
Relion® 650 series

# Line distance protection REL650
# Product Guide

Power and productivity
for a better world™

# Contents

# 1. Description

### Line distance protection IED REL650

The REL650 is designed for protection, monitoring and control of overhead lines and cables. The IED includes extensive functionality, with diverse application opportunities, as well as hardware, to meet specific requirements. The powerful IED provides distance protection for all types of overhead lines, cables and power network earthing.

# 2. Application

The REL650 is used for the protection, control and monitoring of overhead lines and cables in solidly or impedance earthed networks. The IED can be used up to the high voltage levels. It is suitable for the protection of heavily loaded lines and multi-terminal lines where the requirement for fast three-pole tripping is wanted.

The full scheme distance protection provides protection of power lines with high sensitivity and low requirement on remote end communication. The five zones have fully independent measuring and setting which gives high flexibility for all types of lines.

The modern technical solution offers fast operating time of typically 1.5 cycles.

The auto-reclose includes priority features for single-breaker arrangements. It co-operates with the synchrocheck function with high-speed or delayed reclosing.

High set instantaneous phase and earth overcurrent, four step directional or non-directional delayed phase and earth overcurrent, sensitive earth fault, thermal overload and two step under and overvoltage protection are examples of the available functions allowing the user to fulfill any application requirement.

The distance and earth fault protection can communicate with remote end in any teleprotection communication scheme.

The advanced logic capability, where the user logic is prepared with a graphical tool, allows special applications.

Disturbance recording and fault locator are available to allow independent post-fault analysis after primary disturbances.

Two packages has been defined for following applications:

- Five zone distance protection with quadrilateral characteristic (A01)
- Five zone distance protection with mho characteristic (A05)

The packages are configured and ready for direct use. Analogue and tripping IO has been pre-defined for basic use.

Add binary I/O as required for your application at ordering. Other signals need to be applied as required for each application.

The graphical configuration tool ensures simple and fast testing and commissioning.

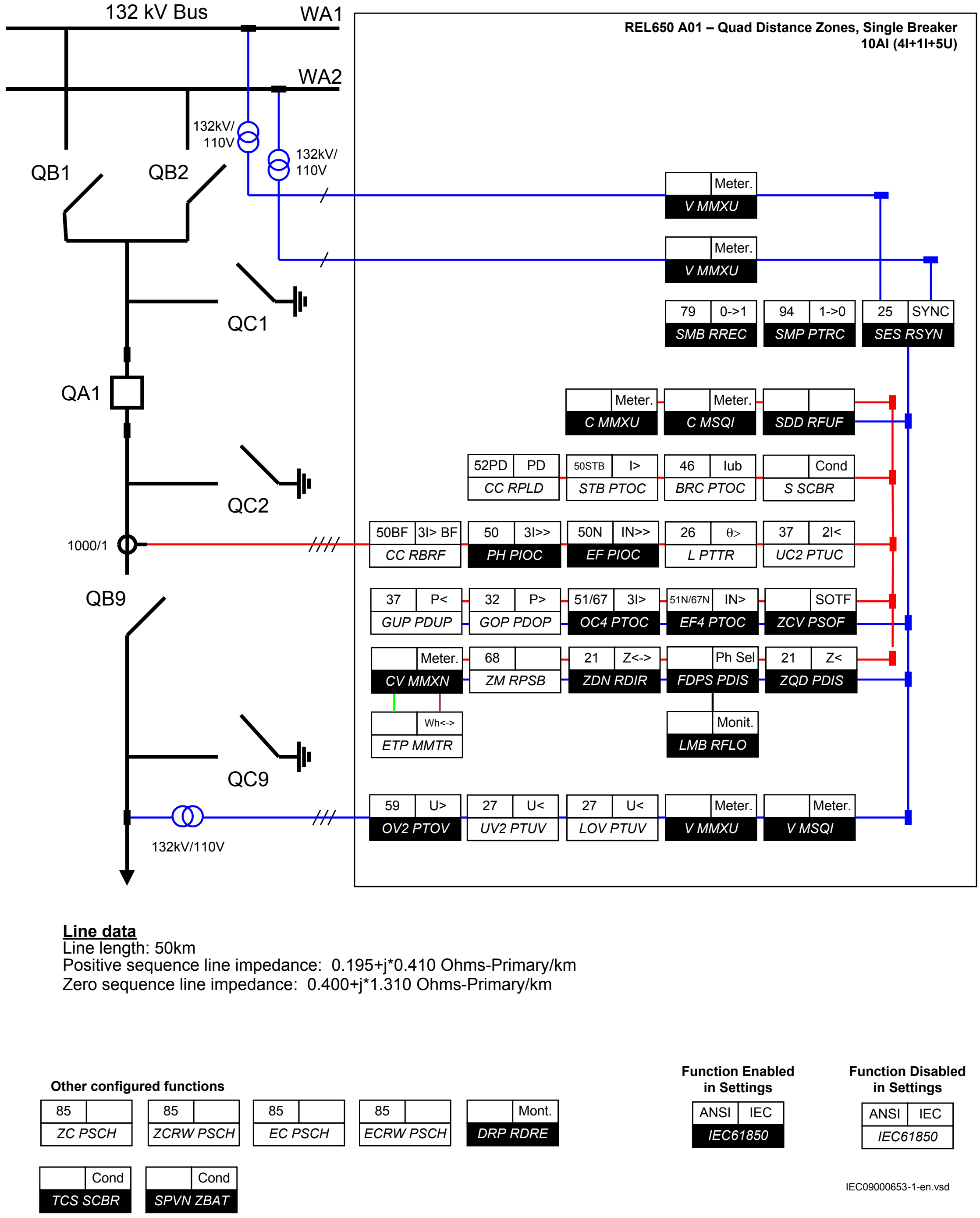


*Figure 1. A typical protection application for quadrilateral distance zones in a single breaker arrangement*

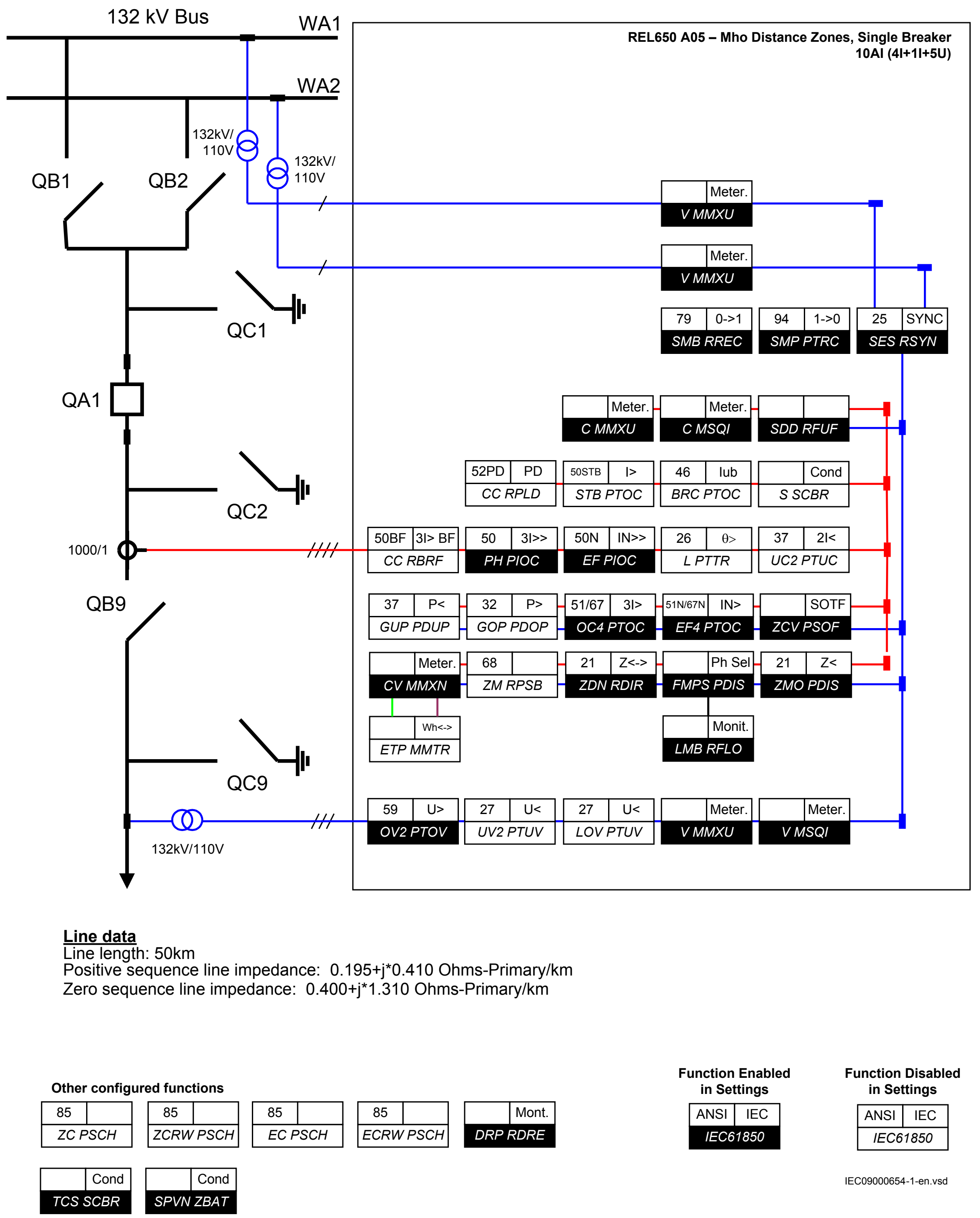


*Figure 2. A typical protection application for mho distance zones in a single breaker arrangement*

# 3. Available functions

## Main protection functions

| IEC 61850 | ANSI | Function description | Line Distance | |
|---|---|---|---|---|
| | | | REL650 (A01) 3Ph/1CB, quad | REL650 (A05) 3Ph/1CB, mho |
| **Impedance protection** | | | | |
| ZQDPDIS | 21 | Five zone distance protection, quadrilateral characteristic | 1 | |
| FDPSPDIS | 21 | Phase selection with load enchroachment, quadrilateral characteristic | 1 | |
| ZMOPDIS | 21 | Five zone distance protection, mho characteristic | | 1 |
| FMPSPDIS | 21 | Faulty phase identification with load enchroachment for mho | | 1 |
| ZDNRDIR | 21 | Directional impedance quadrilateral and mho | 1 | 1 |
| PPLPHIZ | | Phase preference logic | 1 | 1 |
| ZMRPSB | 68 | Power swing detection | 1 | 1 |
| ZCVPSOF | | Automatic switch onto fault logic, voltage and current based | 1 | 1 |

## Back-up protection functions

| IEC 61850 | ANSI | Function description | Line Distance | |
|---|---|---|---|---|
| | | | REL650 (A01) 3Ph/1CB, quad | REL650 (A05) 3Ph/1CB, mho |
| **Current protection** | | | | |
| PHPIOC | 50 | Instantaneous phase overcurrent protection | 1 | 1 |
| OC4PTOC | 51/67 | Four step directional phase overcurrent protection | 1 | 1 |
| EFPIOC | 50N | Instantaneous residual overcurrent protection | 1 | 1 |
| EF4PTOC | 51N/ 67N | Four step directional residual overcurrent protection | 1 | 1 |
| SDEPSDE | 67N | Sensitive directional residual overcurrent and power protection | 1 | 1 |
| UC2PTUC | 37 | Time delayed 2-step undercurrent protection | 1 | 1 |
| LPTTR | 26 | Thermal overload protection, one time constant | 1 | 1 |
| CCRBRF | 50BF | Breaker failure protection | 1 | 1 |
| STBPTOC | 50STB | Stub protection | 1 | 1 |
| CCRPLD | 52PD | Pole discordance protection | 1 | 1 |
| BRCPTOC | 46 | Broken conductor check | 1 | 1 |
| GUPPDUP | 37 | Directional underpower protection | 1 | 1 |
| GOPPDOP | 32 | Directional overpower protection | 1 | 1 |
| DNSPTOC | 46 | Negative sequence based overcurrent function | 1 | 1 |
| **Voltage protection** | | | | |
| UV2PTUV | 27 | Two step undervoltage protection | 1 | 1 |
| OV2PTOV | 59 | Two step overvoltage protection | 1 | 1 |
| ROV2PTOV | 59N | Two step residual overvoltage protection | 1 | 1 |
| LOVPTUV | 27 | Loss of voltage check | 1 | 1 |
| **Frequency protection** | | | | |
| SAPTUF | 81 | Underfrequency function | 2 | 2 |
| SAPTOF | 81 | Overfrequency function | 2 | 2 |
| SAPFRC | 81 | Rate-of-change frequency protection | 2 | 2 |

## Control and monitoring functions

| IEC 61850 | ANSI | Function description | Line Distance | |
|---|---|---|---|---|
| | | | REL650 (A01) 3Ph/1CB, quad | REL650 (A05) 3Ph/1CB, mho |
| **Control** | | | | |
| SESRSYN | 25 | Synchrocheck, energizing check, and synchronizing | 1 | 1 |
| SMBRREC | 79 | Autorecloser | 1 | 1 |
| QCBAY | | Bay control | 1 | 1 |
| LOCREM | | Handling of LR-switch positions | 1 | 1 |
| LOCREMCTRL | | LHMI control of PSTO | 1 | 1 |
| SLGGIO | | Logic Rotating Switch for function selection and LHMI presentation | 15 | 15 |
| VSGGIO | | Selector mini switch extension | 20 | 20 |
| DPGGIO | | IEC 61850 generic communication I/O functions double point | 16 | 16 |
| SPC8GGIO | | Single point generic control 8 signals | 5 | 5 |
| AUTOBITS | | AutomationBits, command function for DNP3.0 | 3 | 3 |
| **Secondary system supervision** | | | | |
| CCSRDIF | 87 | Current circuit supervision | 1 | 1 |
| SDDRFUF | | Fuse failure supervision | 1 | 1 |
| TCSSCBR | | Breaker close/trip circuit monitoring | 3 | 3 |
| **Logic** | | | | |
| SMPPTRC | 94 | Tripping logic | 1 | 1 |
| TMAGGIO | | Trip matrix logic | 12 | 12 |
| OR | | Configurable logic blocks, OR | 283 | 283 |
| INVERTER | | Configurable logic blocks, Inverter | 140 | 140 |
| PULSETIMER | | Configurable logic blocks, PULSETIMER | 40 | 40 |
| GATE | | Configurable logic blocks, Controllable gate | 40 | 40 |
| XOR | | Configurable logic blocks, exclusive OR | 40 | 40 |

| IEC 61850 | ANSI | Function description | Line Distance | |
|---|---|---|---|---|
| | | | REL650 (A01) 3Ph/1CB, quad | REL650 (A05) 3Ph/1CB, mho |
| LOOPDELAY | | Configurable logic blocks, loop delay | 40 | 40 |
| TimeSet | | Configurable logic blocks, timer | 40 | 40 |
| AND | | Configurable logic blocks, AND | 280 | 280 |
| SRMEMORY | | Configurable logic blocks, set-reset memory | 40 | 40 |
| RSMEMORY | | Configurable logic blocks, reset-set memory | 40 | 40 |
| FXDSIGN | | Fixed signal function block | 1 | 1 |
| B16I | | Boolean 16 to Integer conversion | 16 | 16 |
| B16IFCVI | | Boolean 16 to integer conversion with logic node representation | 16 | 16 |
| IB16A | | Integer to Boolean 16 conversion | 16 | 16 |
| IB16FCVB | | Integer to boolean 16 conversion with logic node representation | 16 | 16 |
| **Monitoring** | | | | |
| CVMMXN | | Measurements | 6 | 6 |
| CMMXU | | Phase current measurement | 10 | 10 |
| VMMXU | | Phase-phase voltage measurement | 6 | 6 |
| CMSQI | | Current sequence component measurement | 6 | 6 |
| VMSQI | | Voltage sequence measurement | 6 | 6 |
| VNMMXU | | Phase-neutral voltage measurement | 6 | 6 |
| CNTGGIO | | Event counter | 5 | 5 |
| DRPRDRE | | Disturbance report | 1 | 1 |
| AxRADR | | Analog input signals | 1 | 1 |
| BxRBDR | | Binary input signals | 1 | 1 |
| SPGGIO | | IEC 61850 generic communication I/O functions | 64 | 64 |
| SP16GGIO | | IEC 61850 generic communication I/O functions 16 inputs | 16 | 16 |
| MVGGIO | | IEC 61850 generic communication I/O functions | 16 | 16 |

| IEC 61850 | ANSI | Function description | Line Distance | |
|---|---|---|---|---|
| | | | REL650 (A01) 3Ph/1CB, quad | REL650 (A05) 3Ph/1CB, mho |
| MVEXP | | Measured value expander block | 66 | 66 |
| LMBRFLO | | Fault locator | 1 | 1 |
| SPVNZBAT | | Station battery supervision | 1 | 1 |
| SSIMG | 63 | Insulation gas monitoring function | 1 | 1 |
| SSIML | 71 | Insulation liquid monitoring function | 1 | 1 |
| SSCBR | | Circuit breaker condition monitoring | 1 | 1 |
| **Metering** | | | | |
| PCGGIO | | Pulse counter logic | 16 | 16 |
| ETPMMTR | | Function for energy calculation and demand handling | 3 | 3 |

