
	Reset ratio	0.98

Non-directional earth-fault protection

Low-set stage Io >	Nominal value of earth current	1 A
	Measurement range	0.025 In ...12.5 In [1)]
	Setting range for External earth fault measurement	0.025..0.5 x In in steps of 0.0125, Excludable
	Operate time at DT mode to >	0.1...1 sec insteps of 0.05
	Accuracy of pick-up current	± 5% of set value
	Accuracy of operate time : DMT characteristic	± 5% of set value or ± 30 msec
	Reset ratio	0.98
High-set stage Io >>	Setting range	0.25...12.5 x In in steps of 0.25, Excludable
	Operation mode	Definite time
	Operate time to >>	0.05...0.2 in steps of 0.05
	Accuracy of pick-up current	± 15% of set value
	Accuracy of operate time	± 5% of set value or ± 30 m sec
	Reset ratio	0.98

1) Earth current measurement makes use of the external core balance CT input for currents upto 7 In.When the measured current exceeds 7 In , measurement switches from external input to internal vector summation mode. Conversely, when the measured current reduces to a level below 6 In, measurement switches from internal to external CT input mode. The automatic swicthing of measurement modes, allows a wide dynamic measurement range of 1 : 500 .

Transformer inrush detection

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

Degree of protection of flush-mounted relay

Front side	IP 42
Sides with connection terminal	IP 20

Environmental conditions and tests

Environmental conditions	
Operating temperature range	-25...+70ºC (continuous)
Relative humidity	<93%, non-condensing
Atmospheric pressure	86...106 kPa
Altitude	up to 2000 m
Transport and storage temperature range	-40...+85ºC

Environmental tests

Cold test	IEC 60068-2-1	Test Ad (working) : -25 ± 3ºC for 16 hours, gradual Test Ab (storing) : -40 ± 3ºC for 4 days, gradual
Dry heat test	IEC 60068-2-2	Test Bd (working) : +70 ± 2ºC for 16 hours, gradual A.H. = 20 g/m^3 = R.H. 50% a 35ºC, 1ºC/min Test Bb (storing) : +85 ± 2ºC for 4 days, gradual
Damp heat, Steady state	IEC 60068-2-3 (replaced by : IEC 60068-2-78)	Test Cab (storing/working) : 40°C ± 2°C, 4 days R.H. controlled [93±3%]
Damp Heat, Cyclic	IEC 60068-2-30	Test Db (working): 93% humidity, 2 Cycles, From 25±3°C to 55±2°C

Mechanical tests

Vibration response test	IEC 60255-21-1	Class 2: 10 to 150Hz freq range, Cross-over freq.: 58 Hz Peak displac. (f<fco): 0.075mm Peak accel. (f>fco): 1gn No. of sweep cycles in each axis: 1
Vibration endurance test	IEC 60255-21-1	Class 2: 10 to 150Hz freq range, Constant acceleration: 2 gn No. sweep cycles in each axis: 20

Environmental tests

Shock test	IEC60255-21-2 (based on IEC60068-2-27 test Ea and IEC60068-2-29 test Eb)	Shock response test: Class2. Peak acceleration (A) 10gn, Duration of the pulse (D) 11ms, 3 pulses in each direction Shock withstand test: Class2. Peak acceleration (A) 30gn, Duration of the pulse (D) 11ms, 3 pulses in each direction
Bump test	IEC60255-21-2 (based on IEC60068-2-27 test Ea and IEC60068-2-29 test Eb)	Class2. Peak acceleration (A) 20gn, Duration of the pulse (D) 16ms, 1000 pulses in each direction

Electrical Insulation and mechanical construction tests

Power-Frequency withstand Voltage (Insulation test voltage)	IEC 60255-5	Level 2, 50Hz, 1min:- 2 kVrms (CM)
Lightening Impulse Voltage	IEC 60255-5	Level 3, 1.2/50µs, 500Ω, source Z, 0.5J source energy, - 5kVp (CM)
Insulation resistance	IEC 60255-5	500Vdc (CM) test voltage: >100MΩ
Protective bonding resistance	IEC 60255-27	< 0.1 Ω (60 sec)

Electromagnetic Compatibility tests

Emission Test (For test site measurements,)	IEC 60255-25	30…230MHz: 40dB (µV/m) quasi peak at 10m distance 230…1000MHz: 47dB (µV/m) quasi peak at 10m distance
Power supply Emission	IEC 60255-25	0.15…0.5MHz: 79dB (µV/m) quasi peak 66dB (µV/m) average 0.5…30MHz: 73dB (µV/m) quasi peak 60dB (µV/m) average

Conducted Immunity and Power unit tests

Electrostatic Discharge	IEC 60255-22-2	Level 3, 5/30ns pulse, 5 discharges: ±6kVp contact ±8kVp air
Fast Low Energy Transient (EFT) (Including functional earth port)	IEC 60255-22-4	5/50ns pulse, 2.5 kHz, ±4kVp,

Conducted Immunity and Power unit tests

Slow High Energy Transient (Surge1.2/50us Voltage pulse)	IEC 61000-4-5 IEC 60255-22-5	1.2/50µs pulse ±4kVp (L-Gnd) ±2kVp (L-L)
Radio-Frequency disturbance (Including functional earth port)	IEC 60255-22-6	Level 3, 0.15…80MHz, step 1%, AM 80% @ 1kHz,.: 10Vrms/unmod (CM), Spot freq 27MHz 68Mhz
Voltage Dips.,Short Interruptions (ac)	IEC 61000-4-11	100% (10mS and 30mS),70% and 40%
Voltage Variation immunity tests (ac)	IEC 61000-4-11	Voltage Test level 70%
Damped Oscillatory Waves (HFD)	IEC 61000-4-12	Level 3 1 MHz , 10 transients:± 2.5kVp (CM) , ± 1kVp (DM)
Ripple Voltage	IEC 60255-11 IEC 61000-4-17	Level 3: 10% Un 50, 300 Hz ripple freq.
Voltage Drop, Supply Interruption and voltage variations on d.c. input power port (immunity tests)	IEC61000-4-29	100% @ 50ms
Power Frequency Immunity Test	IEC60255-22-7	Class A : CM: 300Vrms DM: 150Vrms

Radiated Immunity Tests

Radio-Frequency Electromagnetic Field (Amplitude modulated)	IEC 60255-22-3	80…1000MHz, AM 80% @ 1kHz, horizontal and vertical polarization: - 10V/m Spot freq: 80, 160, 450, 900MHz, AM 80% @1kHz
Radio-Frequency Electromagnetic Field from digital radio telephones(Pulse Modul.)	IEC 60255-22-3	Level 4, 900 ± 5MHz, PWM 100% @ 200Hz, 50% D.C.: - 10V/m (10s Dwell time)

Magnetic immunity tests

Power-Frequency Magnetic Field	IEC 61000-4-8	Level 5, X-Y-Z axis : -100A/m continuously -1000A/m short time
Pulse Magnetic Field	IEC 61000-4-9	Level 5, 5 positive and 5 negative, 8/20µs pulses every 10s:- 1000 A/m

Contact tests

Make and carry	IEC 60255-23 (Replaced by IEC61810-2, Ed.1.0)	Signaling : 10A@24VDC for 0.5s and 8A@24VDC for 3s Tripping : 30A@24V DC for 0.5S and 15A@24VDC for 3S
Breaking capacity for d.c., L/R ≤ 40 ms	IEC 60255-23	Signaling: 0.15A@220VDC and 4.5A @30VDC Tripping: 0.2A@220VDC and 5.5A@35VDC
Make and Break capacity for resistive load	IEC 60255-23	Signaling: 6A @240V ac Tripping: 8A@240V ac
Mechanical durability	IEC 60255-6	10,000 operations ; tripping and signaling contacts

EMC compliance

Complies with the EMC directive 2004/108/EC	
Standards	EN 60255-26 (2004)

Product safety

Complies with the LV directive 2006/95/EC	
Standards	EN 60255-27 (2005), EN 60255-6 (1994)

RoHS compliance

Complies with the RoHS directive 2002/95/EC

Data communication (optional)

Protocol : Modbus RTU Communication port : RS485 4-wire

Section 4 Protection Functions

4.1 Three Phase Current Protection

4.1.1 Functionality

The three-phase overcurrent protection is used as one-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 only IDMT (VI) 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, provides alarm, 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 IDMT times (VI Curve) 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 product variant. 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 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 and high stage has only definite time (DT) . 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.

4.2.2 Principle of Operation

REF601 has earth fault protection with low set and high set module. Earth fault modules operates the protection as soon as fault current exceeds the set value of current. It supports only DMT 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 product variant. 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 REF601 employs the most proven technique of blocking based on measured value of second harmonic content to make the protection immune to magnetizing inrush.

4.4 Outputs & Inputs

The relay has pre-defined output contacts. The REF601 has trip / breaker open command output contact and additional NC trip output command which opens 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 by applying the proper voltage input to reset input, will reset all the 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.

4.5 Breaker control & Trip command operation

Relay 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 additional 2 nos. binary inputs. The close / trip control command to the breaker will be generated by respective output contacts.

REF601generates the trip in case of remote trip command, protection trip or breaker open command as shown Figure below.

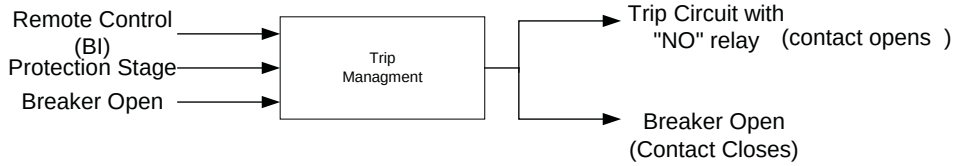


Fig. 4 – Various trip arrangement available in feeder protection relay REF601

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

At power-on, relay will perform internal health check and then change the trip 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. There are four reset commands

-Applying a proper voltage input to the Reset input terminals (XK4.3–XK4.4) as mentioned above.

-Through Menu Navigation

-Through proper command via communication port (XK3)

-Through "UP" + "Enter" key combination

In case of power off without reset command, at next power-on, trip signaling we get restored. In case of power OFF condition and Internal relay fault condition, trip contact will be in open condition.

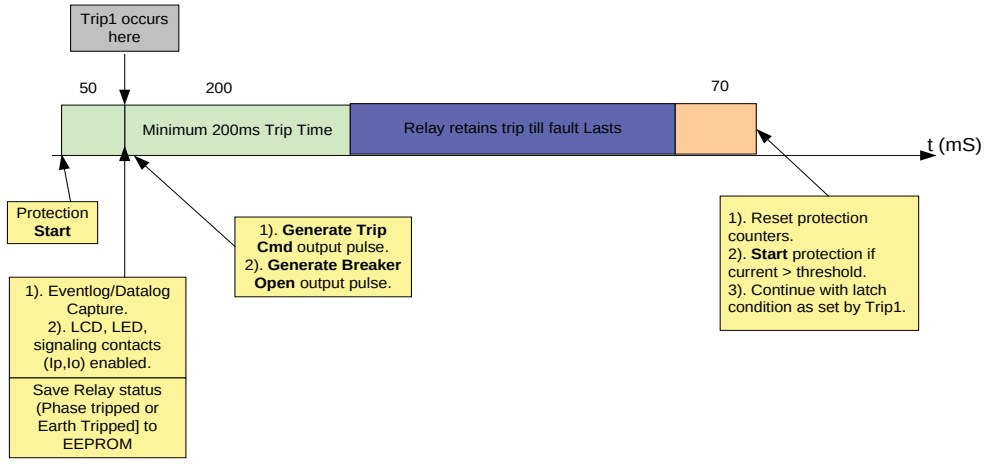


Fig.5 – Trip contact Management

Note: In case of fault current persist for longer duration, Trip pulse duration follows the fault current

4.5.1 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 Remote opening command terminal (XK4.1 – XK4.2), will generate a trip command directly irrespective of current flowing in system. However the remote opening command can be blocked through menu and in such cases it cannot be operated neither through a valid voltage nor through Modbus communication. By applying the proper voltage input to Reset input terminals (XK4.3–XK4.4), will reset all the

4.5.2 Breaker control command inputs

REF601 supports the Breaker control command voltage inputs (Breaker open and Breaker Close) with wide voltage range of 24V-240V AC/DC input. This breaker commands can also be given by push buttons given on front plate of REF601.

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.

4.5.3 Remote -Local Mode

In relay, there are two modes of operation termed as

- Remote mode
- Local mode

These modes changeover happens automatically based on the state of relay. If the relay is in default screen, the relay mode will be automatically set to remote mode. And if the menu navigation access is initiated the mode will get change automatically to local mode.

According to the mode selected, relay operations were either inhibited or allowed to perform. Below mentioned are the relay operations categorized based on type of mode:

Relay operations		Local	Remote
Binary inputs	Breaker Open	X	√
	Breaker Close	X	√
	Reset	√	√
	Remote Trip	√	√
MODBUS related operations	Read *	X	√
	Write	X	√

* A case when relay is in local mode & its parameter got changed, then those latest updated parameter will be reflected on MODBUS side only when relay changeover to remote mode else older data will be read.

As an illustration, if user is performing menu navigation operation, then relay will be automatically configured to local mode. In such a situation any MODBUS related actions & either breaker open or close will be inhibited or will not function. While rest all actions can be performed.

Otherwise, in case relay is in default screen mode then all above mentioned action in table can be performed.

4.6 Signal Diagram

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

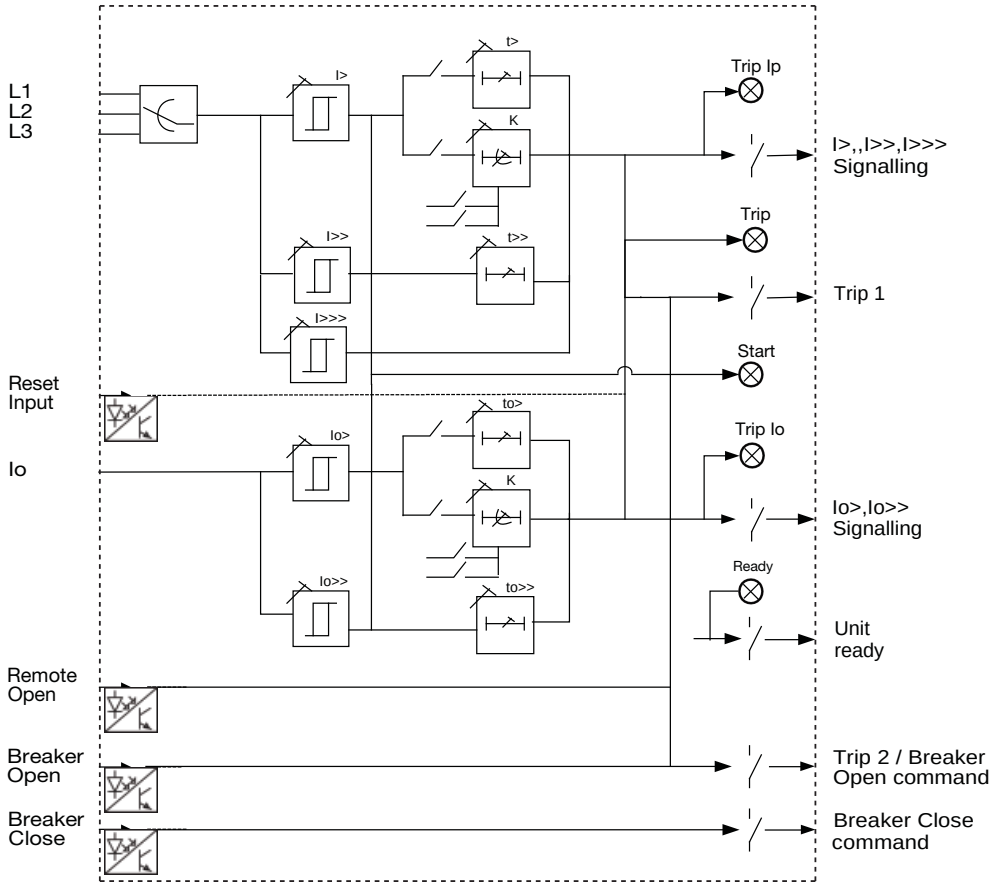


Fig. 6 – Signal diagram of relay REF601

Analogue input:

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

- Binary input:

o Remote Trip — Remote trip command to breaker

o Remote reset — Remote reset command for resetting indications and contacts

- LED indications (on relay front)

o Trip (RED) — Common trip LED for overcurrent and earth fault trip indication

o Trip Ip (RED) — Trip LED for overcurrent faults (I>, I>> and I>>>)

o Trip Io (RED) — Trip LED for earth faults (Io> and Io>>)

o Start (Yellow) — Start LED for any protection function start

o 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

- Trip and Signaling contacts

o 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 O/C Trip signal — Signaling contact over current trip This will operate i.e. changeover to NC, for phase faults (I>, I>> and I>>>)

o E/F Trip signal — Signaling contact earth fault trip This will operate i.e. changeover to NC, for earth faults (Io> and Io>>)

o 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

o Trip 2 / Breaker open — Contact for Breaker open output. This contact will operate i.e. changeover to NC , when healthy Breaker open command is received. It also activate in case of valid trip condition and valid remote opening command.

o Breaker close — Contact for Breaker close command. This contact will operate i.e. changeover to NC , when healthy Breaker close command is received.

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.

4.7 Protection characteristics

4.7.1 Time / Current characteristics

REF601 offers three-stage overcurrent and two stage earth-fault protection functions. The low-set stage of overcurrent protection is equipped with standard Inverse-definite Minimum Time (IDMT) characteristics - Very Inverse (VI), while the low set stage of earth-fault protection has a DMT characteristics for better co-ordination with rest of the network. 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 long-time inverse and one special curve, named RI type curve.

4.7.2 IEC characteristics

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:

$$t = \frac{K * ß}{(I/Iset)^{a} - 1}$$

where,

t = operate time in seconds

K = time multiplier

I = measured current value

I set = set start current value

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

Slope of the time/current curve set	**à**	**ß**
Very inverse	1.0	13.5

In case of REF601, accuracy class 5 is applicable. The details of accuracy points as per BS: 142:1966 are given below:

I/I>	Very Inverse
2	2.34E
5	1.26E
7	---
10	1.01E
20	1.00E

Note: E stands for accuracy class i.e. in this case it is 5 for phase and external earth fault whereas for internal earth fault the accuracy class is 7.5

4.7.3 Very inverse-time characteristics curve

The graphs between I / Isat and related timing for various IDMT curves is attached below. It is common for both earth and phase currents. Phase current measurement is up to 20In while earth measurement is limited up to 12.5In. So corresponding I / Isat get limited depending upon maximum measurement limits. Minimum trip time for IDMT curve is 50ms.

