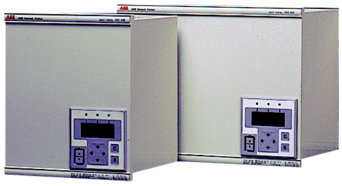
Line distance protection terminal

REL 521*2.3

1MRK 506 144-BEN
Page 1
Revision: -
Issued: March 2003
Data subject to change without notice



Features

- Open terminal with extensive configuration possibilities and expandable hardware design to meet specific user requirements
- Full scheme phase-to-phase and phase-to-earth distance protection with three to five zones
- Separate phase selector
- Wide range of phase and residual overcurrent protection functions
- Line impedance
  - Distance protection (ZM)
  - Phase selection logic (PHS)
  - Power swing detection (PSD)
  - Power swing logic (PSL)
  - Pole slip protection (PSP)
  - Scheme communication logic for distance protection functions (ZCOM)
  - Current reversal and WEI logic for distance protection (ZCAL)
  - Radial feeder protection (PAP)
  - Automatic switch onto fault logic (SOTF)
  - Local acceleration logic (ZCLC)
- Current
  - Instantaneous overcurrent protection (IOC)
  - Time delayed overcurrent protection (TOC)
  - Two step time delayed phase overcurrent protection (TOC2)
  - Two step time delayed directional phase overcurrent protection (TOC3)
  - Thermal overload protection (THOL)
  - Stub protection (STUB)
  - Breaker failure protection (BFP)
  - Definite and inverse time-delayed residual overcurrent protection (TEF)
  - Scheme communication logic for residual overcurrent protection (EFC)
  - Current reversal and weak end infeed logic for residual overcurrent protection (EFCA)
  - Sensitive directional residual overcurrent protections (WEF1)
  - Sensitive directional residual power protection (WEF2)
  - Four step residual overcurrent protection (EF4)
- Voltage
  - Time delayed undervoltage protection (TUV)
  - Time delayed overvoltge protection (TOV)
- Power system supervision
  - Broken conductor check (BRC)
  - Loss of voltage check (LOV)
  - Overload supervision (OVLD)
  - Dead line detection (DLD)
- Secondary system supervision
  - Current circuit supervision (CTSU)
  - Fuse failure supervision (FUSE)
  - Voltage transformer supervision (TCT)
- Control
  - Synchrocheck (SYN)
  - Automatic reclosing function (AR)
  - Single command (CD)
  - Multiple command (CM)
- Logic
  - Trip logic (TR)
  - Pole discordance protection (PD)
  - High speed binary output logic (HSBO)

  - Communication channel test logic (CCHT)
- Binary signal transfer to remote end (RTC)
- Serial communication
  - Simultaneous dual protocol serial communication facilities
- Metering capabilities
  - Pulse counting (PC)
  - Event counting (CN)
- Monitoring
  - LED indication function (HL, HLED)
  - Local Human Machine Interface (HMI)
  - Disturbance report (DRP)
  - Indications
  - Disturbance recorder
  - Event recorder
  - Fault locator (FLOC)
  - Trip value recorder
  - Monitoring of AC analogue measurements
  - Monitoring of DC analogue measurements
  - Increased measuring accuracy
- Additional logic function blocks
- Hardware
  - 18 LEDs for extended indication capabiliteis
- Several input/output module options including measuring mA input module (for transducers)
- Versatile local human-machine interface (HMI)
- Extensive self-supervision with internal event recorder
- Time synchronization with 1 ms resolution
- Four independent groups of complete setting parameters
- Powerful software PC ‘tool-box’ for monitoring, evalution and user configuration

Application

The main purpose of the REL 521 terminal is the protection, control and monitoring of overhead lines and cables in solidly grounded networks. It is suitable for the protection of long heavily loaded lines and multi-circuit lines, and where the requirement for tripping is one-, two-, and/or three-pole. The terminal may also be used to provide backup protection for power transformers, busbars, etc.

Design

Type tested software and hardware that comply with international standards and ABB´s internal design rules together with extensive self monitoring functionality, ensure high reliability of the complete terminal.

The terminal’s closed and partly welded steel case makes it possible to fulfill the stringent EMC requirements.

All serial data communication is via optical connections to ensure immunity against disturbances.

An extensive library of protection, control and monitoring functions is available. This library of functions, together with the flexible hardware design, allows this terminal to be configured to each user´s own specific requirements. This wide application flexibility makes this product an excellent choice for both new installations and the refurbishment of existing installations.

Platform

Application

The platform hardware and common software functions are included for all REx 5xx terminals. It is the foundation on which all terminals are built. Application specific modules and functions are added to create a specific terminal type or family.

Design

The REx 5xx platform consists of a case, hardware modules and a set of basic functions.

The closed and partly welded steel case makes it possible to fulfill stringent EMC requirements. For case size 1/1x19” IP 30 applies for the top and bottom part. IP 54 can be obtained for the front area in flush applications. Mounting kits are available for rack, flush or wall mounting.

All connections are made on the rear of the case. Screw compression type terminal blocks are used for electrical connections. Serial communication connections are made by optical fibre connectors type Hewlett Packard (HFBR) for plastic fibres or bayonet type ST for glass fibres.

A set of hardware modules are always included in a terminal. Application specific modules are added to create a specific terminal type or family.

The basic functions provide a terminal with basic functionality such as self supervision, I/O-system configurator, real time clock and other functions to support the protection and control system of a terminal.

Common functions

Description

Common functions are the software functions that always are included in the terminals.

Time synchronisation (TIME)

Application

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

Functionality

Two main alternatives of external time synchronization are available. Either the synchronization message is applied via any of the communication ports of the terminal as a telegram message including date and time, or as a minute pulse, connected to a binary input. The minute pulse is used to fine tune already existing time in the terminals.

The REx 5xx terminal has its own internal clock with date, hour, minute, second and millisecond. It has a resolution of 1 ms.

The clock has a built-in calendar that handles leap years through 2098. Any change between summer and winter time must be handled manually or through external time synchronization. The clock is powered by a capacitor, to bridge interruptions in power supply without malfunction.

The internal clock is used for time-tagging disturbances, events in Substation monitoring system (SMS) and Substation control system (SCS), and internal events.

Setting group selection (GRP)

Application

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

Functionality

The GRP function block has four functional inputs, each corresponding to one of the setting groups stored within the terminal. Activation of any of these inputs changes the active setting group. Four functional output signals are available for configuration purposes, so that continuous information on active setting group is available.

Setting lockout (HMI)

Application

Unpermitted or uncoordinated changes by unauthorized personnel may cause severe damage to primary and secondary power circuits. Use the setting lockout function to prevent unauthorized setting changes and to control when setting changes are allowed.

By adding a key switch connected to a binary input a simple setting change control circuit can be built simply allowing only authorized keyholders to make setting changes from the built-in HMI.

Functionality

Activating the setting restriction prevents unauthorized personell to purposely or by mistake change terminal settings.

The HMI--BLOCKSET functional input is configurable only to one of the available binary inputs of a REx 5xx terminal. For this reason, the terminal is delivered with the default configuration, where the HMI--BLOCKSET signal is connected to NONE-NOSIGNAL.

The function permits remote changes of settings and reconfiguration through the serial communication ports. The setting restrictions from remote can be activated only from the local HMI.

All other functions of the local human-machine communication remain intact. This means that an operator can read all disturbance reports and other information and setting values for different protection parameters and the configuration of different logic circuits.

I/O system configurator with internal event recorder (IOP)

Application

The I/O system configurator must be used in order for the terminal’s software to recognize added modules and to create internal address mappings between modules and protections and other functions.

Self supervision (INT)

Application

Use the local HMI, SMS or SCS to view the status of the self-supervision function. The self-supervision operates continuously and includes:

- Normal micro-processor watchdog function
- Checking of digitized measuring signals
- Checksum verification of PROM contents and all types of signal communication

Logic function blocks

Application

The user can with the available logic function blocks build logic functions and configure the terminal to meet application specific requirements.

Different protection, control, and monitoring functions within the REx 5xx terminals are quite independent as far as their configuration in the terminal is concerned. The user can not change the basic algorithms for different functions. But these functions combined with the logic function blocks can be used to create application specific functionality.

With additional configurable logic means that an extended number of logic circuits are available. Also Move function blocks (MOF, MOL), used for synchronization of boolean signals sent between logics with slow and fast execution, are among the additional configurable logic circuits.

Functionality

The functionality of the additional logic function blocks are the same as for the basic logic functions, but with an extended number of blocks.

Invert function block (INV)

The inverter function block INV has one input and one output, where the output is in inverse ratio to the input.

OR function block (OR)

The OR function is used to form general combinatory expressions with boolean variables. The OR function block has six inputs and two outputs. One of the outputs is inverted.

AND function block (AND)

The AND function is used to form general combinatory expressions with boolean variables.The AND function block has four inputs and two outputs. One of the inputs and one of the outputs are inverted.

Timer function block (TM)

The function block TM timer has drop-out and pick-up delayed outputs related to the input signal. The timer has a settable time delay (parameter T).

Timer long fuction block (TL)

The function block TL timer with extended maximum time delay at pick-up and at drop-out, is identical with the TM timer. The difference is the longer time delay.

Pulse timer function block (TP)

The pulse function can be used, for example, for pulse extensions or limiting of operation of outputs. The pulse timer TP has a settable length.

Extended length pulse function block (TQ)

The function block TQ pulse timer with extended maximum pulse length, is identical with the TP pulse timer. The difference is the longer pulse length.

Exclusive OR function block (XOR)

The exclusive OR function XOR is used to generate combinatory expressions with boolean variables. The function block XOR has two inputs and two outputs. One of the outputs is inverted. The output signal is 1 if the input signals are different and 0 if they are equal.

Set-reset with memory function block (SR)
The Set-Reset (SR) function is a flip-flop that can set or reset an output from two inputs respectively. Each SR function block has two outputs, where one is inverted.

Set-reset with memory function block (SM)
The Set-Reset function SM is a flip-flop with memory that can set or reset an output from two inputs respectively. Each SM function block has two outputs, where one is inverted. The memory setting controls if the flip-flop after a power interruption will return the state it had before or if it will be reset.

Controllable gate function block (GT)
The GT 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.

Settable timer function block (TS)
The function block TS timer has outputs for delayed input signal at drop-out and at pick-up. The timer has a settable time delay. It also has an Operation setting On, Off that controls the operation of the timer.

Move first function (MOF)
The Move function block MOF is put first in the slow logic and is used for signals coming from fast logic into the slow logic. The MOF function block is only a temporary storage for the signals and does not change any value between input and output.

Move last function block (MOL)
The Move function block MOL is put last in the slow logic and is used for signals going out from the slow logic to the fast logic. The MOL function block is only a temporary storage for the signals and does not change any value between input and output.

Blocking of signals during test

Application
The protection and control terminals have a complex configuration with many included functions. To make the testing procedure easier, the terminals include the feature to individually block a single, several or all functions.

This means that it is possible to see when a function is activated or trips. It also enables the user to follow the operation of several related functions to check correct functionality and to check parts of the configuration etc.

Line impedance

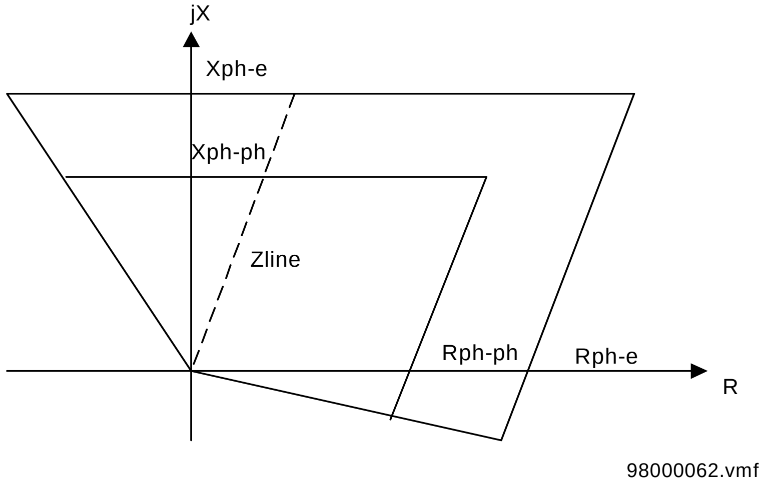
Distance protection (ZM)

Application
The ZM distance protection function provides fast and reliable protection for overhead lines and power cables in all kinds of power networks. For each independent distance protection zone, full scheme design provides continuous measurement of impedance separately in three independent phase-to-phase measuring loops as well as in three independent phase-to-earth measuring loops.

Phase-to-phase distance protection is suitable as a basic protection function against two- and three-phase faults in all kinds of networks, regardless of the treatment of the neutral point. Independent setting of the reach in the reactive and the resistive direction for each zone separately, makes it possible to create fast and selective short circuit protection in power systems.

Phase-to-earth distance protection serves as basic earth fault protection in networks with directly or low impedance earthed networks. Together with an independent phase preference logic, it also serves as selective protection function at cross-country faults in isolated or resonantly earthed networks.

Independent reactive reach setting for phase-to-phase and for phase-to-earth measurement secures high selectivity in networks with different protective relays used for short-circuit and earth-fault protection.

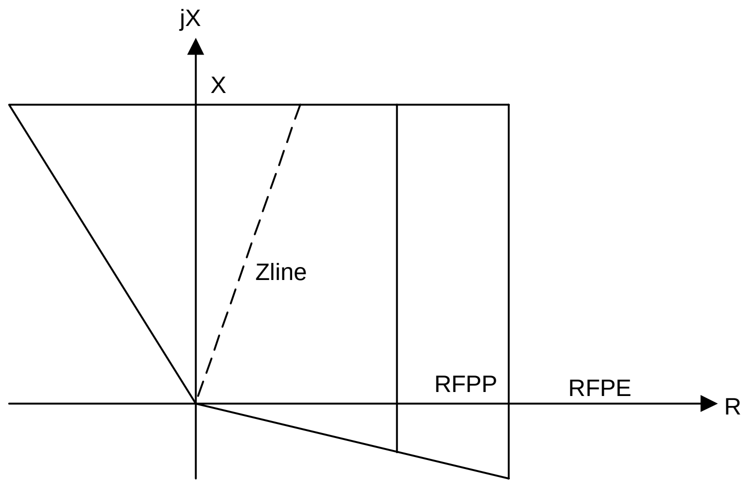


Where:

X_{ph-e}	= reactive reach for ph-e faults
X_{ph-ph}	= reactive reach for ph-ph faults
R_{ph-e}	= resistive reach for ph-e faults
R_{ph-ph}	= resistive reach for ph-ph faults
Z_{line}	= line impedance

Figure 1: Schematic presentation of the operating characteristic for one distance protection zone in forward direction

Distance protection with simplified setting parameters is available on request. It uses the same algorithm as the basic distance protection function. Simplified setting parameters reduce the complexity of necessary setting procedures and make the operating characteristic automatically more adjusted to the needs in combined networks with off-lines and cables.



Where:

X	= reactive reach for all kinds of faults
RFPP	= resistive reach for phase-to-phase faults
RFPE	= resistive reach for phase-to-earth faults
Z_{line}	= line impedance

Figure 2: Schematic presentation of the operating characteristic for one distance protection zone in forward direction with simplified setting parameters

The distance protection zones can operate, independently of each other, in directional (forward or reverse) or non-directional mode. This makes it suitable, together with different communication schemes, for the protection of power lines and cables in complex network configurations, such as double-circuit, parallel lines, multiterminal lines, etc. Zone one, two and three can issue phase selective signals, such as start and trip.

The additional distance protection zones four and five have the same basic functionality as zone one to three, but lack the possibility of issuing phase selective output signals.

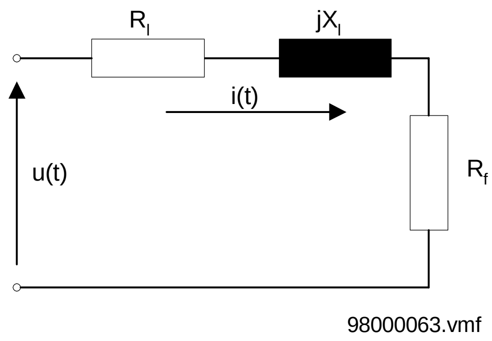
Distance protection zone five has shorter operating time than other zones, but also higher transient overreach. It should generally be used as a check zone together with the SOTF switch onto fault function or as a time delayed zone with time delay set longer than 100ms.

Basic distance protection function is generally suitable for use in non-compensated networks. A special addition to the basic functions is available optionally for use on series compensated and adjacent lines where voltage reversals might disturb the correct directional discrimination of a basic distance protection.

Functionality

Separate digital signal processors calculate the impedance as seen for different measuring loops in different distance protection zones. The results are updated each millisecond, separately for all measuring loops and each distance protection zone. Measurement of the impedance for each loop follows the differential equation, which considers complete line replica impedance, as presented schematically in figure 3.

$$u(t) = (R_l + R_f) \cdot i(t) + \frac{X_l}{\omega} \cdot \frac{\Delta i(t)}{\Delta t}$$



Where:

R_l = line resistance

R_f = fault resistance

X_l = line reactance

ω = $2\pi f$

f = frequency

Figure 3: Schematic presentation of impedance measuring principle.

Settings of all line parameters, such as positive sequence resistance and reactance as well as zero-sequence resistance and reactance, together with expected fault resistance for phase-to-phase and phase-to-earth faults, are independent for each zone. The operating characteristic is thus automatically adjusted to the line characteristic angle, if the simplified operating characteristic has not been especially requested. The earth-return compensation factor for the earth-fault measurement is calculated automatically by the terminal itself.

Voltage polarization for directional measurement uses continuous calculation and updating of the positive sequence voltage for each measuring loop separately. This secures correct directionality of the protection at different evolving faults within the complex network configurations. A memory retaining the pre-fault positive-sequence voltage secures reliable directional operation at close-up three-phase faults.

The distance protection function blocks are independent of each other for each zone. Each function block comprises a number of different functional inputs and outputs, which are freely configurable to different external functions, logic gates, timers and binary inputs and outputs. This makes it possible to influence the operation of the complete measuring zone or only its tripping function by the operation of fuse-failure function, power swing detection function, etc.