## Designed to communicate

| IEC 61850 | ANSI | Function description | Line Distance | |
|---|---|---|---|---|
| | | | REL650 (A01) 3Ph/1CB, quad | REL650 (A05) 3Ph/1CB, mho |
| **Station communication** | | | | |
| | | IEC 61850 communication protocol | 1 | 1 |
| | | DNP3.0 for TCP/IP communication protocol | 1 | 1 |
| GOOSEINTLKRCV | | Horizontal communication via GOOSE for interlocking | 59 | 59 |
| GOOSEBINRCV | | GOOSE binary receive | 4 | 4 |
| **Scheme communication** | | | | |
| ZCPSCH | 85 | Scheme communication logic for distance or overcurrent protection | 1 | 1 |
| ZCRWPSCH | 85 | Current reversal and weak-end infeed logic for distance protection | 1 | 1 |
| ZCLCPLAL | | Local acceleration logic | 1 | 1 |
| ECPSCH | 85 | Scheme communication logic for residual overcurrent protection | 1 | 1 |
| ECRWPSCH | 85 | Current reversal and weak-end infeed logic for residual overcurrent protection | 1 | 1 |

### Basic IED functions

| IEC 61850 | Function description | |
|---|---|---|
| **Basic functions included in all products** | | |
| INTERRSIG | Self supervision with internal event list | 1 |
| | Time synchronization | 1 |
| SETGRPS | Setting group handling | 1 |
| ACTVGRP | Parameter setting groups | 1 |
| TESTMODE | Test mode functionality | 1 |
| CHNGLCK | Change lock function | 1 |
| ATHSTAT | Authority status | 1 |
| ATHCHCK | Authority check | 1 |

# 4. Impedance protection

### Five zone distance protection, quadrilateral characteristic ZQDPDIS

Five zone distance protection, quadrilateral characteristic (ZQDPDIS) is a five zone full scheme protection with three fault loops for phase-to-phase faults and three fault loops for phase-to-earth fault for each of the independent zones. Individual settings for each zone in resistive and reactive reach gives flexibility for use as back-up protection for transformer connected to overhead lines and cables of different types and lengths.

ZQDPDIS together with phase selection with load enchroachment, FDPSPDIS has functionality for load enchroachment which increases the possibility to detect high resistive faults on heavily loaded lines (see figure 3).

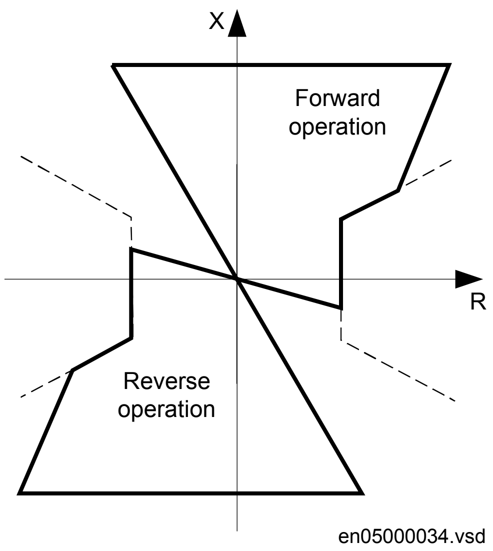


*Figure 3. Typical quadrilateral distance protection zone with Phase selection with load encroachment function (FDPSPDIS) activated*

Built-in adaptive load compensation algorithm prevents overreaching of zone 1 at phase-to-earth faults on heavily loaded power lines.

The distance protection zones can operate, independent of each other, in directional (forward or reverse) or non-directional mode. This makes them suitable, together with different communication schemes, for the protection of power lines and cables in complex network configurations, such as parallel lines, multi-terminal lines etc.

## Phase selection with load encroachment, quadrilateral characteristic FDPSPDIS

The operation of transmission networks today is in many cases close to the stability limit. Due to environmental considerations, the rate of expansion and reinforcement of the power system is reduced e.g. difficulties to get permission to build new power lines. The phase selection function is designed to accurately select the proper fault loop in the distance function dependent on the fault type.

The heavy load transfer that is common in many transmission networks may make fault resistance coverage difficult to achieve. Therefore, the function has a built in algorithm for load encroachment, which gives the possibility to enlarge the resistive setting of both the phase selection and the measuring zones without interfering with the load.

The extensive output signals from the phase selection gives also important information about faulty phase(s) which can be used for fault analysis.

A current-based phase selection is also included. The measuring elements continuously measure three phase currents and the residual current and, compare them with the set values.

## Five zone distance protection, mho characteristic ZMOPDIS

The numerical mho line distance protection is a five zone full scheme protection for back-up detection of short circuit and earth-faults. The full scheme technique provides back-up protection of power lines with high sensitivity and low requirement on remote end communication. The five zones have fully independent measuring and settings which gives high flexibility for all types of lines.

The IED can be used up to high voltage levels. It is suitable for the protection of heavily loaded lines and multi-terminal lines where the requirement for fast three-pole tripping is wanted.

Built-in adaptive load compensation algorithm prevents overreaching at phase-to-earth faults on heavily loaded power lines, see figure 4.

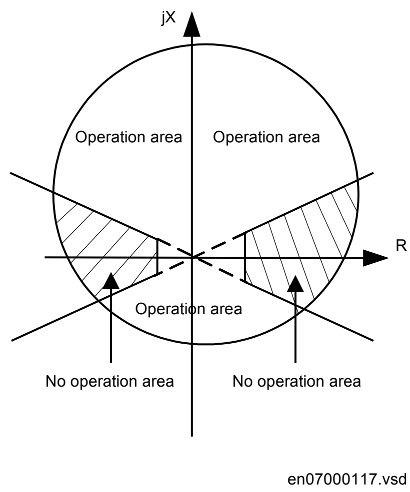


*Figure 4. Load encroachment influence on the offset mho characteristic*

The distance protection zones can operate, independent of each other, in directional (forward or reverse) or non-directional mode (offset). This makes them suitable, together with different communication schemes, for the protection of power lines and cables in complex network configurations, such as parallel lines, multi-terminal lines etc.

## Faulty phase identification with load enchroachment FMPSPDIS

The phase selection function is design to accurate select the proper fault loop in the distance function dependent on the fault type.

The heavy load transfer that is common in many transmission networks may in some cases interfere with the distance protection zone reach and cause unwanted operation. Therefore the function has a built in algorithm for load encroachment, which gives the possibility to enlarge the resistive setting of the measuring zones without interfering with the load.

The output signals from the phase selection function produce important information about faulty phase(s) which can be used for fault analysis as well.

### Directional impedance quadrilateral and mho ZDNRDIR

The phase-to-earth impedance elements can be optionally supervised by a directional function based on symmetrical components.

### Phase preference logic PPLPHIZ

Phase preference logic function (PPLPHIZ) is intended to be used in isolated or high impedance-earthed networks where there is a requirement to trip only one of the faulty lines at cross-country fault.

Phase preference logic inhibits tripping for single phase-to-earth faults in isolated and high impedance earthed networks, where such faults are not to be cleared by distance protection. For cross-country faults, the logic selects either the leading or the lagging phase-earth loop for measurement and initiates tripping of the preferred fault based on the selected phase preference. A number of different phase preference combinations are available for selection.

### Power swing detection ZMRPSB

Power swings may occur after disconnection of heavy loads or trip of big generation plants.

Power swing detection function (ZMRPSB) is used to detect power swings and initiate block of selected distance protection zones. Occurrence of earth-fault currents during a power swing can block the Power swing detection function to allow fault clearance.

### Automatic switch onto fault logic, voltage and current based ZCVPSOF

Automatic switch onto fault logic, voltage and current based (ZCVPSOF) is a function that gives an instantaneous trip at closing of breaker onto a fault. A dead line detection check is provided to activate the function when the line is dead.

Mho distance protections can not operate for switch onto fault condition when the phase voltages are close to zero. An additional logic based on UI Level is used for this purpose.

## 5. Current protection

### Instantaneous phase overcurrent protection PHPIOC

The instantaneous three phase overcurrent function has a low transient overreach and short tripping time to allow use as a high set short-circuit protection function.

### Four step phase overcurrent protection OC4PTOC

The four step phase overcurrent function has an inverse or definite time delay independent for each step separately.

All IEC and ANSI time delayed characteristics are available.

The directional function is voltage polarized with memory. The function can be set to be directional or non-directional independently for each of the steps.

### Instantaneous residual overcurrent protection EFPIOC

The instantaneous residual overcurrent protection (EFPIOC) has a low transient overreach and short tripping times to allow the use for instantaneous earth fault protection, with the reach limited to less than typical eighty percent of the line at minimum source impedance. The function can be configured to measure the residual current from the three phase current inputs or the current from a separate current input. The function can be blocked by activating the input BLOCK.

## Four step residual overcurrent protection EF4PTOC

The four step residual overcurrent protection (EF4PTOC) has an setable inverse or definite time delay independent for step 1 and 4 separately. Step 2 and 3 are always definite time delayed.

All IEC and ANSI time delayed characteristics are available.

The directional function is voltage polarized, current polarized or dual polarized.

The protection can be set directional or non-directional independently for each of the steps.

A second harmonic blocking can be enabled individually for each step.

The protection can be used as main protection for phase-to-earth faults.

The protection can also be used to provide a system back-up for example, in the case of the primary protection being out of service due to communication or voltage transformer circuit failure.

Directional operation can be combined together with corresponding communication logic in permissive or blocking teleprotection scheme. Current reversal and weak-end infeed functionality are available as well.

## Sensitive directional residual overcurrent and power protection SDEPSDE

In isolated networks or in networks with high impedance earthing, the earth fault current is significantly smaller than the short circuit currents. In addition to this, the magnitude of the fault current is almost independent on the fault location in the network. The protection can be selected to use either the residual current or residual power component $3U_0 \cdot 3I_0 \cdot \cos\varphi$, for operating quantity. There is also available one non-directional $3I_0$ step and one non-directional $3U_0$ overvoltage tripping step.

## Time delayed 2-step undercurrent protection UC2PTUC

Time delayed 2-step undercurrent protection (UC2PTUC) function is used to supervise the line for low current, for example, to detect a loss-of-load condition, which results in a current lower than the normal load current.

## Thermal overload protection, one time constant LPTTR

The increasing utilizing of the power system closer to the thermal limits have generated a need of a thermal overload protection also for power lines.

A thermal overload will often not be detected by other protection functions and the introduction of the thermal overload protection can allow the protected circuit to operate closer to the thermal limits.

The three-phase current measuring protection has an $I^2t$ characteristic with settable time constant and a thermal memory.

An alarm level gives early warning to allow operators to take action well before the line is tripped.

## Breaker failure protection CCRBRF

Breaker failure protection (CCRBRF) function ensures fast back-up tripping of surrounding breakers in case of own breaker failure to open. CCRBRF can be current based, contact based, or adaptive combination between these two principles.

A current check with extremely short reset time is used as a check criteria to achieve a high security against unnecessary operation.

A contact check criteria can be used where the fault current through the breaker is small.

Breaker failure protection (CCRBRF) function current criteria can be fulfilled by one or two phase currents, or one phase current plus residual current. When those currents exceed the user defined settings, the function is activated. These conditions increase the security of the back-up trip command.

CCRBRF function can be programmed to give a three-phase re-trip of the own breaker to avoid unnecessary tripping of surrounding breakers at an incorrect initiation due to mistakes during testing.

### Stub protection STBPTOC

When a power line is taken out of service for maintenance and the line disconnector is opened the voltage transformers will mostly be outside on the disconnected part. The primary line distance protection will thus not be able to operate and must be blocked.

The stub protection covers the zone between the current transformers and the open disconnector. The three-phase instantaneous overcurrent function is released from a normally open, NO (b) auxiliary contact on the line disconnector.

### Pole discordance protection CCRPLD

Circuit breakers or disconnectors can due to electrical or mechanical failures end up with the different poles in different positions (close-open). This can cause negative and zero sequence currents which gives thermal stress on rotating machines and can cause unwanted operation of zero sequence or negative sequence current functions.

Normally the own breaker is tripped to correct such a situation. If the situation persists the surrounding breaker should be tripped to clear the unsymmetrical load situation.

The pole discordance function operates based on information from the circuit breaker logic with additional criteria from unsymmetrical phase current when required.

### Broken conductor check BRCPTOC

Conventional protection functions can not detect the broken conductor condition. Broken conductor check (BRCPTOC) function, consisting of continuous current unsymmetry check on the line where the IED is connected will give alarm or trip at detecting broken conductors.

### Directional over/underpower protection GOPPDOP/GUPPDUP

The directional over-/under-power protection (GOPPDOP/GUPPDUP) can be used wherever a high/low active, reactive or apparent power protection or alarming is required. The functions can alternatively be used to check the direction of active or reactive power flow in the power system. There are number of applications where such functionality is needed. Some of them are:

- detection of reversed active power flow
- detection of high reactive power flow

Each function has two steps with definite time delay. Reset times for every step can be set as well.

### Negative sequence based overcurrent function DNSPTOC

Negative sequence based overcurrent function (DNSPTOC) is typically used as sensitive earth-fault protection of power lines, where incorrect zero sequence polarization may result from mutual induction between two or more parallel lines.

Additionally, it is used in applications on underground cables, where zero sequence impedance depends on the fault current return paths, but the cable negative sequence impedance is practically constant.

DNSPTOC protects against all unbalance faults including phase-to-phase faults. Always remember to set the minimum pickup current of the function above natural system unbalance level.

## 6. Voltage protection

### Two step undervoltage protection UV2PTUV

Undervoltages can occur in the power system during faults or abnormal conditions. Two step undervoltage protection (UV2PTUV) function can be used to open circuit breakers to prepare for system restoration at power outages or as long-time delayed back-up to primary protection.

UV2PTUV has two voltage steps, each with inverse or definite time delay.

### Two step overvoltage protection OV2PTOV

Overvoltages may occur in the power system during abnormal conditions, such as, sudden power loss, tap changer regulating failures, open line ends on long lines.

Two step overvoltage protection (OV2PTOV) can be used as open line end detector, normally then combined with directional reactive over-power function or as system voltage supervision, normally then giving alarm only or switching in reactors or switch out capacitor banks to control the voltage.

OV2PTOV has two voltage steps, where step 1 is setable as inverse or definite time delayed. Step 2 is always definite time delayed.

OV2PTOV has an extremely high reset ratio to allow setting close to system service voltage.

### Two step residual overvoltage protection ROV2PTOV

Residual voltages may occur in the power system during earth-faults.

Two step residual overvoltage protection (ROV2PTOV) calculates the residual voltage from the three-phase voltage input transformers or from a single-phase voltage input transformer fed from an open delta or neutral point voltage transformer.

ROV2PTOV has two voltage steps, where step 1 is setable as inverse or definite time delayed. Step 2 is always definite time delayed.

### Loss of voltage check LOVPTUV

Loss of voltage check (LOVPTUV) is suitable for use in networks with an automatic system restoration function. LOVPTUV issues a three-pole trip command to the circuit breaker, if all three phase voltages fall below the set value for a time longer than the set time and the circuit breaker remains closed.

## 7. Frequency protection

### Under frequency protection SAPTUF

Under frequency occurs as a result of lack of generation in the network.

Under frequency protection (SAPTUF) is used for load shedding systems, remedial action schemes, gas turbine start-up and so on.

SAPTUF is provided with an under voltage blocking.

### Over frequency protection SAPTOF

Over frequency protection (SAPTOF) function is applicable in all situations, where reliable detection of high fundamental power system frequency is needed.

Over frequency occurs at sudden load drops or shunt faults in the power network. Close to the generating plant, generator governor problems can also cause over frequency.

SAPTOF is used mainly for generation shedding and remedial action schemes. It is also used as a frequency stage initiating load restoring.

SAPTOF is provided with an under voltage blocking.

### Rate-of-change frequency protection SAPFRC

Rate-of-change frequency protection (SAPFRC) function gives an early indication of a main disturbance in the system. It can be used for generation shedding, load shedding, remedial action schemes etc. SAPFRC can discriminate between positive or negative change of frequency.