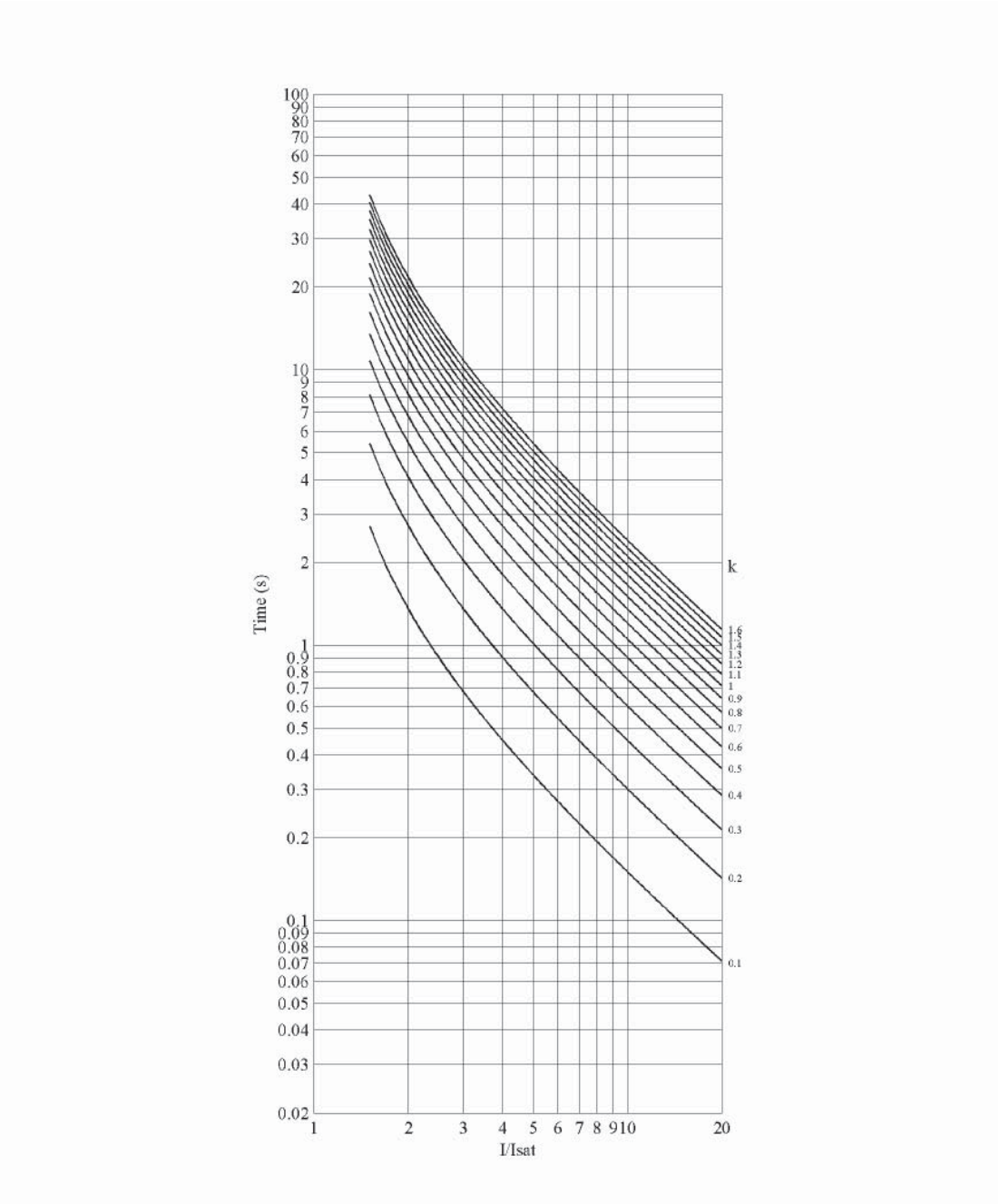


Fig. 7 – Very inverse-time characteristics of relay REF601

Section 5 Menu Structures & LHMI Navigation

5.1 Local HMI

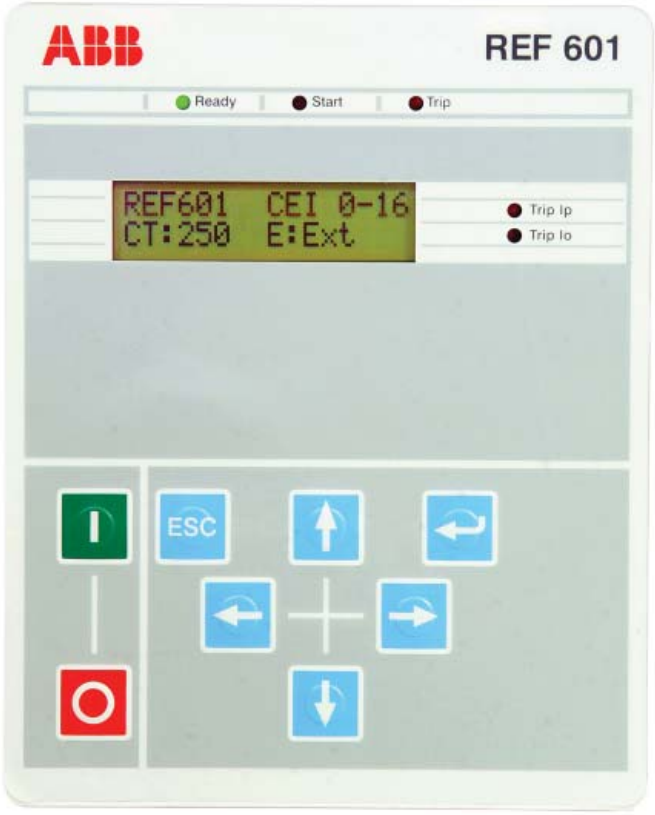


Fig. 8 – Local HMI of relay REF601

The local HMI of the relay contains following elements:

- LCD display
- Navigation buttons
- LED indicators

The LHMI is used for setting, monitoring and controlling.

5.1.1 LCD Display

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

5.1.2 Navigation

The LHMI keypad consists of push buttons which are used to navigate in different views or menus. With control push buttons (in case of REF601 relay) the open or close commands can be given to breaker. The push buttons are also used to acknowledge alarms, reset indications.

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	Used for discarding changed parameter value in edit mode, or for going back to main menu from any level of menu navigation.
	Breaker Close	Control key for providing Breaker Close command.
	Breaker Open	Control key for providing Breaker Open command.

5.1.3 Indication LEDs

The LHMI includes three protection indicators above the display: Ready, Start and Trip. Additionally there are also 2 LEDs for phase & earth fault indication on front of the LHMI.

5.2 LHMI menu navigation

5.2.1 Default screen

The default view of the relay displays all the phase and earth currents which is indicated in Fig. 9. The relay returns to default screen after a delay of 60 seconds if no key is pressed for that duration. Below screen will be refreshed at specific display rate, to display dynamic current changes. Current values displayed in this view for phase current is in “Amp” and for earth current it is in “In” as shown in following figure.

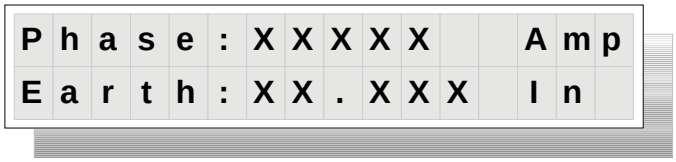


Fig. 9 – Default screen of relay REF601

5.2.2 Main menu

In default screen, by pressing any key the user always get back to the Main Menu. Different views / sub-menus can be seen and selected via Main Menu. In default screen, by pressing any key the user always get back to the Main Menu. However once in menu navigation, escape key should be pressed to return to the Main Menu. After time-out the default view is activated displaying all the phase and earth currents.

Figure 10 shows the main menu of the relay.

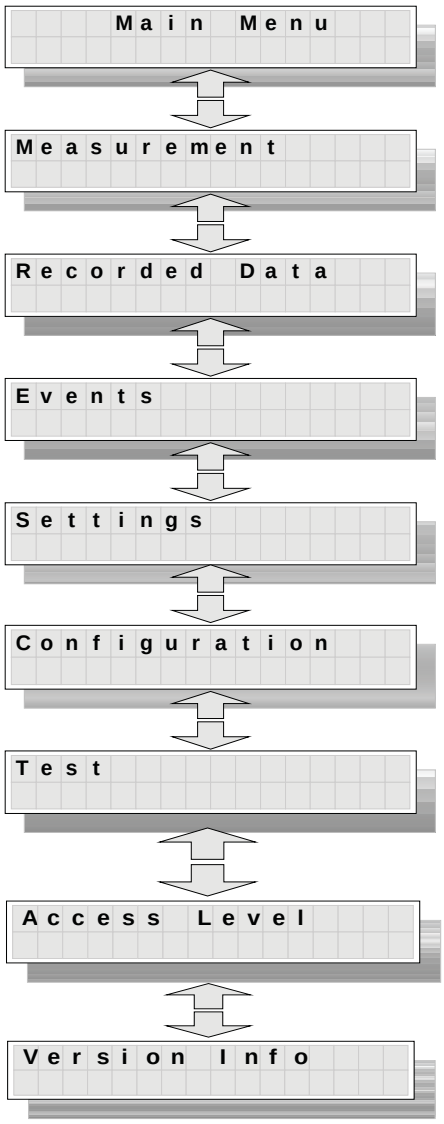


Fig. 10 - Main menu of relay REF601

5.2.3 Authorization

The user categories have been predefined for the LHMI, each with different rights and default passwords.

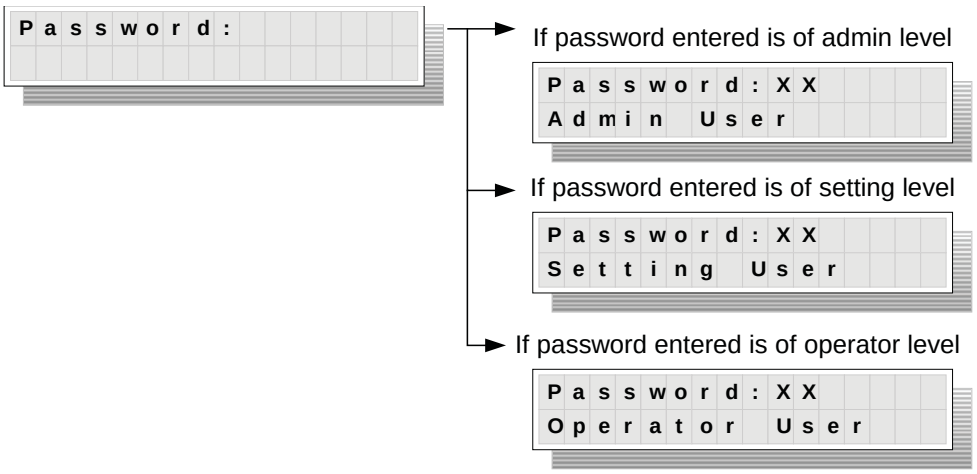


Fig.11- Login process of relay REF601

The user can select from different levels depending on which role he has and where he has an access to (e.g. setting level & administrator). Whenever any key is pressed by the user from the default view, a password screen pops up. Password needs to be entered here as the combination of two keys(The keys need to be pressed for min 3-5 seconds). In case of wrong password being entered by the user, password screen is displayed and no action is taken. Depending on the password entered, only particular menus will be accessible and others will be hidden to the user or edit mode can be disabled. Only the admin level user has access to all the menus & sub-menus and access to editing of relay parameters.

Sr. No.	Feature	Admin User Level	Setting User Level	Operator User Level
1	Password editing	Yes	No	No
2	Relay configuration editing	Yes	No	No
3	COM Board parameter editing	Yes	Yes	No
4	Protection settings editing	Yes	Yes	No
5	Menu Viewing	Yes	Yes	Yes
6	Password key comibation	Back +Down	Up + Back	other than Admin / setting password

5.2.4 Menu - Measurement

When the user selects Measurements sub-menu using right arrow key, an overview of basic measurements of the relay is visible for each analogue input module. Measurements like - Phase currents, neutral current, etc. can be seen in this view. An Up-Down arrow key should be used to switch to the next available screen.

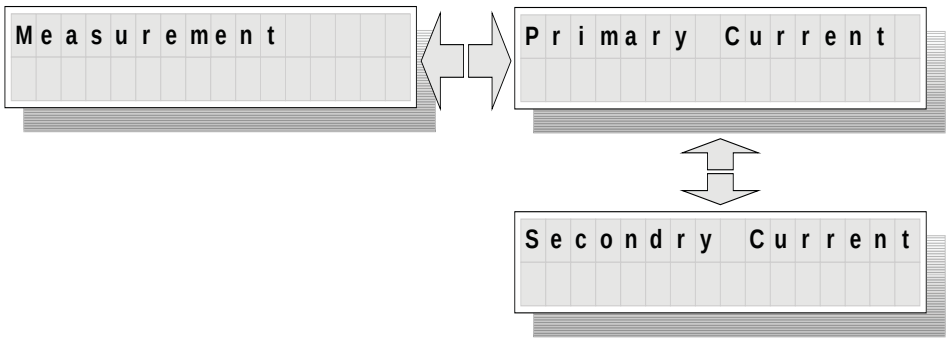


Fig. 12- Measurement menu with its sub menu

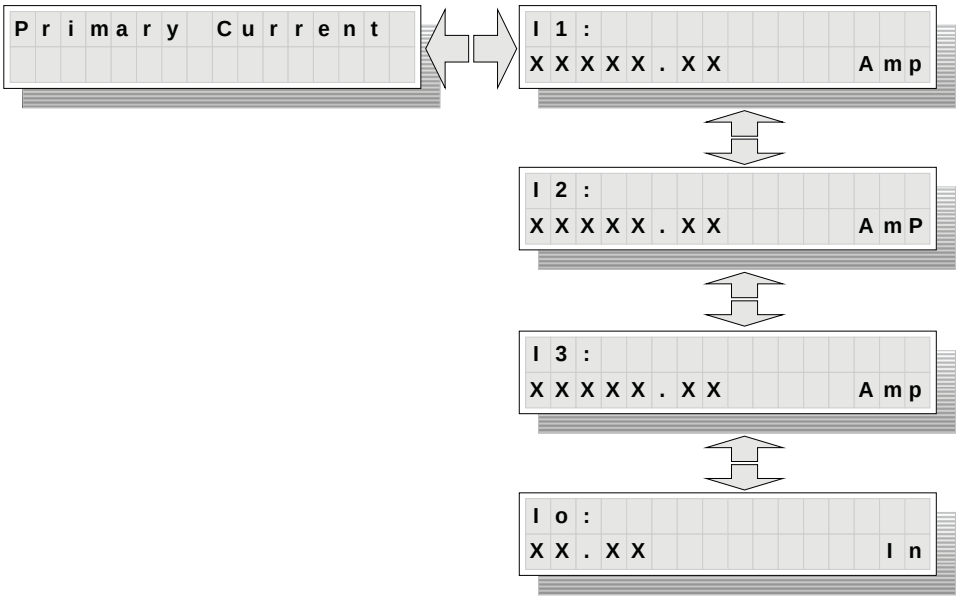


Fig. 13- Measurement menu view with primary current

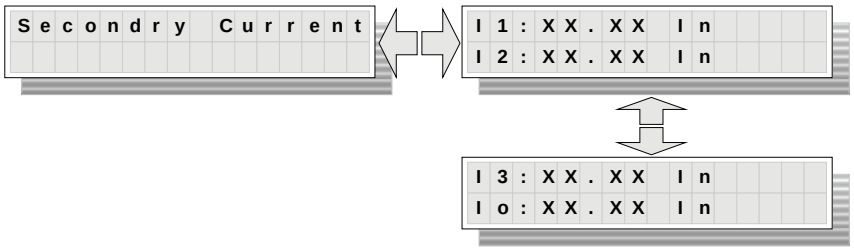


Fig. 14- Measurement menu view with secondary current

5.2.5 Menu – Recorded data

User can select Recording Data for viewing with the right arrow key as shown in the figure 15 and can select current display or trip counter view through the up/down arrow key. In Recorded Current block, user can see the current values for 15 different instants around trip event occurrence. Data recording for two trips is provided in block 1 and block 2, third trip data is saved in block 1 by overwriting previous data. In the Trip Counter block, user can view the value of phase trip counter and earth trip counter through up/down keys. The user cannot reset these counter values.

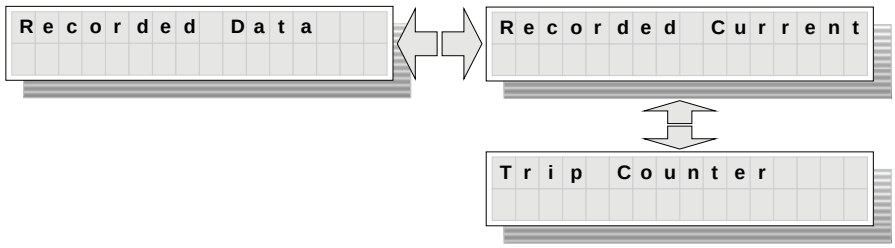
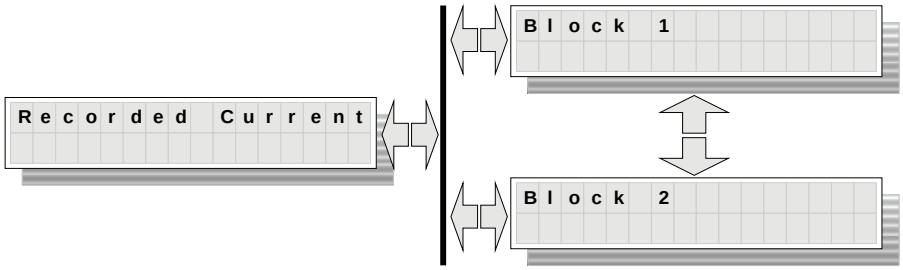


Fig. 15- Recorded data menu with its sub menu



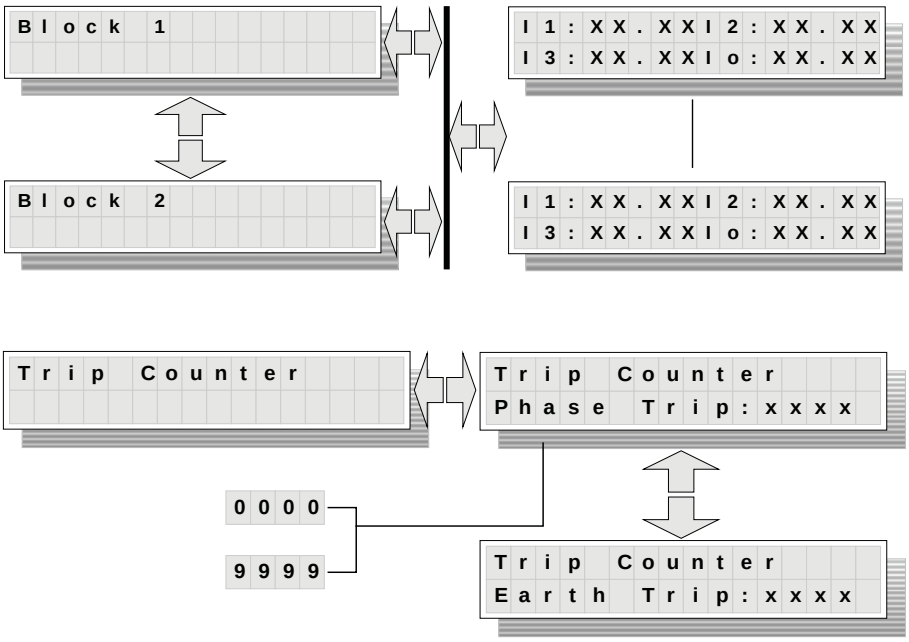


Fig. 16 - Recorded data sub menu view

5.2.6 Menu – Events

User can select Events with the right arrow key as shown in following figure 17 and select any event 1…. 5 through the up/down arrow key. In Events, user can see the trip values of the currents, binary input status for breaker open, binary input status for breaker close, binary input status for reset, binary input status for remote trip control, unit ready status, internal relay fault (IRF) status, phase protection trip status and earth protection trip status which is shown in following figure. ‘Event 1’ will always contain data for the most recent event and ‘Event 2’ previous trip event and so on.