Phase selection logic (PHS)

The PHS phase selection logic function is an independent measuring function. It comprises both impedance and current-based measurement criteria. Its main purpose is to augment the phase selectivity of the complete distance protection in networks with long and heavily loaded lines. It is generally intended for use in directly earthed networks, where correct and reliable phase selection for single-phase-to-earth faults, combined with single-pole tripping and automatic reclosing, secures the stability of complete power systems.

The independent measurement of impedance in all six fault loops secures a high degree of phase selectivity in complex networks. This independent phase selection, combined with directional measurement for each fault loop, also secures selective operation for simultaneous close-in faults on parallel circuits. Independent reactive reach settings for phase-to-phase and phase-to-earth measurement secures high selectivity in networks with different protective relays used for short-circuit and earth-fault protection.

Functionality

For the impedance-based phase selection, all six fault loops are measured separately and continuously. The reactive and resistive reaches are independently settable for phase-to-phase and phase-to-earth faults. Checks based on the level of residual current determine which loops, i.e. phase-to-earth or phase-to-phase, are evaluated. Selection of the faulted phase(s) is determined by which of the selected loops operate. Operation of a loop occurs when the measured impedance within that loop is within the set boundaries of the characteristic. The impedance-based output will activate the selected loop of the distance protection measuring zone(s) to which the impedance-based phase selection output is connected.

The current-based phase selection is based on the same residual current checks as those used to select the phase-to-earth or phase-to-phase loops of the impedance-based phase selection function for evaluation. In this case the current-based output will activate either all the phase-to-earth loops or all the phase-to-phase loops of the distance protection measuring zone(s) to which the current-based phase selection output is configured.

Power swing detection (PSD)

Application

Power swings in the system arise due to big changes in load, or changes in power system configuration due to faults and their clearance. Distance protection detects these power swings as variations with time of the measured impedance along a locus in the impedance plane. This locus can enter the operate characteristic of the distance protection and cause its unwanted operation if no preventive measures are taken. The main purpose of the PSD power swing detection function is to detect power swings in power networks and to provide the blocking signal to the distance function to prevent its unwanted operation.

Functionality

The PSD function comprises an inner and an outer quadrilateral measurement characteristic. Its principle of operation is based on the measurement of the time it takes a power swing transient impedance to pass through the impedance area between the outer and the inner characteristics. Power swings are identified by transition times longer than timer settings. The impedance measuring principle is the same as that used for the distance protection zones. The impedance and the transient impedance time are measured in all three phases separately. One-out-of-three or two-out-of-three operating modes can be selected permanently or adaptively according to the specific system operating conditions.

The PSD function detects power swings with a swing period as low as 200 ms (i.e. with a slip frequency as high as 10% of the rated frequency on a 50 Hz basis). It detects swings under normal system operating conditions, as well as during the dead time of a single-pole automatic reclosing cycle. Different timers are used for initial and consecutive swings, securing a high degree of differentiation between power swing and fault conditions.

It is possible to inhibit the power swing detected output on detection of earth fault current. This can be used to release the operation of the distance protection function for earth faults during power swing conditions.

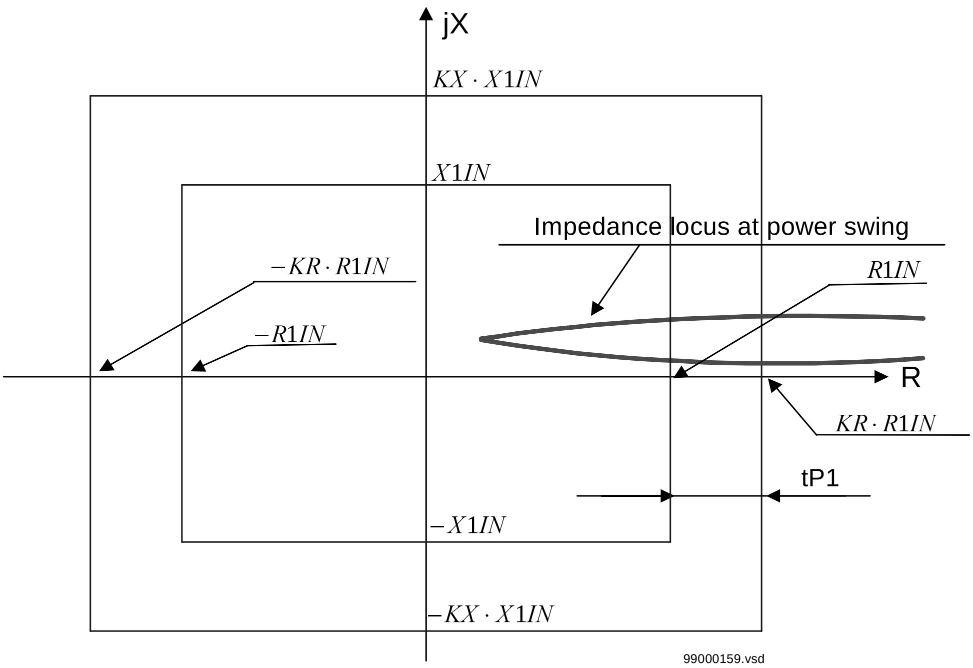


Figure 4: Operating principle and characteristic of the PSD function

Power swing logic (PSL)

Application

The main purpose of the PSL power swing logic is to secure selective and reliable operation of the distance protection for both internal and external faults during power swings. It also ensures stable operation of the distance protection for power swings caused by the clearance of external faults, i.e. power swings that begin from within the characteristic of an overreaching zone, and which are therefore not able to be detected by the power swing detection function in the normal way.

Functionality

The PSL is a supplementary function to the power swing detection function. It requires for its operation inputs from the distance protection function, the power swing detection function, etc., and the teleprotection equipment, when available.

Reliable operation for faults during power swings is achieved by the communication logic within the PSL. For its operation, this function requires inputs from a distance protection zone(s) that are not used for the ordinary distance protection, and therefore that are not blocked by the power swing detection function on detection of a power swing. For this reason it is recommended to include zone 4 and/or zone 5 within the terminal.

The PSL is only activated following detection of a power swing by the power swing detection function.It can operate in both permissive overreaching (one power swing zone required) and permissive underreaching (two power swing zones required) modes. It is possible to use the same communication channels as for the normal scheme communication because the normal distance zones which utilize these channels are blocked during power swings.

For single-line-to-earth faults, an alternative earth fault protection function, e.g. directional earth fault, may be preferred to deal with earth faults during a power swing. It is then possible to block the power swing logic on pickup of this protection, except during the pole open period of a single-pole automatic reclosing cycle.

For power swings caused by external faults measured within the power swing characteristic, stable operation is ensured in these circumstances by automatically replacing the output connections from the normal instantaneous direct tripping distance zone with output connections from the PSL.

Pole slip protection (PSP)

Application

Sudden events in an electrical power system such as large jumps in load, fault occurrence or fault clearance, can cause oscillations referred to as power swings. In a recoverable situation, the power swings will decay and stable operation will be resumed; in a non-recoverable situation, the power swings become so severe that the synchronism is lost, a condition referred to as pole slipping. The main purpose of the PSP pole slip protection is to detect, evaluate, and take the required action for pole slipping occurrences in the power system.

Functionality

The PSP function comprises an inner and an outer quadrilateral measurement characteristic. It detects oscillations in the power system by measuring the time it takes the transient impedance to pass through the impedance area between the outer and the inner characteristics. Oscillations are identified by transition times longer than timer settings. The impedance measuring principle is the same as that used for the distance protection zones. The impedance and the transient impedance time are measured in all three phases separately. One-out-of-three or two-out-of-three operating modes can be selected permanently or adaptively according to the specific system operating conditions.

Oscillations with an oscillation period as low as 200 ms (i.e. with a slip frequency as high as 10% of the rated frequency on a 50 Hz basis) can be detected for normal system operating conditions, as well as during the dead time of a single-pole automatic reclosing cycle. Different timers are used for initial and consecutive pole slips, securing a high degree of differentiation between oscillation and fault conditions.

It is possible to inhibit the ocsillation detected output on detection of earth fault current. This can be used to release the operation of the distance protection function for earth faults during power oscillation conditions.

The PSP function has two tripping areas. These are located within the operating area, which is located within the inner characteristic. On detection of a new oscillation, the activation of a trip output will depend on the applied settings. These determine the direction of the transition for which tripping is permitted, whether tripping will occur on entry of the measured impedance into a tripping area, or on its exit from the tripping area, and through which tripping area the transition must be measured for tripping to occur. The applied settings also determine the number of pole slips required before the trip output is issued.

Scheme communication logic for distance protection function (ZCOM)

Application

It is not possible to set a underreaching distance protection zone to cover the full length of the line, and at the same time not to overreach for faults beyond the protected line. To avoid overreaching, underreaching distance protection zones must always reach short of the remote end of the line by some safety margin of 15-20%. The main purpose of the ZCOM scheme communication logic is to supplement the distance protection function such that fast clearance of faults is also achieved at the line end for which the faults are on the part of the line not covered by its underreaching zone. To accomplish this, one communication channel, capable of transmitting an on/off signal, is required in each direction.

Functionality

The ZCOM function is a logical function built-up from logical elements. It is a supplementary function to the distance protection, requiring for its operation inputs from the distance protection and the teleprotection equipment.

The type of communication-aided scheme to be used can be selected by way of the settings. The ability to select which distance protection zone is assigned to which input of the ZCOM logic makes this logic able to support practically any scheme communication requirements regardless of their basic operating principle. The outputs to initiate tripping and sending of the teleprotection signal are given in accordance with the type of communication-aided scheme selected and the distance protection zone(s) which have operated.

When power line carrier communication channels are used, unblocking logic is provided which uses the loss of guard signal. This logic compensates for the lack of dependability due to the transmission of the command signal over the faulted line.

Current reversal WEI logic for distance protection (ZCAL)

Application

In interconnected systems, for parallel line applications, the direction of flow of the fault current on the healthy line can change when the circuit breakers on the faulty line open to clear the fault. This can lead to unwanted operation of the distance protection on the healthy line when permissive overreach schemes are used. The main purpose of the ZCAL current reversal logic is to prevent such unwanted operations for this phenomenon.

If the infeed of fault current at the local end for faults on the protected line is too low to operate the measuring elements, no trip output will be issued at the local end and no teleprotection signal will be sent to the remote end. This can lead to time delayed tripping at the remote strong infeed end. The main purpose of the ZCAL weak end infeed logic is to enhance the operation of permissive communication schemes and to avoid sequential tripping when, for a fault on the line, the initial infeed of fault current from one end is too weak to operate the measuring elements.

Functionality

The ZCAL function block provides the current reversal and weak end infeed logic functions that supplement the standard scheme communication logic, or the phase segregated scheme communication logic.

On detection of a current reversal, the current reversal logic provides an output to block the sending of the teleprotection signal to the remote end, and to block the permissive tripping at the local end. This blocking condition is maintained long enough to ensure that no unwanted operation will occur as a result of the current reversal.

On verification of a weak end infeed condition, the weak end infeed logic provides an output for sending the received teleprotection signal back to the remote sending end, and other output(s) for tripping. For terminals equipped for single-, two-, and three-pole tripping, outputs for the faulted phase(s) are provided. Undervoltage detectors are used to select the faulted phase (s).

Radial feeder protection (PAP)

Application

The main purpose of the PAP radial feeder protection function is to provide tripping at the ends of radial feeders with passive load or with weak end infeed. To obtain this tripping, the PAP function must be included within the protection terminal at the load / weak end infeed end.

Functionality

The PAP function performs the phase selection using the measured voltages. Each phase voltage is compared to the opposite phase-phase voltage. A phase is deemed to have a fault if its phase voltage drops below a settable percentage of the opposite phase-phase voltage. The phase-phase voltages include memory. This memory function has a settable time constant.

The PAP function has built-in logic for fast tripping as well as time delayed tripping. The voltage-based phase selection is used for both the fast and the delayed tripping. To get fast tripping, scheme communication is required. Delayed tripping does not require scheme communication. It is possible to permit delayed tripping only on failure of the communications channel by blocking the delayed tripping logic with a communications channel healthy input signal.

On receipt of the communications signal, phase selective outputs for fast tripping are given based on the phase(s) in which the phase selection function has operated.

For delayed tripping, the single-pole and three-pole delays are separately and independently settable. Furthermore, it is possible to enable or disable three-pole delayed tripping. It is also possible to select either single-pole delayed tripping or three-pole delayed tripping for single-phase faults. Three-pole delayed tripping for single-phase faults is also dependent on the selection to enable or disable three-pole tripping. For single-phase faults, it is possible to include a residual current check in the tripping logic. Three-pole tripping is always selected for phase selection on more than one phase. Three-phase tripping will also occur if the residual current exceeds the set level during fuse failure for a time longer than the three-pole trip delay time.

The radial feeder protection function also includes logic which provides outputs that are specifically intended for starting the automatic recloser.

Automatic switch onto fault logic (SOTF)

Application

The main purpose of the SOTF switch-on-to-fault function is to provide high-speed tripping when energizing a power line on to a short-circuit fault on the line.

Automatic initiating of the SOTF function using dead line detection can only be used when the potential transformer is situated on the line-side of the circuit breaker. Initiation using dead line detection is highly recommended for busbar configurations where more than one circuit breaker at one line end can energize the protected line.

Generally, directional or non-directional overreaching distance protection zones are used as the protection functions to be released for direct tripping during the activated time. When line-side potential transformers are used, the use of non-directional distance zones secures switch-on-to-fault tripping for fault situations there directional information can not be established, for example, due to lack of polarizing voltage. Use of non-directional distance zones also gives fast fault clearance when energizing a bus from the line with a short-circuit fault on the bus.

Functionality

The SOTF function is a logical function built-up from logical elements. It is a complementary function to the distance protection function.

It is enabled for operation either by the close command to the circuit breaker, by a normally closed auxiliary contact of the circuit breaker, or automatically by the dead line detection. Once enabled, this remains active until one second after the enabling signal has reset. The protection function(s) released for tripping during the activated time can be freely selected from the functions included within the terminal. Pickup of any one of the selected protection functions during the enabled condition will result in an immediate trip output from the SOTF function.

Local acceleration logic (ZCLC)

Application
The main purpose of the ZCLC local acceleration logic is to achieve fast fault clearance for faults anywhere on the whole line for those applications where no communication channel is available.

Functionality
The ZCLC function is a complementary function to the distance protection function.

The local acceleration logic can be enabled for operation in two ways. The first way uses an ‘automatic recloser ready’ signal, either from the internal recloser, or an external recloser. The second way uses loss of load detection. When enabled by either method, the local acceleration logic will produce an immediate output on pickup of the function selected to the method of acceleration enabled.

Current

Instantaneous overcurrent protection (IOC)

Application
Different system conditions, such as source impedance and the position of the faults on long transmission lines influence the fault currents to a great extent. An instantaneous phase overcurrent protection with short operate time and low transient overreach of the measuring elements can be used to clear close-in faults on long power lines, where short fault clearing time is extremely important to maintain system stability.

The instantaneous residual overcurrent protection can be used in a number of applications. Below some examples of applications are given.

- Fast back-up earth fault protection for faults close to the line end.
- Enables fast fault clearance for close in earth faults even if the distance protection or the directional residual current protection is blocked from the fuse supervision function

Functionality
The current measuring element continuously measures the current in all three phases and compares it to the set operate value IP>>. A filter ensures immunity to disturbances and dc components and minimizes the transient overreach. If any phase current is above the set value IP>>, the phase overcurrent trip signal TRP is activated. Separate trip signal for the actual phase(s) is also activated. The input signal BLOCK blocks all functions in the current function block.

The current measuring element continuously measures the residual current and compares it to the set operate value IN>>. A filter ensures immunity to disturbances and dc components and minimizes the transient overreach. If the residual current is above the set value IN>>, the residual overcurrent trip signal TRN is activated. The general trip signal TRIP is activated as well. The input signal BLOCK blocks the complete function.

Time delayed overcurrent protection (TOC)

Application
The time delayed overcurrent protection, TOC, operates at different system conditions for currents exceeding the preset value and which remains high for longer than the delay time set on the corresponding timer. The function can also be used for supervision and fault detector for some other protection functions, to increase the security of a complete protection system. It can serve as a reserve function for the line distance protection, if activated under fuse failure conditions which has disabled the operation of the line distance protection.

The time delayed residual overcurrent protection is intended to be used in solidly and low resistance earthed systems. The time delayed residual overcurrent protection is suitable as back-up protection for phase to earth faults, normally tripped by operation of the distance protection. The protection function can also serve as protection for high resistive phase to earth faults.

Functionality
The current measuring element continuously measures the current in all three phases and compares it to the set operate value IP>. A filter ensures immunity to disturbances and dc components and minimizes the transient overreach. If the current in any of the three phases is above the set value IP>, a common start signal STP and a start signal for the actual phase(s) are activated. The timer tP is

activated and the phase overcurrent trip signal TRP is activated after set time. The general trip signal TRIP is activated as well.

The input signal BLOCK blocks the function. The input signal BLKTR blocks both trip signals TRP and TRIP.

The residual current measuring element continuously measures the residual current and compares it with the set operate value IN>. A filter ensures immunity to disturbances and dc components and minimizes the transient overreach. If the measured current is above the set value IN>, a start signal STN is activated. The timer tN is activated and the residual overcurrent trip signal TRN is activated after set time. The general trip signal TRIP is activated as well. The input signal BLOCK blocks the function. The input signal BLKTR blocks both trip signals TRN and TRIP.

Two step time delayed phase overcurrent protection (TOC2)

Application

The two current/time stages of overcurrent protection TOC2 improve the possibility to get fast operation for nearby faults by using a high set current stage with short time delay. The low current stage is set with appropriate time delay to get selectivity with the adjacent relays in the system. In networks with inverse time delayed relays, selectivity is generally best obtained by using the same type of inverse time characteristic for all overcurrent relays.

Functionality

The current measuring element continuously measures the current in all phases and compares it to the set operate value for the two current stages. A filter ensures immunity to disturbances and dc components and minimizes the transient overreach. If the current in any of the three phases is above the set value I>Low, the start signal for the low current stage is activated. With setting Characteristic = Def, the timer tLow is activated and the trip signal TRLS is activated after set time. If inverse time delay is selected, the timer tMinInv starts when the current is above the set value I>Low. If the current also is above the set value I>Inv, the inverse time evaluation starts. When both time circuits operate, the definite time circuit tLow is activated and the trip signal TRLS is activated after the additional time tLow. If the current is above the set value I>High, the timer tHigh is activated and the trip signal TRHS is activated after set time.