# 8. Secondary system supervision

## Current circuit supervision CCSRDIF

Open or short circuited current transformer cores can cause unwanted operation of many protection functions such as differential, earth fault current and negative sequence current functions.

It must be remembered that a blocking of protection functions at an occurrence of open CT circuit will mean that the situation will remain and extremely high voltages will stress the secondary circuit.

Current circuit supervision (CCSRDIF) compares the residual current from a three phase set of current transformer cores with the neutral point current on a separate input taken from another set of cores on the current transformer.

A detection of a difference indicates a fault in the circuit and is used as alarm or to block protection functions expected to give unwanted tripping.

## Fuse failure supervision SDDRFUF

The aim of the fuse failure supervision function (SDDRFUF) is to block voltage measuring functions at failures in the secondary circuits between the voltage transformer and the IED in order to avoid unwanted operations that otherwise might occur.

The fuse failure supervision function basically has two different algorithms, negative sequence and zero sequence based algorithm and an additional delta voltage and delta current algorithm.

The negative sequence detection algorithm is recommended for IEDs used in isolated or high-impedance earthed networks. It is based on the negative-sequence measuring quantities, a high value of voltage $3U_2$ without the presence of the negative-sequence current $3I_2$.

The zero sequence detection algorithm is recommended for IEDs used in directly or low impedance earthed networks. It is based on the zero sequence measuring quantities, a high value of voltage $3U_0$ without the presence of the residual current $3I_0$.

A criterion based on delta current and delta voltage measurements can be added to the fuse failure supervision function in order to detect a three phase fuse failure, which in practice is more associated with voltage transformer switching during station operations.

For better adaptation to system requirements, an operation mode setting has been introduced which makes it possible to select the operating conditions for negative sequence and zero sequence based function. The selection of different operation modes makes it possible to choose different interaction possibilities between the negative sequence and zero sequence based algorithm.

## Breaker close/trip circuit monitoring TCSSCBR

The trip circuit supervision function TCSSCBR is designed to supervise the control circuit of the circuit breaker. The invalidity of a control circuit is detected by using a dedicated output contact that contains the supervision functionality.

The function operates after a predefined operating time and resets when the fault disappears.

# 9. Control

## Synchronizing, synchrocheck and energizing check SESRSYN

The Synchronizing function allows closing of asynchronous networks at the correct moment including the breaker closing time.

The systems can thus be reconnected after an auto-reclose or manual closing which improves the network stability.

The Synchrocheck, energizing check function (SESRSYN) checks that the voltages on both sides of the circuit breaker are in synchronism, or with at least one side dead to ensure that closing can be done safely.

The function includes a built-in voltage selection scheme for double bus and 1½ or ring busbar arrangements.

Manual closing as well as automatic reclosing can be checked by the function and can have different settings.

For systems which are running asynchronous a synchronizing function is provided. The main purpose of the synchronizing function is to provide controlled closing of circuit breakers when two asynchronous systems are going to be connected. It is used for slip frequencies that are larger than those for synchrocheck and lower than a set maximum level for the synchronizing function.

### Autorecloser SMBRREC

The autoreclosing function provides high-speed and/or delayed auto-reclosing for single breaker applications.

Up to five reclosing attempts can be programmed.

The autoreclosing function can be configured to co-operate with a synchrocheck function.

### Bay control QCBAY

The bay control (QCBAY) function is used to handle the selection of the operator place per bay. QCBAY also provides blocking functions that can be distributed to different apparatuses within the bay.

### Local remote LOCREM /Local remote control LOCREMCTRL

The signals from the local HMI or from an external local/remote switch are applied via function blocks LOCREM and LOCREMCTRL to the Bay control (QCBAY) function block. A parameter in function block LOCREM is set to choose if the switch signals are coming from the local HMI or from an external hardware switch connected via binary inputs.

### Logic rotating switch for function selection and LHMI presentation SLGGIO

The Logic rotating switch for function selection and LHMI presentation (SLGGIO) function block (or the selector switch function block) is used within the ACT tool in order to get a selector switch functionality similar with the one provided by a hardware selector switch. Hardware selector switches are used extensively by utilities, in order to have different functions operating on pre-set values. Hardware switches are however sources for maintenance issues, lower system reliability and extended purchase portfolio. The virtual selector switches eliminate all these problems.

### Selector mini switch VSGGIO

Selector mini switch (VSGGIO) function block is a multipurpose function used in the configuration tool in PCM600 for a variety of applications, as a general purpose switch.

VSGGIO can be controlled from the menu or from a symbol on the single line diagram (SLD) on the local HMI.

### IEC 61850 generic communication I/O functions DPGGIO

The IEC 61850 generic communication I/O functions (DPGGIO) function block is used to send three logical signals to other systems or equipment in the substation. It is especially used in the interlocking and reservation station-wide logics.

### Single point generic control 8 signals SPC8GGIO

The Single point generic control 8 signals (SPC8GGIO) function block is a collection of 8 single point commands, designed to bring in commands from REMOTE (SCADA) to those parts of the logic configuration that do not need complicated function blocks that have the capability to receive commands (for example, SCSWI). In this way, simple commands can be sent directly to the IED outputs, without confirmation. Confirmation (status) of the result of the commands is supposed to be achieved by other means, such as binary inputs and SPGGIO function blocks.

### AutomationBits AUTOBITS

Automation bits function (AUTOBITS) is used within PCM600 in order to get into the configuration of the commands coming through the DNP3 protocol.

## 10. Scheme communication

### Scheme communication logic for distance or overcurrent protection ZCPSCH

To achieve instantaneous fault clearance for all line faults, a scheme communication logic is provided. All types of communication schemes e.g. permissive underreaching, permissive overreaching, blocking, unblocking, intertrip etc. are available.

### Current reversal and weak-end infeed logic for distance protection ZCRWPSCH

The current reversal function is used to prevent unwanted operations due to current reversal when using permissive overreach protection schemes in application with parallel lines when the overreach from the two ends overlap on the parallel line.

The weak-end infeed logic is used in cases where the apparent power behind the protection can be too low to activate the distance protection function. When activated, received carrier signal together with local under voltage criteria and no reverse zone operation gives an instantaneous trip. The received signal is also echoed back to accelerate the sending end.

### Local acceleration logic ZCLCPLAL

To achieve fast clearing of faults on the whole line, when no communication channel is available, local acceleration logic (ZCLCPLAL) can be used. This logic enables fast fault clearing during certain conditions, but naturally, it can not fully replace a communication channel.

The logic can be controlled either by the autorecloser (zone extension) or by the loss-of-load current (loss-of-load acceleration).

### Scheme communication logic for residual overcurrent protection ECPSCH

To achieve fast fault clearance of earth-faults on the part of the line not covered by the instantaneous step of the residual overcurrent protection, the directional residual overcurrent protection can be supported with a logic that uses communication channels.

In the directional scheme, information of the fault current direction must be transmitted to the other line end. With directional comparison, a short operate time of the protection including a channel transmission time, can be achieved. This short operate time enables rapid autoreclosing function after the fault clearance.

The communication logic module for directional residual current protection enables blocking as well as permissive under/overreaching schemes. The logic can also be supported by additional logic for weak-end-infeed and current reversal, included in the ECRWPSCH function.

### Current reversal and weak-end infeed logic for residual overcurrent protection ECRWPSCH

The Current reversal and weak-end infeed logic for residual overcurrent protection (ECRWPSCH) is a supplement to Scheme communication logic for residual overcurrent protection (ECPSCH).

To achieve fast fault clearing for all earth-faults on the line, the directional earth-fault protection function can be supported with logic, that uses communication channels.

The 650 series IEDs have for this reason available additions to scheme communication logic.

If parallel lines are connected to common busbars at both terminals, overreaching permissive communication schemes can trip unselectively due to fault current reversal. This unwanted tripping affects the healthy line when a fault is cleared on the other line. This lack of security can result in a total loss of interconnection between the two buses. To avoid this type of disturbance, a fault current reversal logic (transient blocking logic) can be used.

Permissive communication schemes for residual overcurrent protection, can basically operate only when the protection in the remote terminal can detect the fault. The detection requires a sufficient minimum residual fault current, out from this terminal. The fault current can be too low due to an opened breaker or high positive and/or zero sequence source impedance behind this terminal. To overcome these conditions, weak end infeed (WEI) echo logic is used.

# 11. Logic

## Tripping logic SMPPTRC

A function block for protection tripping is provided for each circuit breaker involved in the tripping of the fault. It provides the pulse prolongation to ensure a trip pulse of sufficient length, as well as all functionality necessary for correct co-operation with autoreclosing functions.

The trip function block includes functionality for breaker lock-out.

## Trip matrix logic TMAGGIO

Trip matrix logic (TMAGGIO) function is used to route trip signals and/or other logical output signals to different output contacts on the IED.

TMAGGIO output signals and the physical outputs are available in PCM600 and this allows the user to adapt the signals to the physical tripping outputs according to the specific application needs.

## Configurable logic blocks

A number of logic blocks and timers are available for user to adapt the configuration to the specific application needs.

- **OR** function block.
- **INVERTER** function blocks that inverts the input signal.
- **PULSETIMER** function block can be used, for example, for pulse extensions or limiting of operation of outputs.
- **GATE** function block is used for controlling if a signal should be able to pass from the input to the output or not depending on a setting.
- **XOR** function block.
- **LOOPDELAY** function block used to delay the output signal one execution cycle.
- **TIMERSET** function has pick-up and drop-out delayed outputs related to the input signal. The timer has a settable time delay.
- **AND** function block.
- **SRMEMORY** function block is a flip-flop that can set or reset an output from two inputs respectively. Each block has two outputs where one is inverted. The memory setting controls if the block after a power interruption should return to the state before the interruption, or be reset. Set input has priority.
- **RSMEMORY** function block is a flip-flop that can reset or set an output from two inputs respectively. Each block has two outputs where one is inverted. The memory

setting controls if the block after a power interruption should return to the state before the interruption, or be reset. Reset input has priority.

### Boolean 16 to Integer conversion B16I

Boolean 16 to integer conversion function (B16I) is used to transform a set of 16 binary (logical) signals into an integer.

### Boolean 16 to integer conversion with logic node representation B16IFCVI

Boolean 16 to integer conversion with logic node representation function (B16IFCVI) is used to transform a set of 16 binary (logical) signals into an integer.

### Integer to Boolean 16 conversion IB16A

Integer to boolean 16 conversion function (IB16A) is used to transform an integer into a set of 16 binary (logical) signals.

### Integer to boolean 16 conversion with logic node representation IB16FCVB

Integer to boolean conversion with logic node representation function (IB16FCVB) is used to transform an integer to 16 binary (logic) signals.

IB16FCVB function can receive remote values over IEC 61850 depending on the operator position input (PSTO).

## 12. Monitoring

### Measurements CVMMXN

The service value function is used to get on-line information from the IED. These service values makes it possible to display on-line information on the local HMI and on the Substation automation system about:

- measured voltages, currents, frequency, active, reactive and apparent power and power factor
- the primary and secondary phasors
- current sequence components
- voltage sequence components
- differential currents, bias currents
- event counters
- measured values and other information of the different parameters for included functions
- logical values of all binary in- and outputs and
- general IED information.

### Event counter CNTGGIO

Event counter (CNTGGIO) has six counters which are used for storing the number of times each counter input has been activated.

### Disturbance report

Complete and reliable information about disturbances in the primary and/or in the secondary system together with continuous event-logging is accomplished by the disturbance report functionality.

Disturbance report, always included in the IED, acquires sampled data of all selected analog input and binary signals connected to the function block that is, maximum 40 analog and 96 binary signals.

Disturbance report functionality is a common name for several functions:

- Event List
- Indications
- Event recorder
- Trip Value recorder
- Disturbance recorder
- Fault Locator (FL)

Disturbance report function is characterized by great flexibility regarding configuration, starting conditions, recording times and large storage capacity.

A disturbance is defined as an activation of an input in the AxRADR or BxRBDR function blocks which is set to trigger the disturbance recorder. All signals from start of pre-fault time to the end of post-fault time, will be included in the recording.

Every disturbance report recording is saved in the IED in the standard Comtrade format. The same applies to all events, which are continuously saved in a ring-buffer. The local HMI is used to get information about the recordings, but the disturbance report files may be uploaded to PCM600 (Protection and Control IED Manager) and further analysis using the disturbance handling tool.

### Event list DRPRDRE

Continuous event-logging is useful for monitoring of the system from an overview perspective and is a complement to specific disturbance recorder functions.

The event list logs all binary input signals connected to the Disturbance report function. The list may contain of up to 1000 time-tagged events stored in a ring-buffer.

### Indications DRPRDRE

To get fast, condensed and reliable information about disturbances in the primary and/or in the secondary system it is important to know, for example binary signals that have changed status during a disturbance. This information is used in the short perspective to get information via the local HMI in a straightforward way.

There are three LEDs on the local HMI (green, yellow and red), which will display status information about the IED and the Disturbance report function (trigged).

The Indication list function shows all selected binary input signals connected to the Disturbance report function that have changed status during a disturbance.

### Event recorder DRPRDRE

Quick, complete and reliable information about disturbances in the primary and/or in the secondary system is vital, for example, time tagged events logged during disturbances. This information is used for different purposes in the short term (for example corrective actions) and in the long term (for example Functional Analysis).

The event recorder logs all selected binary input signals connected to the Disturbance report function. Each recording can contain up to 150 time-tagged events.

The event recorder information is available for the disturbances locally in the IED.

The event recording information is an integrated part of the disturbance record (Comtrade file).

### Trip value recorder DRPRDRE

Information about the pre-fault and fault values for currents and voltages are vital for the disturbance evaluation.

The Trip value recorder calculates the values of all selected analog input signals connected to the Disturbance report function. The result is magnitude and phase angle before and during the fault for each analog input signal.

The trip value recorder information is available for the disturbances locally in the IED.

The trip value recorder information is an integrated part of the disturbance record (Comtrade file).

### Disturbance recorder DRPRDRE

The Disturbance recorder function supplies fast, complete and reliable information about disturbances in the power system. It facilitates understanding system behavior and related primary and secondary equipment during and after a disturbance. Recorded information is used for different purposes in the short perspective (for example corrective actions) and long perspective (for example Functional Analysis).

The Disturbance recorder acquires sampled data from all selected analog input and binary signals connected to the Disturbance report function (maximum 40 analog and 96 binary signals). The binary signals are the same signals as available under the event recorder function.

The function is characterized by great flexibility and is not dependent on the operation of protection functions. It can record disturbances not detected by protection functions.

The disturbance recorder information for the last 100 disturbances are saved in the IED and the local HMI is used to view the list of recordings.

### Fault locator LMBRFLO

The accurate fault locator is an essential component to minimize the outages after a persistent fault and/or to pin-point a weak spot on the line.

The fault locator is an impedance measuring function giving the distance to the fault in percent, km or miles. The main advantage is the high accuracy achieved by compensating for load current.

The compensation includes setting of the remote and local sources and calculation of the distribution of fault currents from each side. This distribution of fault current, together with recorded load (pre-fault) currents, is used to exactly calculate the fault position. The fault can be recalculated with new source data at the actual fault to further increase the accuracy.

Specially on heavily loaded long lines (where the fault locator is most important) where the source voltage angles can be up to 35-40 degrees apart the accuracy can be still maintained with the advanced compensation included in fault locator.

### Station battery supervision SPVNZBAT

The station battery supervision function SPVNZBAT is used for monitoring battery terminal voltage.

SPVNZBAT activates the start and alarm outputs when the battery terminal voltage exceeds the set upper limit or drops below the set lower limit. A time delay for the overvoltage and undervoltage alarms can be set according to definite time characteristics.

In the definite time (DT) mode, SPVNZBAT operates after a predefined operate time and resets when the battery undervoltage or overvoltage condition disappears.

### Insulation gas monitoring function SSIMG

Insulation gas monitoring function (SSIMG) is used for monitoring the circuit breaker condition. Binary information based on the gas pressure in the circuit breaker is used as input signals to the function. In addition to that, the function generates alarms based on received information.

### Insulation liquid monitoring function SSIML

Insulation liquid monitoring function (SSIML) is used for monitoring the circuit breaker condition. Binary information based on the oil level in the circuit breaker is used as input signals to the function. In addition to that, the function generates alarms based on received information.

### Circuit breaker monitoring SSCBR

The circuit breaker condition monitoring function (SSCBR) is used to monitor different parameters of the circuit breaker. The breaker requires maintenance when the number of operations has reached a predefined value. The energy is calculated from the measured input currents as a sum of $I^y t$ values. Alarms are generated when the calculated values exceed the threshold settings.