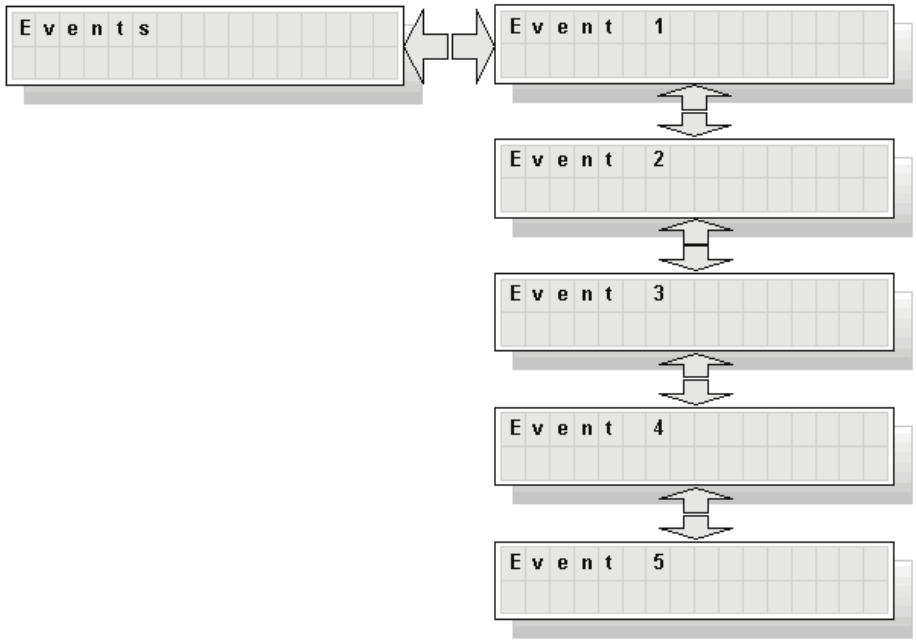


Fig. 17- Event menu with its sub menu

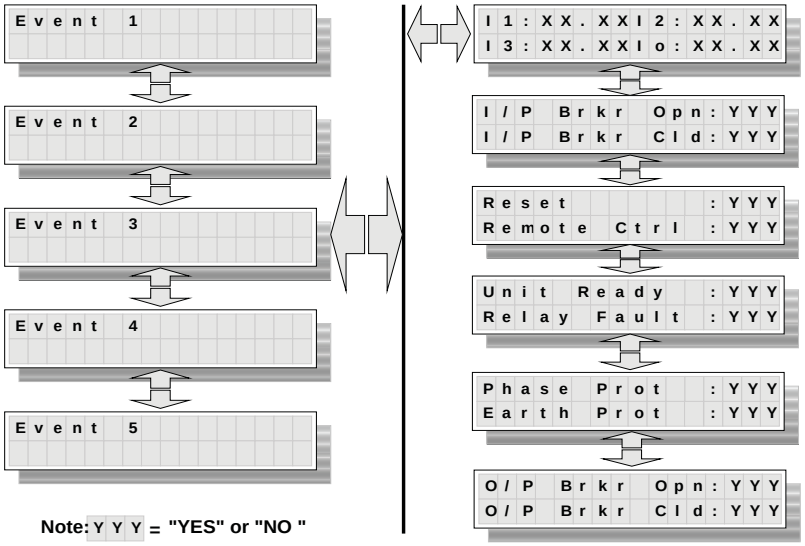


Fig.18- Event sub menu view

5.2.7 Menu – Settings

Only Setting level and Admin level users can modify parameters in this menu. This menu provides the settings for various protection stages as shown in figure 19. User can use the right arrow key for the selection of the particular menu item and up/down arrow key is used to select particular settings of that protection stage. In order to edit any settings, user has to press Cancel & Enter keys simultaneously. Once user selects the required settings of the protection stage, user has to press “Enter” button to save selected settings, or press “Cancel” key to discard modification done.

Depending on the type of protection stage selected, and the Curve selected, either the value of Time or the value of K will be displayed. For example, selection of DT Curve will display Isat and Time. Selection of IDMT Curve will display Isat and K.

User can select curve “VI” for I> & DT for Io> .

•For “Low Set I>” setting, Isat value can be changed from 0.2 to 1.2 In in steps of 0.05, K value can be changed from 0.1 to 1.6 in steps of 0.1.

•Similarly for “High Set I>>” setting, Isat value can be changed from 0.2 to 5 In in steps of 0.1 and Time value can be changed from 0.05 to 1 sec in steps of 0.05.

•For “Very High Set I>>>”, Isat value can be changed from 0.8 to 15.0 In in steps of 0.2 and Time value can be changed from 0.05 to 0.2 sec in steps of 0.05.

•For “Low Set Io>”, Isat value can be changed from 0.025 to 0.5 In in steps of 0.0125 and Time value can be changed from 0.05 to 1 sec in steps of 0.05.

•For “High Set Io>>”, Isat value range is 0.25 to 12.5 In in steps of 0.25 and Time value can be changed from 0.05 to 0.2 sec in steps of 0.05.

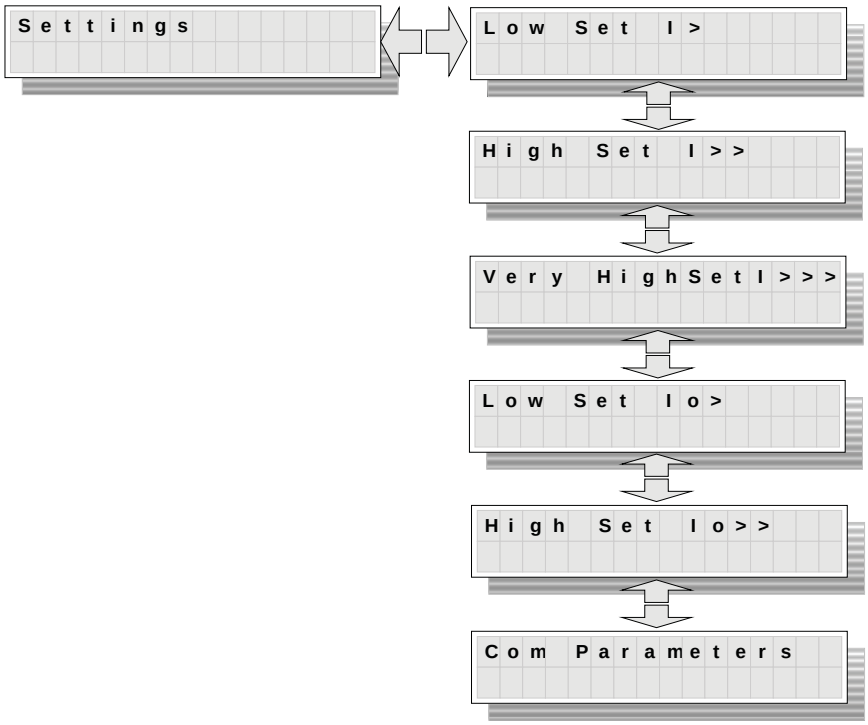


Fig. 19- Setting menu with its sub menu

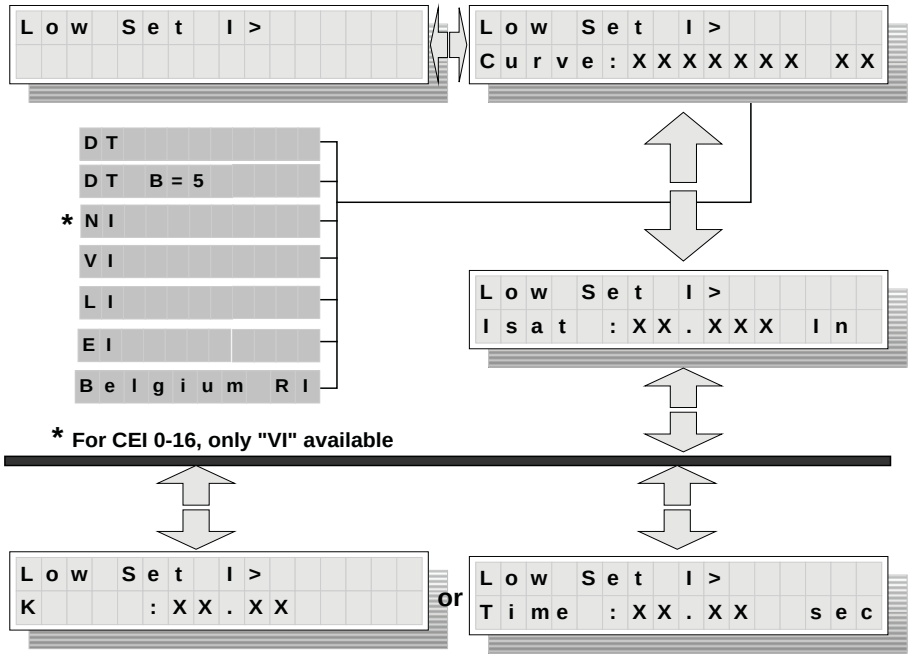


Fig. 20-Setting menu with its sub menu protection stage Low-set over current

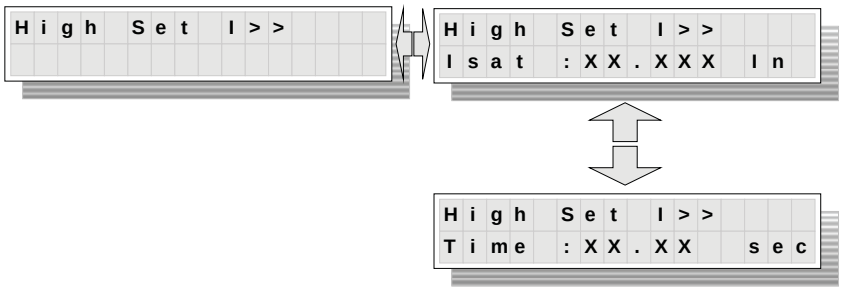


Fig. 21- Setting menu with sub menu protection stage High-set over current

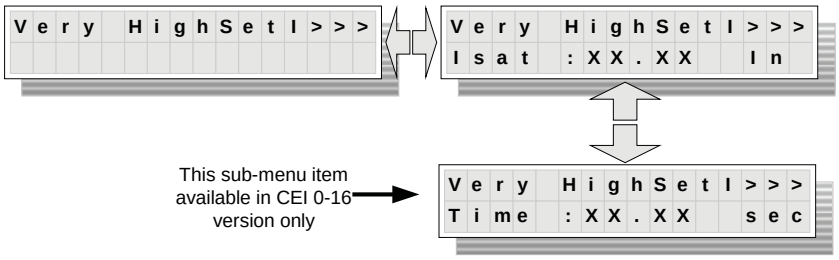


Fig. 22- Setting sub menu protection stage Very High-set over current

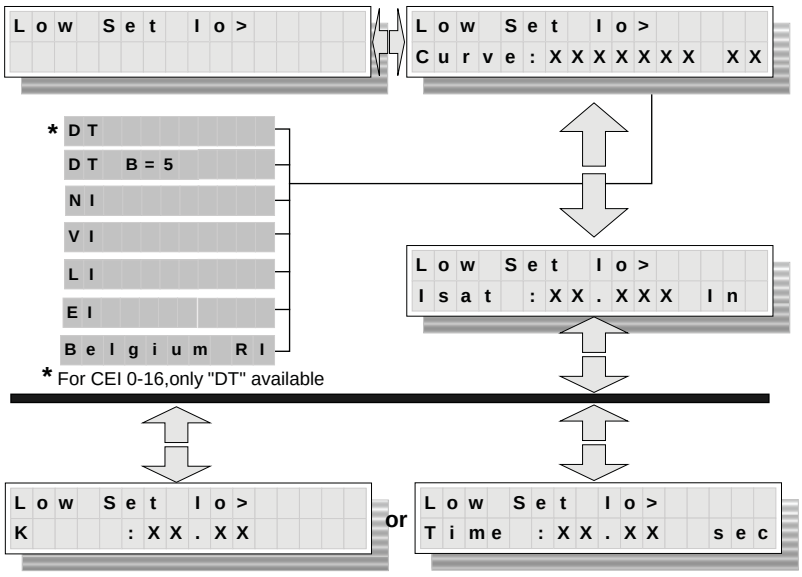


Fig. 23- Setting menu with its sub menu protection stage Low-set earth-fault

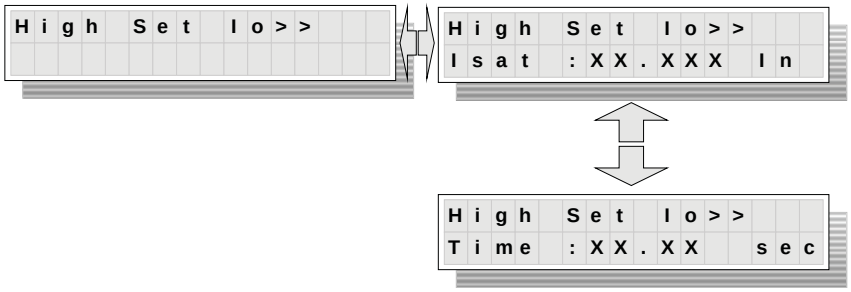


Fig. 24- Setting menu with sub menu protection stage High-set earth-fault

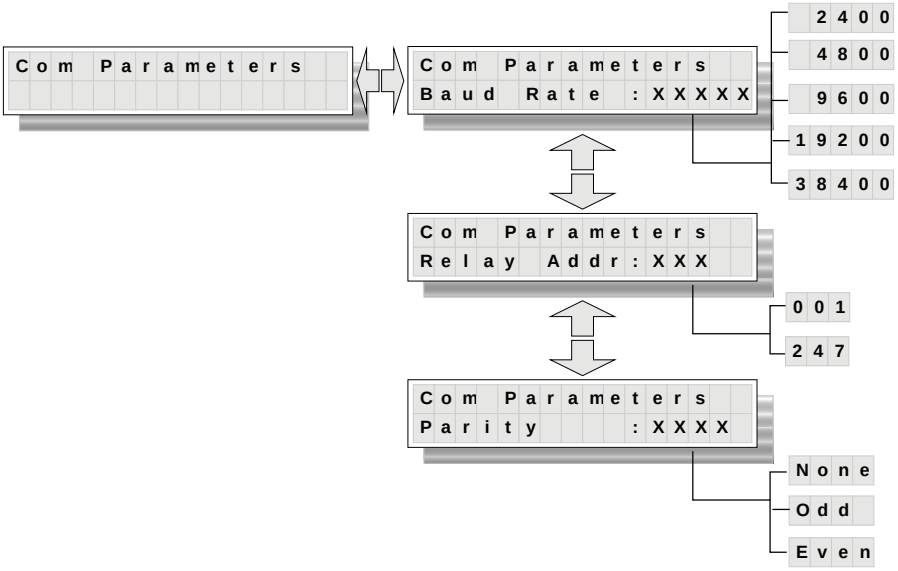


Fig. 25- Setting menu with sub menu communication setting (optional feature)

5.2.8 Menu – Configuration

This menu item basically provides the configuration of below:

-Blocking of particular protection stage or remote trip activation

-Relay configuration settings like Nominal current selection , Product Type Selection & -Earth current calculation method

-Inrush protection related settings

-Selection for loading factory settings (protection parameters only)

- Protection Reset

- Sensor Constant

Fig. 26 indicates the menu navigation for the sub menu and it's display view. Pressing right arrow key can activate submenu and selection from among the available list is done using up/down arrow keys. Activating edit mode by pressing Enter and Cancel button together can change any settings parameter. Also settings parameter of configuration menu item can be edited by optional communication card via MODBUS protocol if "COM Admin Level parameter" is selected "YES".

Protection reset action, other than through menu navigation, can be performed on simultaneous press of "UP" & "ENTER" key combination. The key combination needs to be pressed for approx. 5 sec in case of at default screen on relay else immediate reset action will take place after pressing key combination.