The input signal BLOCK blocks all functions. Each current stage can also be individually blocked.

Two step time deleyed directional phase overcurrent protection (TOC3)

Application

The two current/time stages of the TOC3 overcurrent protection, both with optional directional (Forward release or Reverse block) or non-directional function, improve the possibility to obtain selective function of the overcurrent protection relative other relays even in meshed networks. It must be realized, however, that the setting of a phase overcurrent protection system in a meshed network can be very complicated and a large number of fault current calculations are needed. In some cases, it is not possible to obtain selectivity even when using directional overcurrent protection. In such cases it is suggested to use line differential protection or distance protection function.

Functionality

The current measuring element continuously measures the current in all three phases and compares it to the set operate value for the two current stages. A filter ensures immunity to disturbances and dc components and minimizes the transient overreach. If the current in any of the three phases is above the set value I>Low, the start signal for the low current stage is activated. With setting Characteristic = Def, the timer tLow is activated and the trip signal TRLS is activated after set time. If inverse time delay is selected, the timer tMinInv starts when the current is above the set value I>Low. If the current also is above the set value I>Inv, the inverse time evaluation starts. When both time circuits operate, the definite time circuit tLow is activated and the trip signal TRLS is activated after set time.

If the current is above the set value I>High, the timer tHigh is activated and the trip signal TRHS is activated after set time.The low and the high set current stages can individually be set directional or non-directional. Directional information is calculated from positive sequence polarization voltages and the phase currents. The polarization voltage contains memory voltage to ensure directional function at close-in three-phase faults. The directional element relay characteristic angle (RCA) and operate angle are settable in wide ranges.

The input signal BLOCK blocks all functions. Trip from each current stage can also be individually blocked.

Thermal overload protection (THOL)

Appliction

Load currents that exceed the permissible continuous value may cause damage to the conductors and isolation due to overheating. The permissible load current will vary with the ambient temperature.

The THOL thermal overcurrent function supervises the phase currents and provides a reliable protection against damage caused by excessive currents. The temperature compensation gives a reliable thermal protection even when the ambient temperature has large variations.

Functionality

The final temperature rise of an object relative the ambient temperature is proportional to the square of the current. The rate of temperature rise is determined by the magnitude of the current and the thermal time constant of the object. The same time constant determines the rate of temperature decrease when the current is decreased.

The thermal overload function uses the highest phase current. The temperature change is continuously calculated and added to the figure for the temperature stored in the thermal memory. When temperature compensation is used, the ambient temperature is added to the calculated temperature rise. If no compensation is used, 20^{o} C is added as a fixed value. The calculated temperature of the object is then compared to the set values for alarm and trip.

The information on the ambient temperature is received via a transducer input with for example 0 - 10 mA or 4 - 20 mA.

The output signal THOL--TRIP has a duration of 50 ms. The output signal THOL--START remains activated as long as the calculated temperature is higher than the set trip value minus a settable temperature difference TdReset (hysteresis). The output signal THOL--ALARM has a fixed hysteresis of 5^{o} C.

Stub protection (STUB)

Application

The stub protection operates for faults in the parts of 1 1/2 and ring bus station configurations, which cannot be protected by the distance protection function if the line isolators are opened. The use of the function can be extended to various other purposes, when a three phase overcurrent protection can operate only under special external conditions.

Functionality

The function operates as a three phase instantaneous overcurrent protection. The function is released when the line disconnector is open; a normally closed auxiliary contact of the line disconnector has to be connected to the STUB-RELEASE functional input by configuration.

The operating level of the overcurrent protection is settable over a wide range.

Breaker failure protection (BFP)

Application

In many protection applications local redundancy is used. One part of the fault clearance system is however never duplicated, namely the circuit breaker. Therefore a breaker failure protection can be used.

The breaker failure protection is initiated by trip signals from different protection functions within or outside the protection terminal. When a trip signal is sent to the breaker failure protection first, with no or a very short delay, a re-trip signal can be sent to the protected breaker. If fault current is flowing through the breaker still after a setting time a back-up trip signal is sent to the adjacent breakers. This will ensure fault clearance also if the circuit breaker is out of order.

Functionality

Breaker failure protection, BFP, provides backup protection for the primary circuit breaker if it fails to clear a system fault. It is obtained by checking that fault current persists after a brief time from the operation of the object protection and issuing then a three phase trip command to the adjacent circuit breakers (back-up trip).

Correct operation at evolving faults is ensured by phase segregated starting command, phase segregated current check and phase segregated settable timers.

Additionally, the retrip of the faulty circuit breaker after a settable time is possible. The retrip can be controlled by current check or carried out as direct retrip.

Definite and inverse time-delayed residual overcurrent protection (TEF)

Application

Use the dependent and independent time delayed residual overcurrent functions in solidly earthed systems to get a sensitive and fast fault clearance of phase to earth faults.

The nondirectional protection can be used when high sensitivity for earth fault protection is required. It offers also a very fast back-up earth fault protection for the part of a transmission line, closest to the substation with the protection.

The nondirectional residual overcurrent protection can be given a relatively low current pick-up setting. Thus the protection will be sensitive, in order to detect high resistive phase to earth faults.

The directional residual overcurrent protection can be used in a number of applications:

1. Main protection for phase to earth faults on the radial lines in solidly earthed systems. Selectivity is achieved by using time delayed function according to practices in the system (independent time delay or some type of dependent time characteristic).
2. Main protection for phase to earth faults on lines in a meshed solidly earthed system. The directional function can be used in an permissive overreach communication scheme or a blocking scheme. In this application the directional residual overcurrent function is used together with the communication logic for residual overcurrent protection.
3. Back-up protection for phase to earth faults for lines in solidly earthed systems. By using the directional residual protection as back-up function, the back-up fault clearance time can be kept relatively short together with the maintained selectivity.
4. Etc.

Functionality

The residual overcurrent protection (TEF) measures the residual current of the protected line. This current is compared to the current settings of the function. If the residual current is larger than the setting value a trip signal will be sent to the output after a set delay time. The time delay can be selected between the independent or dependent possibility.

In order to avoid unwanted trip for transformer inrush currents, the function is blocked if the second harmonic content of the residual current is larger than 20% of the measured residual current.

As an option the residual overcurrent protection can have directional function. The residual voltage is used as a polarizing quantity. This voltage is either derived as the vectorial sum of inputs U1+U2+U3 or as the input U4. The fault is defined to be in the forward direction if the residual current component in the characteristic angle 65° (residual current lagging the reference voltage, -3U0), is larger than the set operating current in forward direction. The same kind of measurement is performed also in the reverse direction.

Scheme communication logic for residual overcurrent protection

Application

The EFC directional comparison function contains logic for blocking overreaching and permissive overreaching schemes. The function is applicable together with TEF time delayed directional residual overcurrent protection in order to decrease the total operate time of a complete scheme.

One communication channel, which can transmit an on / off signal, is required in each direction. It is recommended to use the complementary additional communication logic EFCA, if the weak infeed and/or current reversal conditions are expected together with permissive overreaching scheme.

Functionality

The communication logic for residual overcurrent protection contains logics for blocking overreach and permissive overreach schemes.

In the blocking scheme a signal is sent to the remote end of the line if the directional element, in the directional residual overcurrent protection (sending end), detects the fault in the reverse direction. If no blocking signal is received and the directional element, in the directional residual overcurrent protection (receiving end), detects the fault in the forward direction, a trip signal will be sent after a settable time delay.

In the permissive overreach scheme a signal is sent to the remote end of the line if the directional element, in the directional residual overcurrent protection (sending end), detects the fault in the forward direction. If an acceleration signal is received and the directional element, in the directional residual overcurrent protection (receiving end), detects the fault in the forward direction, a trip signal will be sent, normally with no time delay. In case of risk for fault current reversal or weak end infeed, an additional logic can be used to take care of this.

Current reversal and weak end infeed logic for residual overcurrent protection (EFCA)

Application

The EFCA additional communication logic is a supplement to the EFC scheme communication logic for the residual overcurrent protection.

To achieve fast fault clearing for all earth faults on the line, the TEF earth-fault protection function can be supported with logic, that uses communication channels. REx 5xx terminals 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.

Functionality

The reverse directed signal from the directional residual overcurrent function, starts the operation of a current reversal logic. The output signal, from the logic, will be activated, if the fault has been detected in reverse direction for more than the tPickUp time set on the corresponding timers. The tDelay timer delays the reset of the output signal. The signal blocks the operation of the overreach permissive scheme for residual current, and thus prevents unwanted operation due to fault current reversal.

The weak end infeed logic uses normally a forward and reverse signal from the directional residual overcurrent function. The weak end infeed logic echoes back the received permissive signal, if none of the directional measuring elements have been activated during the last 200 ms. Further, it can be set to give signal to trip the breaker if the echo conditions are fulfilled and the residual voltage is above the set operate value for $3U_0$>.

Sensitive directional residual overcurrent protection (WEF1)

Application

In isolated networks or in networks with high impedance earthing, the phase to 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 uses the residual current component $3I_0 \cos\varphi$, where φ is the angle between the residual current and the reference voltage, compensated with a characteristic angle. The characteristic angle is chosen to -90° in an isolated system. The characteristic angle is chosen to 0° in compensated systems.

Functionality

The function measures the residual current and voltage. The angle between the residual voltage and residual current (angle between 3I0 and -3U0 i.e U0 is 180 degrees adjusted) is calculated. This angle is used in two functions namely first to determine if the fault is in forward or reverse direction, and secondly to calculate the residual current component in the characteristic angle direction.

The residual current component in the characteristic angle direction is compared with the set operating value. If this current component is larger than the setting this is one criterion for function of the protection. The residual voltage is compared to a set operating value. If the measured voltage is larger than the setting this is another criterion for the operation of the protection. If both the criteria are fulfilled and the set time delay has elapsed, the function will give a trip signal.

Due to the demands on accuracy and sensitivity for this function, special current input transformers must be used.

Sensitive directional residual power protection (WEF2)

Application

In isolated networks or in networks with high impedance earthing, the phase to 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 uses the residual power component $3U_0 \, .3I_0.\cos\varphi$, where φ is the angle between the residual current and the reference voltage, compensated with a characteristic angle. The characteristic angle is chosen to -90° in an isolated system. The characteristic angle is chosen to 0° in compensated systems.

Functionality

The function measures the residual current and voltage. The angle between the residual voltage and residual current is calculated. This angle is used in two functions namely first to determine if the fault is in forward or reverse direction, and secondly to calculate the residual power component in the characteristic angle direction.

The residual voltage ($3U_0$) is compared with a setting value. The residual current ($3I_0$) is compared to a setting value. The residual power component in the characteristic angle direction (S_N) is compared to a power reference setting. If the power is larger than the setting this is one criterion for function of the protection. The voltage and current measurement are two other criteria that must be fulfilled for function. The information on power is the input to a dependent time delay function. The function will give a trip signal when all three criteria for function are fulfilled and the time delay has elapsed.

Due to the demands on accuracy and sensitivity for this function, special current input circuits must be used.

Four step residual overcurrent protection (EF4)

Application

Use the four step earth fault overcurrent protection in solidly earthed systems in a similar way as a distance protection. As the majority of faults involve earth connection, the protection will be able to clear most of the faults in solidly grounded systems.

The normal application of the four step earth fault current protection can be described as follows: The instantaneous and directional step 1 will normally cover most of the line. The rest of the line is covered by the directional and delayed step 2. Step 2 will also detect and trip earth faults on the remote busbar. The directional step 3 has a longer time delay and will act as a selective protection for earth faults with some degree of fault resistance. The non-directional step 4 has the longest delay. This step will detect and clear high resistive earth faults as well as the majority of series faults.

The four step residual overcurrent protection can also be used together with the communication logic for residual overcurrent protection, in order to realize blocking or permissive overreaching communication schemes.

Functionality

The function operates on the basis of the residual current and voltage measurement. The function has four steps with individual settings (current, delay, etc.). Step 1, 2 and 3 have independent time delay. The time delay for step 4 can be selected between independent or dependent mode of operation.

For each step the current is compared to the set current of the step. Further the following quantities are checked to be used as release or blocking of function from the steps:

- Direction, forward or reverse direction to the fault. The residual current component lagging the reference (-3.U0) voltage 65° is derived. If this current component is larger than the directional current setting, forward direction is detected.
- The second harmonic of the residual current is derived. If this current is larger than 20/32 % of the total residual current, a signal is given that can be used for blocking of the steps.

If the conditions for function is fulfilled for a step, a trip signal is given after the set time delay. For step 1, 2 and 3 independent time delay is used. For step 4 independent or dependent time delay can be used.

Voltage

Time delayed undervoltage protection (TUV)

Application

The time delayed undervoltage protection function, TUV, is applicable in all situations, where reliable detection of low phase voltages is necessary. The function can also be used as a supervision and fault detection function for some other protection functions, to increase the security of a complete protection system.

Time delayed overvoltage protection (TOV)

Application

The time delayed phase overvoltage protection is used to protect the electrical equipment and its insulation against overvoltage by measuring three phase voltages. In this way, it prevents the damage to the exposed primary and secondary equipment in the power systems.

The residual overvoltage protection function is mainly used in distribution networks, mainly as a backup protection for the residual overcurrent protection in the line feeders, to secure the disconnection of earth-faults.

Functionality

The phase overvoltage protection function continuously measures the three phase voltages and initiates the corresponding output signals if the measured phase voltages exceed the preset value (starting) and remain high longer than the time delay setting on the timers (trip). This function also detects the phases which caused the operation.

The residual overvoltage protection function calculates the residual voltage (3U0) from the measuring three phase voltages and initiates the corresponding output signals if the residual voltage is larger than the preset value (starting) and remains high longer than the time delay setting (trip).

Power system supervision

Broken conductor check (BRC)

Application

The main purpose of the BRC broken conductor check function is the detection of broken conductors on protected power lines and cables (series faults). It is also able to detect interruptions in the secondary current circuits.

Functionality

The BRC function detects a broken conductor condition by detecting the non symmetry between currents in the three phases. It does this by measuring the difference between the maximum and minimum phase currents, i.e. it compares the magnitude of the minimum current with that of the maximum current, and gives an output if the minimum current is less than 80% of the maximum current for a set time interval. At the same time, the highest current must be higher than a set percentage of the terminal rated current.

Loss of voltage check (LOV)

Application

The loss of voltage detection, LOV, is suitable for use in networks with an automatic restoration function. The LOV function 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 7 seconds, and the circuit breaker remains closed.

Functionality
The operation of LOV function is based on line voltage measurement. The function is provided with a logic, which automatically recognises if the line was restored for at least three seconds before starting the seven seconds timer. Additionally, the function is automatically blocked if only one or two phase voltages have been detected low for more than 10 seconds. The LOV function operates again only if the line has been fully energised.

Operation of LOV function is also inhibited by fuse failure and open circuit breaker information signals, by their connection to dedicated inputs of the function block.

The operation of the function is supervised by the fuse-failure function and the information about the closed position of the associated circuit breaker.

Overload supervision (OVLD)

Application
The overload protection, OVLD, prevents excessive loading of power transformers, lines and cables.

Alternative application is the detection of primary current transformer overload, as they usually can withstand a very small current beyond the rated value.

Functionality
The function continuously measures the three phase currents flowing through the terminal. If any of the three currents is beyond the preset overcurrent threshold for a time longer than the preset value, a trip signal is activated.

Dead line detection (DLD)

Application
The main purpose of the dead line detection is to provide different protection, control and monitoring functions with the status of the line, i.e whether or not it is connected to the rest of the power system.

Functionality
The dead line detection function continuously measures all three phase currents and phase voltages of a protected power line. The line is declared as dead (not energized) if all three measured currents and voltages fall below the preset values for more than 200 ms.

Secondary system supervision

Current circuit supervision (CTSU)

Application
Faulty information about current flows in a protected element might influence the security (line differential protection) or dependability (line distance protection) of a complete protection system.

The main purpose of the current circuit supervision function is to detect different faults in the current secondary circuits and influence the operation of corresponding main protection functions.

The signal can be configured to block different protection functions or initiate an alarm.

Functionality
The function compares the sum of the three phase currents from one current transformer core with a reference zero sequence current from another current transformer core.

The function issues an output signal when the difference is greater than the set value.

Fuse failure supervision (FUSE)

Application
The fuse failure supervision function, FUSE, continuously supervises the ac voltage circuits between the voltage instrument transformers and the terminal. Different output signals can be used to block, in case of faults in the ac voltage secondary circuits, the operation of the distance protection and other voltage-dependent functions, such as the synchro-check function, undervoltage protection, etc.

Different measurement principles are available for the fuse failure supervision function.

The FUSE function based on zero sequence measurement principle, is recommended in directly or low impedance earthed systems.

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

Functionality
The FUSE function based on the zero sequence measurement principle continuously measures the zero sequence current and voltage in all three phases. It operates if the measured zero sequence voltage increases over preset operating value, and if the measured zero sequence current remains below the preset operating value.

The $\Delta I/\Delta t$ and $\Delta U/\Delta t$ algorithm, detects a fuse failure if a sufficient negative change in voltage amplitude without a sufficient change in current amplitude is detected in each phase separately. This check is performed if the circuit breaker is closed. Information about the circuit breaker position is brought to the function input CBCLOSED through a binary input of the terminal.

Three output signals are available. The first depends directly on the voltage and current measurement. The second depends on the operation of the dead line detection function, to prevent unwanted operation of the distance protection if the line has been deenergised and energised under fuse failure conditions. The third depends on the loss of all three measured voltages. A special function input serves the connection to the auxiliary contact of a miniature circuit breaker, MCB (if used), to secure correct operation of the function on simultaneous interruption of all three measured phase voltages also when the additional delta current and delta voltage algorithm is not present in the function block.

Voltage transformer supervision (TCT)

Application
The main purpose of the voltage transformer supervision function is to indicate failure in the measuring voltage from a capacitive voltage transformer.

Functionality
The voltage transformer supervision function checks all of the three phase-phase voltages and the residual voltage. If the residual voltage exceeds the setpoint value and any of the phase-phase voltages is higher than 80% of the rated phase-phase voltage the output is activated after a settable time delay.

Control

Synchrocheck (SYN)

Application
The main purpose of the synchrocheck function is to provide controlled closing of circuit breakers in interconnected networks.