The function contains a blocking functionality. It is possible to block the function outputs, if desired.

## 13. Metering

### Pulse counter logic PCGGIO

Pulse counter (PCGGIO) function counts externally generated binary pulses, for instance pulses coming from an external energy meter, for calculation of energy consumption values. The pulses are captured by the BIO (binary input/output) module and then read by the PCGGIO function. A scaled service value is available over the station bus.

### Function for energy calculation and demand handling ETPMMTR

Outputs from Measurements (CVMMXN) function can be used to calculate energy. Active as well as reactive values are calculated in import and export direction. Values can be read or generated as pulses. Maximum demand power values are also calculated by the function.

## 14. Human Machine interface

### Local HMI

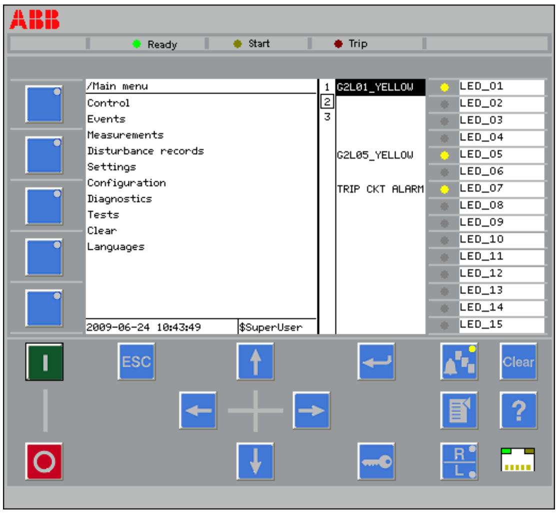


*Figure 5. Local human-machine interface*

The LHMI of the IED contains the following elements:

- Display (LCD)
- Buttons
- LED indicators
- Communication port

The LHMI is used for setting, monitoring and controlling.

The Local human machine interface, LHMI includes a graphical monochrome LCD with a resolution of 320x240 pixels. The character size may vary depending on local language selected. The amount of characters and rows fitting the view depends on the character size and the view that is shown.

LHMI can be detached from the main unit. The detached LHMI can be wall mounted up to a distance of 1-5 m from the main unit. The units are connected with the ethernet cable included in the delivery.

The LHMI is simple and easy to understand – the whole front plate is divided into zones, each of them with a well-defined functionality:

- Status indication LEDs
- Alarm indication LEDs which can indicate three states with the colors green, yellow and red, with user printable label. All LEDs are configurable from the PCM600 tool
- Liquid crystal display (LCD)
- Keypad with push buttons for control and navigation purposes, switch for selection between local and remote control and reset
- Five user programmable function buttons
- An isolated RJ45 communication port for PCM600

## 15. Basic IED functions

### Self supervision with internal event list

Self supervision with internal event list (INTERRSIG and SELFSUPEVLST) function listens and reacts to internal system events, generated by the different built-in self-supervision elements. The internal events are saved in an internal event list.

### Time synchronization

Use the time synchronization source selector to select a common source of absolute time for the IED when it is a part of a protection system. This makes comparison of events and disturbance data between all IEDs in a station automation system possible.

### Parameter setting groups ACTVGRP

Use the four sets of settings to optimize IED operation for different system conditions. By creating and switching between fine tuned setting sets, either from the local HMI or configurable binary inputs, results in a highly adaptable IED that can cope with a variety of system scenarios.

### Test mode functionality TESTMODE

The protection and control IEDs have many included functions. To make the testing procedure easier, the IEDs include the feature which allows to individually block a single, several or all functions.
There are two ways of entering the test mode:

- By configuration, activating an input signal of the function block TESTMODE
- By setting the IED in test mode in the local HMI

While the IED is in test mode, all functions are blocked.

Any function can be unblocked individually regarding functionality and event signalling. It enables the user to follow the operation of one or several related functions to check functionality and to check parts of the configuration etc.

### Change lock function CHNGLCK

Change lock function (CHNGLCK) is used to block further changes to the IED configuration and settings once the commissioning is complete. The purpose is to block inadvertent IED configuration changes beyond a certain point in time.

### Authority status ATHSTAT

Authority status (ATHSTAT) function is an indication function block for user log on activity.

### Authority check ATHCHCK

To safeguard the interests of our customers, both the IED and the tools that are accessing the IED are protected, subject of authorization handling. The concept of authorization, as it is implemented in the IED and in PCM600 is based on the following facts:

There are two types of access points to the IED:

- local, through the local HMI
- remote, through the communication ports

## 16. Station communication

### IEC 61850-8-1 communication protocol

The IED supports communication protocols IEC 61850-8-1 and DNP3 over TCP/IP. All operational information and controls are available through these protocols. However, some communication functionality, for example, horizontal communication (GOOSE) between the IEDs, is only enabled by the IEC 61850-8-1 communication protocol.

The IED is equipped an optical Ethernet rear port for substation communication standard IEC 61850-8-1. IEC 61850-8-1 communication is also possible from the optical Ethernet front port. IEC 61850-8-1 protocol allows intelligent devices (IEDs) from different vendors to exchange information and simplifies system engineering. Peer-to-peer communication according to GOOSE is part of the standard. Disturbance files uploading is provided.

Disturbance files are accessed using the IEC 61850-8-1 protocol. Disturbance files are available to any Ethernet based application in the standard COMTRADE format. Further, the IED sends and receives binary signals from other IEDs using the IEC 61850-8-1 GOOSE profile. The IED meets the GOOSE performance requirements for tripping applications in substations, as defined by the IEC 61850 standard. The IED interoperates with other IEC 61850 compliant IEDs, tools and systems and simultaneously reports events to five different clients on the IEC 61850 station bus.

All communication connectors, except for the front port connector, are placed on integrated communication modules. The IED is connected to Ethernet-based communication systems via the fibre-optic multimode LC connector (100BASE-FX).

The IED supports SNTP and IRIG-B time synchronization methods with a time-stamping resolution of 1 ms.

- Ethernet based: SNTP and DNP3
- With time synchronization wiring: IRIG-B

**Table 1. Supported communication interface and protocol alternatives**

| Interfaces/ Protocols | Ethernet 100BASE-FX LC |
|---|---|
| IEC 61850-8-1 | ● |
| DNP3 | ● |
| ● = Supported | |

## DNP3 protocol

DNP3 (Distributed Network Protocol) is a set of communications protocols used to communicate data between components in process automation systems. For a detailed description of the DNP3 protocol, see the DNP3 Communication protocol manual.

## Horizontal communication via GOOSE for interlocking

GOOSE communication can be used for gathering interlocking information via the station communication bus.

# 17. Hardware description

## Layout and dimensions

### Mounting alternatives

Following mounting alternatives (IP40 protection from the front) are available:

- 19” rack mounting kit
- Wall mounting kit
- Flush mounting kit
- 19" dual rack mounting kit

See ordering for details about available mounting alternatives.

### Flush mounting the IED

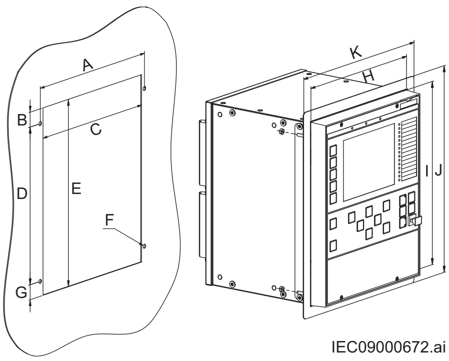


*Figure 6. Flush mounting the IED into a panel cut-out*

| | | | |
|---|---|---|---|
| A | 240 mm | G | 21.55 mm |
| B | 21.55 mm | H | 220 mm |
| C | 227 mm | I | 265.9 mm |
| D | 228.9 mm | J | 300 mm |
| E | 272 mm | K | 254 mm |
| F | ∅6 mm | | |

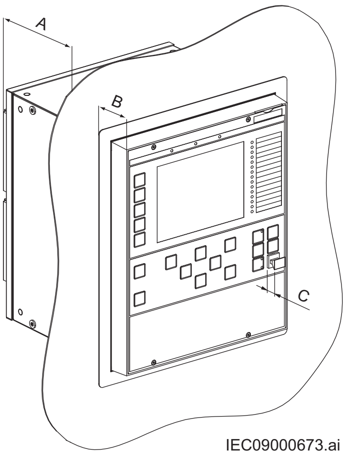


*Figure 7. Flush mounted IED*

| | |
|---|---|
| A | 222 mm |
| B | 27 mm |
| C | 13 mm |

## Rack mounting the IED

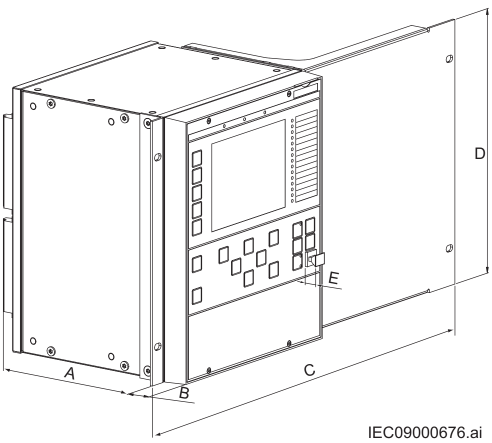


*Figure 8. Rack mounted IED*

| | |
|---|---|
| A | 224 mm + 12 mm with ring-lug connector |
| B | 25.5 mm |
| C | 482.6 mm (19") |
| D | 265.9 mm (6U) |
| E | 13 mm |

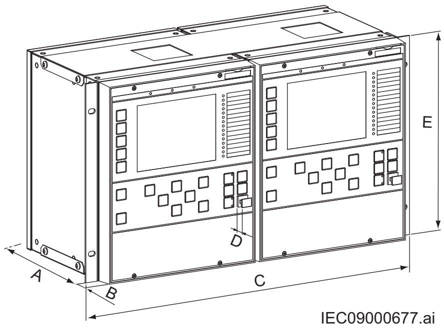


*Figure 9. Two rack mounted IEDs side by side*

| | |
|---|---|
| A | 224 mm + 12 mm with ring-lug connector |
| B | 25.5 mm |
| C | 482.6 mm (19") |
| D | 13 mm |
| E | 265.9 mm (6U) |

## Wall mounting the IED

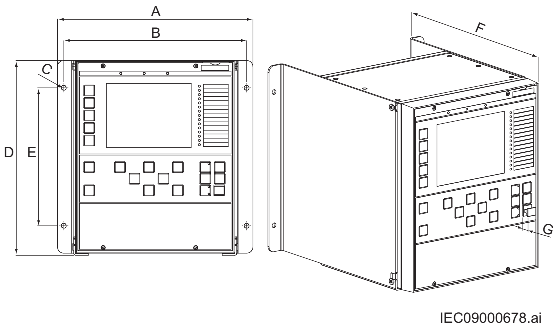


*Figure 10. Wall mounting the IED*

| | | | |
|---|---|---|---|
| A | 270 mm | E | 190.5 mm |
| B | 252.5 mm | F | 296 mm |
| C | ∅6.8 mm | G | 13 mm |
| D | 268.9 mm | | |

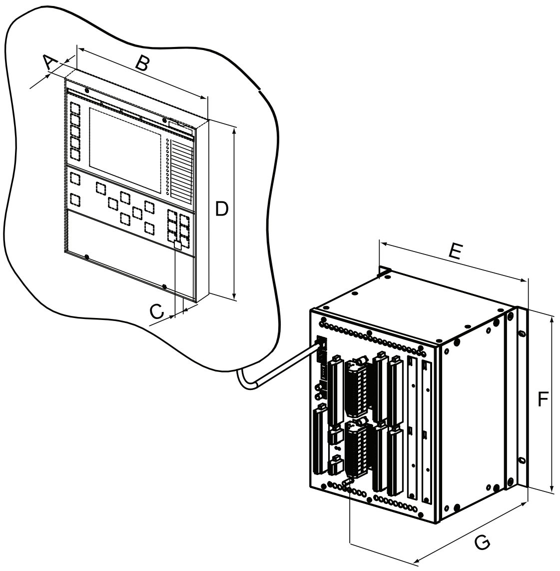


*Figure 11. Main unit and external LHMI display*

| | | | |
|---|---|---|---|
| A | 25.5 mm | E | 258.6 mm |
| B | 220 mm | F | 265.9 mm |
| C | 13 mm | G | 224 mm |
| D | 265.9 mm | | |

# 18. Connection diagrams

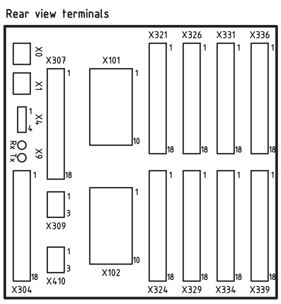


*Figure 12. Designation for 6U, 1/2x19" casing with 1 TRM*

| Module | Rear Position |
|---|---|
| COM | X0, X1, X4, X9,X304 |
| PSM | X307, X309, X410 |
| TRM | X101, X102 |
| BIO | X321, X324 |
| BIO | X326, X329 |
| BIO | X331, X334 |
| BIO | X336, X339 |