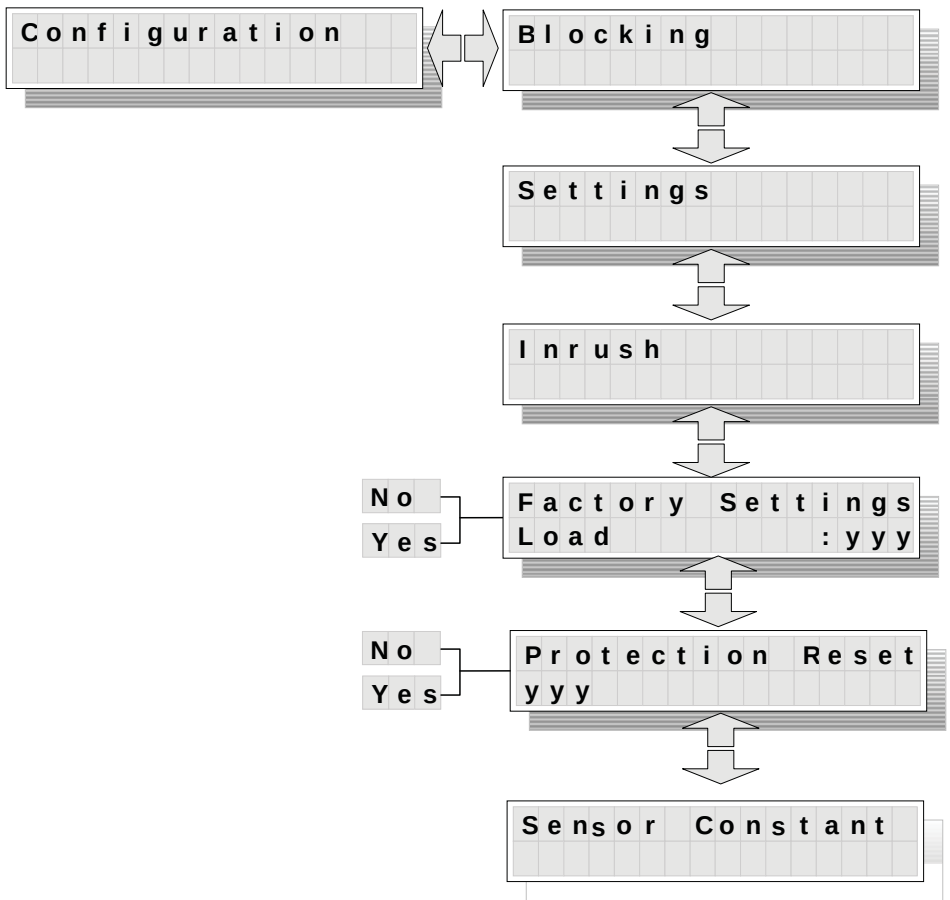


Fig. 26- Configuration menu with sub menu

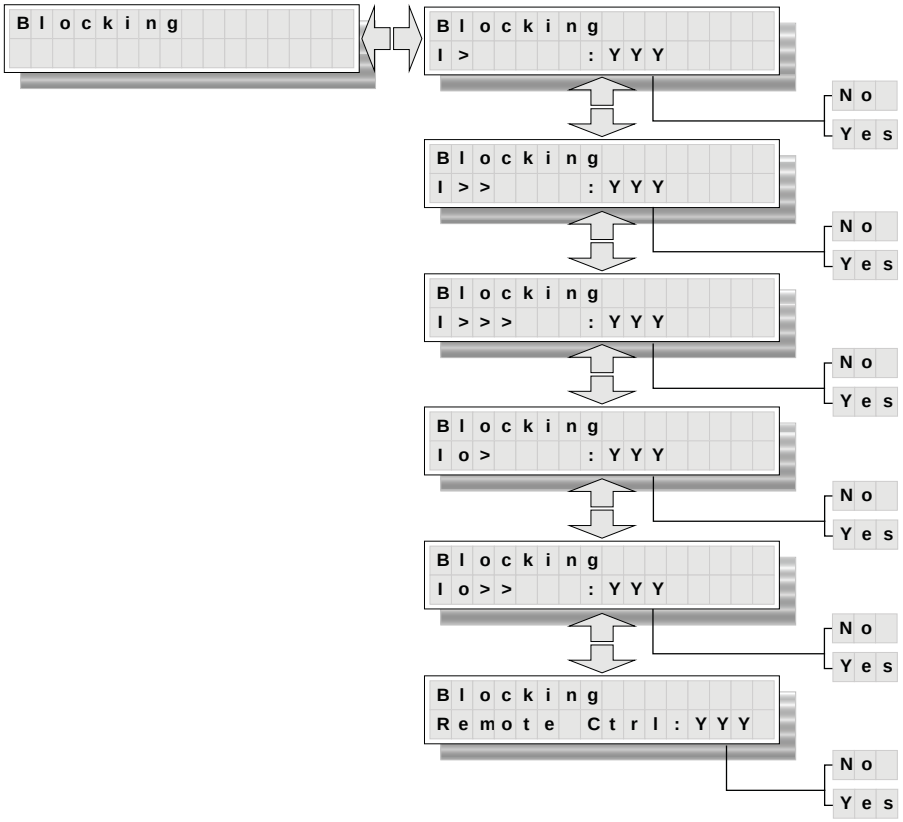


Fig. 27- Configuration sub menu protection blocking

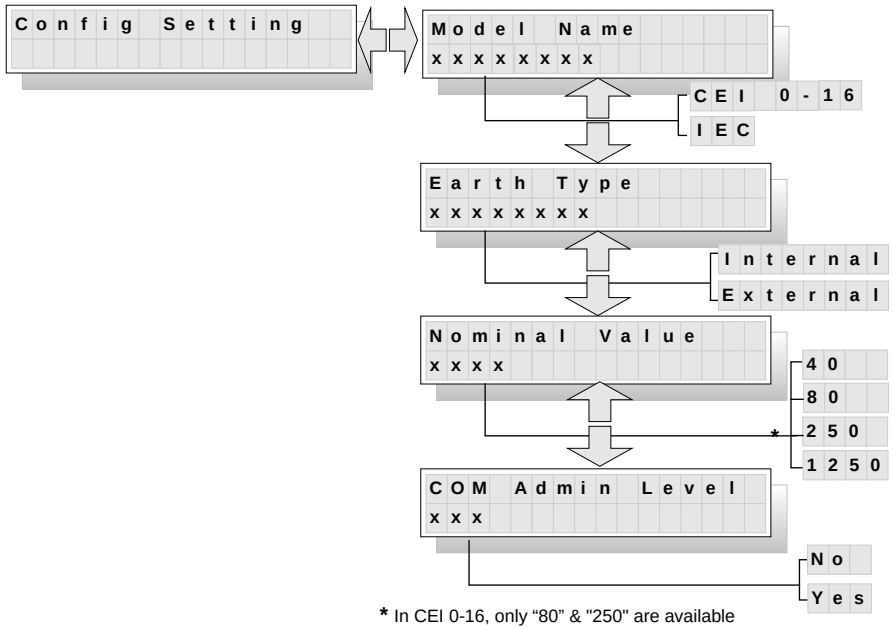


Fig. 28- Configuration sub menu settings with display

Note:

- Model Name (i.e. CEI 0-16 & IEC) will be configured during manufacturing only & can’t be altered afterwards.
- For IEC model :

  Earth Type: selection between Internal or External

  Nominal Value: selection between 40, 80, 250 or 1250
- For CEI 0-16 model :

  Earth Type: Always External

  Nominal Value: Selection between 80 or 250

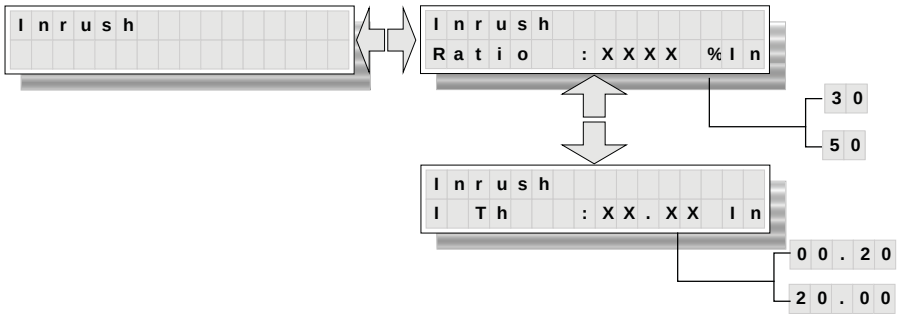


Fig. 29- Configuration sub menu Inrush with settings

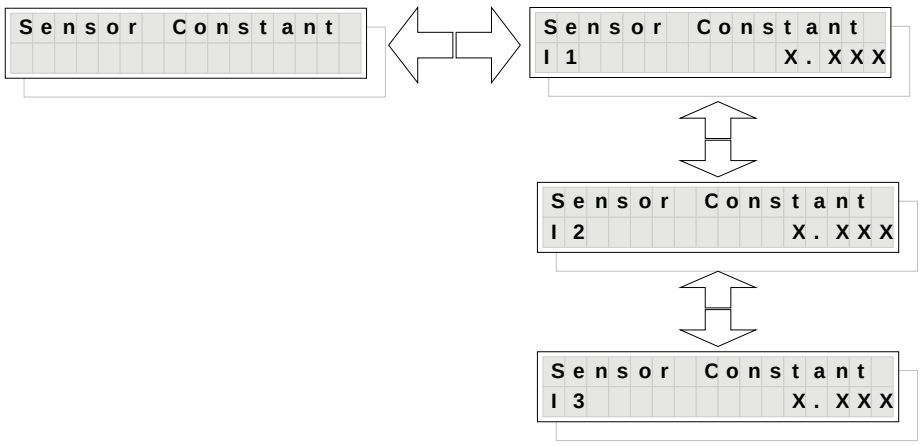


Fig. 30- Configuration Sensor constant with display

Configuration Status Display at Key press:

After the key timeout, default screen is displayed with the view shown in above section. After this whenever any key is pressed, user gets information about the relay configuration settings in a temporary screen lasting for about 5 seconds as shown below. Following figure shows configuration status screen for various possible combinations.

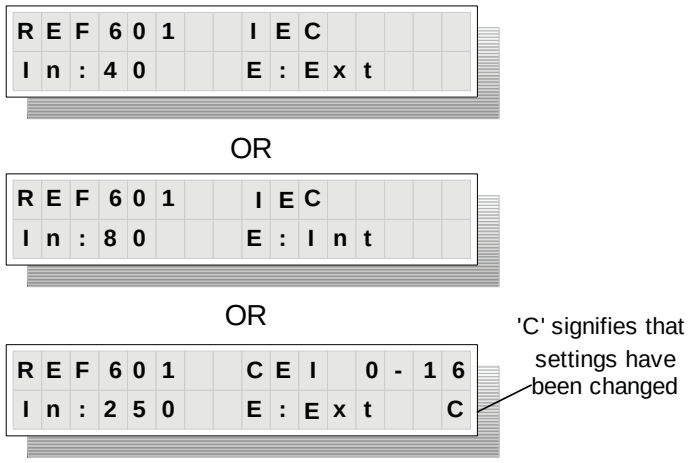


Fig. 31- Configuration status display screen

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.

5.2.9 Menu – Test

This menu item basically provides the calibration, test of various I/P –O/P ports and LED indications for various events. User needs extra hardware to check the functionality of some of the submenu items in this menu. Pressing right arrow key can activate submenu and selection from among the available list is done using up/down arrow keys. Activating edit mode by pressing Save and Cancel button together can provide selection of particular test. The details of functions available in test mode is described as under:

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

-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.

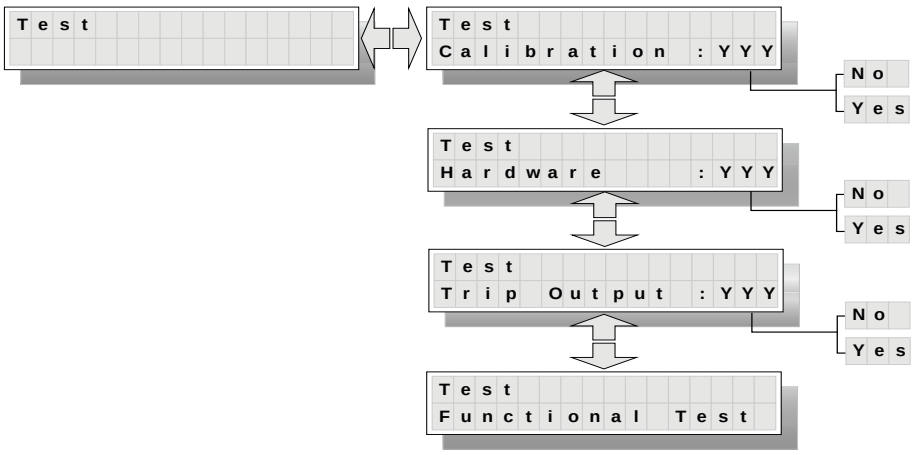


Fig. 32 Test menu with sub menu

5.2.9.1 Sub menu – Calibration

It is required to calibrate the fixed error in the measurement chain because of attenuation resistor in Line 1, Line 2 & Line 3 and also to calibrate the earth channel. Interactive user screens provide step-by-step procedure for calibration process. Calibration process is divided into subsections based on the type of CT selected. User can select or skip calibration for particular CT.

In case of no selection during each calibration point from user i.e. either Yes or No, automatically next screen will appear after timeout of 5sec.

Figure 33 shows complete calibration process flow.

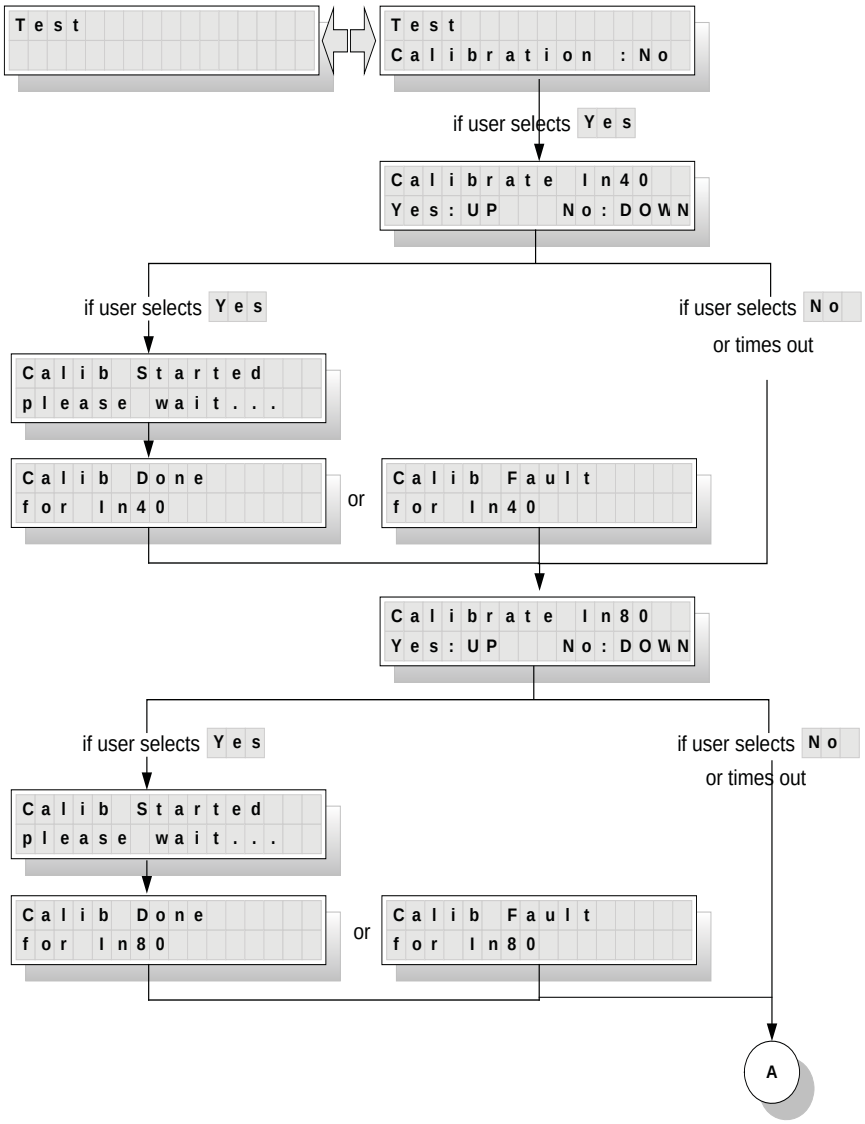


Fig. 33- Test sub menu calibration with display

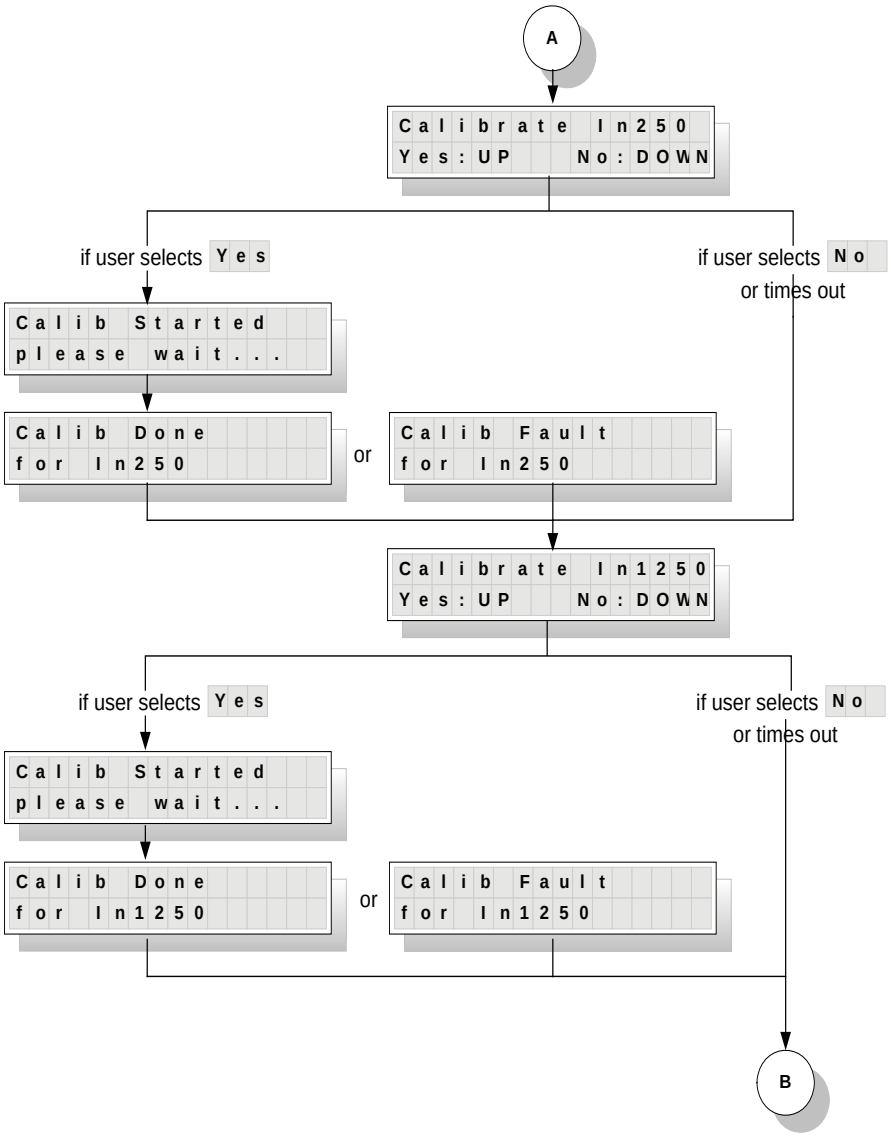


Fig. 33-Test sub menu calibration with display (contd.)

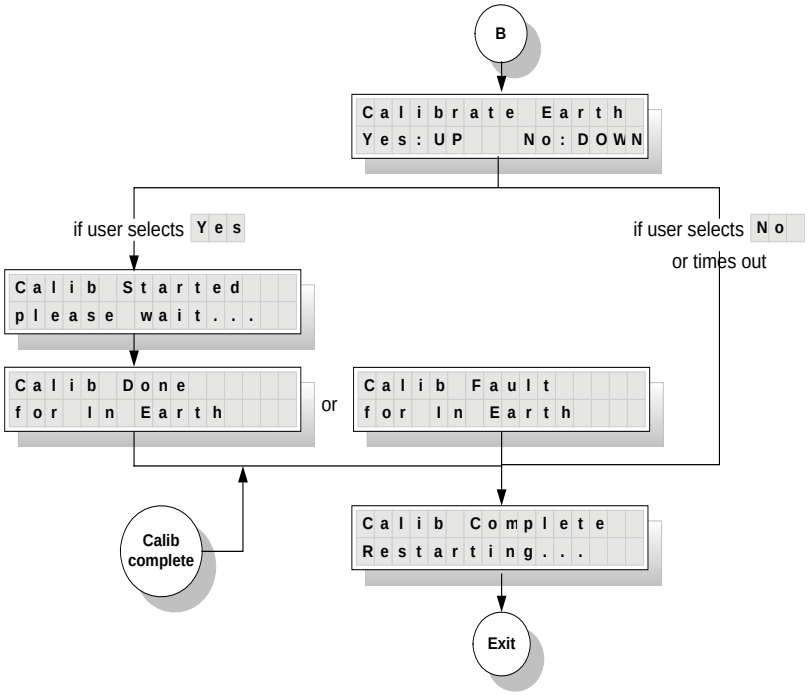


Fig. 33- Test sub menu calibration with display (contd.)