The main purpose of the energizing check function is to facilitate the controlled reconnection of a disconnected line or bus to, respectively, an energized bus or line.

The main purpose of the phasing 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.

The phasing function is only available together with the synchrocheck and energizing check functions.

To meet the different application arrangements, a number of identical SYN function blocks may be provided within a single terminal. The number of these function blocks that may be included within any given terminal depends on the type of terminal. Therefore, the specific circuit breaker arrangements that can be catered for, or the number of bays of a specific arrangement that can be catered for, depends on the type of terminal.

Functionality
The synchrocheck function measures the conditions across the circuit breaker and compares them to set limits. The output is only given when all measured conditions are simultaneously within their set limits.

The energizing check function measures the bus and line voltages and compares them to both high and low threshold detectors. The output is only given when the actual measured conditions match the set conditions.

The phasing function measures the conditions across the circuit breaker, and also determines the angle change during the closing delay of the circuit breaker from the measured slip frequency. The output is only given when all measured conditions are simultaneously within their set limits. The issue of the output is timed to give closure at the optimal time.

For single circuit breaker, the SYN function blocks have the capability to make the necessary voltage selection. For single circuit breaker arrangements, selection of the correct voltage is made using auxiliary contacts of the bus disconnectors.

Automatic reclosing function (AR)

Application

The majority of power line faults are transient in nature, i.e. they do not recur when the line is re-energized following disconnection. The main purpose of the AR automatic reclosing function is to automatically return power lines to service following their disconnection for fault conditions.

Especially at higher voltages, the majority of line faults are single-phase-to-earth. Faults involving all three phases are rare. The main purpose of the single- and two-pole automatic reclosing function, operating in conjunction with a single- and two-pole tripping capability, is to limit the effect to the system of faults involving less than all three phases. This is particularly valuable for maintaining system stability in systems with limited meshing or parallel routing.

Functionality

The AR function is a logical function built up from logical elements. It operates in conjunction with the trip output signals from the line protection functions, the OK to close output signals from the synchrocheck and energizing check function, and binary input signals. The binary input signals can be for circuit breaker position/status or from other external protection functions.

Of the six reclosing programs, one provides for three-pole reclosing only, while the others provide for single- and two-pole reclosing as well. For the latter, only the first shot may be single- or two-pole. All subsequent shots up to the maximum number will be three-pole. For some of the programs, depending on the initial trip, no shot, or only one shot, will be permitted irrespective of the number of shots selected.

Single command (CD)

Application

The terminals may be provided with a function to receive signals either from a substation automation system (SMS and/or SCS) or from the local human-machine interface, HMI. That receiving function block has 16 outputs that can be used, for example, to control high voltage apparatuses in switchyards. For local control functions, the local HMI can also be used. Together with the configuration logic circuits, the user can govern pulses or steady output signals for control purposes within the terminal or via binary outputs.

Functionality

The single command function consists of a function block CD for 16 binary output signals.

The output signals can be of the types Off, Steady, or Pulse. The setting is done on the MODE input, common for the whole block, from the CAP 531 configuration tool.

The outputs can be individually controlled from the operator station, remote-control gateway, or from the local HMI. Each output signal can be given a name with a maximum of 13 characters from the CAP 531 configuration tool.

The output signals, here OUT1 to OUT16, are then available for configuration to built-in functions or via the configuration logic circuits to the binary outputs of the terminal.

Multiple command (CM)

Application

The terminals may be provided with a function to receive signals either from a substation automation system or from other terminals via the interbay bus. That receiving function block has 16 outputs that can be used, together with the configuration logic circuits, for control purposes within the terminal or via binary outputs. When it is used to communicate with other terminals, these terminals must have a corresponding event function block to send the information.

Functionality

One multiple command function block CM01 with fast execution time also named *Binary signal interbay communication, high speed* and/or 79 multiple command function blocks CM02-CM80 with slower execution time are available in the REx 5xx terminals as options.

The output signals can be of the types Off, Steady, or Pulse. The setting is done on the MODE input, common for the whole block, from the CAP 531 configuration tool.

The multiple command function block has 16 outputs combined in one block, which can be controlled from the operator station or from other terminals. One common name for the block, with a maximum of 19 characters, is set from the configuration tool CAP 531.

The output signals, here OUT1 to OUT16, are then available for configuration to built-in functions or via the configuration logic circuits to the binary outputs of the terminal.

The command function also has a supervision function, which sets the output VALID to 0 if the block did not receive data within a configured INTERVAL time.

Logic

Trip logic (TR)

Application

The main purpose of the TR trip logic function is to serve as a single node through which all tripping for the entire terminal is routed.

The main purpose of the single- and two-pole extension to the basic three-pole tripping function is to cater for applications where, for reasons of system stability, single-pole tripping is required for single-phase faults, and/or two-pole tripping is required for two-phase faults, e.g. on double circuit parallel lines.

To meet the different single, double, 1 and 1/2 or other multiple circuit breaker arrangements, one or more identical TR function blocks may be provided within a single terminal. The actual number of these TR function blocks that may be included within any given terminal depends on the type of terminal. Therefore, the specific circuit breaker arrangements that can be catered for, or the number of bays of a specific arrangement that can be catered for, depends on the type of terminal.

Functionality

The minimum duration of a trip output signal from the TR function is settable.

The TR function has a single input through which all trip output signals from the protection functions within the terminal, or from external protection functions via one or more of the terminal’s binary inputs, are routed. It has a single trip output for connection to one or more of the terminal’s binary outputs, as well as to other functions within the terminal requiring this signal.

The expanded TR function for single- and two-pole tripping has additional phase segregated inputs for this, as well as inputs for faulted phase selection. The latter inputs enable single- and two-pole tripping for those functions which do not have their own phase selection capability, and therefore which have just a single trip output and not phase segregated trip outputs for routing through the phase segregated trip inputs of the expanded TR function. The expanded TR function has two inputs for these functions, one for impedance tripping (e.g. carrier-aided tripping commands from the scheme communication logic), and one for earth fault tripping (e.g. tripping output from a residual overcurrent protection). Additional logic secures a three-pole final trip command for these protection functions in the absence of the required phase selection signals.

The expanded TR function has three trip outputs, one per phase, for connection to one or more of the terminal’s binary outputs, as well as to other functions within the terminal requiring these signals.

The expanded TR function is equipped with logic which secures correct operation for evolving faults as well as for reclosing on to persistent faults. A special input is also provided which disables single- and two-pole tripping, forcing all tripping to be three-pole.

Pole discordance protection (PD)

Application

Breaker pole position discordance can occur on the operation of a breaker with independent operating gears for the three poles. The reason may be an interruption in the closing or trip coil circuit, or a mechanical failure resulting in a stuck breaker pole. A pole discordance can be tolerated for a limited time, for instance during a single-phase trip-reclose cycle. The pole discordance function detects a breaker pole discordancy not generated by auto-reclose cycle and issues a trip signal for the circuit breaker.

Functionality

The operation of the pole discordance logic, PD, is based on checking the position of the breaker auxiliary contacts. Three parallel normally open contacts in series with three normally closed contacts in parallel of the respective breaker poles form a condition of pole discordance, connected to a binary input dedicated for the purpose.

High speed binary output logic (HSBO)

Application

The time taken for signals to be transferred from binary inputs to protection functions, and from protection functions to binary outputs contributes to the overall tripping time. The main purpose of the HSBO high speed binary output logic is to minimize overall tripping times by establishing the critical connections to/from the binary outputs/inputs in a more direct way than with the regular I/O connections.

Functionality

The outputs from the HSBO logic utilize ‘fast’ connections to initiate binary outputs. The inputs to the HSBO logic utilize the same ‘fast’ connections. Input connections to the logic are derived from binary inputs, from outputs of the high speed distance protection, and from inputs to the regular trip logic and scheme communication logic. The HSBO scheme communication logic runs in parallel with the regular scheme communication logic.

The ‘fast’ connections to and from the HSBO logic comprise so called hard connections in software. This configuration is made internally and cannot be altered. The only exceptions are the connections to the binary outputs where limited configuration is possible, and required, on the part of the user.

Communication channel test logic (CCHT)

Application

Many secondary system applications require testing of different functions with confirmed information about the result of the test. The main purpose of the CCHT communication channel test logic is to perform testing of communication channels (power line carrier) in applications where continuous monitoring by some other means is not possible due to technical or economic reasons, and to indicate the result of the test.

Functionality

Starting of a communications channel test may be performed manually (by means of an external pushbutton) or automatically (by means of an included timer). When started, the CCHT logic initiates the sending of an impulse (carrier send signal) to the remote end. This action starts the operation of the applicable external functions. On receipt of the sent signal at the remote end terminal, a return signal is immediately sent back to the initiating end by the identical CCHT logic function within that terminal. The initiating end waits for this returned signal. It reports a successful or an unsuccessful response to the initiated test based on the receipt or not of this signal. An input is provided through which it is possible to abort the test by means of an external signal.

Binary signal transfer to remote end (RTC)

General

In this function, there are two function blocks, RTC1-, and RTC2-. They are identical in all aspects.

Application

The main purpose of the RTC binary signal transfer to remote end function is the exchange of communication scheme related signals, trip signals and/or other binary signals between opposite ends of the line.

Functionality

The RTC function comprises two identical function blocks, each able to handle up to 16 inputs and 16 outputs, giving a total of 32 signals that can be transmitted in each direction.

The updated status of the selected binary signals is packaged within a data message which is sent once every computation loop.

Serial communication

Application

One or two optional optical serial interfaces, one with LON protocol and the other with SPA or IEC 60870-5-103 protocol, for remote communication, enables the terminal to be part of a Substation Control System (SCS) and/or Substation Monitoring System (SMS). These interfaces are located at the rear of the terminal. The two interfaces can be configured independent of each other, each with different functionalities regarding monitoring and setting of the functions in the terminal.

Serial communication, SPA (SPA-bus V 2.4 protocol)

Application

This communication bus is mainly used for SMS. It can include different numerical relays/terminals with remote communication possibilities. Connection to a personal computer (PC) can be made directly (if the PC is located in the substation) or by telephone modem through a telephone network with CCITT characteristics.

Functionality

When communicating with a PC, using the rear SPA port, the only hardware needed for a station monitoring system is optical fibres and opto/electrical converter for the PC. Remote communication over the telephone network also requires a telephone modem. The software needed in the PC when using SPA, either locally or remotely, is SMS 510 or/and CAP 540.

SPA communication is applied when using the front communication port, but for this purpose, no special serial communication function is required in the terminal. Only the software in the PC and a special cable for front connection is needed.

Serial communication, IEC (IEC 60870-5-103 protocol)

Application

This communication protocol is mainly used when a protection terminal communicates with a third party control system. This system must have a program that can interpret the IEC 60870-5-103 communication messages.

Functionality

As an alternative to the SPA communication the same port can be used for the IEC communication. The IEC 60870-5-103 protocol implementation in REx 5xx consists of these functions:

- Event handling
- Report of analog service values (measurements)
- Fault location
- Command handling
  - Autorecloser ON/OFF
  - Teleprotection ON/OFF
  - Protection ON/OFF
  - LED reset
  - Characteristics 1 - 4 (Setting groups)
- File transfer (disturbance files)
- Time synchronization

The events created in the terminal available for the IEC protocol are based on the event function blocks EV01 - EV06 and disturbance function blocks DRP1 - DRP3. The commands are represented in a dedicated function block ICOM. This block has output signals according to the IEC protocol for all commands.

Serial communication, LON

Application

An optical network can be used within the Substation Automation system. This enables communication with the terminal through the LON bus from the operator’s workplace, from the control center and also from other terminals.

Functionality

An optical serial interface with LON protocol enables the terminal to be part of a Substation Control System (SCS) and/or Substation Monitoring System (SMS). This interface is located at the rear of the terminal. The hardware needed for applying LON communication depends on the application, but one very central unit needed is the LON Star Coupler and optic fibres connecting the star coupler to the terminals. To communicate with the terminals from a Personal Computer (PC), the SMS 510, software or/and the application library LIB 520 together with MicroSCADA is needed.

Event function (EV)

Application

When using a Substation Automation system, events can be spontaneously sent or polled from the terminal to the station level. These events are created from any available signal in the terminal that is connected to the event function block. The event function block can also handle double indication, that is normally used to indicate positions of high-voltage apparatuses. With this event function block, data also can be sent to other terminals over the interbay bus.

Functionality

As basic, 12 event function blocks EV01-EV12 running with a fast cyclicity, are available in REx 5xx. When the function Apparatus control is used in the terminal, additional 32 event function blocks EV13-EV44, running with a slower cyclicity, are available.

Each event function block has 16 connectables corresponding to 16 inputs INPUT1 to INPUT16. Every input can be given a name with up to 19 characters from the CAP 540 configuration tool.

The inputs can be used as individual events or can be defined as double indication events.

The inputs can be set individually, from the Parameter Setting Tool (PST) under the Mask-Event function, to create an event at pick-up, drop-out or at both pick-up and drop-out of the signal.

The event function blocks EV01-EV06 have inputs for information numbers and function type, which are used to define the events according to the communication standard IEC 60870-5-103.

Event counter (CN)

Application

The function consists of six counters which are used for storing the number of times each counter has been activated. It is also provided with a common blocking function for all six counters, to be used for example at testing. Every counter can separately be set on or off by a parameter setting.

Functionality

The function block has six inputs for increasing the counter values for each of the six counters respectively. The content of the counters are stepped one step for each positive edge of the input respectively.

The function block also has an input BLOCK. At activation of this input all six counters are blocked.

Monitoring

Led indication function (HL, HLED)

Application

Each LED indication on the HMI LED module can be set individually to operate in six different sequences; two as follow type and four as latch type. Two of the latching types are intended to be used as a protection indication system, either in collecting or re-starting mode, with reset functionality. The other two are intended to be used as a signaling system in collecting mode with an acknowledgment functionality.

Functionality

The LED indication function consists of one common function block named HLED and one function block for each LED named HL01, HL02,..., HL18.

The color of the LEDs can be selected in the function block to red, yellow or green individually. The input signal for an indication has separate inputs for each color. If more than one color is used at the same time, the following priority order is valid; red, yellow and green, with red as highest priority.

The information on the LEDs is stored at loss of the auxiliary power for the terminal, so that the latest LED picture appears immediately after the terminal has restarted succesfully.

Disturbance report (DRP)

Application

Use the disturbance report to provide the network operator with proper information about disturbances in the primary network. The function comprises several subfunctions enabling different types of users to access relevant information in a structured way.

Select appropriate binary signals to trigger the red HMI LED to indicate trips or other important alerts.

Functionality

The disturbance report collects data from each subsystem for up to ten disturbances. The data is stored in nonvolatile memory, used as a cyclic buffer, always storing the latest occurring disturbances. Data is collected during an adjustable time frame, the collection window. This window allows for data collection before, during and after the fault.

The collection is started by a trigger. Any binary input signal or function block output signal can be used as a trigger. The analog signals can also be set to trigger the data collection. Both over levels and under levels are available. The trigger is common for all subsystems, hence it activates them all simultaneously.

A triggered report cycle is indicated by the yellow HMI LED, which will be lit. Binary signals may also be used to activate the red HMI LED for additional alerting of fault conditions. A disturbance report summary can be viewed on the local HMI.

Indications

Application
Use the indications list to view the state of binary signals during the fault. All binary input signals to the disturbance report function are listed.

Functionality
The indications list tracks zero-to-one changes of binary signals during the fault period of the collection window. This means that constant logic zero, constant logic one or state changes from logic one to logic zero will not be visible in the indications list. Signals are not time tagged. In order to be listed in the indications list the:

1. signal must be connected to the DRP function block.
2. setting parameter, IndicationMask, for the input must be set to Show.

Output signals of other function blocks of the configuration will be listed by the signal name listed in the corresponding signal list. Binary input signals are listed by the name defined in the configuration.

The indications can be viewed on the local HMI and via SMS.

Disturbance recorder

Application
Use the disturbance recorder to record analog and binary signals during fault conditions in order to analyze disturbances. The analysis may include fault severity, fault duration and protection performance. Replay the recorded data in a test set to verify protection performance.

Functionality
The disturbance recorder records both analog and binary signal information.

Analog and digital signals can be used as triggers. A trigger signal does not need to be recorded.

A trigger is generated when the analog signal moves under and/or over set limit values. The trig level is compared to the signal's average peak-to-peak value, making the function insensible to DC offset. The trig condition must occur during at least one full period, that is, 20 ms for a 50 Hz network.

The recorder continuously records data in a cyclic buffer capable of storing the amount of data generated during the set pre-fault time of the collection window. When triggered, the pre-fault data is saved and the data for the fault and post-fault parts of the collection window is recorded.

The RAM area for temporary storage of recorded data is divided into subareas, one for each recording. The size of a subarea depends on the set recording times. There is sufficient memory for four consecutive recordings with a maximum number of analog channels recorded and with maximum time settings. Should no subarea be free at a new disturbance, the oldest recording is overwritten.

When a recording is completed, the post recording process:

- merges the data for analog channels with corresponding data for binary signals stored in an event buffer
- compresses the data without loosing any data accuracy
- stores the compressed data in a non-volatile memory

The disturbance recordings can be viewed via SMS or SCS.

Event recorder

Application
Use the event recorder to obtain a list of binary signal events that occurred during the disturbance.

Functionality
When a trigger condition for the disturbance report is activated, the event recorder collects time tagged events from the 48 binary signals

that are connected to disturbance report and lists the changes in status in chronological order. Each list can contain up to 150 time tagged events that can come from both internal logic signals and binary input channels. Events are recorded during the total recording time which depends on the set recording times and the actual fault time.

Events can be viewed via SMS and SCS.

Fault locator (FLOC)

Application

An accurate fault locator is an essential complement to the line protection. The fault locator provides distance to fault together with information about the measuring loop that has been used in the calculation.

Reliable information on fault location reduces the outage time and minimises the need for patrolling.

The function has limitations for applications with series compensated lines.

Functionality

The fault locator can be started by any internal or external binary signal. Pre-fault and fault phasors of currents and voltages, that were filtered from disturbance data stored into digital sample buffers, are then used for the distance to fault calculation. The phase selective signals from the built-in protection functions provide the necessary information for the selection of the loop to be used for the calculation. It is also possible to use the external phase selection information.