## Connection diagrams for REL650 A01 and A05

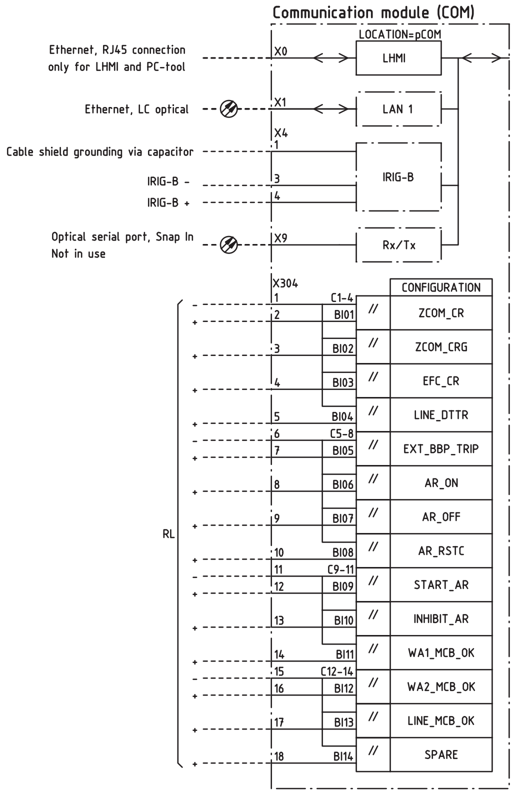


*Figure 13. Communication module (COM)*

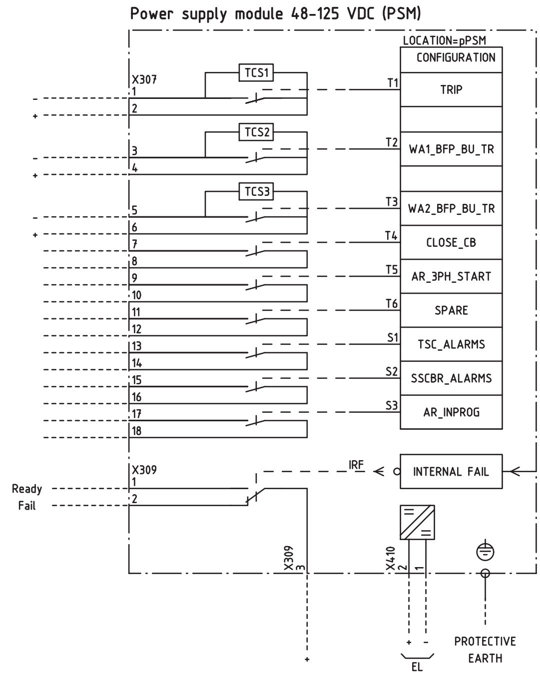


*Figure 14. Power supply module (PSM) 48-125V DC*

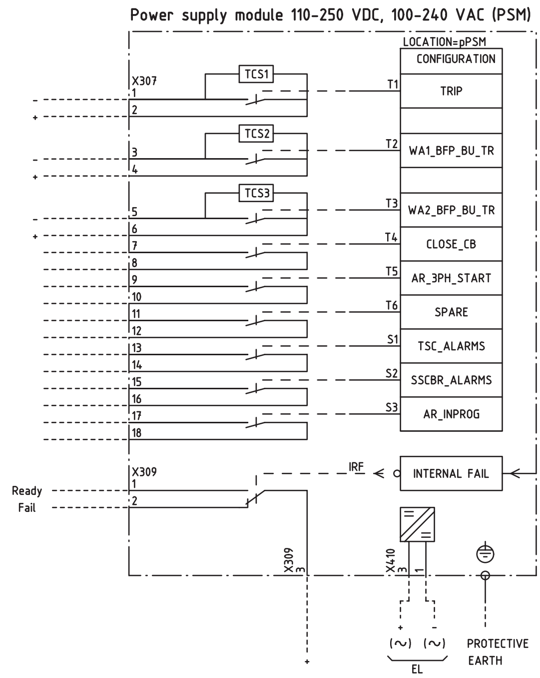


*Figure 15. Power supply module (PSM) AC, 110-250V DC*

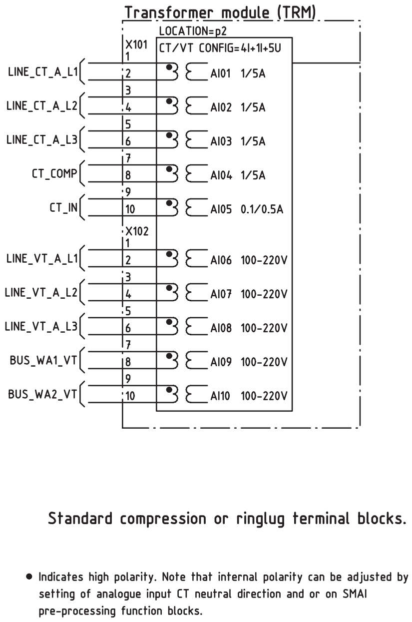


*Figure 16. Transformer module (TRM)*

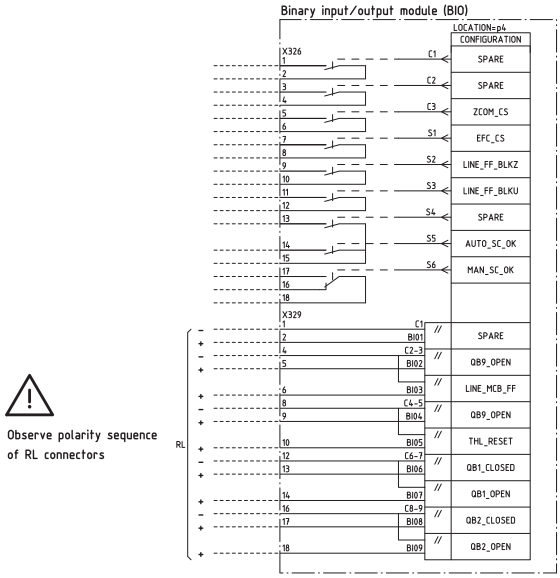


*Figure 18. Binary input/output (BIO) option (Terminal X326, X329)*

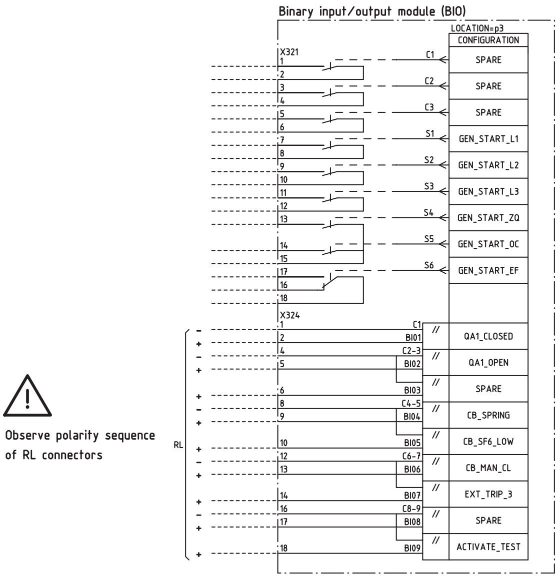


*Figure 17. Binary input/output (BIO) option (Terminal X321, X324)*

# 19. Technical data

## General

| Definitions | |
|---|---|
| Reference value | The specified value of an influencing factor to which are referred the characteristics of the equipment |
| Nominal range | The range of values of an influencing quantity (factor) within which, under specified conditions, the equipment meets the specified requirements |
| Operative range | The range of values of a given energizing quantity for which the equipment, under specified conditions, is able to perform its intended functions according to the specified requirements |

## Energizing quantities, rated values and limits

## Analog inputs

**Table 2. Energizing inputs**

| Description | | Value | |
|---|---|---|---|
| Rated frequency | | 50/60 Hz | |
| Operating range | | Rated frequency ± 5 Hz | |
| Current inputs | Rated current, $I_n$ | 0.1/0.5 A[1)] | 1/5 A[2)] |
| | Thermal withstand capability:<br>• Continuously<br>• For 1 s<br>• For 10 s | <br><br>4 A<br>100 A<br>25 A | <br><br>20 A<br>500 A<br>100 A |
| | Dynamic current withstand:<br>• Half-wave value | <br><br>250 A | <br><br>1250 A |
| | Input impedance | <100 mΩ | <10 mΩ |
| Voltage inputs | Rated voltage | 100 V/ 110 V/ 115 V/ 120 V (Parametrization) | |
| | Voltage withstand:<br>• Continuous<br>• For 10 s | <br>2 x $U_n$ (240 V)<br>3 x $U_n$ (360 V) | |
| | Burden at rated voltage | <0.05 VA | |

1) Residual current
2) Phase currents or residual current

### Auxiliary DC voltage

**Table 3. Power supply**

| Description | Type 1 | Type 2 |
| --- | --- | --- |
| $U_{aux}$nominal | 100, 110, 120, 220, 240 V AC, 50 and 60 Hz | 48, 60, 110, 125 V DC |
| | 110, 125, 220, 250 V DC | |
| $U_{aux}$variation | 85...110% of $U_n$ (85...264 V AC) | 80...120% of $U_n$ (38.4...150 V DC) |
| | 80...120% of $U_n$ (88...300 V DC) | |
| Maximum load of auxiliary voltage supply | 35 W | |
| Ripple in the DC auxiliary voltage | Max 15% of the DC value (at frequency of 100 Hz) | |
| Maximum interruption time in the auxiliary DC voltage without resetting the IED | 50 ms at $U_{aux}$ | |

### Binary inputs and outputs

**Table 4. Binary inputs**

| Description | Value |
| --- | --- |
| Operating range | Maximum input voltage 300 V DC |
| Rated voltage | 24...250 V DC |
| Current drain | 1.6...1.8 mA |
| Power consumption/input | <0.3 W |
| Threshold voltage | 15...221 V DC (parametrizable in the range in steps of 1% of the rated voltage) |

**Table 5. Signal output and IRF output**

| IRF relay change over - type signal output relay | |
|---|---|
| **Description** | **Value** |
| Rated voltage | 250 V AC/DC |
| Continuous contact carry | 5 A |
| Make and carry for 3.0 s | 10 A |
| Make and carry 0.5 s | 30 A |
| Breaking capacity when the control-circuit time constant L/R<40 ms, at U< 48/110/220 V DC | ≤0.5 A/≤0.1 A/≤0.04 A |
| Minimum contact load | 100 mA at 24 V AC/DC |

**Table 6. Power output relays, with or without TCS function**

| Description | Value |
|---|---|
| Rated voltage | 250 V AC/DC |
| Continuous contact carry | 8 A |
| Make and carry for 3.0 s | 15 A |
| Make and carry for 0.5 s | 30 A |
| Breaking capacity when the control-circuit time constant L/R<40 ms, at U< 48/110/220 V DC | ≤1 A/≤0.3 A/≤0.1 A |
| Minimum contact load | 100 mA at 24 V AC/DC |

**Table 7. Power output relays with TCS function**

| Description | Value |
|---|---|
| Control voltage range | 20...250 V DC |
| Current drain through the supervision circuit | ~1.0 mA |
| Minimum voltage over the TCS contact | 20 V DC |

**Table 8. Ethernet interfaces**

| Ethernet interface | Protocol | Cable | Data transfer rate |
|---|---|---|---|
| LAN/HMI port (X0)[1)] | - | CAT 6 S/FTP or better | 100 MBits/s |
| LAN1 (X1) | TCP/IP protocol | Fibre-optic cable with LC connector | 100 MBits/s |

1) Only available for the external HMI option.

**Table 9. Fibre-optic communication link**

| Wave length | Fibre type | Connector | Permitted path attenuation[1)] | Distance |
|---|---|---|---|---|
| 1300 nm | MM 62.5/125 µm glass fibre core | LC | <8 dB | 2 km |

1) Maximum allowed attenuation caused by connectors and cable together

**Table 10. X4/IRIG-B interface**

| Type | Protocol | Cable |
|---|---|---|
| Screw terminal, pin row header | IRIG-B | Shielded twisted pair cable<br>Recommended: CAT 5, Belden RS-485 (9841-9844) or Alpha Wire (Alpha 6222-6230) |

**Table 11. Serial rear interface**

| Type | Counter connector |
|---|---|
| Serial port (X9) | Optical serial port, snap-in (not in use) |

## Influencing factors

**Table 12. Degree of protection of flush-mounted IED**

| Description | Value |
|---|---|
| Front side | IP 40 |
| Rear side, connection terminals | IP 20 |

**Table 13. Degree of protection of the LHMI**

| Description | Value |
|---|---|
| Front and side | IP 42 |

**Table 14. Environmental conditions**

| Description | Value |
|---|---|
| Operating temperature range | -25...+55°C (continuous) |
| Short-time service temperature range | -40...+85°C (<16h)<br>Note: Degradation in MTBF and HMI performance outside the temperature range of -25...+55°C |
| Relative humidity | <93%, non-condensing |
| Atmospheric pressure | 86...106 kPa |
| Altitude | up to 2000 m |
| Transport and storage temperature range | -40...+85°C |

**Table 15. Environmental tests**

| Description | Type test value | Reference |
|---|---|---|
| Dry heat test (humidity <50%) | • 96 h at +55°C<br>• 16 h at +85°C | IEC 60068-2-2 |
| Cold test | • 96 h at -25°C<br>• 16 h at -40°C | IEC 60068-2-1 |
| Damp heat test, cyclic | • 6 cycles at +25…55°C, humidity 93…95% | IEC 60068-2-30 |
| Storage test | • 96 h at -40°C<br>• 96 h at +85°C | IEC 60068-2-48 |

## Type tests according to standards

**Table 16. Electromagnetic compatibility tests**

| Description | Type test value | Reference |
| --- | --- | --- |
| 100 kHz and 1 MHz burst disturbance test | | IEC 61000-4-18<br>IEC 60255-22-1, level 3 |
| • Common mode | 2.5 kV | |
| • Differential mode | 1.0 kV | |
| Electrostatic discharge test | | IEC 61000-4-2<br>IEC 60255-22-2, level 4 |
| • Contact discharge | 8 kV | |
| • Air discharge | 15 kV | |
| Radio frequency interference tests | | |
| • Conducted, common mode OK | 10 V (emf), f=150 kHz...80 MHz | IEC 61000-4-6<br>IEC 60255-22-6, level 3 |
| • Radiated, amplitude-modulated | 20 V/m (rms), f=80...1000 MHz and f=1.4...2.7 GHz | IEC 61000-4-3<br>IEC 60255-22-3 |
| Fast transient disturbance tests | | IEC 61000-4-4<br>IEC 60255-22-4, class A |
| • Communication | 2 kV | |
| • Other ports | 4 kV | |
| Surge immunity test | | IEC 61000-4-5<br>IEC 60255-22-5, level 4/3 |
| • Binary inputs | 2 kV line-to-earth, 1kV line-to-line | |
| • Communication | 1 kV line-to-earth | |
| • Other ports | 4 kV line-to-earth, 2 kV line-to-line | |
| Power frequency (50 Hz) magnetic field | | IEC 61000-4-8, level 5 |
| • 3 s | 1000 A/m | |
| • Continuous | 100 A/m | |

**Table 16. Electromagnetic compatibility tests, continued**

| Description | Type test value | Reference |
|---|---|---|
| Power frequency immunity test<br>• Common mode<br>• Differential mode | <br>300 V rms<br>150 V rms | IEC 60255-22-7, class A<br>IEC 61000-4-16 |
| Voltage dips and short interruptions | Dips:<br>40%/200 ms<br>70%/500 ms<br>Interruptions:<br>0-50 ms: No restart<br>0...∞ s : Correct behaviour at power down | IEC 60255-11<br>IEC 61000-4-11 |
| Electromagnetic emission tests<br>• Conducted, RF-emission (mains terminal) OK<br>0.15...0.50 MHz<br>0.5...30 MHz<br>• Radiated RF -emission<br>0...230 MHz<br>230...1000 MHz | <br><br>< 79 dB(µV) quasi peak<br>< 66 dB(µV) average<br>< 73 dB(µV) quasi peak<br>< 60 dB(µV) average<br><br>< 40 dB(µV/m) quasi peak, measured at 10 m distance<br>< 47 dB(µV/m) quasi peak, measured at 10 m distance | EN 55011, class A<br>IEC 60255-25 |

**Table 17. Insulation tests**

| Description | Type test value | Reference |
|---|---|---|
| Dielectric tests:<br>• Test voltage | <br>2 kV, 50 Hz, 1 min<br>1 kV, 50 Hz, 1min, communication | IEC 60255-5 |
| Impulse voltage test:<br>• Test voltage | <br>5 kV, unipolar impulses, waveform 1.2/50 μs, source energy 0.5 J<br>1 kV, unipolar impulses, waveform 1.2/50 μs, source energy 0.5 J, communication | IEC 60255-5 |
| Insulation resistance measurements<br>• Isolation resistance | <br>>100 MΩ, 500 V DC | IEC 60255-5 |
| Protective bonding resistance<br>• Resistance | <br><0.1 Ω (60 s) | IEC 60255-27 |

**Table 18. Mechanical tests**

| Description | Reference | Requirement |
|---|---|---|
| Vibration response tests (sinusoidal) | IEC 60255-21-1 | Class 2 |
| Vibration endurance test | IEC60255-21-1 | Class 1 |
| Shock response test | IEC 60255-21-2 | Class 1 |
| Shock withstand test | IEC 60255-21-2 | Class 1 |
| Bump test | IEC 60255-21-2 | Class 1 |
| Seismic test | IEC 60255-21-3 | Class 2 |

## Product safety

**Table 19. Product safety**

| Description | Reference |
|---|---|
| LV directive | 2006/95/EC |
| Standard | EN 60255-27 (2005) |

## EMC compliance

**Table 20. EMC compliance**

| Description | Reference |
|---|---|
| EMC directive | 2004/108/EC |
| Standard | EN 50263 (2000)<br>EN 60255-26 (2007) |

## Impedance protection

**Table 21. Distance measuring zone, Quad ZQDPDIS**

| Function | Range or value | Accuracy |
|---|---|---|
| Number of zones | 5 with selectable direction | - |
| Minimum operate residual current | (5-30)% of IBase | ± 1,0 % of $I_r$ |
| Minimum operate current, phase-to-phase and phase-to-earth | (10-30)% of IBase | ± 1,0 % of $I_r$ |
| Positive sequence impedance reach for zones | 0.005 - 3000.000 | ± 2.0% static accuracy<br>± 2.0 degrees static angular accuracy<br>Conditions:<br>Voltage range: (0.1-1.1) x $U_r$<br>Current range: (0.5-30) x $I_r$<br>Angle: at 0 degrees and 85 degrees |
| Fault resistance, phase-to-earth | (1.00-9000.00) Ω/loop | |
| Fault resistance, phase-to-phase | (1.00-3000.00) Ω/loop | |
| Line angle for zones | (0 - 180) degrees | |
| Magnitude of earth return compensation factor KN for zones | 0.00 - 3.00 | - |
| Angle for earth return compensation factor KN for zones | (-180 - 180) degrees | - |
| Dynamic overreach | <5% at 85 degrees measured with CVT's and 0.5<SIR<30 | - |
| Impedance zone timers | (0.000-60.000) s | ± 0.5% ± 10 ms |
| Operate time | 1.5 cycles typically | - |
| Reset ratio | 105% typically | - |
| Reset time | 30 ms typically | - |

**Table 22. Phase selection with load encroachment, quadrilateral characteristic FDPSPDIS**

| Function | Range or value | Accuracy |
|---|---|---|
| Minimum operate current | (5-30)% of IBase | ± 1.0% of $I_r$ |
| Reactive reach, positive sequence | (0.50–3000.00) | ± 2.0% static accuracy<br>± 2.0 degrees static angular accuracy<br>Conditions:<br>Voltage range: (0.1-1.1) x UBase<br>Current range: (0.5-30) x IBase<br>Angle: at 0 degrees and 85 degrees |
| Reactive reach, zero sequence, forward and reverse | (0.50 - 3000.00) | |
| Fault resistance, phase-to-earth faults, forward and reverse | (1.00–9000.00) Ω/loop | |
| Fault resistance, phase-to-phase faults, forward and reverse | (0.50–3000.00) Ω/loop | |
| Load encroachment criteria:<br>Load resistance, forward and reverse<br>Safety load impedance angle | (1.00–3000.00) Ω/phase<br>(5-70) degrees | |
| Reset ratio | 105% typically | - |