5.2.9.2 Sub menu – Hardware Testing

Several hardware modules can be tested through this menu. Interactive procedure through key inputs and LCD output provides user interface. The following components on the Digital PCBA can be tested:

- 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.

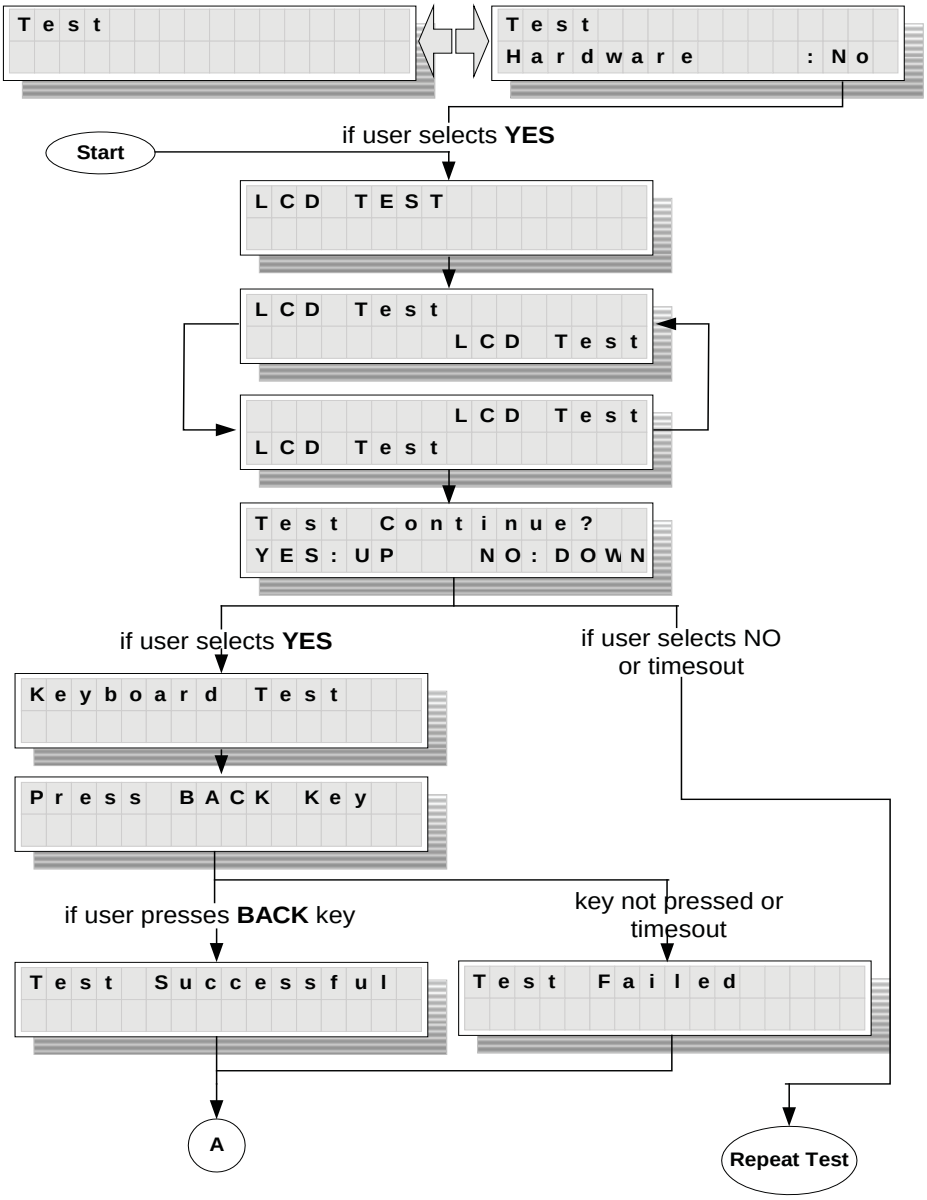


Fig.34- Hardware Test menu with its display view.

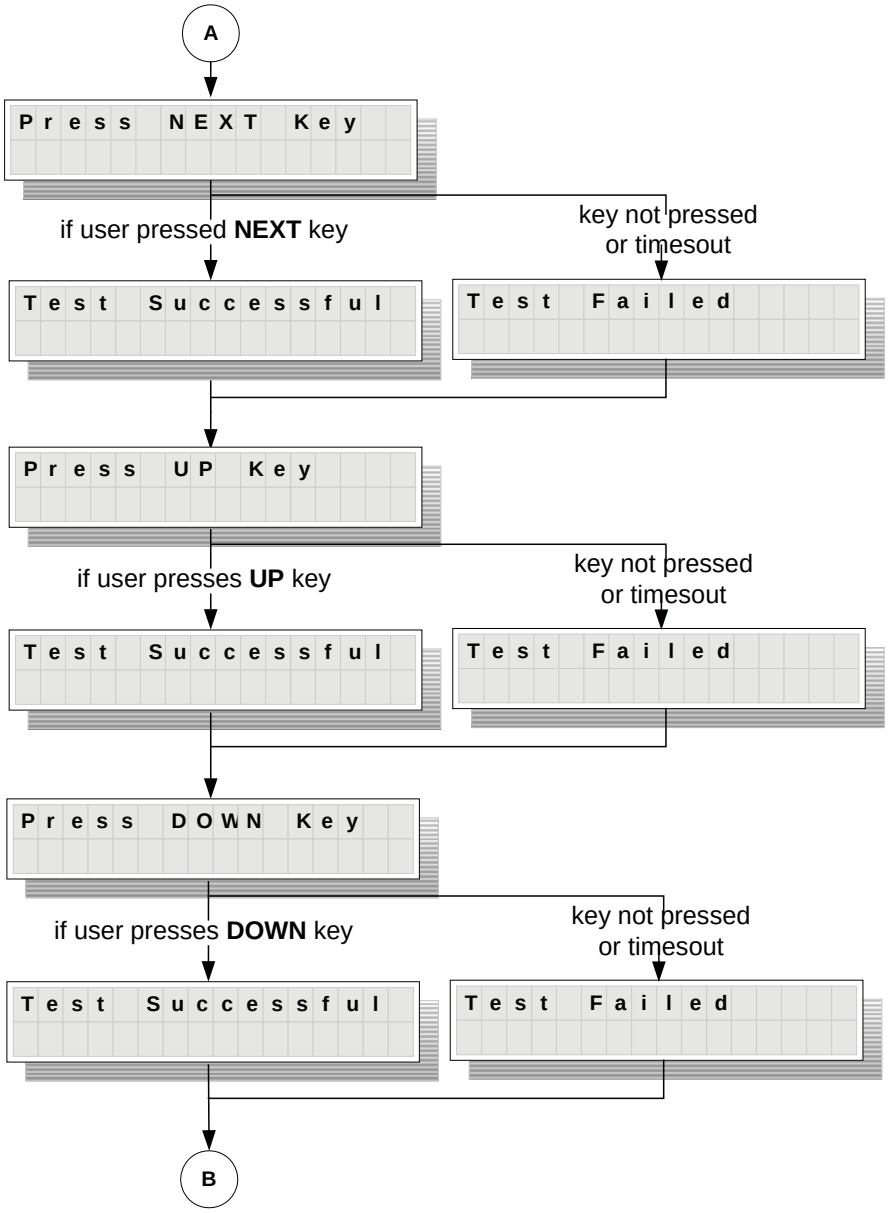


Fig.34- Hardware Test menu with its display view (contd.)

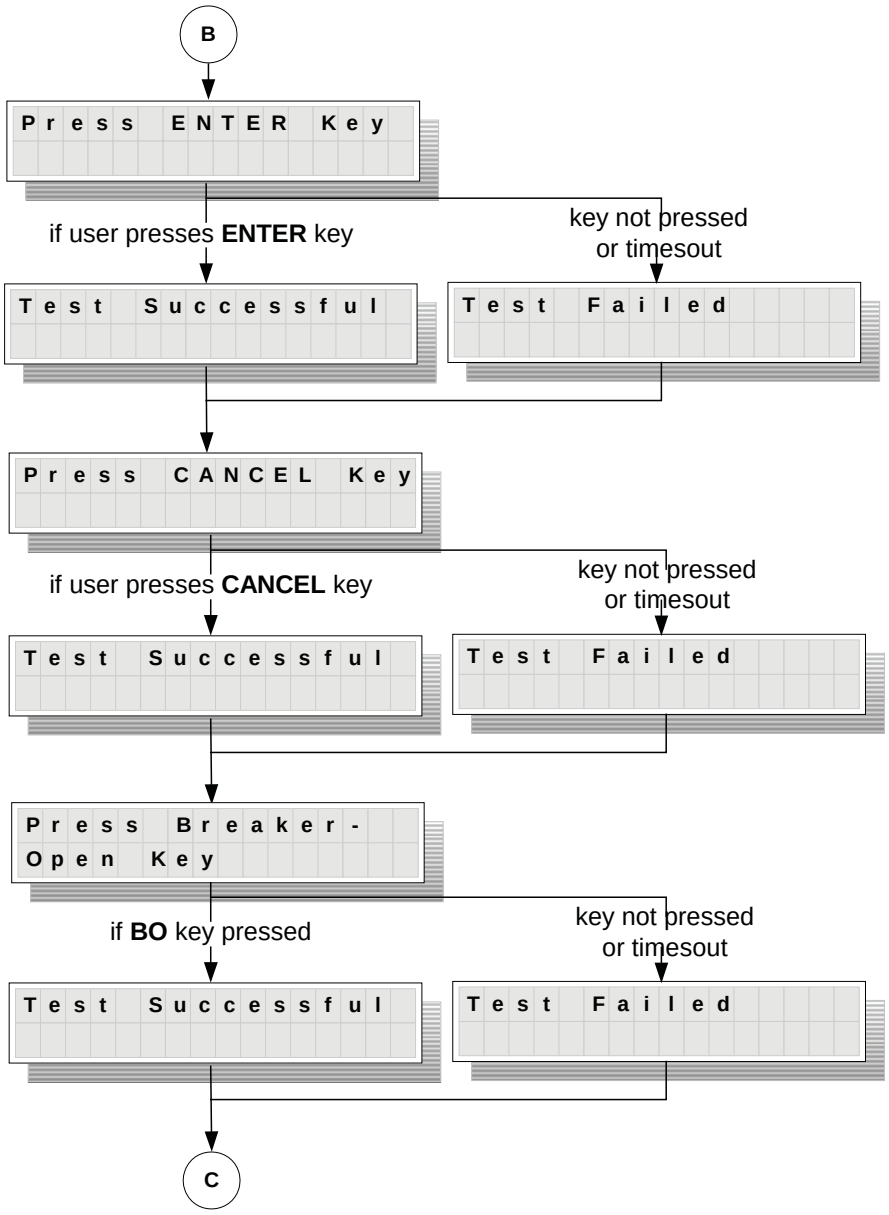


Fig.34- Hardware Test menu with its display view (contd.)

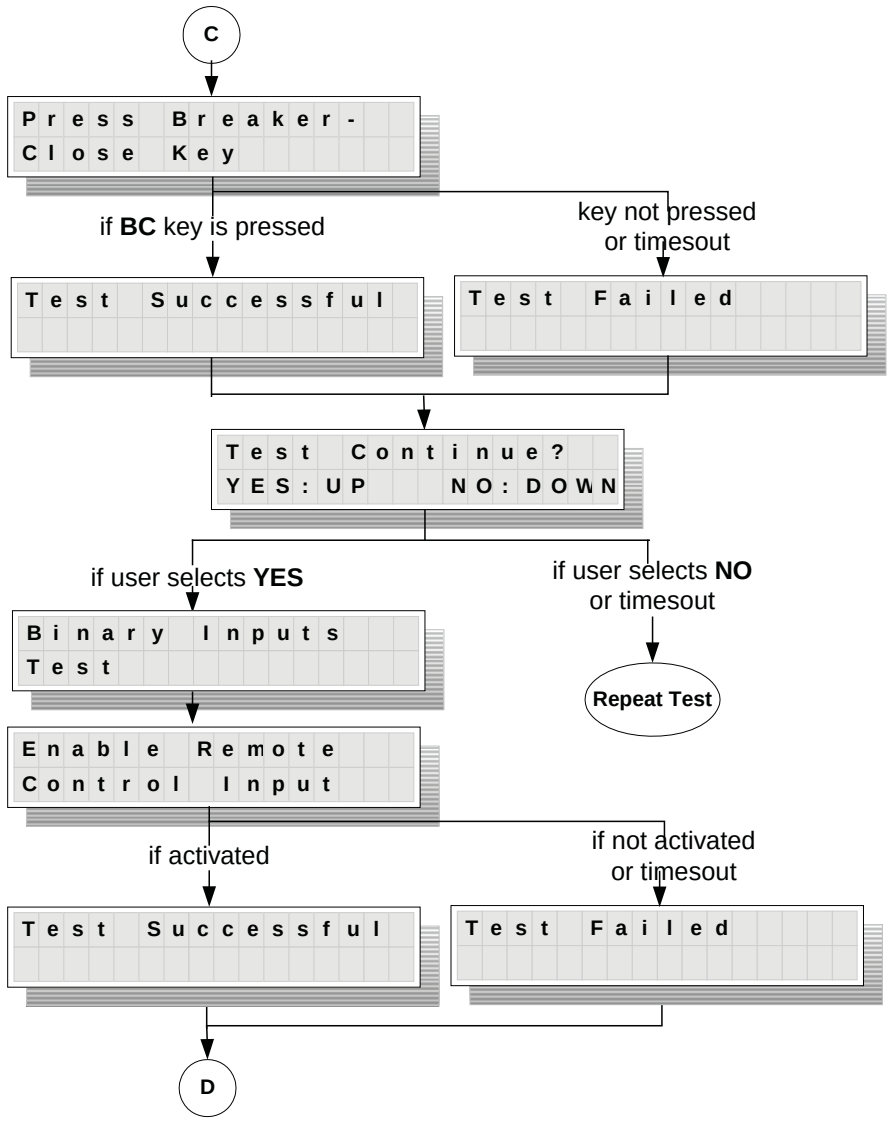


Fig.34- Hardware Test menu with its display view (contd.)

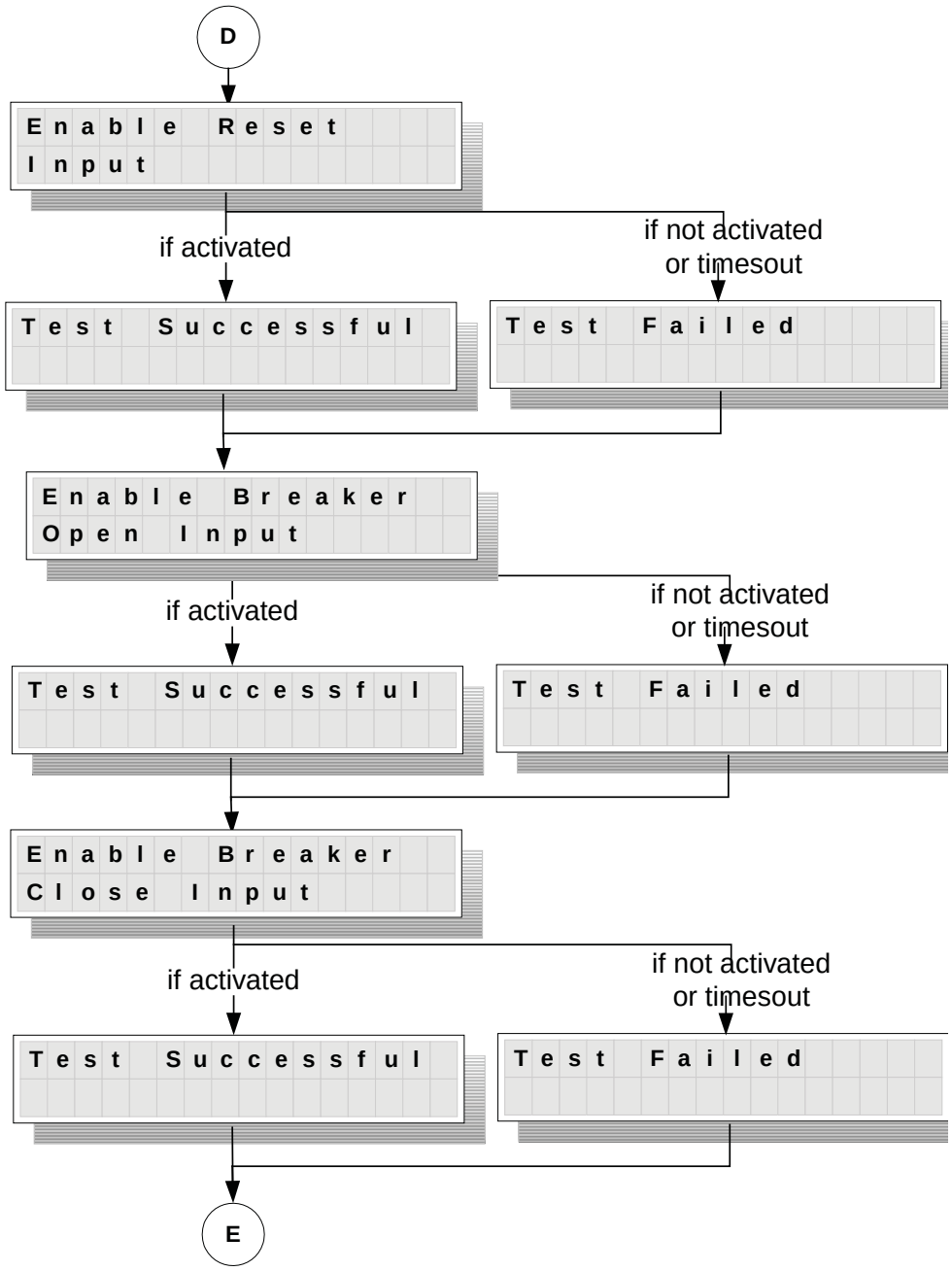


Fig.34- Hardware Test menu with its display view (contd.)