For the distance to fault calculation, a line modelling algorithm that takes into account the sources at both ends of the line, is used. In this way, the influence of the load current, the infeed from the remote end and the fault resistance, can be compensated for, resulting in a highly accurate calculation.

In case of double circuit lines, the influence of the zero-sequence mutual impedance Zm0 is compensated for by considering the residual current on the parallel line.

The function indicates the distance to the fault as a percentage of the line length, in kilometers or miles as selected.

Possibility to make recalculations with changed parameter settings exists.

Information on the last ten disturbances is stored.

Trip value recorder

Application

Use the trip value recorder to record fault and prefault phasor values of voltages and currents to be used in detailed analysis of the severity of the fault and the phases that are involved. The recorded values can also be used to simulate the fault with a test set.

Functionality

Pre-fault and fault phasors of currents and voltages are filtered from disturbance data stored in digital sample buffers.

When the disturbance report function is triggered, the function looks for non-periodic change in the analog channels. Once the fault interception is found, the function calculates the pre-fault RMS values during one period starting 1,5 period before the fault interception. The fault values are calculated starting a few samples after the fault interception and uses samples during 1/2 - 2 periods depending on the waveform.

If no error sample is found the trigger sample is used as the start sample for the calculations. The estimation is based on samples one period before the trigger sample. In this case the calculated values are used both as pre-fault and fault values.

The recording can be viewed on the local HMI or via SMS.

Monitoring of AC analogue measurements

Application

Use the AC monitoring function to provide three phase or single phase values of voltage and current. At three phase measurement, the values of apparent power, active power, reactive power, frequency and the RMS voltage and current for each phase are calculated. Also the average values of currents and voltages are calculated.

Functionality

Alarm limits can be set and used as triggers, e.g. to generate trip signals.

The software functions to support presentation of measured values are always present in the terminal. In order to retrieve actual values, however, the terminal must be equipped with the appropriate hardware measuring module(s), i.e. Transformer Input Module (TRM) or Optical Receiver Module (ORM).

Monitoring of DC analogue measurements

Application

Use the DC monitoring function to measure and process signals from different measuring transducers. Many devices used in process control uses low currents, usually in the range 4-20 mA or 0-20 mA to represent various parameters such as frequency, temperature and DC battery voltage.

Functionality

Alarm limits can be set and used as triggers, e.g. to generate trip signals.

The software functions to support presentation of measured values are always present in the terminal. In order to retrieve actual values, however, the terminal must be equipped with the mA Input Module (MIM).

Increased measuring accuracy

Application

Select the increased accuracy option to increase the measuring accuracy of analog input channels, thus also increasing the accuracy of calculated quantities such as frequency, active and reactive power.

Functionality

The increased accuracy is reached by a factory calibration of the hardware. Calibration factors are stored in the terminal. If the transformer input module, A/D conversion module or the main processing module is replaced, the terminal must be factory calibrated again to retain the increased accuracy.

Metering

Pulse counter logic (PC)

Application

The pulse counter logic 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 binary input module and then read by the pulse counter function. The number of pulses in the counter is then reported via LON to the station control system or read via SPA from the station monitoring system as a service value.

Functionality

Up to 12 inputs located on binary input modules can be used for counting of pulses with a frequency of up to 40 Hz. The registration of pulses is done for positive transitions (0 to 1) on any of the 16 binary input channels on the input module.

Pulse counter values are read from the operator workplace with predefined cyclicity without reset. The integration time period can be set in the range from 30 seconds to 60 minutes and is synchronized with absolute system time.

The counter value is a 32-bit, signed integer with a range 0...+2147483647. The reported value over the communication bus contains Identity, Value, Time and Pulse Counter Quality.

Hardware modules

Modules

Modules

Table 1: Basic, always included, modules

Module	Description
Backplane module	The size of the module depends on the size of the case.
Power supply module (PSM)	Available in two different versions, each including a regulated DC/DC converter that supplies auxiliary voltage to all static circuits. • For case size 1/2x19” and 3/4x19” a version with four binary inputs and four binary outputs are used. An internal fail alarm output is also available. • For case size 1/1x19” a version without binary I/O:s and increased output power is used.
Main processing module (MPM)	Module for overall application control. All information is processed or passed through this module, such as configuration, settings and communication.
Human machine interface (LCD-HMI)	The module consist of LED:s, a LCD, push buttons and an optical connector for a front connected PC
Signal processing module (SPM)	Module for protection algorithm processing. Carries up to 12 digital signal processors, performing all measuring functions.

Table 2: Application specific modules

Module	Description
Milliampere input module (MIM)	Analog input module with 6 independent, galvanically separated channels.
Binary input module (BIM)	Module with 16 optically isolated binary inputs
Binary output module (BOM)	Module with 24 single outputs or 12 double-pole command outputs including supervision function
Binary I/O module (IOM)	Module with 8 optically isolated binary inputs, 10 outputs and 2 fast signalling outputs.
Data communication modules (DCMs)	Modules used for digital communication to remote terminal.
Transformer input module (TRM)	Used for galvanic separation of voltage and/or current process signals and the internal circuitry.
A/D conversion module (ADM)	Used for analog to digital conversion of analog process signals galvanically separated by the TRM.

Module	Description
Optical receiver module (ORM)	Used to interface process signals from optical instrument transformers.
Serial communication module (SCM)	Used for SPA/LON/IEC communication
LED module (LED-HMI)	Module with 18 user configurable LEDs for indication purposes

Transformer input module (TRM)

Functionality

A transformer input module can have up to 10 input transformers. The actual number depends on the type of terminal. Terminals including only current measuring functions only have current inputs. Fully equipped the transformer module consists of:

- Five voltage transformers
- Five current transformers

The inputs are mainly used for:

- Phase currents
- Residual current of the protected line
- Residual current of the parallel circuit (if any) for compensation of the effect of the zero sequence mutual impedance on the fault locator measurement or residual current of the protected line but from a parallel core used for CT circuit supervision function or independent earth fault function.
- Phase voltages
- Open delta voltage for the protected line (for an optional directional earth-fault protection)
- Phase voltage for an optional synchronism and energizing check.

A/D-conversion module (ADM)

Functionality

The inputs of the A/D-conversion module (ADM) are fed with voltage and current signals from the transformer module. The current signals are adapted to the electronic voltage level with shunts. To gain dynamic range for the current inputs, two shunts with separate A/D channels are used for each input current. By that a 16-bit dynamic range is obtained with a 12 bits A/D converter.

The input signals passes an anti aliasing filter with a cut-off frequency of 500 Hz.

Each input signal (5 voltages and 5 currents) is sampled with a sampling frequency of 2 kHz.

The A/D-converted signals are low-pass filtered with a cut-off frequency of 250 Hz and down-sampled to 1 kHz in a digital signal processor (DSP) before transmitted to the main processing module.

Binary I/O capabilities

Application

Input channels with high EMI immunity can be used as binary input signals to any function. Signals can also be used in disturbance or event recording. This enables extensive monitoring and evaluation of the operation of the terminal and associated electrical circuits.

Functionality

Inputs are designed to allow oxide burn-off from connected contacts, and increase the disturbance immunity during normal protection operate times. This is achieved with a high peak inrush current while having a low steady-state current. Inputs are debounced by software.

Well defined input high and input low voltages ensures normal operation at battery supply earth faults.

The voltage level of the inputs is selected when ordering.

I/O events are time stamped locally on each module for minimum time deviance and stored by the event recorder if present.

Binary input module (BIM)

Application

Use the binary input module, BIM, when a large amount of inputs are needed. The BIM is available in two versions, one standard and one with enhanced pulse counting inputs to be used with the pulse counter function.

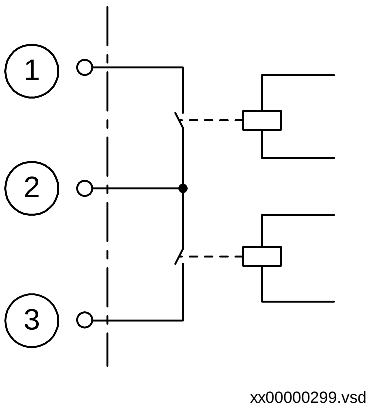
Functionality
The binary input module, BIM, has 16 optically isolated binary inputs.

A signal discriminator detects and blocks oscillating signals. When blocked, a hysteresis function may be set to release the input at a chosen frequency, making it possible to use the input for pulse counting. The blocking frequency may also be set.

Binary output module (BOM)

Application
Use the binary output module, BOM, for trip output or any signalling purpose when a large amount of outputs is needed.

Functionality
The binary output module, BOM, has 24 software supervised output relays, pairwise connected to be used as single-output channels with a common or as command output channels.



1	Output connection from relay 1
2	Common input connection
3	Output connection from relay 2

Figure 5: Relay pair example

I/O module (IOM)

Application
Use the binary I/O module, IOM, when few input and output channels are needed. The ten output channels are used for trip output or any signalling purpose. The two high speed signal output channels are used for applications where short operating time is essential, for example time synchronization.

Functionality
The binary I/O module, IOM, has eight optically isolated inputs and ten output relays. One of the outputs has a change-over contact. The nine remaining output contacts are connected in two groups. One group has five contacts with a common and the other group has four contacts with a common, to be used as single-output channels.

The binary I/O module also has two high speed output channels where a reed relay is connected in parallel to the standard output relay.

Note: The making capacity of the reed relays are limited.

mA input module (MIM)

Application
Use the milliampere input module, MIM, to interface transducer signals in the +/-20 mA range from for example temperature and pressure transducers.

Functionality
The milliampere input module has six input channels, each with a separate protection and filter circuit, A/D converter and optically isolated connection to the backplane.

The digital filter circuits have individually programmable cut-off frequencies, and all parameters for filtering and calibration are stored in a nonvolatile memory on the module. The calibration circuitry monitors the module temperature and commences an automatical calibration procedure if the temperature drift increase outside the allowed range. The module uses the serial CAN bus for backplane communication.

Signal events are time stamped locally for minimum time deviance and stored by the event recorder if present.

Power supply module (PSM)

Application
The 20 W power supply module, PSM, with built in binary I/O is used in 1/2 and 3/4 of full width 19” units. It has four optically isolated binary inputs and five binary outputs, out of which one binary output is dedicated for internal fail.

The 30 W power supply module, PSM, is used to provide power for the extended number of modules in a full width 19” unit. It has one binary output dedicated to internal fail.

Functionality

The power supply modules contain a built-in, self-regulated DC/DC converter that provides full isolation between the terminal and the battery system.

The 20 W power supply module, PSM, has four optically isolated binary inputs and four output relays.

Human machine interface module (HMI)

Application

The human machine interface is used to monitor and in certain aspects affect the way the product operates. The configuration designer can add functions for alerting in case of important events that needs special attention from you as an operator.

Use the terminals built-in communication functionality to establish SMS communication with a PC with suitable software tool.

Connect the PC to the optical connector on the local HMI with the special front communication cable including an opto-electrical converter for disturbance free and safe communication.

LED Indication module (HMI-LED)

Application

The LED indication module is an additional feature for the REx 5xx terminals for protection and control and consists totally of 18 LEDs (Light Emitting Diodes). The main purpose is to present on site an immediate visual information such as protection indications or alarm signals. It is located on the front of the protection and control terminals.

Functionality

The human-machine interface consists of:

- the human-machine interface (HMI) module.
- the LED module.

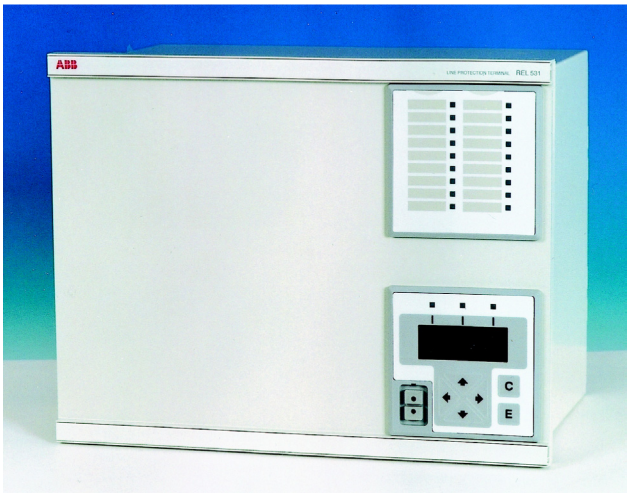
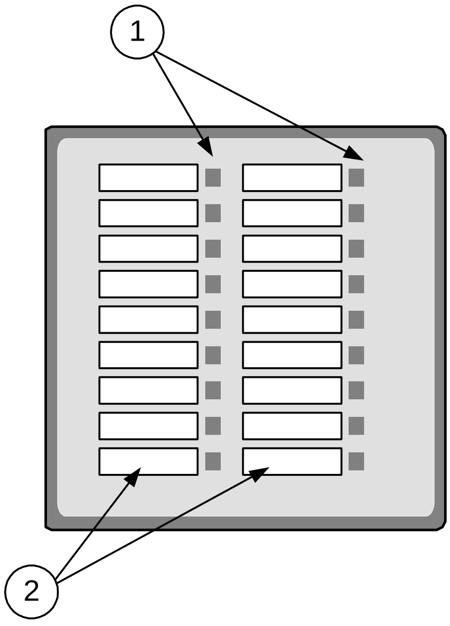


Figure 6: The figure shows the LED (upper) and the HMI (lower).

The LED indication module is equipped with 18 LEDs, which can light or flash in either red, yellow or green color. A description text can be added for each of the LEDs.

See LED indication function (HL, HLED) for details on application and functionality.



1	Three-color LEDs
2	Descriptive label, user exchangeable

Figure 7: The LED module

Optical receiver module (ORM)

Application

The optical receiver module (ORM) is used to interface signals from optical instrument transformers (OITP) to the terminal. The ORM module can replace the conventional analog input modules. Either 50 or 60 Hz signals is handled by the module. Only one of the frequencies must be selected and used for all inputs.

Functionality

The optical receiver module has four optical input channels that handles data from optical instrument transformers (OITP). It converts the OITP data to a format used in the terminal. The received data is processed in different ways depending on the setting of the eight pole dip-switch of the module.

Serial communication modules (SCM)

Functionality, SPA/IEC

The serial communication module for SPA/IEC is placed in a slot at the rear part of the main processing module. The serial communication module can have connectors for two plastic fibre cables or two glass fibre cables.The incoming optical fibre is connected to the RX receiver input and the outgoing optical fibre to the TX transmitter output. When the fibre optic cables are laid out, pay special attention to the instructions concerning the handling, connection, etc. of the optical fibres. The module is identified with a number on the label on the module.

Functionality, LON

The serial communication module for LON is placed in a slot at the rear part of the Main processing module. The serial communication module can have connectors for two plastic fibre cables or two glass fibre cables The incoming optical fibre is connected to the RX receiver input and the outgoing optical fibre to the TX transmitter output. Pay special attention to the instructions concerning the handling, connection, etc. of the optical fibres. The module is identified with a number on the label on the module.

Data communication modules

Application

The remote terminal communication modules are used both for differential line protection applications and for binary transfer of up to 32 signals to remote end (RTC), for example for distance protections. The following hardware modules are available:

- V.36
- X.21
- RS530
- G.703
- Short-range galvanic module
- Fibre optical communication module
- Short-range fibre optical module

The galvanic data communication modules according to V.36, X.21 and RS530 can be used for galvanic short range communication covering distances up to 100 m in low noise environment. Only contra-directional operation is recommended in order to get best system performance.These modules are designed for 64 kbit/s operation but can also be used at 56 kbit/s.

The galvanic data communication module according to G.703 is not recomended for distances above 10 m. Special attention must be paid to avoid problems due to noise interference. This module is designed only for 64 kbit/s operation.

The short-range galvanic module can be used for communication over galvanic pilot wires and can operate up to distances between 0,5 and 4 km depending on pilot wire cable. Twisted-pair, double-screened cable is recommended.

The fibre optical communication module can be used both with multi-mode and single-mode fibres.The communication distance can typically be up to 30 km for single mode fibre, with high quality fibres even longer. This interface can also be used for direct connection to communication equipment of type FOX from ABB.

The short-range fibre optical module can only be used with multi-mode fibre .The communication distance can normally be up to 5 km. This module can also be used for direct connection to communication equipments of type 21-15xx and 21-16xx from FIBERDATA

Front communication

Application

The special front connection cable is used to connect a PC COM-port to to the optical contact on the left side of the local HMI.

Functionality

The cable includes an optical contact, an opto/electrical converter and an electrical cable with a standard 9-pole D-sub contact. This ensures a disturbance immune and safe communication with the terminal.