**Table 23. Full-scheme distance protection, Mho characteristic ZMOPDIS**

| Function | Range or value | Accuracy |
|---|---|---|
| Number of zones with selectable directions | 5 with selectable direction | - |
| Minimum operate current | (10–30)% of $I_{Base}$ | ± 2,0 % of $I_r$ |
| Positive sequence impedance | (0.005–3000.000) Ω/phase | ± 2.0% static accuracy<br>Conditions:<br>Voltage range: (0.1-1.1) x $U_r$<br>Current range: (0.5-30) x $I_r$<br>Angle: at 0 degrees and 85 degrees |
| Reverse positive sequence impedance | (0.005–3000.000) Ω/phase | |
| Impedance reach for phase-to-phase elements | (0.005–3000.000) Ω/phase | |
| Angle for positive sequence impedance, phase-to-phase elements | (10–90) degrees | |
| Reverse reach of phase-to-phase loop | (0.005–3000.000) Ω/phase | |
| Magnitude of earth return compensation factor KN | (0.00–3.00) | |
| Angle for earth compensation factor KN | (-180–180) degrees | |
| Dynamic overreach | <5% at 85 degrees measured with CVT's and 0.5<SIR<30 | - |
| Timers | (0.000-60.000) s | ± 0.5% ± 10 ms |
| Operate time | 1.5 cycles typically | - |
| Reset ratio | 105% typically | - |
| Reset time | 30ms typically | - |

**Table 24. Faulty phase identification with load encroachment FMPSPDIS**

| Function | Range or value | Accuracy |
|---|---|---|
| Load encroachment criteria: Load resistance, forward and reverse | (1.00–3000) Ω/phase<br>(5–70) degrees | ± 2.0% static accuracy<br>Conditions:<br>Voltage range: (0.1–1.1) x $U_n$<br>Current range: (0.5–30) x $I_n$ |

**Table 25. Phase preference logic PPLPHIZ**

| Function | Range or value | Accuracy |
|---|---|---|
| Operate value, phase-to-phase and phase-to-neutral undervoltage | (10.0 - 100.0)% of UBase | ± 0,5% of $U_r$ |
| Reset ratio, undervoltage | < 105% | - |
| Operate value, residual voltage | (5.0 - 300.0)% of UBase | ± 0,5% of $U_r$ |
| Reset ratio, residual voltage | > 95% | - |
| Operate value, residual current | (10 - 200)% of IBase | ± 1,0% of $I_r$ for I < Ir<br>± 1,0% of I for I > Ir |
| Reset ratio, residual current | > 95% | - |
| Timers | (0.000 - 60.000) s | ± 0,5% ± 10ms |
| Operating mode | No Filter, NoPref<br>Cyclic: 1231c, 1321c<br>Acyclic: 123a, 132a, 213a, 231a, 312a, 321a | |

**Table 26. Power swing detection ZMRPSB**

| Function | Range or value | Accuracy |
|---|---|---|
| Reactive reach | (0.10-3000.00) Ω | ± 2.0% static accuracy<br>Conditions:<br>Voltage range: (0.1-1.1) x $U_r$<br>Current range: (0.5-30) x $I_r$<br>Angle: at 0 degrees and 85 degrees |
| Resistive reach | (0.10–1000.00)Ω | |
| Timers | (0.000-60.000) s | ± 0.5% ± 10 ms |

**Table 27. Automatic switch onto fault logic, voltage and current based ZCVPSOF**

| Parameter | Range or value | Accuracy |
|---|---|---|
| Operate voltage, detection of dead line | (1–100)% of UBase | ± 0.5% of $U_r$ |
| Operate current, detection of dead line | (1–100)% of IBase | ± 1.0% of $I_r$ |
| Delay following dead line detection input before Automatic switch onto fault logic function is automatically turned On | (0.000–60.000) s | ± 0.5% ± 10 ms |
| Time period after circuit breaker closure in which Automatic switch onto fault logic function is active | (0.000–60.000) s | ± 0.5% ± 10 ms |

## Current protection

**Table 28. Instantaneous phase overcurrent protection PHPIOC**

| Function | Range or value | Accuracy |
|---|---|---|
| Operate current | (5-2500)% of lBase | ± 1.0% of $I_r$ at $I \leq I_r$<br>± 1.0% of I at $I > I_r$ |
| Reset ratio | > 95% | - |
| Operate time | 20 ms typically at 0 to 2 x $I_{set}$ | - |
| Reset time | 25 ms typically at 2 to 0 x $I_{set}$ | - |
| Critical impulse time | 10 ms typically at 0 to 2 x $I_{set}$ | - |
| Operate time | 10 ms typically at 0 to 10 x $I_{set}$ | - |
| Reset time | 35 ms typically at 10 to 0 x $I_{set}$ | - |
| Critical impulse time | 2 ms typically at 0 to 10 x $I_{set}$ | - |
| Dynamic overreach | < 5% at $\tau$ = 100 ms | - |

**Table 29. Four step phase overcurrent protection OC4PTOC**

| Function | Setting range | Accuracy |
|---|---|---|
| Operate current | (5-2500)% of lBase | ± 1.0% of $I_r$ at $I \leq I_r$<br>± 1.0% of I at $I > I_r$ |
| Reset ratio | > 95% | - |
| Min. operating current | (1-100)% of lBase | ± 1.0% of $I_r$ |
| Independent time delay | (0.000-60.000) s | ± 0.5% ± 10 ms |
| Minimum operate time for inverse characteristics | (0.000-60.000) s | ± 0.5% ± 10 ms |
| Inverse characteristics, see table 77, table 78 and table 79 | 17 curve types | See table 77, table 78 and table 79 |
| Operate time, nondirectionalstart function | 20 ms typically at 0 to 2 x $I_{set}$ | - |
| Reset time, nondirectional start function | 25 ms typically at 2 to 0 x $I_{set}$ | - |
| Operate time, directional start function | 30 ms typically at 0 to 2 x $I_{set}$ | - |
| Reset time, directional start funciton | 25 ms typically at 2 to 0 x $I_{set}$ | - |
| Critical impulse time | 10 ms typically at 0 to 2 x $I_{set}$ | - |
| Impulse margin time | 15 ms typically | - |

**Table 30. Instantaneous residual overcurrent protection EFPIOC**

| Function | Range or value | Accuracy |
|---|---|---|
| Operate current | (1-2500)% of lBase | ± 1.0% of $I_r$ at $I \leq I_r$<br>± 1.0% of I at $I > I_r$ |
| Reset ratio | > 95% | - |
| Operate time | 20 ms typically at 0 to 2 x $I_{set}$ | - |
| Reset time | 30 ms typically at 2 to 0 x $I_{set}$ | - |
| Critical impulse time | 10 ms typically at 0 to 2 x $I_{set}$ | - |
| Operate time | 10 ms typically at 0 to 10 x $I_{set}$ | - |
| Reset time | 40 ms typically at 10 to 0 x $I_{set}$ | - |
| Critical impulse time | 2 ms typically at 0 to 10 x $I_{set}$ | - |
| Dynamic overreach | < 5% at $\tau$ = 100 ms | - |

**Table 31. Four step residual overcurrent protection EF4PTOC**

| Function | Range or value | Accuracy |
|---|---|---|
| Operate current | (1-2500)% of lBase | $\pm$ 1.0% of $I_r$ at $I \leq I_r$<br>$\pm$ 1.0% of I at $I > I_r$ |
| Reset ratio | > 95% | - |
| Operate current for directional comparison | (1–100)% of lBase | $\pm$ 1.0% of $I_r$ |
| Timers | (0.000-60.000) s | $\pm$ 0.5% $\pm$ 10 ms |
| Inverse characteristics, see table 77, table 78 and table 79 | 17 curve types | See table 77, table 78 and table 79 |
| Second harmonic restrain operation | (5–100)% of fundamental | $\pm$ 2.0% of $I_r$ |
| Relay characteristic angle | (-180 to 180) degrees | $\pm$ 2.0 degrees |
| Minimum polarizing voltage | (1–100)% of UBase | $\pm$ 0.5% of $U_r$ |
| Minimum polarizing current | (2-100)% of IBase | $\pm$1.0% of $I_r$ |
| Real part of source Z used for current polarization | (0.50-1000.00) Ω/phase | - |
| Imaginary part of source Z used for current polarization | (0.50–3000.00) Ω/phase | - |
| Operate time, start function | 30 ms typically at 0.5 to 2 x Iset | - |
| Reset time, start function | 30 ms typically at 2 to x $I_{set}$ | - |
| Critical impulse time | 10 ms typically at 0 to 2 x $I_{set}$ | - |
| Impulse margin time | 15 ms typically | - |

**Table 32. Sensitive directional residual overcurrent and power protection SDEPSDE**

| Function | Range or value | Accuracy |
|---|---|---|
| Operate level for $3I_0 \cdot \cos\varphi$ directional residual overcurrent | (0.25-200.00)% of lBase<br><br>At low setting:<br>(2.5-10) mA<br>(10-50) mA | ± 1.0% of $I_r$ at $I \leq I_r$<br>± 1.0% of I at $I > I_r$<br><br>±0.5 mA<br>±1.0 mA |
| Operate level for $3I_0 \cdot 3U_0 \cdot \cos\varphi$ directional residual power | (0.25-200.00)% of SBase<br><br>At low setting:<br>(0.25-5.00)% of SBase | ± 1.0% of $S_r$ at $S \leq S_r$<br>± 1.0% of S at $S > S_r$<br><br>± 10% of set value |
| Operate level for $3I_0$ and φ residual overcurrent | (0.25-200.00)% of lBase<br><br>At low setting:<br>(2.5-10) mA<br>(10-50) mA | ± 1.0% of $I_r$ at $\leq I_r$<br>± 1.0% of I at $I > I_r$<br><br>±0.5 mA<br>±1.0 mA |
| Operate level for non directional overcurrent | (1.00-400.00)% of lBase<br><br>At low setting:<br>(10-50) mA | ± 1.0% of $I_r$ at $I \leq I_r$<br>± 1.0% of I at $I > I_r$<br><br>± 1.0 mA |
| Operate level for non directional residual overvoltage | (1.00-200.00)% of UBase | ± 0.5% of $U_r$ at $U \leq U_r$<br>± 0.5% of U at $U > U_r$ |
| Residual release current for all directional modes | (0.25-200.00)% of lBase<br><br>At low setting:<br>(2.5-10) mA<br>(10-50) mA | ± 1.0% of $I_r$ at $I \leq I_r$<br>± 1.0% of I at $I > I_r$<br><br>±0.5 mA<br>± 1.0 mA |
| Residual release voltage for all directional modes | (1.00 - 300.00)% of UBase | ± 0.5% of $U_r$ at $U \leq U_r$<br>± 0.5% of U at $> U_r$ |
| Reset ratio | > 95% | - |
| Timers | (0.000-60.000) s | ± 0.5% ± 10 ms |
| Inverse characteristics, see table 77, table 78 and table 79 | 17 curve types | See table 77, table 78 and table 79 |
| Relay characteristic angle RCA | (-179 to 180) degrees | ± 2.0 degrees |
| Relay open angle ROA | (0-90) degrees | ± 2.0 degrees |

**Table 32. Sensitive directional residual overcurrent and power protection SDEPSDE, continued**

| Function | Range or value | Accuracy |
|---|---|---|
| Operate time, non directional residual over current | 35 ms typically at 0.5 to 2 $\cdot I_{set}$ | - |
| Reset time, non directinal residual over current | 40 ms typically at 1.2 to 0 $\cdot I_{set}$ | - |
| Operate time, nondirectional residual overvoltage | 150 ms typically at 0.8 to 1.5 $\cdot U_{set}$ | - |
| Reset time, nondirectional residual overvoltage | 60 ms typically at 1.2 to 0.8 $\cdot U_{set}$ | - |

**Table 33. Time delayed 2-step undercurrent protection UC2PTUC**

| Function | Setting range | Accuracy |
|---|---|---|
| Low-set step of undercurrent limit, ILLow< | 5.0-100.0% of Ibase in steps of 0.1% | ± 2.5 % of $I_r$ |
| High-set step of undercurrent limit, ILHigh< | 5.0-100.0% of Ibase in steps of 0.1% | ± 2.5 % of $I_r$ |
| Time delayed operation of low-set step, tLow | 0.000-60.000 s in steps of 1 ms | ± 0.5 % ± 10 ms |
| Time delayed operation of high-set step, tHigh | 0.000-60.000 s in steps of 1 ms | ± 0.5 % ± 10 ms |
| Reset ratio | > 106% typically | |

**Table 34. Thermal overload protection, one time constant LPTTR**

| Function | Range or value | Accuracy |
|---|---|---|
| Reference current | (0-400)% of IBase | ± 1.0% of $I_r$ |
| Start temperature reference | (0-400)°C | ± 1.0°C |
| Operate time: $$t = \tau \cdot \ln\left(\frac{I^2 - I_p^{\,2}}{I^2 - I_b^{\,2}}\right)$$ (Equation 1) I = actual measured current $I_p$ = load current before overload occurs $I_b$ = base current, IBase | Time constant τ = (0–1000) minutes | IEC 60255-8, class 5 + 200 ms |
| Alarm temperature | (0-200)°C | ± 2.0% of heat content trip |
| Trip temperature | (0-600)°C | ± 2.0% of heat content trip |
| Reset level temperature | (0-600)°C | ± 2.0% of heat content trip |

**Table 35. Breaker failure protection CCRBRF**

| Function | Range or value | Accuracy |
|---|---|---|
| Operate phase current | (5-200)% of lBase | ± 1.0% of $I_r$ at $I \leq I_r$<br>± 1.0% of I at $I > I_r$ |
| Reset ratio, phase current | > 95% | - |
| Operate residual current | (2-200)% of lBase | ± 1.0% of $I_r$ at $I \leq I_r$<br>± 1.0% of I at $I > I_r$ |
| Reset ratio, residual current | > 95% | - |
| Phase current level for blocking of contact function | (5-200)% of lBase | ± 1.0% of $I_r$ at $I \leq I_r$<br>± 1.0% of I at $I > I_r$ |
| Reset ratio | > 95% | - |
| Timers | (0.000-60.000) s | ± 0.5% ± 10 ms |
| Operate time for current detection | 10 ms typically | - |
| Reset time for current detection | 15 ms maximum | - |

**Table 36. Stub protection STBPTOC**

| Function | Range or value | Accuracy |
|---|---|---|
| Operating current | (1-2500)% of IBase | ± 1.0% of $I_r$ at $I \leq I_r$<br>± 1.0% of I at $I > I_r$ |
| Reset ratio | > 95% | - |
| Operating time | 20 ms typically at 0 to 2 x $I_{set}$ | - |
| Resetting time | 25 ms typically at 2 to 0 x $I_{set}$ | - |
| Critical impulse time | 10 ms typically at 0 to 2 x $I_{set}$ | - |
| Impulse margin time | 15 ms typically | - |

**Table 37. Pole discordance protection CCRPLD**

| Function | Range or value | Accuracy |
|---|---|---|
| Operate value, current unsymmetry level | (0-100) % | ± 1.0% of $I_r$ |
| Reset ratio | >95% | - |
| Operate current, current release level | (0–100)% of IBase | ± 1.0% of $I_r$ |
| Time delay | (0.000-60.000) s | ± 0.5% ± 10 ms |

**Table 38. Broken conductor check BRCPTOC**

| Function | Range or value | Accuracy |
|---|---|---|
| Minimum phase current for operation | (5–100)% of IBase | ± 1.0% of $I_r$ |
| Unbalance current operation | (50-90)% of maximum current | ± 1.0% of $I_r$ |
| Timer | (0.00-6000.00) s | ± 0.5% ± 10 ms |
| Operate time for start function | 25 ms typically | - |
| Reset time for start function | 15 ms typically | - |
| Critical impulse time | 15 ms typically | - |
| Impulse margin time | 10 ms typically | - |

**Table 39. Directional over/underpower protection GOPPDOP/GUPPDUP**

| Function | Range or value | Accuracy |
|---|---|---|
| Power level | (0.0–500.0)% of Sbase<br><br>At low setting:<br>(0.5-2.0)% of Sbase<br>(2.0-10)% of Sbase | ± 1.0% of $S_r$ at S < $S_r$<br>± 1.0% of S at S > $S_r$<br><br>< ±50% of set value<br>< ± 20% of set value |
| Characteristic angle | (-180.0–180.0) degrees | 2 degrees |
| Timers | (0.010 - 6000.000) s | ± 0.5% ± 10 ms |