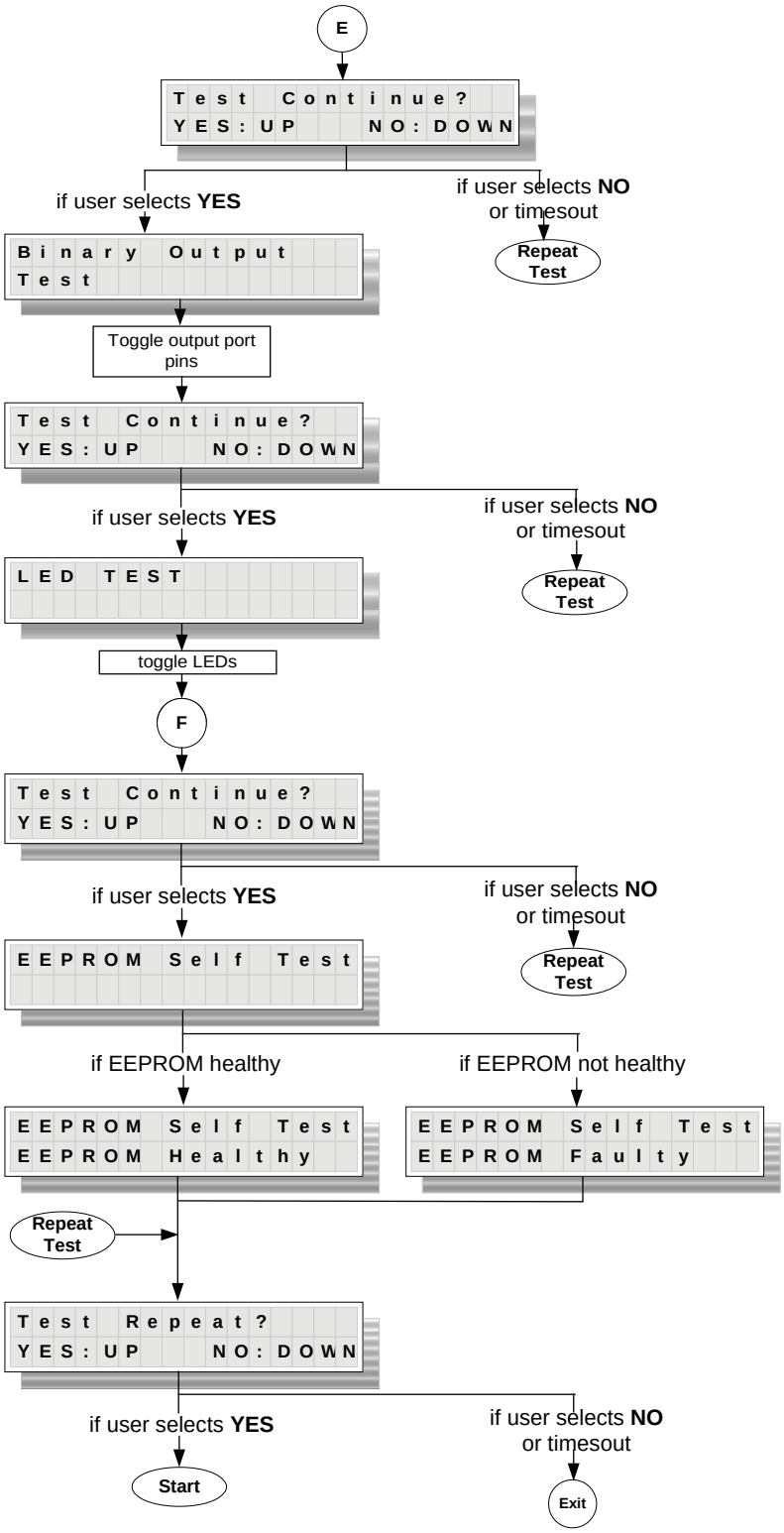


Fig.34- Hardware Test menu with its display view (contd.)

5.2.9.3 Trip Output Test

This submenu selection provides testing of trip circuit connected to the product. Pulse of definite duration will be generated at the trip command output port of the product, which energizes the trip coil connected therein. 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.

5.2.9.4 Functional Test

This menu provides selection of one of the several protection parameter groups available in the product. User is required to connect specific hardware and apply typical current signals to specified phase/earth inputs. Protection algorithm then can be run with the selected protection parameter group and trip signaling timings can be observed on either on LEDs or optionally on CRO.

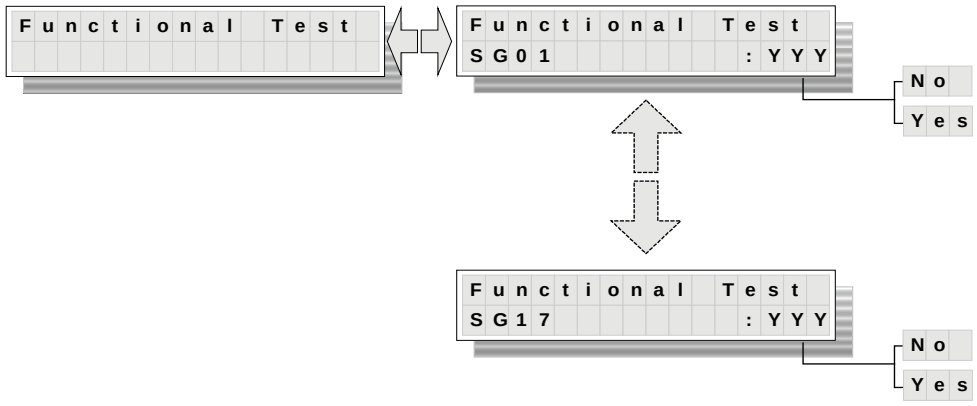


Fig.35- Functional test with its display view

Following table shows the functional test group parameter values.

SG	Parameter	SG	Parameter
1	Curve: VI K = 0.1 I> = 0.2 In	10	Curve: DT I0> = 0.2 In t0> = 0.2 sec
2	Curve: VI K = 0.1 I> = 0.5 In	11	Curve: DT I0> = 0.5 In t0> = 0.05 sec
3	Curve: VI K = 0.1 I> = 1.2 In	12	Curve: DT I0> = 0.1 In t0> = 0.2 sec
4	I>>> = 0.8 In t>>> = 0.05 sec	13	Curve: DT I0> = 0.025 In t0> = 0.05 sec
5	I>>> = 5.0 In t>>> = 0.05 sec	14	Curve: DT I0> = 0.4 In t0> = 0.3 sec
6	I>>> = 5.0 In t>>> = 0.2 sec	15	I0>> = 0.25 In t0>> = 0.05 sec
7	I>> = 0.2 In t>> = 0.05 sec	16	I0>> = 1.0 In t0>> = 0.2 sec
8	I>> = 2.1 In t>> = 0.3 sec	17	I0>> = 2.0 In t0>> = 0.1 sec
9	I>> = 4.2 In t>> = 0.5 sec		

5.3 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 Save and Cancel button together can change password. User can then enter new password. Save 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

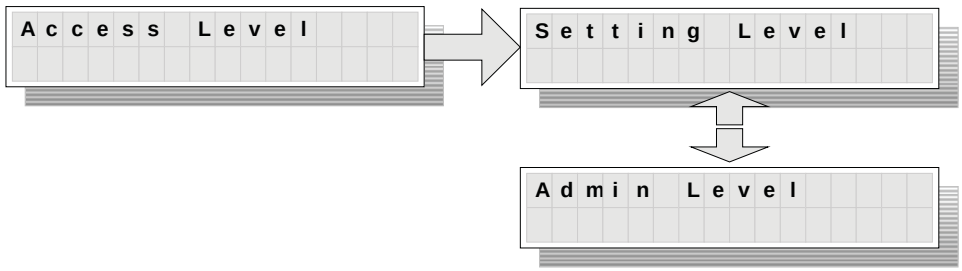


Fig.36- Access Level Menu

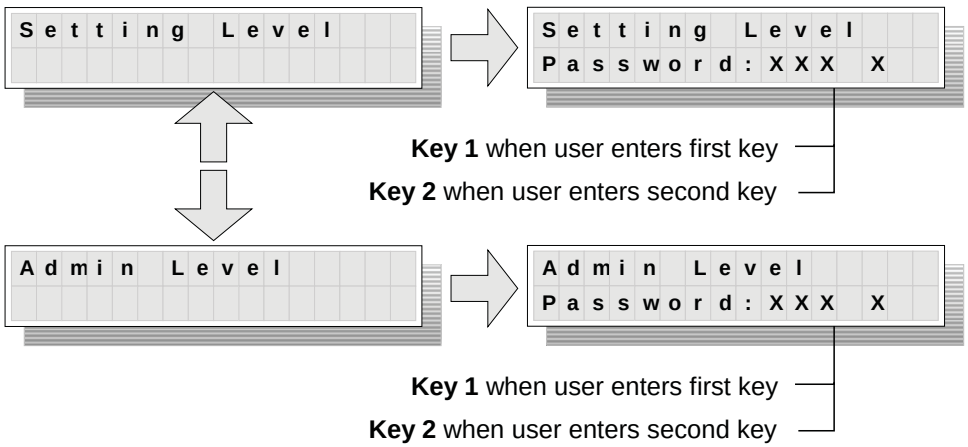
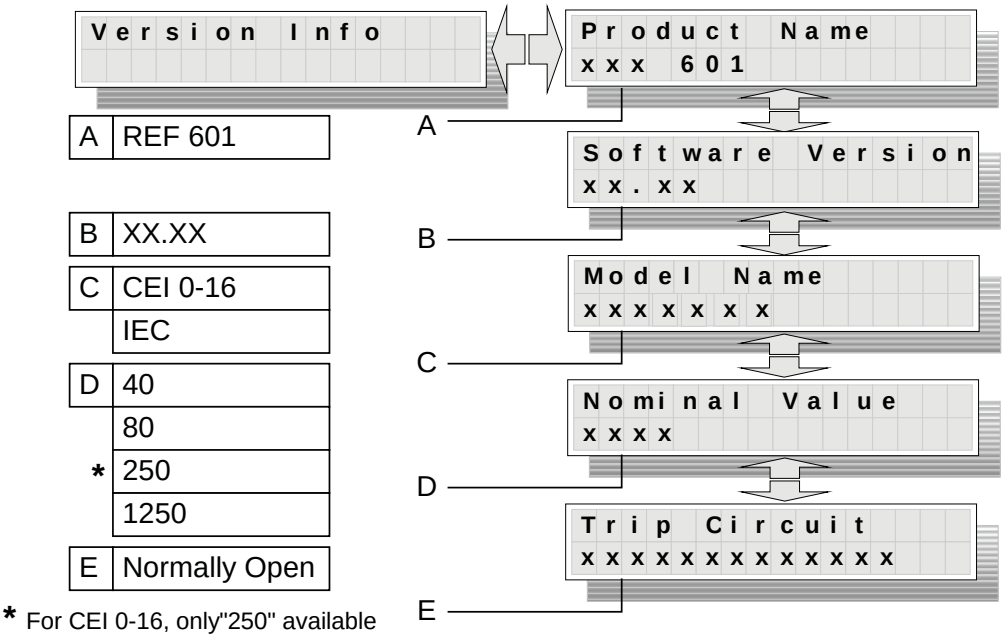


Fig.37- Access Level Sub Menu with its display view

5.4 Version Info

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.



A	REF 601
B	XX.XX
C	CEI 0-16
	IEC
D	40
	80
*	250
	1250
E	Normally Open

* For CEI 0-16, only"250" available

Fig.38– Version Info Display

Section 6 Installation and commissioning

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 chap. 7.1. 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 conditions 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 Mounting the relay

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 101 mm
Cutout dimensions (H x W) : 151.5 x 121.5 mm
Weight : 1.2 kg

6.5 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

6.6 Relay mounting dimensions

The over all dimensions of the relay are as follows:

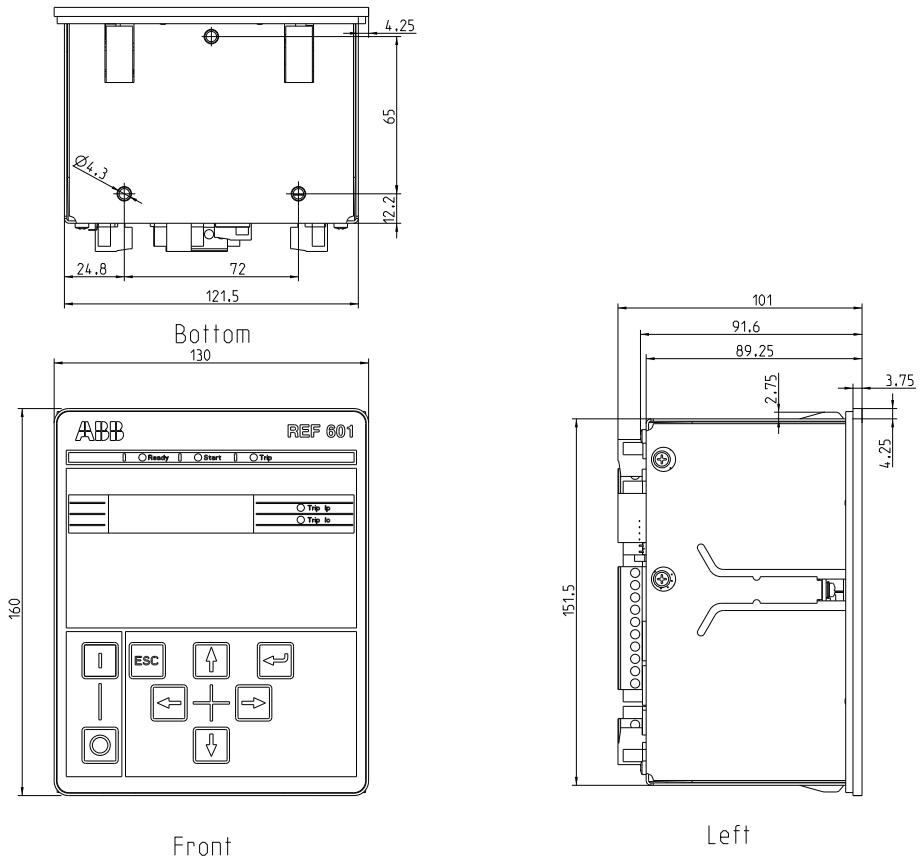


Fig. 39– Relay mounting dimensions with Flush (Panel) mounting

The relay also have breaker mounting version. The details of the same are indicated in Figure 37:

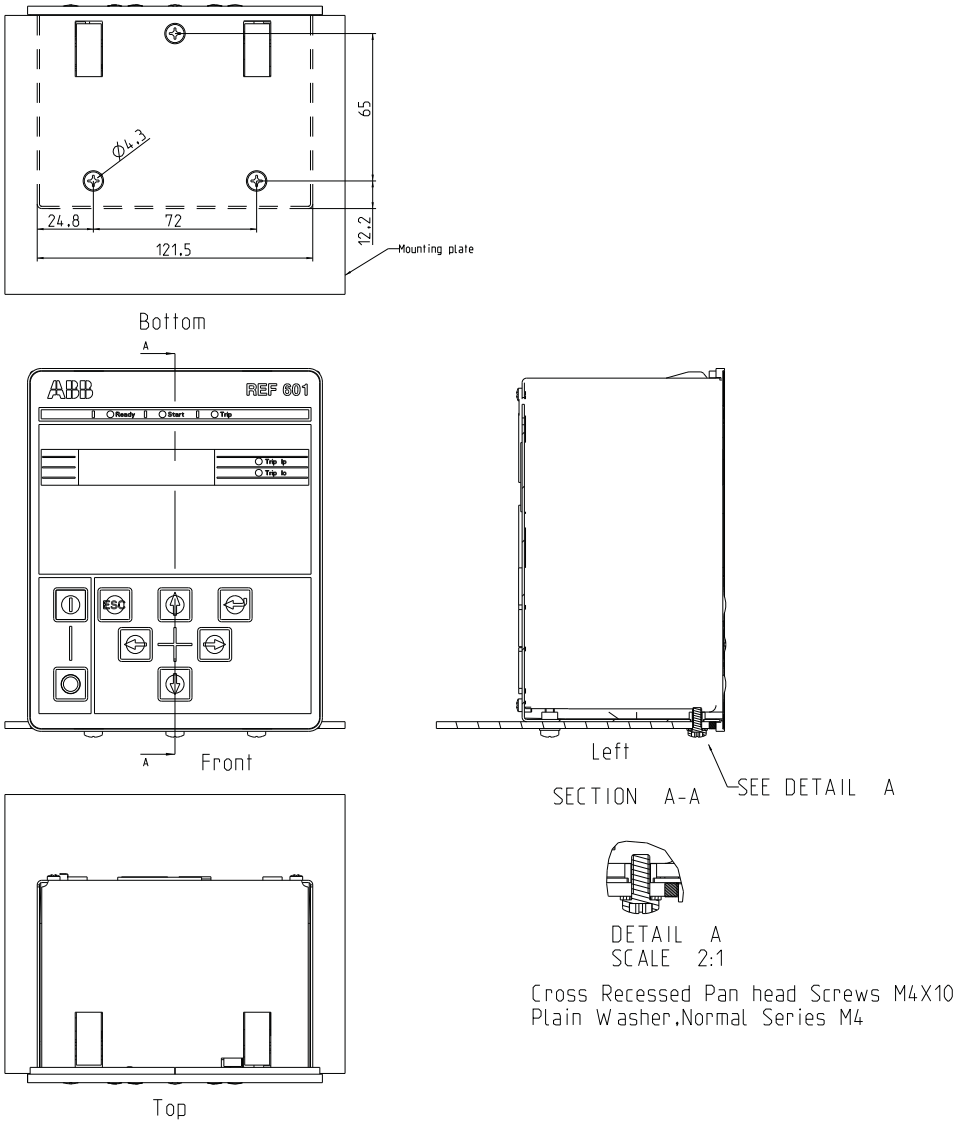


Fig. 40 – Relay mounting dimensions with Breaker mounting

6.7 Relay connection diagram

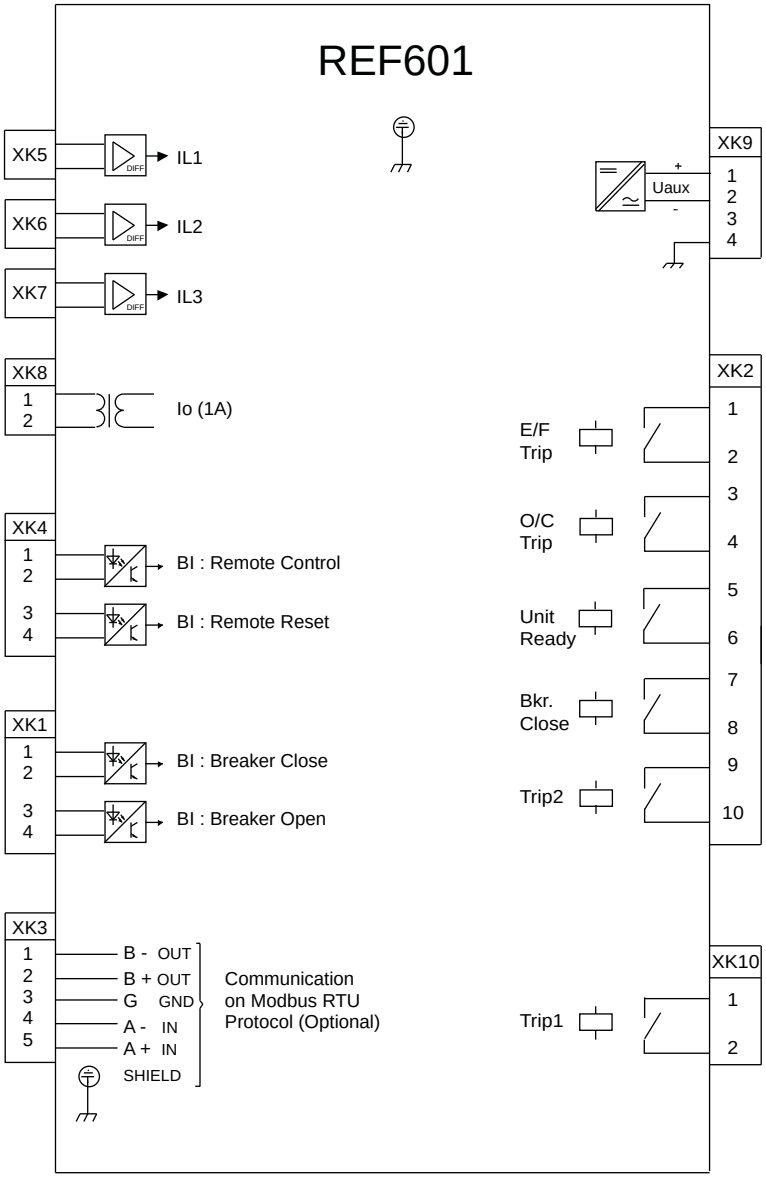


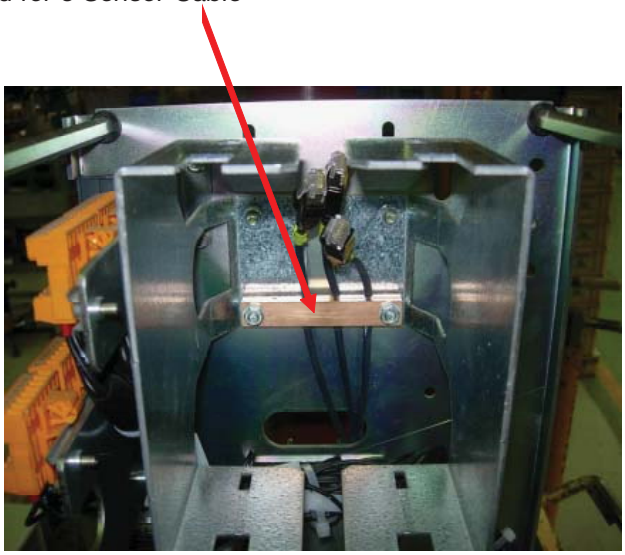
Fig. 41 – Connection diagram for relay REF601