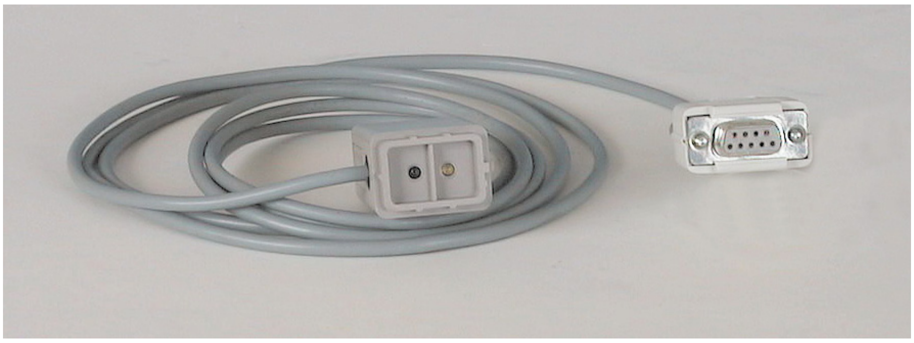


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Figure 8: Front connection cable

Hardware design

Layouts and dimensions

Design

Dimensions, case without rear cover

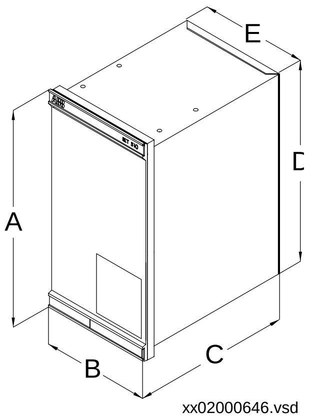


Figure 9: Case without rear cover

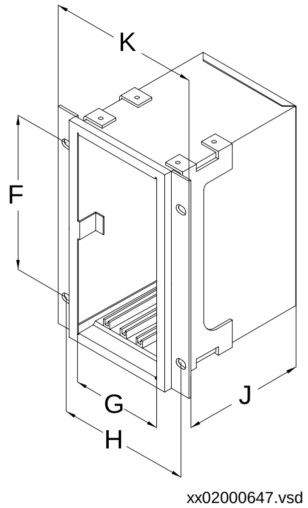


Figure 10: Case without rear cover with 19” rack mounting kit

Case size	A	B	C	D	E	F	G	H	J	K
6U, 1/2 x 19”	265.9	223.7	204.1	252.9	205.7	190.5	203.7	-	186.6	-
6U, 3/4 x 19”		336			318		316	-		-
6U, 1/1 x 19”		448.3			430.3		428.3	465.1		482.6
(mm)										
The H and K dimensions are defined by the 19” rack mounting kit										

Dimensions, case with rear cover

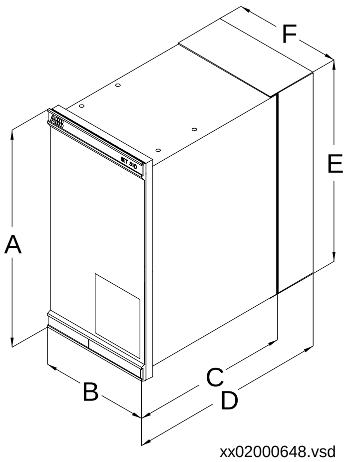


Figure 11: Case with rear cover

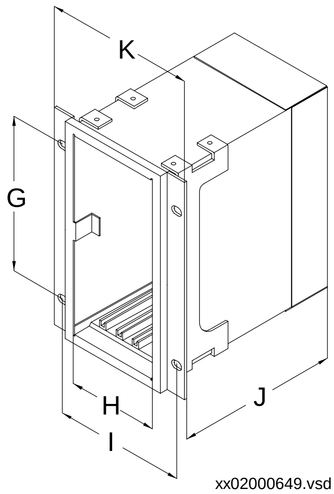


Figure 12: Case with rear cover and 19” rack mounting kit

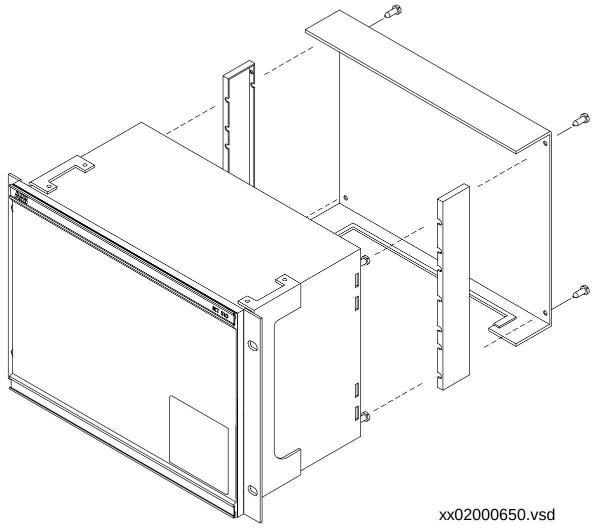
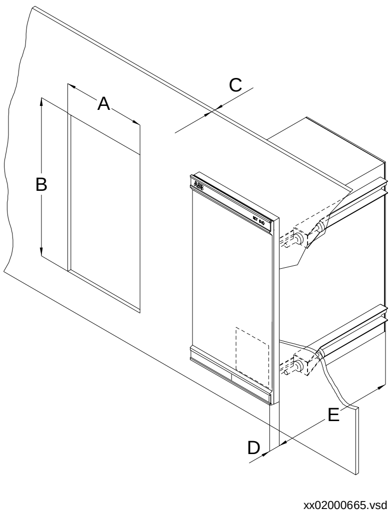


Figure 13: Case with rear cover

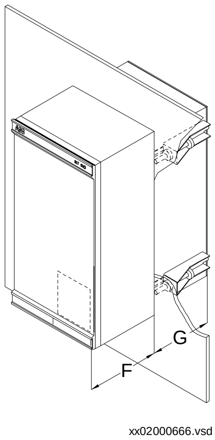
<table>
<tr><th>Case size</th><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th><th>G</th><th>H</th><th>I</th><th>J</th><th>K</th></tr>
<tr><td>6U, 1/2 x 19”</td><td rowspan="3">265.9</td><td>223.7</td><td rowspan="3">204.1</td><td rowspan="3">245.1</td><td rowspan="3">255.8</td><td>205.7</td><td rowspan="3">190.5</td><td>203.7</td><td>-</td><td rowspan="3">227.6</td><td>-</td></tr>
<tr><td>6U, 3/4 x 19”</td><td>336</td><td>318</td><td>316</td><td>-</td><td>-</td></tr>
<tr><td>6U, 1/1 x 19”</td><td>448.3</td><td>430.3</td><td>428.3</td><td>465.1</td><td>482.6</td></tr>
<tr><td colspan="12">(mm)
The I and K dimensions are defined by the 19” rack mounting kit.</td></tr>
</table>

Panel cut-outs for REx 500 series, single case

Flush mounting



Semi-flush mounting



Case size	Cut-out dimensions (mm)	
	A+/-1	B+/-1
6U, 1/2 x 19”	210.1	254.3
6U, 3/4 x 19”	322.4	254.3
6U, 1/1 x 19”	434.7	254.3

C = 4-10 mm

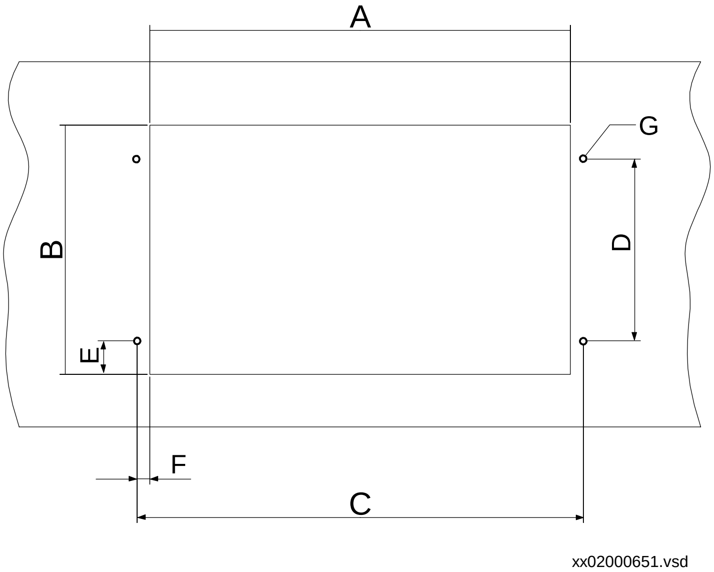
D = 16.5 mm

E = 187.6 mm without rear protection cover, 228.6 mm with rear protection cover

F = 106.5 mm

G = 97.6 mm without rear protection cover, 138.6 mm with rear protection cover

Panel cut-out for REx 500 series, side by side cases



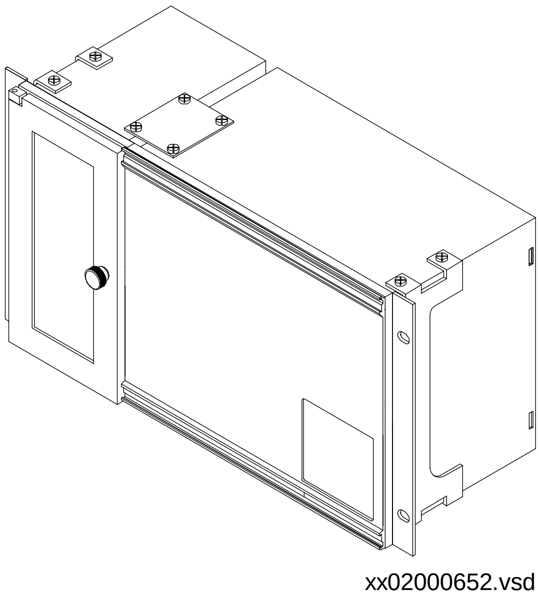
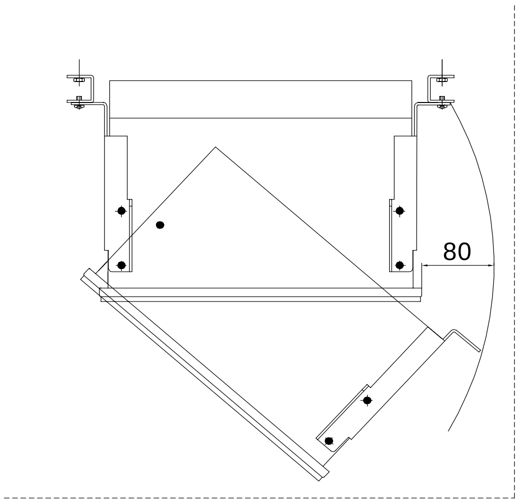


Figure 14: Flush mounting of side by side cases

Case size	Cut-out dimensions						
	A	**B**	**C**	**D**	**E**	**F**	**G**
6U, 3/4 x 19”	326.4	259.3	352.8	190.5	34.4	13.2	ø 6.4
6U, 1/1 x 19”	438.7	259.3	465.1	190.5	34.4	13.2	ø 6.4
							(mm)

Dimensions, wall mounting



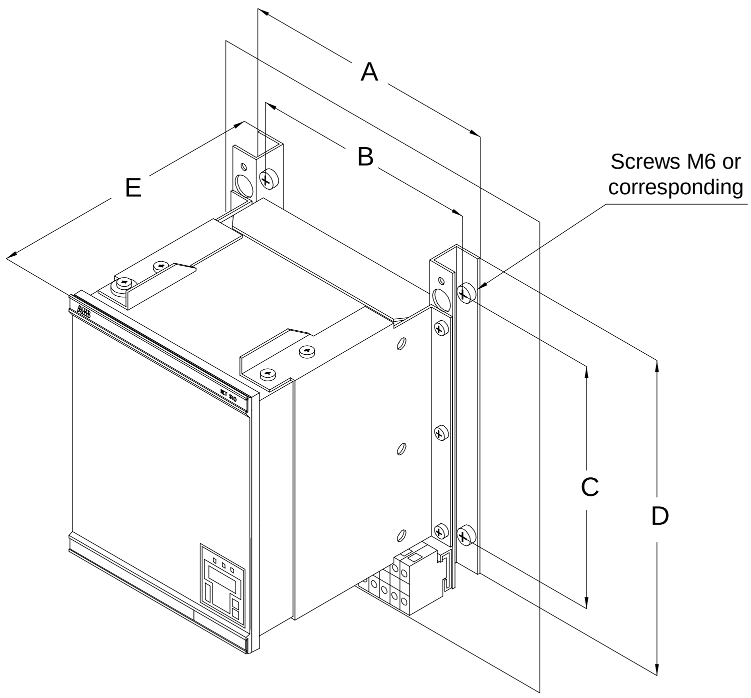
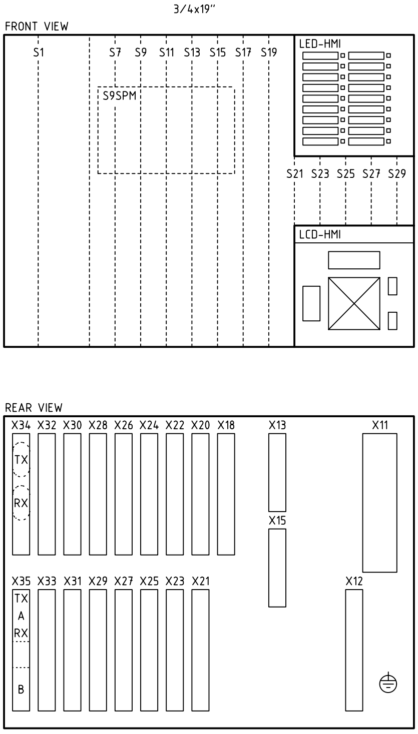


Figure 15: Wall mounting

Case size (mm)	A	B	C	D	E
6U, 1/2 x 19”	292	267.1	272.8	390	247
6U, 3/4 x 19”	404.3	379.4			
6U, 1/1 x 19”	516	491.1			

Terminal diagram

Drawings

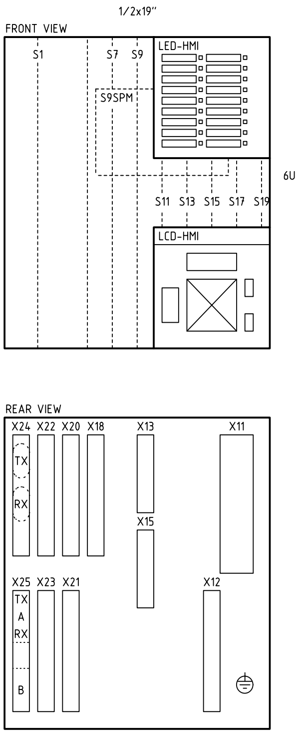


DESIGNATION CORRESPONDING TO CASING 3/4x19"		
MODULE	FRONT	REAR
TRM 1)	S1	X11,12
ADM 1)	S7	-
ORM 1)	S7	-
MPM	S9	X13,15
PSM	S13	X18
2)	S15	X20,21
2)	S17	X22,23
2)	S19	X24,25
2)	S21	X26,27
2)	S23	X28,29
2)	S25	X30,31
2)	S27	X32,33
3)	S29	X34,35

TABLE 2

1) OPTION TRM AND ADM OR ORM
2) BIM, BOM, IOM AND/OR MIM
3) BIM, BOM, IOM, MIM OR DCM
LED-HMI: OPTION

Figure 16: Hardware structure of the 3/4 of full width 19” case

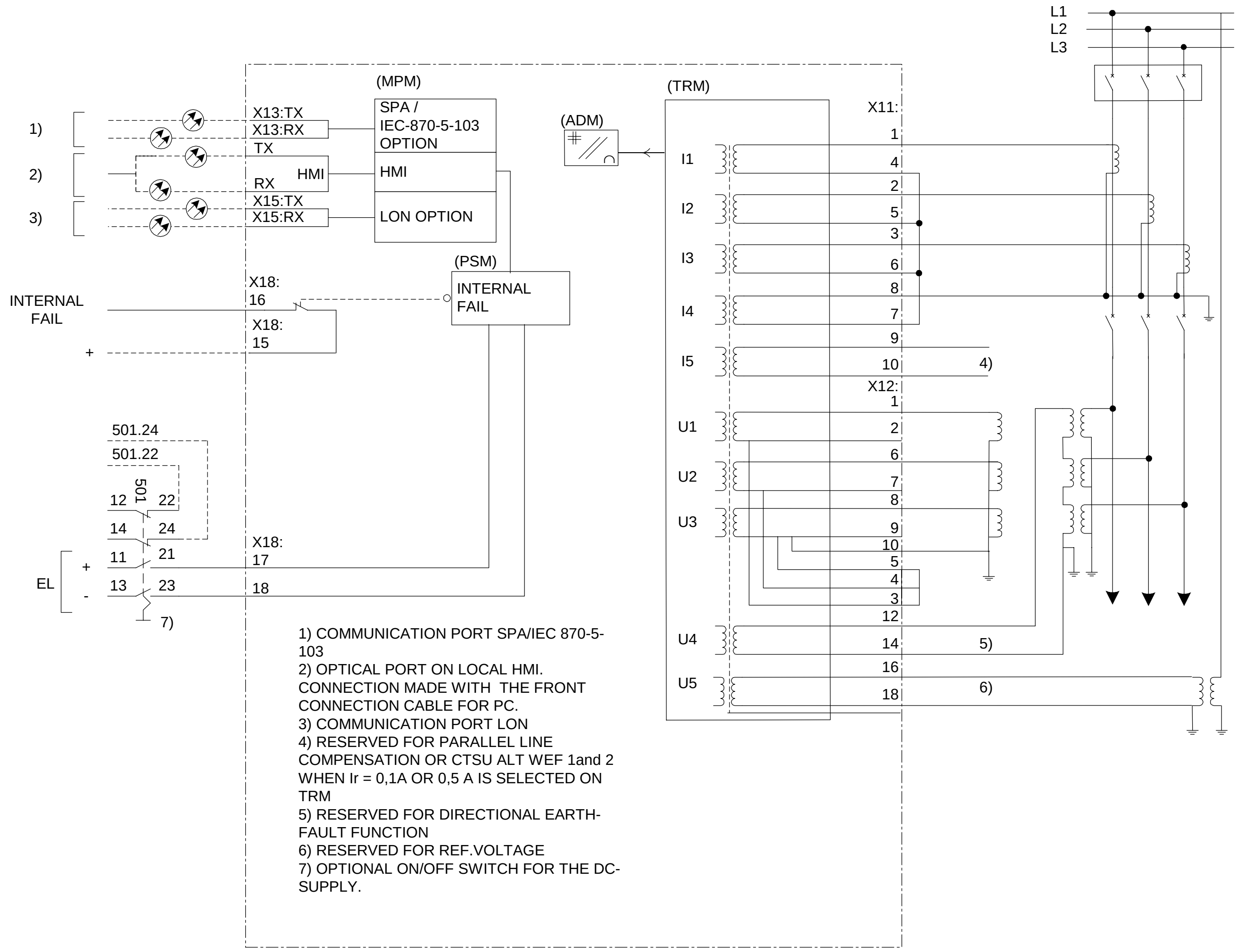


DESIGNATION CORRESPONDING TO CASING 1/2x19"		
MODULE	FRONT	REAR
TRM 1)	S1	X11,12
ADM 1)	S7	-
ORM 1)	S7	-
MPM	S9	X13,15
PSM	S13	X18
2)	S15	X20,21
2)	S17	X22,23
3)	S19	X24,25

TABLE 1

1) OPTION TRM AND ADM OR ORM
2) BIM, BOM, IOM AND/OR MIM
3) BIM, BOM, IOM, MIM OR DCM
LED-HMI: OPTION

Figure 17: Hardware structure of the 1/2 of full width 19” case



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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) whithin 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.