**Table 40. Negative sequence based overcurrent function DNSPTOC**

| Function | Range or value | Accuracy |
|---|---|---|
| Operate current | (2.0 - 5000.0) % of IBase | ± 1.0% of $I_r$ at I <$I_r$<br>± 1.0% of I at I > $I_r$ |
| Reset ratio | > 95 % | - |
| Low voltage level for memory | (0.0 - 5.0) % of UBase | < ± 0,5% of $U_r$ |
| Relay characteristic angle | (-180 - 180) degrees | ± 2,0 degrees |
| Relay operate angle | (1 - 90) degrees | ± 2,0 degrees |
| Timers | (0.00 - 6000.00) s | ± 0.5% ± 10 ms |
| Operate time, nondirectional | 25 ms typically at 0 to 2 x $I_{set}$<br>15 ms typically at 0 to 10 x $I_{set}$ | - |
| Reset time, nondirectional | 30 ms typically at 2 to 0 x $I_{set}$ | - |
| Operate time, directional | 25 ms typically at 0.5 to 2 x $I_{set}$<br>15 ms typically at 0 to 10 x $I_{set}$ | - |
| Reset time, directional | 30 ms typically at 2 to 0 x $I_{set}$ | - |
| Critical impulse time | 10 ms typically at 0 to 2 x $I_{set}$<br>2 ms typically at 0 to 10 x $I_{set}$ | - |
| Impulse margin time | 15 ms typically | - |
| Dynamic overreach | < 10% at t = 300 ms | - |

## Voltage protection

**Table 41. Two step undervoltage protection UV2PTUV**

| Function | Range or value | Accuracy |
|---|---|---|
| Operate voltage, low and high step | (1–100)% of UBase | ± 0.5% of $U_r$ |
| Reset ratio | <105% | - |
| Inverse time characteristics for low and high step, see table 80 | - | See table 80 |
| Definite time delay, step 1 | (0.00 - 6000.00) s | ± 0.5% ± 10 ms |
| Definite time delays, step 2 | (0.000-60.000) s | ± 0.5% ±10 ms |
| Minimum operate time, inverse characteristics | (0.000–60.000) s | ± 0.5% ± 10 ms |
| Operate time, start function | 20 ms typically at 2 to 0.5 x $U_{set}$ | - |
| Reset time, start function | 25 ms typically at 0.5 to 2 x $U_{set}$ | - |
| Critical impulse time | 10 ms typically at 2 to 0 x $U_{set}$ | - |
| Impulse margin time | 15 ms typically | - |

**Table 42. Two step overvoltage protection OV2PTOV**

| Function | Range or value | Accuracy |
|---|---|---|
| Operate voltage, low and high step | (1-200)% of Ubase | ± 0.5% of $U_r$ at $U < U_r$<br>± 0.5% of U at $U > U_r$ |
| Reset ratio | >95% | - |
| Inverse time characteristics for low and high step, see table 81 | - | See table 81 |
| Definite time delay, step 1 | (0.00 - 6000.00) s | ± 0.5% ± 10 ms |
| Definite time delays, step 2 | (0.000-60.000) s | ± 0.5% ± 10 ms |
| Minimum operate time, Inverse characteristics | (0.000-60.000) s | ± 0.5% ± 10 ms |
| Operate time, start function | 20 ms typically at 0 to 2 x $U_{set}$ | - |
| Reset time, start function | 25 ms typically at 2 to 0 x $U_{set}$ | - |
| Critical impulse time | 10 ms typically at 0 to 2 x $U_{set}$ | - |
| Impulse margin time | 15 ms typically | - |

**Table 43. Two step residual overvoltage protection ROV2PTOV**

| Function | Range or value | Accuracy |
|---|---|---|
| Operate voltage, step 1 | (1-200)% of Ubase | ± 0.5% of $U_r$ at $U < U_r$<br>± 0.5% of U at $U > U_r$ |
| Operate voltage, step 2 | (1–100)% of Ubase | ± 0.5% of $U_r$ at $U < U_r$<br>± % of U at $U > U_r$ |
| Reset ratio | >95% | - |
| Inverse time characteristics for low and high step, see table 82 | - | See table 82 |
| Definite time setting, step 1 | (0.00–6000.00) s | ± 0.5% ± 10 ms |
| Definite time setting, step 2 | (0.000–60.000) s | ± 0.5% ± 10 ms |
| Minimum operate time for step 1 inverse characteristic | (0.000-60.000) s | ± 0.5% ± 10 ms |
| Operate time, start function | 20 ms typically at 0 to 2 x $U_{set}$ | - |
| Reset time, start function | 25 ms typically at 2 to 0 x $U_{set}$ | - |
| Critical impulse time | 10 ms typically at 0 to 2 x $U_{set}$ | - |
| Impulse margin time | 15 ms typically | - |

**Table 44. Loss of voltage check LOVPTUV**

| Function | Range or value | Accuracy |
|---|---|---|
| Operate voltage | (0–100)% of Ubase | ± 0.5% of $U_r$ |
| Reset ratio | <105% | - |
| Pulse timer | (0.050–60.000) s | ± 0.5% ± 10 ms |
| Timers | (0.000–60.000) s | ± 0.5% ± 10 ms |

## Frequency protection

**Table 45. Under frequency protection SAPTUF**

| Function | Range or value | Accuracy |
|---|---|---|
| Operate value, start function | (35.00-75.00) Hz | ± 2.0 mHz |
| Operate value, restore frequency | (45 - 65) Hz | ± 2.0 mHz |
| Operate time, start function | 200 ms typically at $f_r$ to 0.99 x $f_{set}$ | - |
| Reset time, start function | 50 ms typically at 1.01 x $f_{set}$ to $f_r$ | - |
| Timers | (0.000-60.000)s | ± 0.5% + 10 ms |

**Table 46. Over frequency protection SAPTOF**

| Function | Range or value | Accuracy |
|---|---|---|
| Operate value, start function | (35.00-75.00) Hz | ± 2.0 mHz at symmetrical three-phase voltage |
| Operate time, start function | 200 ms typically at $f_r$ to 1.01 x $f_{set}$ | - |
| Reset time, start function | 50 ms typically at 1.01 x $f_{set}$ to $f_r$ | - |
| Timer | (0.000-60.000)s | ± 0.5% + 10 ms |

**Table 47. Rate-of-change frequency protection SAPFRC**

| Function | Range or value | Accuracy |
|---|---|---|
| Operate value, start function | (-10.00-10.00) Hz/s | ± 10.0 mHz/s |
| Operate value, restore enable frequency | (45.00 - 65.00) Hz | |
| Timers | (0.000 - 60.000) s | ± 0.5% + 10 ms |
| Operate time, start function | 100 ms typically | - |

## Secondary system supervision

**Table 48. Current circuit supervision CCSRDIF**

| Function | Range or value | Accuracy |
|---|---|---|
| Operate current | (5-200)% of $I_r$ | ± 10.0% of $I_r$ at $I \leq I_r$<br>± 10.0% of I at $I > I_r$ |
| Block current | (5-500)% of $I_r$ | ± 5.0% of $I_r$ at $I \leq I_r$<br>± 5.0% of I at $I > I_r$ |

**Table 49. Fuse failure supervision SDDRFUF**

| Function | Range or value | Accuracy |
|---|---|---|
| Operate voltage, zero sequence | (1-100)% of UBase | ± 0.5% of $U_r$ |
| Operate current, zero sequence | (1–100)% of IBase | ± 1.0% of $I_r$ |
| Operate voltage, negative sequence | (1–100)% of UBase | ± 0.5% of $U_r$ |
| Operate current, negative sequence | (1–100)% of IBase | ± 1.0% of $I_r$ |
| Operate voltage change level | (1–100)% of UBase | ± 5.0% of $U_r$ |
| Operate current change level | (1–100)% of IBase | ± 5.0% of $I_r$ |

**Table 50. Breaker close/trip circuit monitoring  TCSSCBR**

| Function | Range or value | Accuracy |
|---|---|---|
| Operate time delay | (0.020 - 300.000)s | ± 0,5% ± 10ms |

## Control

**Table 51. Synchronizing, synchrocheck check and energizing check SESRSYN**

| Function | Range or value | Accuracy |
|---|---|---|
| Phase shift, $\varphi_{line}$ - $\varphi_{bus}$ | (-180 to 180) degrees | - |
| Voltage ratio, $U_{bus}/U_{line}$ | 0.20-5.00 | - |
| Frequency difference limit between bus and line | (0.003-1.000) Hz | ± 2.0 mHz |
| Phase angle difference limit between bus and line | (5.0-90.0) degrees | ± 2.0 degrees |
| Voltage difference limit between bus and line | (2.0-50.0)% of Ubase | ± 0.5% of $U_r$ |
| Time delay output for synchrocheck | (0.000-60.000) s | ± 0.5% ± 10 ms |
| Time delay for energizing check | (0.000-60.000) s | ± 0.5% ± 10 ms |
| Operate time for synchrocheck function | 160 ms typically | - |
| Operate time for energizing function | 80 ms typically | - |

**Table 52. Autorecloser SMBRREC**

| Function | Range or value | Accuracy |
|---|---|---|
| Number of autoreclosing shots | 1 - 5 | - |
| Autoreclosing open time:<br>shot 1 - t1 3Ph | (0.000-60.000) s | ± 0.5% ± 10 ms |
| shot 2 - t2 3Ph<br>shot 3 - t3 3Ph<br>shot 4 - t4 3Ph<br>shot 5 - t5 3Ph | (0.00-6000.00) s | |
| Autorecloser maximum wait time for sync | (0.00-6000.00) s | |
| Maximum trip pulse duration | (0.000-60.000) s | |
| Inhibit reset time | (0.000-60.000) s | |
| Reclaim time | (0.00-6000.00) s | |
| Minimum time CB must be closed before AR becomes ready for autoreclosing cycle | (0.00-6000.00) s | |
| CB check time before unsuccessful | (0.00-6000.00) s | |
| Wait for master release | (0.00-6000.00) s | |
| Wait time after close command before proceeding to next shot | (0.000-60.000) s | |

## Scheme communication

**Table 53. Scheme communication logic for distance or overcurrent protection ZCPSCH**

| Function | Range or value | Accuracy |
| --- | --- | --- |
| Scheme type | Off<br>Intertrip<br>Permissive UR<br>Permissive OR<br>Blocking | - |
| Co-ordination time for blocking communication scheme | (0.000-60.000) s | ± 0.5% ± 10 ms |
| Minimum duration of a carrier send signal | (0.000-60.000) s | ± 0.5% ± 10 ms |
| Security timer for loss of guard signal detection | (0.000-60.000) s | ± 0.5% ± 10 ms |
| Operation mode of unblocking logic | Off<br>NoRestart<br>Restart | - |

**Table 54. Current reversal and weak-end infeed logic for distance protection ZCRWPSCH**

| Function | Range or value | Accuracy |
| --- | --- | --- |
| Operating mode of WEI logic | Off<br>Echo<br>Echo & Trip | - |
| Detection level phase-to-neutral and phase-to-phase voltage | (10-90)% of UBase | ± 0.5% of $U_r$ |
| Reset ratio | <105% | - |
| Operate time for current reversal logic | (0.000-60.000) s | ± 0.5% ± 10 ms |
| Delay time for current reversal | (0.000-60.000) s | ± 0.5% ± 10 ms |
| Coordination time for weak-end infeed logic | (0.000-60.000) s | ± 0.5% ± 10 ms |

**Table 55. Scheme communication logic for residual overcurrent protection ECPSCH**

| Function | Range or value | Accuracy |
|---|---|---|
| Scheme type | Off<br>Intertrip<br>Permissive UR<br>Permissive OR<br>Blocking | - |
| Communication scheme coordination time | (0.000-60.000) s | ± 0.5% ± 10 ms |
| Minimum duration of a send signal | (0.000-60.000) s | ± 0.5% ± 10 ms |
| Security timer for loss of carrier guard detection | (0.000-60.000) s | ± 0.5% ± 10 ms |

**Table 56. Current reversal and weak-end infeed logic for residual overcurrent protection ECRWPSCH**

| Function | Range or value | Accuracy |
|---|---|---|
| Operating mode of WEI logic | Off<br>Echo<br>Echo & Trip | - |
| Operate voltage $3U_0$ for WEI trip | (5-70)% of UBase | ± 1.0% of $U_r$ |
| Reset ratio | >95% | - |
| Operate time for current reversal logic | (0.000-60.000) s | ± 0.5% ± 10 ms |
| Delay time for current reversal | (0.000-60.000) s | ± 0.5% ± 10 ms |
| Coordination time for weak-end infeed logic | (0.000–60.000) s | ± 0.5% ± 10 ms |

## Logic

**Table 57. Tripping logic SMPPTRC**

| Function | Range or value | Accuracy |
|---|---|---|
| Trip action | 3-ph | - |
| Minimum trip pulse length | (0.000-60.000) s | ± 0.5% ± 10 ms |

**Table 58. Configurable logic blocks**

| Logic block | Quantity with cycle time | | | Range or value | Accuracy |
|---|---|---|---|---|---|
| | 5 ms | 20 ms | 100 ms | | |
| LogicAND | 60 | 60 | 160 | - | - |
| LogicOR | 60 | 60 | 160 | - | - |
| LogicXOR | 10 | 10 | 20 | - | - |
| LogicInverter | 30 | 30 | 80 | - | - |
| LogicSRMemory | 10 | 10 | 20 | - | - |
| LogicGate | 10 | 10 | 20 | - | - |
| LogicPulseTimer | 10 | 10 | 20 | (0.000–90000.000) s | ± 0.5% ± 10 ms |
| LogicTimerSet | 10 | 10 | 20 | (0.000–90000.000) s | ± 0.5% ± 10 ms |
| LogicLoopDelay | 10 | 10 | 20 | | |

## Monitoring

**Table 59. Measurements CVMMXN**

| Function | Range or value | Accuracy |
|---|---|---|
| Frequency | $(0.95\text{-}1.05) \times f_r$ | ± 2.0 mHz |
| Connected current | $(0.2\text{-}4.0) \times I_r$ | ± 0.5% of $I_r$ at $I \leq I_r$<br>± 0.5% of I at $I > I_r$ |

**Table 60. Event counter CNTGGIO**

| Function | Range or value | Accuracy |
|---|---|---|
| Counter value | 0-10000 | - |
| Max. count up speed | 10 pulses/s | - |

**Table 61. Disturbance report DRPRDRE**

| Function | Range or value | Accuracy |
|---|---|---|
| Current recording | - | ± 1,0% of $I_r$ at I ≤ $I_r$<br>± 1,0% of I at I > Ir |
| Voltage recording | - | ± 1,0% of $U_r$ at U ≤ $U_r$<br>± 1,0% of U at U > $U_r$ |
| Pre-fault time | (0.05–3.00) s | - |
| Post-fault time | (0.1–10.0) s | - |
| Limit time | (0.5–8.0) s | - |
| Maximum number of recordings | 100 | - |
| Time tagging resolution | 1 ms | See time synchronization technical data |
| Maximum number of analog inputs | 30 + 10 (external + internally derived) | - |
| Maximum number of binary inputs | 96 | - |
| Maximum number of phasors in the Trip Value recorder per recording | 30 | - |
| Maximum number of indications in a disturbance report | 96 | - |
| Maximum number of events in the Event recording per recording | 150 | - |
| Maximum number of events in the Event list | 1000, first in - first out | - |
| Maximum total recording time (3.4 s recording time and maximum number of channels, typical value) | 340 seconds (100 recordings) at 50 Hz, 280 seconds (80 recordings) at 60 Hz | - |
| Sampling rate | 1 kHz at 50 Hz<br>1.2 kHz at 60 Hz | - |
| Recording bandwidth | (5-300) Hz | - |

**Table 62. Fault locator LMBRFLO**

| Function | Value or range | Accuracy |
|---|---|---|
| Reactive and resistive reach | (0.001-1500.000) Ω/phase | ± 2.0% static accuracy<br>± 2.0% degrees static angular accuracy<br>Conditions:<br>Voltage range: (0.1-1.1) x $U_r$<br>Current range: (0.5-30) x $I_r$ |
| Phase selection | According to input signals | - |
| Maximum number of fault locations | 100 | - |

**Table 63. Event list DRPRDRE**

| Function | | Value |
|---|---|---|
| Buffer capacity | Maximum number of events in the list | 1000 |
| Resolution | | 1 ms |
| Accuracy | | Depending on time synchronizing |

**Table 64. Indications DRPRDRE**

| Function | | Value |
|---|---|---|
| Buffer capacity | Maximum number of indications presented for single disturbance | 96 |
| | Maximum number of recorded disturbances | 100 |