6.8 Bonding of Sensor Cable Shield

6.8.1 Shield connection at relay side

- Remove the isolation of the sensor cable for the specific section at relay side. About 15 cm before the connector, typical.
- The braid to be mounted at the rear of the relay at the mechanical support.
- Insert into braid and close it
- Tighten screws and check that cable didn't get sandwich or damaged through misalignment
- 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 construction as shown on image below

Fig. - Braid for 3 Sensor Cable



6.8.2 Shield connection at the 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)

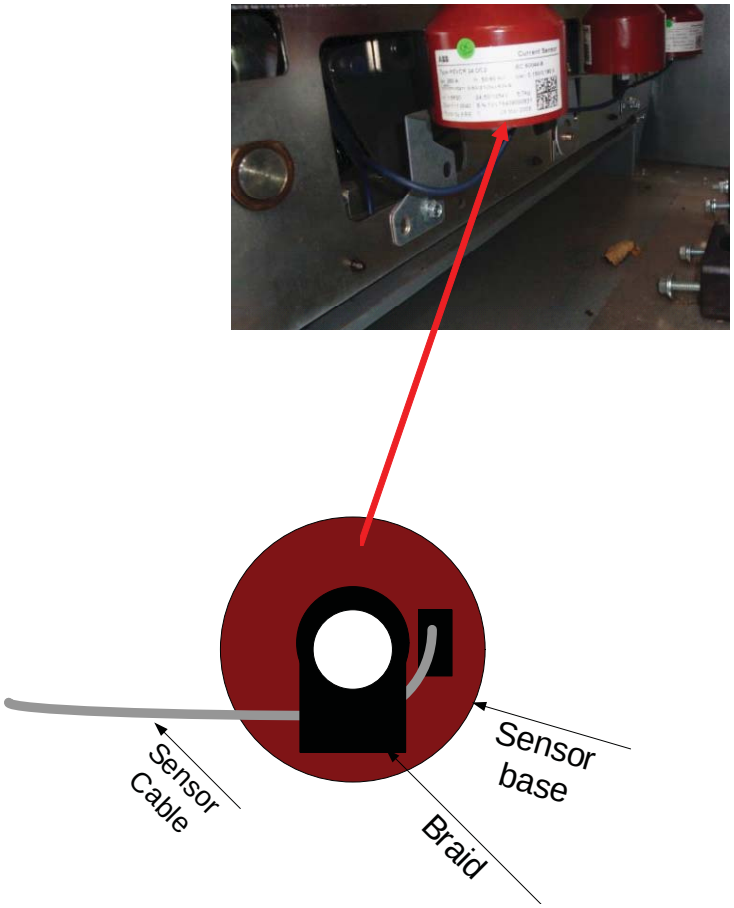
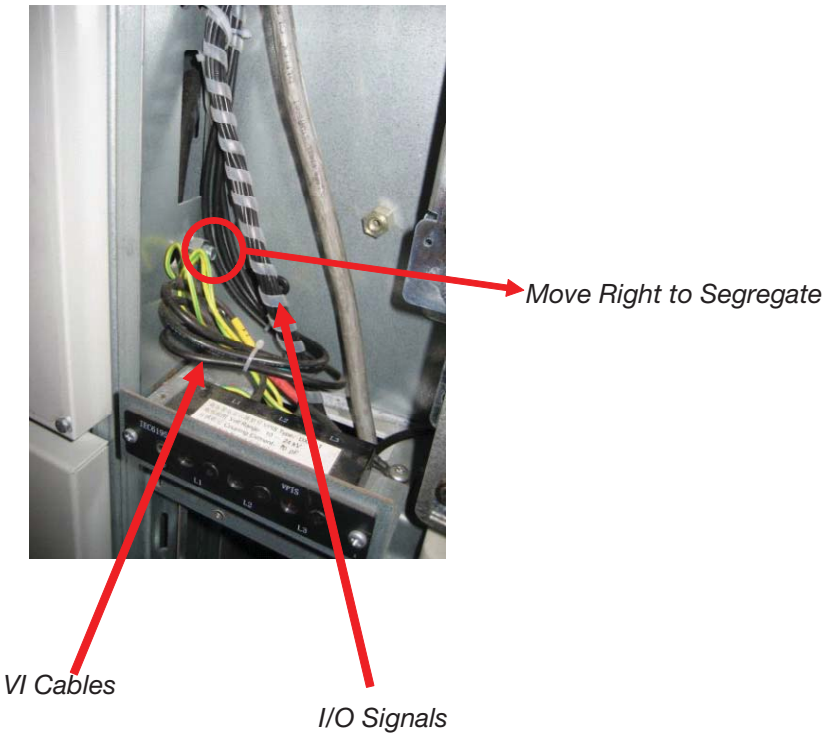


Fig. - Bottom view of sensor

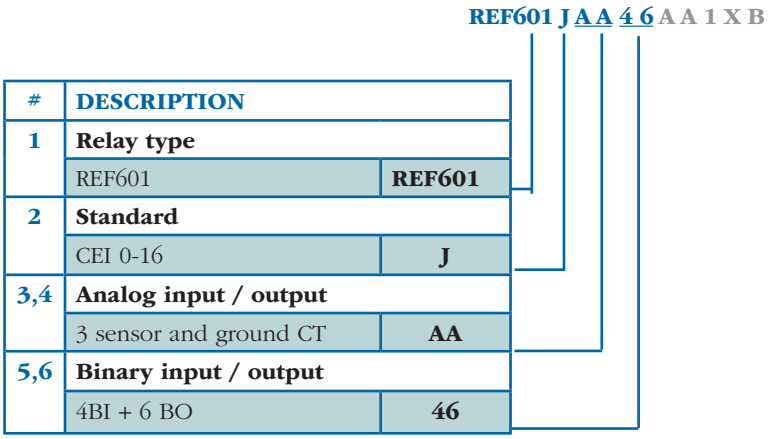
6.8.3 Segregation of Voltage Indicator System

- VI Cables to be moved on the right side in case of UniSec. 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

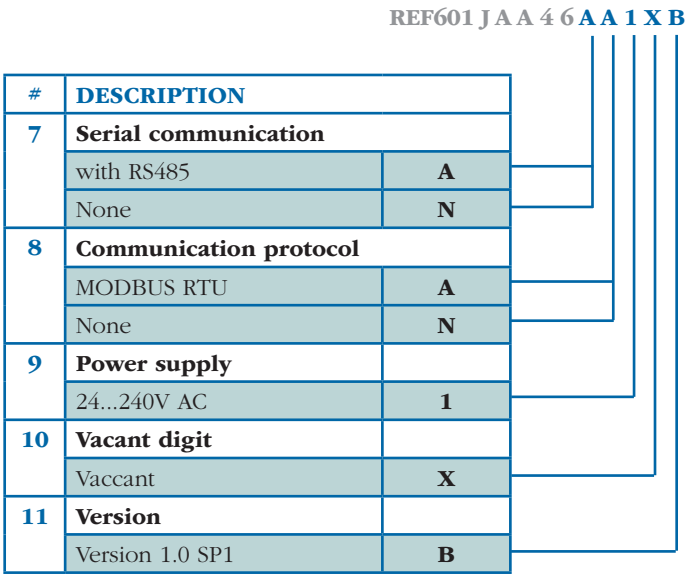


6.9 Relay ordering information

The relay is available in four variant. The ordering code of the relay is as below:



#	DESCRIPTION	
1	**Relay type**	
	REF601	**REF601**
2	**Standard**	
	CEI 0-16	**J**
3,4	**Analog input / output**	
	3 sensor and ground CT	**AA**
5,6	**Binary input / output**	
	4BI + 6 BO	**46**



#	DESCRIPTION	
7	**Serial communication**	
	with RS485	**A**
	None	**N**
8	**Communication protocol**	
	MODBUS RTU	**A**
	None	**N**
9	**Power supply**	
	24...240V AC	**1**
10	**Vacant digit**	
	Vaccant	**X**
11	**Version**	
	Version 1.0 SP1	**B**

Example code: **REF601 J A A 4 6** A A 1 X B

Your ordering code:

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

Fig. Figure 42 – Ordering details of relay REF601

Specific sensors needs to be used along with the relays. The ordering details for the same can be available from sensor data sheet no. 1YMA583791R0001-4.

Section 7 Serial communication

7.1 Modbus Protocol Overview

The Modbus protocol was first introduced by Modicon Inc. The protocol determines how each controller connected to the Modbus network will recognize a message addressed to it. It also determines the task to be performed and extracts any data or other information contained in the message. If a reply is required, the controller will construct a reply message and send it using the Modbus protocol.

The communication technique used in the Modbus protocol is a master-slave technique. This means that only one device can be the master and initiate transactions, while other devices connected to the network are slaves and can accordingly not initiate any transactions.

7.2 Wiring

7.2.1 Communication Connector

The relay equipped with the communication board which provides an RS485 communication ports for Modbus RTU communication support. The communication port allows the relay REF601 to network with up to 31 other slave REF601 devices on a Modbus RTU link.

The below diagram shows the connection details for networking of the relay to PC.

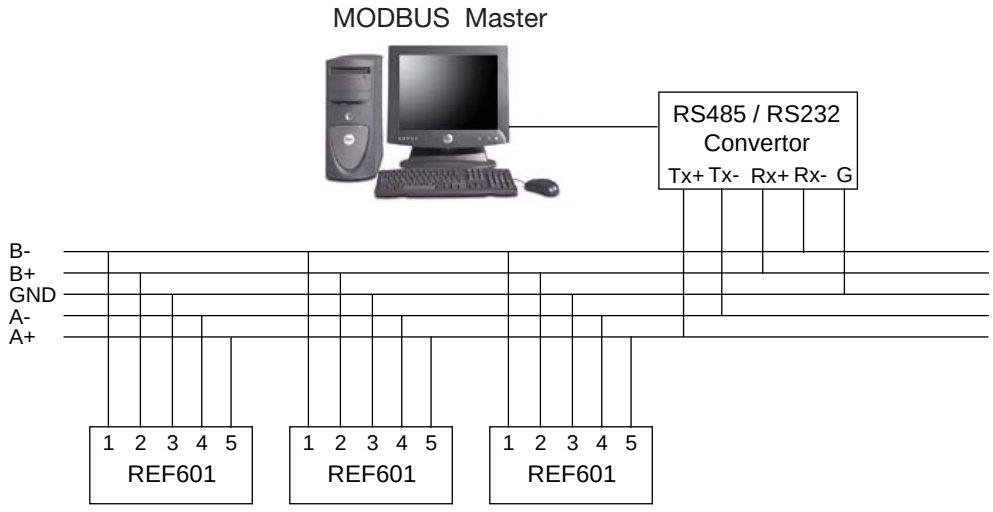


Fig. 43– Connection details for MODBUS RTU communication

7.2.2 RS-485 Serial Communication

When connecting the REF 601 to an RS485 communication link, you must use termination resistors at each end of link.

As a reference, cable number 9842 from Belden (4 wire cable) or any equivalent cable can be used to for the RS485 connection.

7.3 Modbus RTU message format

7.3.1 Modbus message RTU framing:

For Modbus serial line using the RTU (Remote Terminal Unit) mode, each 8–bit byte in a message contains two 4–bit hexadecimal characters. The main advantage of this mode is that its greater character density allows better data throughput than ASCII mode for the same baud rate. Each message must be transmitted in a continuous stream of characters.

The format for each byte (11 bits) in RTU mode is:

Coding System:	8–bit binary
Bits per Byte:	1 start bit 8 data bits, least significant bit sent first 1 bit for parity completion 1 stop bit
Parity:	Even, other modes (odd parity, no parity). The default parity mode must be even parity.
Baud rate:	default 19200, Baud rates supported are 2400,4800,9600,19200,38400
Remark:	The use of no parity requires 2 stop bits.

A Modbus message is placed by the transmitting device into a frame that has a known beginning and ending point. This allows devices that receive a new frame to begin at the start of the message, and to know when the message is completed. Partial messages must be detected and errors must be set as a result.
In RTU mode, message frames are separated by a silent interval of at least 3.5 character times this time interval is called t3,5.

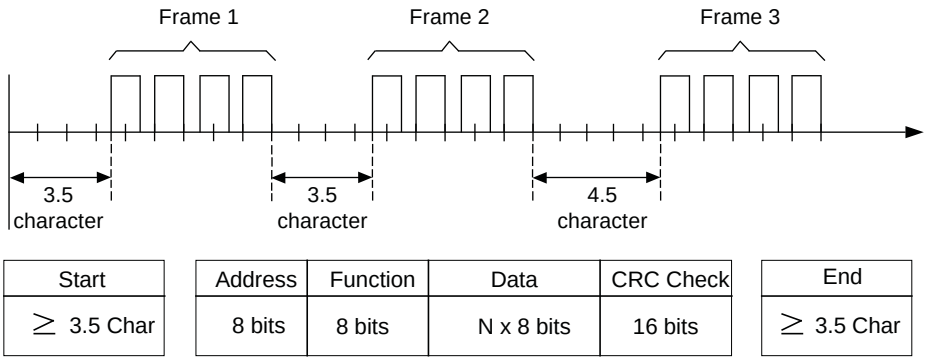


Fig. 44 – RTU Message Frame

The entire message frame must be transmitted as a continuous stream of characters. If a silent interval of more than 1.5 character times occurs between two characters, the message frame is declared incomplete and should be discarded by the receiver.

7.3.2 CRC Checking:

The RTU mode includes an error–checking field that is based on a cyclical redundancy checking (CRC) method performed on the message contents. The CRC field checks the contents of the entire message. It is applied regardless of any parity checking method used for the individual characters of the message.

The CRC field contains a 16–bit value implemented as two 8–bit bytes. The CRC field is appended to the message as the last field in the message. When this is done, the low–order byte of the field is appended first, followed by the high–order byte. The CRC high–order byte is the last byte to be sent in the message.

7.4 Modbus RTU function codes

Table 1 & 2 below lists the Modbus RTU Function Code definitions, the maximum number of registers allowed per request.

Table 1 : Modbus RTU function codes definitions

Function Code		Name	Usage
Dec	Hex		
03 / 04	03/04	Read Holding Registers / Read Input Registers	Read Data in 16-bit register format (high / low). Used to read process data. Registers are consecutive and are imaged from the instrument to the host.
05	05	Change digital output	Change the state of a digital output
06	06	Preset Single Register	Write data in 16-bit integer format (high /low) only.
08	08	Loop back Test	Used for diagnostic testing of the communications port.
16	10	Preset Multiple Registers	Write data in 16-bit format (high / low). Used to write integer and floating point override data. Registers are consecutive and are imaged from the host to the instrument.
70	46	Read Module settings	Read baud rate, parity and relay address settings.

Table 2 : Maximum number of resistors allowable per request

Function Code		Maximum number of resistors
Dec	Hex	
03	03	16
04	04	16
05	05	04
08	08	08

7.4.1 Function Code: 03 (Read Relay Settings)

This function code is used to read the parameter settings of the relay unit. The request packet specifies the starting register address and the number of registers. In the packet, registers are addressed starting at zero. Therefore registers numbered 1-15 are addressed as 0-14.

The register data in the response message are packed as two bytes per register, with the binary contents right justified within each byte. For each register, the first byte contains the high order bits and the second contains the low order bits.

Request

Slave Address	Function Code	Starting Address High	Starting Address Low	Quantity of registers High	Quantity of registers Low	CRC	CRC
01	03	00	01	00	05	CRC	CRC

Example: Read relay settings 1 to 5, from slave at address 01.

Response message format for function code 03

Slave Address	Function Code	Byte Count	Data1 Hi	Data1 Lo	Data5 Lo	Data5 Lo	CRC	CRC
01	03	0 Ah	00	05	00	56	CRC	CRC

In the response the relay settings is shown as data bytes. The byte count provides the number of bytes that will follow.

The register mapping of relay settings to addresses for IEC and CEI 0-16 models is shown in table-3 and table-4 respectively.