Table 3: Unit

Material	Steel sheet
Front plate	Aluminium profile with cut-out for HMI and for 18 LED when included
Surface treatment	Aluzink preplated steel
Finish	Light beige (NCS 1704-Y15R)
Degree of protection	Front side: IP40, optional IP54 with sealing strip. Rear side: IP20

Table 4: Weight

Case size	Weight
6U, 1/2 x 19”	≤ 8.5 kg
6U, 3/4 x 19”	≤ 11 kg

Table 5: PSM 20/30 W

Quantity	Rated value	Nominal range
Auxiliary dc voltage	EL = (48 - 250) V	+/- 20%

Table 6: TRM, Energizing quantities, rated values and limits

Quantity	Rated value	Nominal range
Current Operative range Permissive overload Burden	I_r = 1 or 5 A I_r=0.1, 0.5, 1 or 5 A for I_5 (0.004-100) x I_r $4 \times I_r$ cont. $100 \times I_r$ for 1 s $^{*)}$ < 0.25 VA at I = 1 or 5 A < 0.02 Va at Ir = 0.1 or 0.5 A	(0.2-30) $\times I_r$
Ac voltage for the terminal Operative range Permissive overload Burden	U_r = 110 V **) or U_r = 220 V **) (0.001-1.5) x U_r $1.5 \times U_r$ cont. 2.5 x U_r for 1 s < 0.2 VA at U_r	100/110/115/120 V 200/220/230/240 V
Frequency	f_r = 50/60 Hz	+/-5%
*) max. 350 A for 1 s when COMBITEST test switch is included. **) The rated voltage of each individual voltage input U1 to U5 is $U_r/\sqrt{3}$		

Table 7: Temperature and humidity influence

Parameter	Reference value	Nominal range	Influence
Ambient temperature Operative range	+20 °C -25 °C to +55°C	-5 °C to +55 °C	0.01%/°C
Relative humidity Operative range	10%-90% 0%-95%	10%-90%	-
Storage temperature	-40 °C to +70 °C	-	-

Table 8: Auxiliary DC supply voltage influence on functionality during operation

Dependence on:		Within nominal range
Ripple, in DC auxiliary voltage		Max 12%
Interrupted auxiliary DC voltage	Without reset	<50 ms
	Correct function	0-∞ s
	Restart time	<120 s

Table 9: Electromagnetic compatibility

Test	Type test values	Reference standards
1 MHz burst disturbance	2.5 kV	IEC 60255-22-1, Class III
Electrostatic discharge	8 kV	IEC 60255-22-2, Class III
Fast transient disturbance	4 kV	IEC 60255-22-4, Class IV
Radiated electromagnetic field disturbance	10 V/m, 25-1000 MHz	IEC 60255-22-3, Class III IEEE/ANSI C37.90.2

Table 10: Insulation

Test	Type test values	Reference standard
Dielectric test	2.0 kVAC, 1 min.	IEC 60255-5
Impulse voltage test	5 kV, 1.2/50 μs, 0.5 J	
Insulation resistance	>100 MΩ at 500 VDC	

Table 11: CE compliance

Test	According to
Immunity	EN 50082-2
Emissivity	EN 50081-2
Low voltage directive	EN 50178

Table 12: Mechanical tests

Test	Type test values	Reference standards
Vibration	Class I	IEC 60255-21-1
Shock and bump	Class I	IEC 60255-21-2
Seismic	Class I	IEC 60255-21-3

Table 13: Calendar and clock

Parameter	Range
Built-in calender	With leap years through 2098

Table 14: Internal event list

Data	Value
Recording manner	Continuous, event controlled
List size	40 events, first in-first out

Table 15: TIME, Time synchronisation

Function	Accuracy
Time tagging resolution	1 ms
Time tagging error with synchronisation at least once/60 s	+/- 1.5 ms
Drift of clock without synchronisation	+/- 3 ms/min

Table 16: Front communication

Function	Value
Protocol	SPA
Communication speed for the cable	0.3-115 Kbaud
Slave number	1 to 899
Remote change of active group allowed	Yes
Remote change of settings allowed	Yes

Table 17: Available logic function blocks as basic

Update rate	Block	Availability
6 ms	AND	30 gates
	OR	60 gates
	INV	20 inverters
	TM	10 timers
	TP	10 pulse timers
	SM	5 flip-flops
	GT	5 gates
	TS	5 timers
200 ms	TL	10 timers
	TQ	10 pulse timers
	SR	5 flip-flops
	XOR	39 gates

Table 18: Additional logic function blocks

Update rate	Block	Availability
6 ms	TP	40 pulse timers
200 ms	AND	239 gates
	OR	159 gates
	INV	59 inverters
	MOF	3 registers
	MOL	3 registers

Line impedance

Table 19: ZM1, 2, 3, 4, 5 Zone impedance measuring elements

Function			Value
Operate time	Typical		28 ms
	Min and max		Please refer to the separate isochrone diagrams
Min. operate current			(10-30) % of I1b in steps of 1 %
Resetting ratio			Typical 110 %
Resetting time			Typical 40 ms
Output signals start and trip		Zone 1-3	Three phase Single phase and/or three phase
		Zone 4, 5	Three phase start and trip
Setting accuracy			Included in the measuring accuracy
Number of zones			3, 4 or 5, direction selectable
Impedance setting range at I_r = 1 A (to be divided by 5 at I_r = 5 A)	Reactive reach	Positive-sequence reactance	(0.10-400.00) Ω/phase in steps of 0.01 Ω
		Zero sequence reactance	(0.10-1200.00) Ω/phase in steps of 0.01 Ω
	Resistive reach	Positive-sequence resistance	(0.10-400.00) Ω/phase in steps of 0.01 Ω
		Zero sequence resistance	(0.10-1200.00) Ω/phase in steps of 0.01 Ω
	Fault resistance	For phase - phase faults	(0.10-400.00) Ω/loop in steps of 0.01 Ω
		For phase-earth faults	(0.10-400.00) Ω/loop in steps of 0.01 Ω
Setting range of timers for impedance zones			(0.000-60.000) s in steps of 1 ms
Static accuracy at 0 degrees and 85 degrees	Voltage range (0.1-1.1) x U_r		+/- 5 %
	Current range (0.5-30) x I_r		
Static angular accuracy at 0 degrees and 85 degrees	Voltage range (0.1-1,1) x U_r		+/- 5 degrees
	Current range (0.5-30) x I_r		
Max dynamic overreach at 85 degrees measured with CVT's 0.5 < SIR < 30			+ 5 %

Table 20: Phase selection logic

Function			Value
Impedance setting range at I_r=1 A	Reactive reach	Positive sequence reactance	0.10-400.00 ohm/phase in steps of 0.01 ohm/phase
		Zero sequence reactance	0.10-1200.00 ohm/phase in steps of 0.01 ohm/phase
	Resistive reach	For phase to phase faults	0.10-400.00 ohm/loop in steps of 0.01 ohm/loop
		For phase to ground faults	0.10-400.00 ohm/loop in steps of 0.01 ohm/loop
Static angular accuracy at 0 degrees and 85 degrees	Voltage range (0.1-1.1) x U_r		+/-5 degrees
	Current range (0.5-30) x I_r		

Table 21: Power swing detection

Parameter		Setting range	Accuracy
Impedance setting range at I_r =1A (divide values by 5 for I_r = 5A)	Reactive reach, XIN	0.10-400.00 ohm/phase in steps of 0.01 ohm/phase	–
	Resistive reach, RIN	0.10-400.00 ohm/phase in steps of 0.01ohm/phase	–
Reach multiplication factor, KX		120-200% of XIN in steps of 1%	–
Reach multiplication factor, KR		120-200% of RIN in steps of 1%	–
Initial PSD timer, tP1		0.000-60.000 s in steps of 1 ms	+/- 0.5 % +/- 10 ms
Fast PSD timer, tP2		0.000-60.000 s in steps of 1 ms	+/- 0.5 % +/- 10 ms
Hold timer tW for activation of fast PSD timer		0.000-60.000 s in steps of 1 ms	+/- 0.5 % +/- 10 ms
Hold timer tH for PSD detected		0.000-60.000 s in steps of 1 ms	+/- 0.5 % +/- 10 ms
Timer tEF overcoming 1ph reclosing dead time		0.000-60.000 s in steps of 1 ms	+/- 0.5 % +/- 10 ms
Timer tR1 to time delay block by the residual current		0.000-60.000 s in steps of 1 ms	+/- 0.5 % +/- 10 ms
Timer tR2 to time delay block at very slow swings		0.000-60.000 s in steps of 1 ms	+/- 0.5 % +/- 10 ms

Table 22: Power swing additional logic

Parameter	Setting range	Accuracy
Permitted operate time difference between higher and lower zones, tDZ	0.000-60.000 s in steps of 1 ms	+/- 0.5 %+/- 10 ms
Time delay to permitted operation of lower zone with detected difference in operating time, tZL	0.000-60.000 s in steps of 1 ms	+/- 0.5 %+/- 10 ms
Conditional timer for sending of carrier signal at power swings, tCS	0.000-60.000 s in steps of 1 ms	+/- 0.5 %+/- 10 ms
Conditional timer for tripping at power swings, tTrip	0.000-60.000 s in steps of 1 ms	+/- 0.5 %+/- 10 ms
Timer for extending the blocking of tripping by the non-controlled zone(s), tBlkTr	0.000-60.000 s in steps of 1 ms	+/- 0.5 %+/- 10 ms

Table 23: Pole slip protection

Parameter	Setting range
Reactive and resistive reach for all setting parameters at I_r=1 A (for I_r = 5 A, divide values by 5)	0.10-400.00 ohm/phase in steps of 0.01ohm/phase
Timers	0.000-60.000s in steps of 0.001s
Counters	0-10 in steps of 1

Parameter	
Reset ratio for impedance measuring elements	105% typically

Table 24: ZCOM - Scheme communication logic for distance protection

Parameter	Setting range	Accuracy
Coordination timer, tCoord	0.000-60.000 s in steps of 1 ms	+/-0.5% +/-10ms
Minimum send time, tSendMin	0.000-60.000 s in steps of 1 ms	+/-0.5% +/-10ms
Security timer, tSec	0.000-60.000 s in steps of 1 ms	+/-0.5% +/-10ms

Table 25: Current reversal and weak end infeed logic

Parameter	Setting range	Accuracy
Pickup time for current reversal logic	0.000-60.000 s in steps of 0.001s	+/-0.5% +/-10ms
Delay time for reset of current reversal output	0.000-60.000 s in steps of 0.001s	+/-0.5% +/-10ms

Parameter	Setting range	Accuracy
Coordination time delaying receipt of carrier receive signal into weak end infeed logic	0.000-60.000 s in steps of 0.001s	+/-0.5% +/-10ms
Detection level phase to neutral voltage	10-100% of U1b	+/-5% of U_b
Detection level phase to phase voltage	20-170% of U1b	+/-5% of U_b for $U<=U_b$ +/-5% of U_b for $U>=U_b$

Table 26: Radial feeder protection function

Parameter	Setting range	Accuracy
Faulted phase voltage detection level in % of cross-polarised phase-phase voltage divided by sqrt(3)	50-100% of U_{ref} in steps of 1%	+/- 2.5% of U_r
Time constant for reference voltages	1-60s in steps of 1s	
Residual current detection level	10-150% of I_r in steps of 1%	2.5% of I_r at $I \le I_r$ 2.5% of I at $I > I_r$
Time delay tM for single-pole tripping	0.00-60.00s in steps of 0.01s	+/-0.5% +/-10 ms
Time delay tT for three-pole tripping	0.00-60.00s in steps of 0.01s	+/-0.5% +/-10 ms
Time delay tPIR for residual current tripping (or indication)	0.00-60.00s in steps of 0.01s	+/-0.5% +/-10 ms

Table 27: SOTF - Automatic switch onto fault function

Parameter	Value	Accuracy
Delay following dead line detection input before SOTF function is automatically enabled	200 ms	+/-0.5% +/-10 ms
Time period after circuit breaker closure in which SOTF function is active	1000 ms	+/-0.5% +/-10 ms

Current

Table 28: IOC - Instantaneous overcurrent protection

Function		Setting range	Operate time	Accuracy
Operate current I>>	Phase measuring elements	(50-2000)% of I1b In steps of 1%	-	+/- 2.5 % of I_r at $I \le I_r$ +/- 2.5 % of I at $I > I_r$
	Residual measuring elements	(50-2000)% of I1b In steps of 1%	-	+/- 2.5 % of I_r at $I \le I_r$ +/- 2.5 % of I at $I > I_r$
Operate time at $I > 10 \times I_{set}$			Max 15ms	-
Dynamic overreach at τ< 100 ms			-	< 5%

Table 29: TOC - Time delayed overcurrent protection

Function		Setting range	Accuracy
Operate current I>	Phase measuring elements	(10-400) % of $I1_b$ in steps of 1 %	+/- 2.5 % of I_r at $I \le I_r$
			+/- 2.5 % of I at $I > I_r$
	Residual measuring elements	(10-150) % of $I4_b$ in steps of 1 %	+/- 2.5 % of I_r at $I \le I_r$
			+/- 2.5 % of I at $I > I_r$
Time delay	Phase measuring elements	(0.000-60.000) s in steps of 1 ms	+/- 0.5 % of t +/- 10 ms
	Residual measuring elements	(0.000-60.000) s in steps of 1 ms	+/- 0.5 % of t +/- 10 ms
Dynamic overreach at τ< 100 ms		-	< 5 %

Table 30: TOC3-Two step directional overcurrent protection

Function	Setting range	Accuracy
Operate value of low set function	(20-2000)% of I1b in steps of 1%	+/- 2.5 % of I_r at $I \le I_r$ +/- 2.5 % of I at $I>I_r$
Base current for inverse time calculation	(20-500) % of I1b in steps of 1 %	+/- 2.5 % of I_r at $I \le I_r$ +/- 2.5 % of I at $I>I_r$
Minimum operate time	(0.000-60.000) s in steps of 1 ms	+/- 0.5 % +/- 10 ms
Definite time delay for low set function	(0.000-60.000) s in step of 1ms	+/- 0.5 % +/- 10 ms
Operate value of high set function	(20-2000) % of I1b in steps of 1 %	+/- 2.5 % of I_r at $I \le I_r$ +/- 2.5 % of I at $I>I_r$
Definite time delay for high set function	(0.000-60.000) in steps of 1 ms	+/- 0.5 % +/- 10 ms
Static angular accuracy at 0 degrees and 85 degrees	Voltage range (0.1-1.1) x U_r Current range (0.5-30) x I_r	+/- 5 degrees
Normal inverse characteristic $I = I_{meas}/I_{set}$	$t = \frac{0.14}{I^{0.02}-1} \cdot k$	IEC 60255-3 class 5 +/- 60 ms
Very inverse characteristic	$t = \frac{13.5}{I-1} \cdot k$	IEC 60255-3 class 7.5 +/- 60 ms
Extremely inverse characteristic	$t = \frac{80}{I^2-1} \cdot k$	IEC 60255-3 class 7.5 +/- 60 ms
Dynamic overreach at t< 100 ms		<5%

Table 31: TOC2 - Two step time delayed overcurrent protection

Function	Setting range	Accuracy
Operate value for low set function I > Low	(5-500)% of I1b in steps of 1%	+/- 2.5% of $I1_r$ at $I \le I1_r$ +/- 2.5 % of I at $I>I1_r$
Base current for inverse time calculation I > Inv	(5-500) % of I1b in steps of 1%	+/- 2.5 % of $I1_r$ at $I \le I1_r$ +/- 2.5 % of I at $I> I1_r$
Minimum operate time tMinInv	(0.000-60.000)s in steps of 1 ms	+/- 0.5 % +/- 10 ms
Definite time delay for low set function tLow	(0.000-60.000)s in steps of 1 ms	+/- 0.5 % +/- 10 ms
Operate value of high set function I > High	(50-2000)% of I1b in steps of 1%	+/- 2.5% of $I1_r$ at $I \le I1_r$ +/- 2.5 % of I at $I>I1_r$
Definite time delay for high set function tHigh	(0.000-60.000) s in steps of 1 ms	+/- 0.5 % +/- 10 ms
Normal inverse characteristic $I = I_{meas}/I_{set}$	$t = \frac{0.14}{I^{0.02} - 1} \cdot k$	IEC 60255-3 class 5+/- 60 ms
Very inverse characteristic	$t = \frac{13.5}{I - 1} \cdot k$	IEC 60255-3 class 7.5+/- 60 ms
Extremely inverse characteristic	$t = \frac{80}{I^2 - 1} \cdot k$	IEC 60255-3 class 7.5+/- 60 ms
Dynamic overreach at t< 100 ms		<5%

Table 32: THOL - Thermal overload protection

Function	Setting range	Accuracy
Mode of operation	Off / NonComp / Comp (Function blocked/No temp. compensation/Temp. comp.)	
Basic current IBase	(10 - 200) % of I1b in steps of 1 %	+/- 2.5% of I_r
Temperature rise at IBase TBase	(0 - 100) °C in steps of 1 °C	+/- 1°C
Time constant tau	(1 - 62) min in steps of 1 min	+/- 1 min

Function	Setting range	Accuracy
Alarm temperature TAlarm	(50 - 150) °C in steps of 1°C	
Trip temperature TTrip	(50 - 150) °C in steps of 1 °C	
Temp. difference for reset of trip TdReset	(5 - 30) °C in steps of 1°C	

Table 33: Thermal overload protection mA input

Function	Setting range	Accuracy
Upper value for mA input MI11-1_Max	-25.00 - 25.00 mA in steps of 0.01 mA	+/- 0.5% of set value
Lower value for mA input MI11-I_Min	-25.00 - 25.00 mA in steps of 0.01 mA	+/- 0.5% of set value
Temp. corresponding to the MI11-1_Max setting MI11-MaxValue	-1000 - 1000 °C in steps of 1 °C	+/- 1% of set value +/- 1°C
Temp. corresponding to the MI11-1_Min setting MI11-MinValue	-1000 - 1000° C in steps of 1 °C	+/- 1% of set value +/- 1°C

Table 34: STUB - Stub protection

Function	Setting range	Accuracy
Operate current I>	(20-300) % of I1b	+/- 2.5 % of I_r at I ≤I_r +/- 2.5 % of I at I > I_r

Table 35: BFP - Breaker failure protection

Parameter	Setting range	Accuracy
Operate current (one measuring element per phase)	5-200% of I1b in steps of 1%	+/-2.5% of I_r at I ≤ I_r +/-2.5% of I at I > I_r
Retrip time delay t1	0.000-60.000 s in steps of 1 ms	+/-0.5% +/-10 ms
Back-up trip time delay t2	0.000-60.000 s in steps of 1 ms	+/-0.5% +/-10 ms