**Table 65. Event recorder DRPRDRE**

| Function | | Value |
|---|---|---|
| Buffer capacity | Maximum number of events in disturbance report | 150 |
| | Maximum number of disturbance reports | 100 |
| Resolution | | 1 ms |
| Accuracy | | Depending on time synchronizing |

**Table 66. Trip value recorder DRPRDRE**

| Function | | Value |
|---|---|---|
| Buffer capacity | Maximum number of analog inputs | 30 |
| | Maximum number of disturbance reports | 100 |

**Table 67. Disturbance recorder DRPRDRE**

| Function | | Value |
|---|---|---|
| Buffer capacity | Maximum number of analog inputs | 40 |
| | Maximum number of binary inputs | 96 |
| | Maximum number of disturbance reports | 100 |
| Maximum total recording time (3.4 s recording time and maximum number of channels, typical value) | | 340 seconds (100 recordings) at 50 Hz<br>280 seconds (80 recordings) at 60 Hz |

**Table 68. Station battery supervision SPVNZBAT**

| Function | Range or value | Accuracy |
|---|---|---|
| Lower limit for the battery terminal voltage | (60-140) % of Ubat | ± 0,5% of set battery voltage |
| Reset ratio, lower limit | <105 % | - |
| Upper limit for the battery terminal voltage | (60-140) % of Ubat | ± 0,5% of set battery voltage |
| Reset ratio, upper limit | >95 % | - |
| Timers | (0.000-60.000) s | ± 0.5% ± 10 ms |

**Table 69. Insulation gas monitoring function SSIMG**

| Function | Range or value | Accuracy |
|---|---|---|
| Pressure alarm | 0.00-25.00 | - |
| Pressure lockout | 0.00-25.00 | - |
| Temperature alarm | -40.00-200.00 | - |
| Temperature lockout | -40.00-200.00 | - |
| Timers | (0.000-60.000) s | ± 0.5% ± 10 ms |

**Table 70. Insulation liquid monitoring function SSIML**

| Function | Range or value | Accuracy |
|---|---|---|
| Alarm, oil level | 0.00-25.00 | - |
| Oil level lockout | 0.00-25.00 | - |
| Temperature alarm | -40.00-200.00 | - |
| Temperature lockout | -40.00-200.00 | - |
| Timers | (0.000-60.000) s | ± 0.5% ± 10 ms |

**Table 71. Circuit breaker condition monitoring SSCBR**

| Function | Range or value | Accuracy |
|---|---|---|
| RMS current setting below which energy accumulation stops | (5.00-500.00) A | ± 1.0% of $I_r$ at $I \leq I_r$<br>± 1.0% of I at $I>I_r$ |
| Alarm level for accumulated energy | 0.00-20000.00 | < ± 5.0% of set value |
| Lockout limit for accumulated energy | 0.00-20000.00 | < ± 5.0% of set value |
| Alarm levels for open and close travel time | (0-200) ms | ± 0.5% ± 10ms |
| Setting of alarm for spring charging time | (0.00-60.00) s | ± 0.5% ± 10ms |
| Time delay for gas pressure alarm | (0.00-60.00) s | ± 0.5% ± 10ms |
| Time delay for gas pressure lockout | (0.00-60.00) s | ± 0.5% ± 10ms |

## Metering

**Table 72. Pulse counter PCGGIO**

| Function | Setting range | Accuracy |
|---|---|---|
| Cycle time for report of counter value | (1–3600) s | - |

**Table 73. Function for energy calculation and demand handling ETPMMTR**

| Function | Range or value | Accuracy |
|---|---|---|
| Energy metering | kWh Export/Import, kvarh Export/Import | Input from MMXU. No extra error at steady load |

## Hardware

### IED

**Table 74. Degree of protection of flush-mounted IED**

| Description | Value |
|---|---|
| Front side | IP 40 |
| Rear side, connection terminals | IP 20 |

**Table 75. Degree of protection of the LHMI**

| Description | Value |
|---|---|
| Front and side | IP 42 |

### Dimensions

**Table 76. Dimensions**

| Description | Type | Value |
|---|---|---|
| Width | half 19" | 220 mm |
| Height | half 19" | |
| Depth | half 19" | 249.5 mm |
| Weight | half 19" box | <10 kg (6U) |
| | half 19" LHMI | 1.3 kg (6U) |

## Inverse time characteristics

**Table 77. ANSI Inverse time characteristics**

| Function | Range or value | Accuracy |
|---|---|---|
| Operating characteristic: $t = \left( \frac{A}{\left( I^{P} - 1 \right)} + B \right) \cdot k$ (Equation 2) $I = I_{measured}/I_{set}$ | k = 0.05-999 in steps of 0.01 unless otherwise stated | - |
| ANSI Extremely Inverse | A=28.2, B=0.1217, P=2.0 | ANSI/IEEE C37.112, class 5 + 40 ms |
| ANSI Very inverse | A=19.61, B=0.491, P=2.0 | |
| ANSI Normal Inverse | A=0.0086, B=0.0185, P=0.02, tr=0.46 | |
| ANSI Moderately Inverse | A=0.0515, B=0.1140, P=0.02 | |
| ANSI Long Time Extremely Inverse | A=64.07, B=0.250, P=2.0 | |
| ANSI Long Time Very Inverse | A=28.55, B=0.712, P=2.0 | |
| ANSI Long Time Inverse | k=(0.01-1.20) in steps of 0.01<br>A=0.086, B=0.185, P=0.02 | |

**Table 78. IEC Inverse time characteristics**

| Function | Range or value | Accuracy |
|---|---|---|
| Operating characteristic: $t = \left( \frac{A}{\left( I^{P} - 1 \right)} \right) \cdot k$ (Equation 3) $I = I_{measured}/I_{set}$ | k = (0.05-1.10) in steps of 0.01 | - |
| IEC Normal Inverse | A=0.14, P=0.02 | IEC 60255-3, class 5 + 40 ms |
| IEC Very inverse | A=13.5, P=1.0 | |
| IEC Inverse | A=0.14, P=0.02 | |
| IEC Extremely inverse | A=80.0, P=2.0 | |
| IEC Short time inverse | A=0.05, P=0.04 | |
| IEC Long time inverse | A=120, P=1.0 | |

**Table 79. RI and RD type inverse time characteristics**

| Function | Range or value | Accuracy |
|---|---|---|
| RI type inverse characteristic<br>$$t = \frac{1}{0.339 - \frac{0.236}{I}} \cdot k$$<br>(Equation 4)<br>$I = I_{measured}/I_{set}$ | k=(0.05-999) in steps of 0.01 | IEC 60255-3, class 5 + 40 ms |
| RD type logarithmic inverse characteristic<br>$$t = 5.8 - \left(1.35 \cdot \ln \frac{I}{k}\right)$$<br>(Equation 5)<br>$I = I_{measured}/I_{set}$ | k=(0.05-1.10) in steps of 0.01 | IEC 60255-3, class 5 + 40 ms |

**Table 80. Inverse time characteristics for Two step undervoltage protection UV2PTUV**

| Function | Range or value | Accuracy |
|---|---|---|
| Type A curve:<br>$$t = \frac{k}{\left(\frac{U< - U}{U<}\right)}$$<br>(Equation 6)<br>$U< = U_{set}$<br>$U = UV_{measured}$ | k = (0.05-1.10) in steps of 0.01 | Class 5 +40 ms |
| Type B curve:<br>$$t = \frac{k \cdot 480}{\left(32 \cdot \frac{U< - U}{U<} - 0.5\right)^{2.0}} + 0.055$$<br>(Equation 7)<br>$U< = U_{set}$<br>$U = U_{measured}$ | k = (0.05-1.10) in steps of 0.01 | |

**Table 81. Inverse time characteristics for Two step overvoltage protection OV2PTOV**

| Function | Range or value | Accuracy |
|---|---|---|
| Type A curve:<br>$$t = \frac{k}{\left(\frac{U - U>}{U>}\right)}$$<br>(Equation 8)<br>U> = $U_{set}$<br>U = $U_{measured}$ | k = (0.05-1.10) in steps of 0.01 | Class 5 +40 ms |
| Type B curve:<br>$$t = \frac{k \cdot 480}{\left(32 \cdot \frac{U - U>}{U>} - 0.5\right)^{2.0} - 0.035}$$<br>(Equation 9) | k = (0.05-1.10) in steps of 0.01 | |
| Type C curve:<br>$$t = \frac{k \cdot 480}{\left(32 \cdot \frac{U - U>}{U>} - 0.5\right)^{3.0} - 0.035}$$<br>(Equation 10) | k = (0.05-1.10) in steps of 0.01 | |

**Table 82. Inverse time characteristics for Two step residual overvoltage protection ROV2PTOV**

| Function | Range or value | Accuracy |
| --- | --- | --- |
| Type A curve: $$t = \frac{k}{\left(\frac{U - U>}{U>}\right)}$$ (Equation 11) U> = $U_{set}$ U = $U_{measured}$ | k = (0.05-1.10) in steps of 0.01 | Class 5 +40 ms |
| Type B curve: $$t = \frac{k \cdot 480}{\left(32 \cdot \frac{U - U>}{U>} - 0.5\right)^{2.0} - 0.035}$$ (Equation 12) | k = (0.05-1.10) in steps of 0.01 | |
| Type C curve: $$t = \frac{k \cdot 480}{\left(32 \cdot \frac{U - U>}{U>} - 0.5\right)^{3.0} - 0.035}$$ (Equation 13) | k = (0.05-1.10) in steps of 0.01 | |

# 20. Ordering

**Guidelines**
Carefully read and follow the set of rules to ensure problem-free order management.
Please refer to the available functions table for included application functions.

To obtain the complete ordering code, please combine code from the tables, as given in the example below.

Exemple code: REL650*1.0-A01X00-X00-B1A5-A-A-SA-A-RA3-AAXX-A. Using the code of each position #1-11 specified as REL650*1-2 2-3-4 4-5-6-7 7-8-9 9-10 10 10 10-11

| # | 1 | - | 2 | | - | 3 | - | 4 | | - | 5 | 6 | - | 7 | | - | 8 | - | 9 | | - | 10 | | | | - | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REL650* | | - | | | - | | - | | | - | | | - | | | . | | - | | | - | | | | | . | |

| | Position | |
|---|---|---|
| **SOFTWARE** | **#1** | **Notes and Rules** |
| **Version number** | | |
| Version no | 1.0 | |
| **Selection for position #1.** | | |

| **Configuration alternatives** | **#2** | | **Notes and Rules** |
|---|---|---|---|
| Single breaker, 3-phase tripping, quadrilateral | A01 | | |
| Single breaker, 3-phase tripping, mho | A05 | | |
| **ACT configuration** | | | |
| ABB standard configuration | | X00 | |
| **Selection for position #2.** | | | |

| **Software options** | **#3** | **Notes and Rules** |
|---|---|---|
| No option | X00 | |
| **Selection for postition #3** | | |

| **First HMI language** | **#4** | | **Notes and Rules** |
|---|---|---|---|
| English IEC | B1 | | |
| **Selection for position #4.** | | | |
| **Additional HMI language** | | #4 | |
| No second HMI language | | X0 | |
| Chinese | | A5 | |
| **Selection for position #4.** | | | |

| Casing | #5 | Notes and Rules |
|---|---|---|
| Rack casing, 6 U 1/2 x 19" | A | |
| **Selection for position #5.** | | |

| Mounting details with IP40 of protection from the front | #6 | Notes and Rules |
|---|---|---|
| No mounting kit included | X | |
| Rack mounting kit for 6 U 1/2 x 19" | A | |
| Wall mounting kit for 6U 1/2 x 19" | D | |
| Flush mounting kit for 6U 1/2 x 19" | E | |
| Rear wall mounting kit 6U 1/2 x 19" | G | |
| **Selection for position #6.** | | |

| Connection type for Power supply, Input/output and Communication modules | #7 | | Notes and Rules |
|---|---|---|---|
| Compression terminals | S | | |
| Ringlug terminals | R | | |
| **Power supply** | | | |
| **Slot position:** | | pPSM | |
| 100-240V AC, 110-250V DC, 9BO | | A | |
| 48-125V DC, 9BO | | B | |
| **Selection for position #7.** | | | |

| Human machine interface | #8 | | Notes and Rules |
|---|---|---|---|
| Local human machine interface, OL3000, IEC 6U 1/2 x 19", Basic | A | | |
| **Detached LHMI** | | | |
| No detached mounting of LHMI | | X0 | |
| Detached mounting of LHMI incl. ethernet cable, 1m | | B1 | |
| Detached mounting of LHMI incl. ethernet cable, 2m | | B2 | |
| Detached mounting of LHMI incl. ethernet cable, 3m | | B3 | |
| Detached mounting of LHMI incl. ethernet cable, 4m | | B4 | |
| Detached mounting of LHMI incl. ethernet cable, 5m | | B5 | |
| **Selection for position #8.** | | | |

| Connection type for Analog modules | #9 | | Notes and Rules |
|---|---|---|---|
| Compression terminals | S | | |
| Ringlug terminals | R | | |
| **Analog system** | | | |
| **Slot position:** | | p2 | |
| Transformer module, 4I, 1/5A+1I, 0.1/0.5A+5U, 100/220V | | A3 | |
| **Selection for position #9.** | | | |

| Binary input/output module | #10 | | | | Notes and Rules |
|---|---|---|---|---|---|
| **Slot position (rear view)** | p3 | p4 | p5 | p6 | |
| Available slots in 1/2 case | | | | | |
| No board in slot | | | X | X | |
| Binary input/output module 9 BI, 3 NO Trip, 5 NO Signal, 1 CO Signal | A | A | A | A | |
| **Selection for position #10.** | A | A | | | |

| Communication and processing module | #11 | Notes and Rules |
|---|---|---|
| **Slot position (rear view)** | pCOM | |
| 14BI, IRIG-B, Ethernet, LC optical | D | |
| **Selection for position #11.** | | |

# Accessories

## Configuration and monitoring tools

| | | | |
|---|---|---|---|
| Front connection cable between LCD-HMI and PC | Quantity: | ☐ | 1MRK 001 665-CA |
| LED Label special paper A4, 1 pc | Quantity: | ☐ | 1MRK 002 038-CA |
| LED Label special paper Letter, 1 pc | Quantity: | ☐ | 1MRK 002 038-DA |

# Manuals

Note: One (1) IED Connect CD containing user documentation (Operation manual, Technical manual, Installation manual, Commissioning manual, Application manual, Communication protocol manual, DNP, Communication protocol manual, IEC61850, Type test certificate, Engineering manual and Point list manual, DNP3, Connectivity packages and LED label template is always included for each IED.

*Rule: Specify additional quantity of IED Connect CD requested*

| | | | | |
|---|---|---|---|---|
| User documentation | | Quantity: | ☐ | 1MRK 003 500-AA |

*Rule: Specify the number of printed manuals requested*

| | | | | |
|---|---|---|---|---|
| Operation manual | IEC | Quantity: | ☐ | 1MRK 500 088-UEN |
| Technical manual | IEC | Quantity: | ☐ | 1MRK 506 304-UEN |
| Commissioning manual | IEC | Quantity: | ☐ | 1MRK 506 307-UEN |
| Application manual | IEC | Quantity: | ☐ | 1MRK 506 305-UEN |
| Communication protocol manual, DNP3 | | Quantity: | ☐ | 1MRK 511 224-UEN |
| Communication protocol manual, IEC 61850 | | Quantity: | ☐ | 1MRK 511 205-UEN |
| Engineering manual | | Quantity: | ☐ | 1MRK 511 206-UEN |
| Installation manual | | Quantity: | ☐ | 1MRK 514 013-UEN |
| Point list manual, DNP3 | | Quantity: | ☐ | 1MRK 511 225-UEN |

## Reference information

For our reference and statistics we would be pleased to be provided with the following application data:

Country: End user:

Station name: Voltage level: kV

# Related documents

| Documents related to REL650 | Identity number |
|---|---|
| Commissioning manual | 1MRK 506 307-UEN |
| Technical manual | 1MRK 506 304-UEN |
| Application manual | 1MRK 506 305-UEN |
| Product Guide, configured | 1MRK 506 308-BEN |
| Type test certificate | 1MRK 506 308-TEN |

| Documents related to | Identity number |
|---|---|
| Operation manual | 1MRK 500 088-UEN |
| Communication protocol manual, DNP3 | 1MRK 511 224-UEN |
| Communication protocol manual, IEC 61850 | 1MRK 511 205-UEN |
| Engineering manual | 1MRK 511 206-UEN |
| Installation manual | 1MRK 514 013-UEN |
| Point list manual, DNP3 | 1MRK 511 225-UEN |

Latest versions of the described documentation can be found on www.abb.com/substationautomation

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