The same function code is also used to read the relay configuration parameters. The address range to read the configuration parameters is 0x20 – 0x26, and maximum number of registers is 7. The mapping of address to configuration parameter read is shown in table 5

7.4.2 Function Code: 04 (Read Data log, Event log, Measurement of Phase and Earth current)

This function code is used to read data log of last two events and event log of last five events occurred in the relay. The same function code is also used to read the phase and earth current (i.e. I1-I2-I3-I0). The mapping of current measurement is 1In = 1000. For example, a current value of 2In will be displayed in Hex format as 0x07D0 (2000 in decimal). The measurement will not be a real time measurement but it will be a query based communication between the base relay and the communication board and subsequently for the modbus.

The request packet specifies the starting register address and the number of registers. The register data in the response message are packed as two bytes per register, with the binary contents right justified within each byte. For each register, the first byte contains the high order bits and the second contains the low order bits.

Request

Slave Address	Function Code	Starting Address High	Starting Address Low	Quantity of registers High	Quantity of registers Low	CRC	CRC
01	04	00	01	00	16	CRC	CRC

Example: Read data_0 log from slave at address 01.

Response message format for function code 04

Slave Address	Function Code	Byte Count	Data1 Hi	Data1 Lo	Data 16 Hi	Data 16 Lo	CRC	CRC
01	04	20	05	01	C0	F6	CRC	CRC

In the response the data log of the last event is shown as data bytes. The byte count provides the number of bytes that will follow.

The register mapping of data log is shown in table - 6, event log is explained in table – 7, 8, 9, and register mapping for current measurement is shown in Table 10.

7.4.3 Function Code: 05 (Change Digital output)

This function code is used to enable digital output in a relay device. The possible digital outputs are listed in table 11. A value of 0xFF00 or 0x0000 requests the output to be enabled or disabled. However, in the commands implemented for REF601, writing a value 0x0000 will have no effect, since there are no such operations that need to be disabled.

The normal response is an echo of the request, returned after the coil state has been written. A value other then 0xFF00 or 0x0000 will generate an exception for illegal data value and any address other then those mentioned in Table 11 will generate an exception of illegal data address.

Request

Slave Address	Function Code	Output Address High	Output Address Low	Output value High	Output value Low	CRC	CRC
01	05	00	01	FFh	00	CRC	CRC

Example: Change the breaker close output

Response message format for function code 0x05

Slave Address	Function Code	Output Address High	Output Address Low	Output value High	Output value Low	CRC	CRC
01	0E	00	01	FFh	00	CRC	CRC

7.4.4 Function Code: 06 (Write single register-Change relay setting)

This function code is used to change single setting of relay device. The request packet specifies the address of the register to be written. The normal response is an echo of the request, returned after the register contents have been written.

For editing the settings of the relay, refer table 3 and 4 for IEC version and CEI 0-16 version respectively. The same function code is also used for editing the configuration of the relay.
The configuration parameters that can be edited through the MODBUS include the Nominal Value Type selection between 40,80,250,1250 and Earth Type (Internal-External) for the IEC version of relay,
For the CEI 0-16 version, the Earth type is non-editable and is fixed. The Nominal Value Type selection allowed is only 80 & 250. The Nominal Value Type cannot be changed to 40 & 1250.
For editing configuration parameters of the relay, refer Table 12 for address and data values.

Request

Slave Address	Function Code	Starting Address High	Starting Address Low	Setting value high	Setting value low	CRC	CRC
01	06	00	05	00	0 Ah	CRC	CRC

Example: Write 0Ah value to resistor value with address 0x0005 on slave at add. 01

Response message format for function code 06

Slave Address	Function Code	Starting Address High	Starting Address Low	Setting value high	Setting value low	CRC	CRC
01	06	00	05	00	0 Ah	CRC	CRC

7.4.5 Function Code: 08 (Diagnostics - Loop back message)

Echoes received query message. Message can be any length from 4 to 16 bytes.

Request

Slave Address	Function Code	Any data, length limited from 4 to 16 bytes				CRC	CRC
01	08	01	02	03	04	CRC	CRC

Response

Slave Address	Function Code	Any data, length limited from 4 to 16 bytes				CRC	CRC
01	08	01	02	03	04	CRC	CRC

7.4.6 Function Code: 70 (46h) (Read Module settings)

This function code is used to read the settings of the module. The following sub-function codes are supported.

Sub-function Code	Description
01	Read the module address
02	Read the communication settings – Baud rate
03	Read the communication settings – Parity

Sub-function 01: Read Module Address

This sub-function code is used to read the address of a module.

Request

Slave Address	Function Code	Sub Function Code	CRC	CRC
01	46h	01	CRC	CRC

Response message format for function code 06

Slave Address	Function Code	Sub Function Code	Data	CRC	CRC
01	46h	01	01	CRC	CRC

Sub-function 02: Read Baud rate

This sub-function code is used to read the operating baud rate of the MODBUS communication.

Sub-function 03: Read parity

This sub-function code is used to read the operating parity of the MODBUS communication.

The Baud rate setting mapping is as shown in table 13 and Parity settings is as shown in table 14.

7.5 Exception Response

When a client device sends a request to a slave device it expects a normal response. But, if the slave device cannot handle the request (for example, if the request is to read a non–existent output or register), it will return an exception response informing the master of the nature of the error.

The exception response message has two fields that differentiate it from a normal response:

Function Code Field: In a normal response, the server echoes the function code of the original request in the function code field of the response. All function codes have a most significant bit (MSB) of 0 (their values are all below 80 hexadecimal). In an exception response, the server sets the MSB of the function code to 1. This makes the function code value in an exception response exactly 80 hexadecimal higher than the value would be for a normal response. With the function code's MSB set, the client's application program can recognize the exception response and can examine the data field for the exception code.

Data Field: In a normal response, the server may return data or statistics in the data field (any information that was requested in the request). In an exception response, the server returns an exception code in the data field. This defines the server condition that caused the exception.

An Example for the same is as below:

Request format

Slave Address	Function Code	Starting Address High	Starting Address Low	Quantity of resistors High	Quantity of resistors Low	CRC	CRC
01	01	00	01	00	05	CRC	CRC

This creates an exception and the response format is as below:

Response message format

Slave Address	Function Code	Exception Code	CRC	CRC
01	81	01	CRC	CRC

81h in the starting field indicates that the frame is for exception frame and exception code 01h indicates that the requested function code is not implemented in the slave device.

The various exception codes are listed in table 15

Table 3: Modbus communication: Relay settings to address mapping (IEC)

Address		Range		Description	Step Size (Original value)	Multiplier to get original value
Dec	Hex	Non DT B=1 Curve (Original value)	DT B=1 Curve (Original value)			
00	0x0000	0-6 (0-6)	0-6 (0-6)	Phase Low set I > Curve : 0 - DT B=1 1 - DT B=5 2 - NI Curve 3 - VI Curve 4 - LI Curve 5 - EI Curve 6 - RI Curve	1 (1)	1
01	0x0001	2-32 (0.1-1.6)	2-32 (0.1-1.6)	Phase Low set I > K	2 (0.1)	0.05
02	0x0002	40-200 (0.2-1)	40-200 (0.2-1)	Phase Low set I > Isat	5 (0.025)	0.005
03	0x0003	10-160 (0.5-8.0)	2-32 (0.1-1.6)	Phase Low set I > Time	2 (0.1) (if curve =DT-B1) 10 (0.5) (For other curves)	0.05
04	0x0004	20-55 (1-2.75)	20-55 (1-2.75)	Phase High set I >> Isat	5 (0.25)	0.05
05	0x0005	2-9 (0.1-0.45)	2-9 (0.1-0.45)	Phase High set I >> Time	1 (0.05)	0.05
06	0x0006	4-30 (2-15)	4-30 (2-15)	Phase Very Highset I >>> Isat	2 (1)	0.5
07	0x0007	-	-	-	-	-

Table 3: Modbus communication: Relay settings to address mapping (IEC) Cont...

Address		Range		Description	Step Size (Original value)	Multiplier to get original value
Dec	Hex	Non DT B=1 Curve (Original value)	DT B=1 Curve (Original value)			
08	0x0008	0-6 (0-6)	0-6 (0-6)	Earth Low set Io > Curve : 0 - DT B=1 1 - DT B=5 2 - NI Curve 3 - VI Curve 4 - LI Curve 5 - EI Curve 6 - RI Curve	1 (1)	1
09	0x0009	2-32 (0.1-1.6)	2-32 (0.1-1.6)	Earth Low set Io > K	2 (0.1)	0.05
10	0x000A	1-20 (0.05-1) Earth=Ex 4-20 (0.2-1) Earth=In	1-20 (0.05-1)	Earth Low set Io > Isat	1 (0.05)	0.05
11	0x000B	10-160 (0.5-8.0)	2-32 (0.1-1.6)	Earth Low set Io > Time	2 (0.1) (if curve =DT-B1) 10 (0.5) (For other curves)	0.05
12	0x000C	10-80 (0.5-4)	10-80 (0.5-4)	Earth High set Io >> Isat	5 (0.25)	0.05
13	0x000D	0-15 (0-0.75)	0-15 (0-0.75)	Earth High set Io >> Time	1 (0.05)	0.05
14	0x000E	2-200 (0.2-20)	2-200 (0.2-20)	Inrush current threshold	1 (0.1)	0.10
15	0x000F	30-50 (30-50)	30-50 (30-50)	Inrush ratio	5(5)	1

Table 4: MODBUS comm. Relay settings to address mapping (CEI 0-16)

Address		Range	Description	Step Size (Original value)	Multiplier to get original value
Dec	Hex	(Original value)			
00	0x0000	3(3)	Phase Low set I > Curve : 3 - VI Curve	-	1
01	0x0001	2-32 (0.1-1.6)	Phase Low set I > K	2 (0.1)	0.05
02	0x0002	20-120 (0.2-1.2)	Phase Low set I > Isat	5 (0.05)	0.01
03	0x0003	-	Phase Low set I > Time		
04	0x0004	10-250 (0.2-5)	Phase High set I >> Isat	5 (0.1)	0.02
05	0x0005	1-20 (0.05-1)	Phase High set I >> Time	1 (0.05)	0.05
06	0x0006	8-150 (0.8-15)	Phase Very Highset I >>> Isat	2 (0.2)	0.1
07	0x0007	1-4 (0.05 - 0.2)	Phase Very Highset I >>> Time	1(0.05)	0.05
08	0x0008	0(0)	Earth lowset Io> Curve 0-DT B=1	-	-
09	0x0009	-	Earth lowset Io> k	-	-
10	0x000A	2-40 (0.025 - 0.5)	Earth lowset Io> Isat	1(0.0125)	0.0125
11	0x000B	1-20(0.05-1)	Earth lowset Io> Time	1(0.05)	0.05
12	0x000C	5-250(0.25 - 12.5)	Earth Highset Io>> Isat	5(0.25)	0.05
13	0x000D	1-4(0.05 - 0.2)	Earth Highset Io>> Time	1 (0.05)	0.05
14	0x000E	2-200 (0.2 -20)	Inrush Current Threshold	1(0.1)	0.1
15	0x000F	30 -50 (30-50)	Inrush ratio	5(5)	1

Table 5: Relay configuration parameters read

Address Value		Data Value	Description
Dec	Hex		
0032	0x0020	0	Model type CEI 0-16
		1	Model type IEC
0033	0x0021	0	Nominal current 0040 A
		1	Nominal current 0080 A
		2	Nominal current 0250 A
		3	Nominal current 1250 A
0034	0x0022	0	Product type REF601
0035	0x0023	0	Earth type - Internal
		1	Earth type - External
0036	0x0024	0 - 9999	Software version
0037	0x0025	0 - 9999	Phase trip counter
0038	0x0026	0 - 9999	Earth trip counter

Table 6: Data log to address mapping

Block 1		
Address range		Description
Dec	Hex	
0000 - 0015	0x0000 - 0x000F	Data samples 01 to 04
0016 - 0031	0x0010 - 0x001F	Data samples 05 to 08
0032 - 0047	0x0020 - 0x002F	Data samples 09 to 12
0048 - 0059	0x0030 - 0x003B	Data samples 13 to 15
Block 2		
Address range		Description
Dec	Hex	
0060 - 0063	0x003C - 0x003F	Data samples 01
0064 - 0079	0x0040 - 0x004F	Data samples 02 to 05
0080 - 0095	0x0050 - 0x005F	Data samples 06 to 09
0096 - 0111	0x0060 - 0x006F	Data samples 10 to 13
0112 - 0119	0x0070 - 0x0077	Data samples 14 to 15

The 2 blocks of data log contains 15 current values in each block with 5 pre-trip and 10 post trip values. An example to read the above table is as follows:

Address range		Data log mapping	Description
Dec	Hex		
0000	0x0000	Current I1 of 1st sample	Data log of 1st sample
0001	0x0001	Current I2 of 1st sample	
0002	0x0002	Current I3 of 1st sample	
0003	0x0003	Current I0 of 1st sample	
0004	0x0004	Current I1 of 2nd sample	Data log of 2nd sample
0005	0x0005	Current I2 of 2nd sample	
0006	0x0006	Current I3 of 2nd sample	
0007	0x0007	Current I0 of 2nd sample	
0008	0x0008	Current I1 of 3rd sample	Data log of 3rd sample
0009	0x0009	Current I2 of 3rd sample	
0010	0x000A	Current I3 of 3rd sample	
0011	0x000B	Current I0 of 3rd sample	
0012	0x000C	Current I1 of 4th sample	Data log of 4th sample
0013	0x000D	Current I2 of 4th sample	
0014	0x000E	Current I3 of 4th sample	
0015	0x000F	Current I0 of 4th sample	

Table 7: Event log to address mapping

Address range		Event log mapping	Description
Dec	Hex		
256	0x0100	Event Word for I1	Event 1
257	0x0101	Event Word for I2	
258	0x0102	Event Word for I3	
259	0x0103	Event Word for I0	
260	0x0104	Port Status	
261	0x0105	Event Word for I1	Event 2
262	0x0106	Event Word for I2	
263	0x0107	Event Word for I3	
264	0x0108	Event Word for I0	
265	0x0109	Port Status	
266	0x010A	Event Word for I1	Event 3
267	0x010B	Event Word for I2	
268	0x010C	Event Word for I3	
269	0x010D	Event Word for I0	
270	0x010E	Port Status	
271	0x010F	Event Word for I1	Event 4
272	0x0110	Event Word for I2	
273	0x0111	Event Word for I3	
274	0x0112	Event Word for I0	
275	0x0113	Port Status	
276	0x0114	Event Word for I1	Event 5
277	0x0115	Event Word for I2	
278	0x0116	Event Word for I3	
279	0x0117	Event Word for I0	
280	0x0118	Port Status	

Each event log from event 1 to event 5 contains the current values of I1-I2-I3-I0 and port status at the time of event, as shown in the following table. It should be noted that each event has to be read in group of five words only, i.e. starting address has to be one of 0x0100, 0x0105, 0x010A, 0x010F or 0x0114, with length 5 so as to give the event log data.

The below table shows the mapping of individual register with its address:

Table 8: Event log data to address mapping - description

Value	Address range		Event log mapping
	Dec	Hex	
Event word for 0	0 - 65535	0-0xFFFF	Event on current I1
Event word for 1	0 - 65535	0-0xFFFF	Event on current I2
Event word for 2	0 - 65535	0-0xFFFF	Event on current I3
Event word for 3	0 - 65535	0-0xFFFF	Event on current Io
Event word for 4	0 - 1023	0-0xFFFF	Port Status as per table 9

The port status is a 2 byte field where bit positions 0 – 7 form the byte 1 and bit position 8-9 forms byte 2.

Byte 1:

7	6	5	4	3	2	1	0

Byte 2:

-	-	-	-	-	-	9	8

Table 9: Event log - Port status mapping

Bit position	Value (1=on, 0=off)	Description
0	0 - 1	Input breaker open
1	0 - 1	Input breaker closed
2	0 - 1	Input reset
3	0 - 1	Remote control
4	0 - 1	Unit ready
5	0 - 1	IRF output
6	0 - 1	Phase protection
7	0 - 1	Earth protection
8	0 - 1	Output breaker open
9	0 - 1	Output breaker close

Table 10: Current measurement address mapping

Address range		Data range		Data log mapping
Dec	Hex	Dec	Hex	
0512	0x0200	0 - 65535	0-0xFFFF	Current measurement on I1
0513	0x0201	0 - 65535	0-0xFFFF	Current measurement on I2
0514	0x0202	0 - 65535	0-0xFFFF	Current measurement on I3
0515	0x0203	0 - 65535	0-0xFFFF	Current measurement on Io

Table 11: Digital output channel to address mapping

CH#	Address		Data log mapping
	Dec	Hex	
01	00	0x00	Breaker open
02	01	0x01	Breaker close
03	02	0x02	Reset protection command
04	03	0x03	Remote trip command

Table 12: Relay configuration write

Address		Data Value	Data log mapping
Dec	Hex		
		IEC MODE	
0033	0x0021	0	Nominal current 0040A
		1	Nominal current 0080A
		2	Nominal current 0250A
		3	Nominal current 1250A
0035	0x0023	0	Earth type - Internal
		1	Earth type - External
		CEI MODE	
0033	0x0021	1	Nominal current 0080A
		2	Nominal current 0250A

Table 13: Baud rate mapping

Baud Rate response value	Description
0	2400 baud
1	4800 baud
2	9600 baud
3	19200 baud
0	38400 baud

Table 14: Parity mapping

Parity response value	Description
0	None parity
1	Odd parity
2	Even parity

Table 15: Mobus Exception codes

Exception Code		Definition	Description
Decimal	Hex		
01	0x01	Illegal Function	The function code received in the query is not an allowable action for the slave. This may be because the function code is only applicable to newer devices, and was not implemented in the unit selected. It could also indicate that the slave is in the wrong state to process a request of this type, for example because it is un-configured and is being asked to return register values.
02	0x02	Illegal Data Address	The data address received in the query is not an allowable address for the slave. More specifically, the combination of reference number and transfer length is invalid. For a controller with 100 registers, a request with offset 96 and length 4 would succeed a request with offset 96 and length 5 will generate exception 02.
03	0x03	Illegal Data Value	A value contained in the query data field is not an allowable value for slave. This also indicates a fault in the structure of the remainder of a complex request, such as that the implied length is incorrect.
08	0x08	Memory Parity Error	The slave attempted to read record file but detected a parity error in the memory.

7.6 Communication troubleshooting

Possible faults in:

RS485

- Are the termination resistors placed at the end of the line?
- Are 2 termination resistors placed at each bus segment?
- Is the line polarity correct? Are the lines by accident swapped?
- Is the maximum line length exceeded?

Modbus Communication parameters

- Is baud rate correctly adjusted?
- Are the parity and the stop bit correctly adjusted?
- Is the slave address correct?
- Are there two devices with the same address in the system? If yes, fix it!

Modbus master

- Is the request to response timeout correct?
- Is the Modbus silent interval between two telegrams > 3.5 character times?
- Notice that the slave device will not give any response when it is addressed with a broadcast (slave address = 0).

Modbus slave

- Has the device a unique Modbus address?
- Is the function code supported by the device?
- Has the request a valid address?
- Has the request a valid quantity of coils, inputs, and registers?
- Is the power supply turned on for the relay unit?

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