Parameter	Value
Trip operate time	Max 18 ms
Reset time	Max 10 ms

Table 36: TEF - Independent and dependent time delayed residual protection function

Parameter		Setting range	Accuracy
Start current, definite time or inverse time delay I_N		5-300% of I_r in steps of 1%	+/-5% of set value
Operate value for directional current measurement	Forward I_N at φ=65 degrees	5-35% of I_r in steps of 1%	+/-1.5% of I_r
	Reverse	60% of the setting for forward operation	+/-1.5% of I_r
Definite time delay		0.000 - 60.000 s in steps of 1ms	+/- 0.5 % +/-10 ms
Time multiplier for inverse time delay k		0.05-1.10 in steps of 0.01	According to IEC 60255-3
Normal inverse characteristic $I = I_{meas}/I_{set}$		$t = \frac{0.14}{I^{0.02}-1} \cdot k$	IEC 60255-3 class 5 +/- 60 ms
Very inverse characteristic		$t = \frac{13.5}{I-1} \cdot k$	IEC 60255-3 class 7.5 +/- 60 ms
Extremely inverse characteristic		$t = \frac{80}{I^2-1} \cdot k$	IEC 60255-3 class 7.5 +/- 60 ms
Min. operate current for dependent characteristic		100-400% of IN in steps of 1%	+/-5% of I_{set}
Minimum operate time		0.000-60.000 s in steps of 1 ms	+/- 0.5 % +/-10 ms
Characteristic angles		65 degrees lagging	+/-5 degrees at 20 V and I_{set}=35% of I_r
Logarithmic characteristic		$t = 5.8\text{-}1.35 \cdot \ln I$	+/- 5 % of t at $I = (1.3\text{-}29) \times 3I_0$
Minimum polarising voltage		1 % of U_r	At 50 Hz: 1% of U_r +/-5% At 60 Hz: 1% of U_r -15% to -5%
Reset time		<70 ms	-

Table 37: EFC - Scheme communication logic for residual overcurrent protection

Parameter	Setting range	Accuracy
Coordination timer	0.000-60.000 s in steps of 1 ms	+/-0.5% +/-10 ms

Table 38: Current reversal and weak end infeed logic for residual overcurrent protection (EFCA)

Parameter	Setting range	Accuracy
Operate voltage for WEI trip	5-70 % of U1b in steps of 1%	+/-5% of U_r
Current reversal pickup timer	0.000-60.000 s in steps of 1 ms	+/-0.5% +/-10 ms
Current reversal delay timer	0.000-60.000 s in steps of 1 ms	+/-0.5% +/-10 ms

Table 39: Sensitive directional residual overcurrent protection function, WEF1

Function	Setting range	Accuracy
Operate current	(3.0 - 2000.0) % of Ib in steps of 0.1%	+/-2.5% of I_r at $I \le I_r$ +/-2.5% of I at $I > I_r$
Operate voltage	(5.0 - 70.0) % of Ub in steps of 0.1%	+/-2.5% of U_r at $U \le U_r$ +/-2.5% of U at $U > U_r$
Characteristic Angle	(-90.0 - +90.0) degrees in steps of 0.1 degrees	
Independent time delay	(0.000 - 60.000) s in steps of 1 ms	+/-0.5% +/- 10 ms

Table 40: Sensitive directional residual power protection function, WEF2

Function	Setting range	Accuracy
Operate current	(5.0 - 400.0) % of I_b in steps of 0.1%	+/-2.5% of I_r at $I \le I_r$ +/-2.5% of I at $I > I_r$
Operate voltage	(1.0-70.0) % of U_b in steps of 0.1%	+/-2.5% of U_r at $U \le U_r$ +/-2.5% of U at $U > U_r$
Characteristic angle	(-90.0 -90.0) degrees in steps of 0.1 degrees	
Independent time delay	(0.000-60.000) s in steps of 1 ms	+/-0.5% +/- 10 ms
Inverse characteristic $T_i = \frac{k \cdot S_{ref}}{S_{measured}}$	k = (0.0-2.0) in steps of 0.01 Sref = (5.0 - 50.0) % of Sb in steps of 0.1%	IEC 60255-3 class 5 +/- 60 ms

Table 41: EF4-Four step earth fault overcurrent protection

Parameter	Setting range	Accuracy
Current level for step 1	50 - 2500% of Ib in steps of 1%	+/- 5 % of I_r at $I \le I_r$ +/- 5% of I at $I > I_r$
Definite time delay for step 1	0.000 - 60.000 s in steps of 1ms	+/- 0.5 % +/- 10 ms
Current level for step 2	20 - 1500 % of Ib in steps of 1%	+/- 5 % of I_r at $I \le I_r$ +/- 5% of I at $I > I_r$

Parameter		Setting range	Accuracy
Definite time delay for step 2		0.000 - 60.000 s in steps of 1 ms	+/- 0.5 % +/- 10 ms
Current level for step 3		20 - 1500 % of Ib in steps of 1%	+/- 5 % of I_r at $I \leq I_r$ +/- 5% of I at $I > I_r$
Definite time delay for step 3		0.000 - 60.000 s in steps of 1 ms	+/- 0.5 % +/- 10 ms
Current level for step 4 definite time delay or minimum operate current for inverse time delay		4 - 440 % of Ib in steps of 0.1%	+/- 5 % of I_r at $I \leq I_r$ +/- 5% of I at $I > I_r$
Definite time delay for step 4 or inverse time additional delay		0.000 - 60.000 s in steps of 1 ms	+/- 0.5 % +/- 10 ms
Base current for inverse time delay		4 - 110% of Ib in steps of 1%	+/- 5 % of I_r at $I \leq I_r$ +/- 5% of I at $I > I_r$
Time multiplier for inverse time delay		0.05 - 1.10 in steps of 0.01	-
Inverse time minimum delay step 4		0.000 - 60.000 s in steps of 1 ms	+/- 0.5 % +/- 10 ms
Operate value for directional current measurement	Forward $3I_0$ at φ= 65°	5-40% of Ib in steps of 1%	+/- 2.5 % of I_r at $I \leq I_r$ +/- 2.5% of I at $I > I_r$
	Reverse	60% of Forward	+/- 2.5 % of I_r at $I \leq I_r$ +/- 2.5% of I at $I > I_r$
Level of harmonic restrain		20% or 32%	+/- 5%
Characteristic angle $I = I_{meas}/I_{set}$		65 degrees lagging	+/- 5 degrees at 20 V and I_{set}= 35 % of I_r
Normal inverse characteristic $I = I_{meas}/I_{set}$		$t = \frac{0.14}{I^{0.02}-1} \cdot k$	IEC 60255-3 class 5 +/- 60 ms
Very inverse characteristic		$t = \frac{13.5}{I-1} \cdot k$	IEC 60255-3 class 7.5 +/- 60 ms
Extremely inverse characteristic		$t = \frac{80}{I^2-1} \cdot k$	IEC 60255-3 class 7.5 +/- 60 ms
Logarithmic characteristic		$t = 5.8\text{-}1.35 \cdot \ln I$	+/- 5 % of t at I = (1.3-29) $\times 3I_0$
Switch onto fault active time		0.000 - 60.000 s in steps of 1 ms	+/- 0.5 % +/-10 ms

Voltage

Table 42: TUV - Time delayed undervoltage protection

Function	Setting range	Accuracy
Operate voltage UPE<	(10-100) % of U1b in steps of 1%	+/- 2.5 % of U_r
Time delay	(0.000-60.000) s in steps of 1ms	+/- 0.5 % +/- 10 ms

Table 43: TOV - Time delayed overvoltage protection

Function		Setting range	Accuracy
Operate voltage U>	Phase measuring elements	(50-200)% of U1b in steps of 1%	+/- 2.5 % of U_r at U U_r +/- 2.5 % of U at U > U_r
Time delay	Phase measuring elements	(0.000-60.000) s in steps of 1ms	+/- 0.5 % +/- 10 ms
Operate voltage 3U0>	Residual measuring elements	(5-100)% of U1b in steps of 1%	+/- 2.5 % of U_r at U ≤ U_r +/- 2.5 % of U at U > U_r
Time delay	Residual measuring elements	(0.000-60.000) s in steps of 1ms	+/- 0.5 % +/- 10 ms

Power system supervision

Table 44: Broken conductor check

Parameter	Setting range	Accuracy
Minimum level of highest phase current for operation	10-100% of I1b in steps of 1%	+/-2.5% of I_r
Output time delay	0.000-60.000 s in steps of 0.001s	+/-0.5% +/-10ms

Table 45: Loss of voltage check

Parameter	Setting range	Accuracy
Operate voltage, U<	10-100% of U1b in steps of 1%	+/-2.5% of U_r

Table 46: Overload supervision function

Parameter	Setting range	Accuracy
Operate current I>	20-300% of I1b in steps of 1%	+/-2.5% of I_r at $I \leq I_r$ +/-2.5% of I at $I > I_r$
Time delay	0.0-90000.0 s Step: 0.1	+/-0.5% +/- 10 ms

Table 47: DLD - Dead line detection

Function		Setting range	Accuracy
Automatic check of dead line condition	Operate phase current	(5-100) % of I1b in steps of 1%	+/- 2.5 % of I_r
	Operate phase voltage	(10-100) % of U1b in steps of 1%	+/- 2.5 % of U_r

Secondary system supervision

Table 48: Current circuit supervision

Function	Setting range	Accuracy
Operate current I>	5-100% of I1b in steps of 1%	+/-2.5% of I_r

Table 49: FUSE - Fuse failure supervision function

Function		Setting range	Accuracy
Zero-sequence quantities:	Operate voltage $3U_0$	(10-50)% of U1b in steps of 1%	+/- 2.5 % of U_r
	Operate current $3I_0$	(10-50)% of I1b in steps of 1%	+/- 2.5 % of I_r

Table 50: Fuse failure supervision function

Function	Setting range	Accuracy
Operate voltage change level	(50-90)% of U1b in steps of 1%	+/-2.5% of Ur
Operate current change level	(10-50)% of I1b in steps of 1%	+/- 2.5% of Ir

Table 51: Voltage transformer supervision

Parameter	Setting range	Accuracy
Residual overvoltage limit, UN>	1.0-80.0% of U1b in steps of 0.1%	+/- 2.5% of U_r
Time delayed operation for start signal, tDelay	0.000-300.000 s in steps of 1 ms	+/- 0.5% +/- 10 ms

Control

Table 52: Phasing check option (specific parameters)

Parameter	Setting range	Accuracy
Frequency difference limit	50-500 mHz in steps of 10 mHz	≤20 mHz
Circuit breaker closing pulse duration	0.000-60.000 s in steps of 1 ms	+/-0.5% +/-10 ms
Circuit breaker closing time	0.000-60.000 s in steps of 1 ms	+/-0.5% +/-10 ms

Parameter	Value
Bus / line voltage frequency range limit	+/-5 Hz from f_r
Bus / line voltage frequency rate of change limit	<0.21 Hz/s

Table 53: AR - Automatic reclosing function

Parameter	Setting range	Accuracy
Automatic reclosing open time:		
shot 1 - t1 1ph	0.000-60.000 s in steps of 1 ms	+/- 0.5% +/- 10 ms
shot 1 - t1 2ph	0.000-60.000 s in steps of 1 ms	+/- 0.5% +/- 10 ms
shot 1 - t1 3ph	0.000-60.000 s in steps of 1 ms	+/- 0.5% +/- 10 ms
shot 2 - t2 3ph	0-90000.0 s in steps of 0.1 s	+/- 0.5% +/- 10 ms
shot 3 - t3 3ph	0-90000.0 s in steps of 0.1 s	+/- 0.5% +/- 10 ms
shot 4 - t4 3ph	0-90000.0 s in steps of 0.1 s	+/- 0.5% +/- 10 ms
Maximum wait time for OK to close from synchronizing function tSync	0-90000.0 s in steps of 0.1 s	+/- 0.5% +/- 10 ms
Duration of close pulse to circuit breaker tPulse	0.000-60.000 s in steps of 1 ms	+/- 0.5% +/- 10 ms
Duration of reclaim time tReclaim	0-90000.0 s in steps of 0.1 s	+/- 0.5% +/- 10 ms
Inhibit reclosing reset time tInhibit	0.000-60.000 s in steps of 1 ms	+/- 0.5% +/- 10 ms
Maximum trip pulse duration tTrip (longer trip pulse durations will either extend the dead time or interrupt the reclosing sequence)	0.000-60.000 s in steps of 1 ms	+/- 0.5% +/- 10 ms
Maximum wait time for release from Master tWaitForMaster	0-9000.0 s in steps of 0.1 s	+/- 0.5% +/- 10 ms
Wait time following close command before continuing with further reclosing attempts without new start signal if circuit breaker does not close tAutoWait	0.000-60.000 s in steps of 1 ms	+/- 0.5% +/- 10 ms
Time delay before indicating reclosing unsuccessful tUnsuc	0-9000.0 s in steps of 0.1 s	+/- 0.5% +/- 10 ms
Time CB must be closed before AR becomes ready for a reclosing cycle tCBClosed	0.000-60.000 s in steps of 1 ms	+/- 0.5% +/- 10 ms

Table 54: Automatic reclosing function

Parameter	Value
Reclosing shots	1-4
Programs	Three pole trip: 1 Single, two and three pole trip: 6
Number of instances	Up to six depending on terminal type (different terminal types support different CB arrangements and numbers of bays)
Breaker closed before start	5 s

Logic

Table 55: TR - Trip logic

Parameter	Value	Accuracy
Setting for the minimum trip pulse length, tTripMin	0.000 - 60.000 s in steps of 0.001 s	+/-0.5% +/-10 ms

Table 56: PD - Pole discordance, contact and current based

Function	Setting range	Accuracy
Auxiliary-contact-based function - time delay	(0.000-60.000) s in steps of 1 ms	+/- 0.5% +/- 10 ms
Operate current	10% of I1b	+/- 2.5 % of I_r
Time delay	(0.000-60.000) s in steps of 1 ms	+/- 0.5 % +/- 10 ms

Table 57: Communication channel test logic

Parameter	Setting range	Accuracy
tStart Time interval between automatic starts of testing cycle	0.0-90000.0 s in steps of 0.1 s	+/-0.5% +/-10 ms
tWait Time interval available for test of the external function to be registered as successful	0.0-90000.0 s in steps of 0.1 s	+/-0.5% +/-10 ms
tCh Minimum time interval required before repeated test of the external function	0.0-90000.0 s in steps of 0.1 s	+/-0.5% +/-10 ms
tCS Duration of CS output signal	0.0-90000.0 s in steps of 0.1 s	+/-0.5% +/-10 ms
tChOK Duration of CHOK output signal	0.0-90000.0 s in steps of 0.1 s	+/-0.5% +/-10 ms
tInh Duration of inhibit condition extension after the BLOCK input signal resets	0.0-90000.0 s in steps of 0.1 s	+/-0.5% +/-10 ms

Table 58: Serial communication (SPA)

Function	Value
Protocol	SPA
Communication speed	300, 1200, 2400, 4800, 9600, 19200 or 38400 bit/s
Slave number	1 to 899
Remote change of active group allowed	yes/no
Remote change of settings allowed	yes/no
Connectors and optical fibres	glass or plastic

Table 59: Serial communication (LON)

Function	Value
Protocol	LON
Communication speed	1.25 Mbit/s
Connectors and optical fibres	glass or plastic

Table 60: Serial communication (IEC 60870-5-103)

Function	Value
Protocol	IEC 60870-5-103
Communication speed	9600, 19200 bit/s
Connectors and optical fibres	glass or plastic

Table 61: CN - Event counter function

Function	Value
Counter value	0-10000
Max. count up speed	10 pulses/s

Monitoring

Table 62: Disturbance report setting performance

Data	Setting range
Pre-fault time	50-300 ms in steps of 10 ms
Post-fault time	100-5000 ms in steps of 100 ms
Limit time	500-6000 ms in steps of 100 ms
Number of recorded disturbances	Max. 10

Table 63: Disturbance recorder setting performance

Function	Setting range
Overcurrent triggering	0-5000% of Inb in steps of 1%

Function	Setting range
Undercurrent triggering	0-200% of Inb in steps of 1%
Overvoltage triggering	0-200% of Unb in steps of 1% at 100 V sec.
Undervoltage triggering	0-110% of Unb in steps of 1%

Table 64: Disturbance recorder performance

<table>
<tr><th colspan="3">Data</th><th>Value</th></tr>
<tr><td colspan="3">Number of binary signals</td><td>48</td></tr>
<tr><td colspan="3">Number of analog signals</td><td>10</td></tr>
<tr><td colspan="3">Sampling rate</td><td>2 kHz</td></tr>
<tr><td colspan="3">Recording bandwidth</td><td>5-250 Hz</td></tr>
<tr><td colspan="3">Total recording time with ten analog and 48 binary signals recorded. (The amount of harmonics can affect the maximum storage time)</td><td>40 s typically</td></tr>
<tr><td rowspan="4">Voltage channels</td><td colspan="2">Dynamic range</td><td>(0.01-2.0) x U_r at 100/200 V sec.</td></tr>
<tr><td colspan="2">Resolution</td><td>0.1% of U_r</td></tr>
<tr><td rowspan="2">Accuracy at rated frequency</td><td>$U \leq U_r$</td><td>2.5% of U_r</td></tr>
<tr><td>$U > U_r$</td><td>2.5% of U</td></tr>
<tr><td rowspan="5">Current channels</td><td rowspan="2">Dynamic range</td><td>Without DC off-set</td><td>(0.01-110) $\times I_r$</td></tr>
<tr><td>With full DC off-set</td><td>(0.01-60) $\times I_r$</td></tr>
<tr><td colspan="2">Resolution</td><td>0.5 % of I_r</td></tr>
<tr><td rowspan="2">Accuracy at rated frequency</td><td>$I \leq I_r$</td><td>+/-2.5 % of I_r</td></tr>
<tr><td>$I > I_r$</td><td>+/-2.5 % of I</td></tr>
</table>

Table 65: Event recorder

<table>
<tr><th colspan="2">Function</th><th>Value</th></tr>
<tr><td rowspan="2">Event buffering capacity</td><td>Max. number of events/disturbance report</td><td>150</td></tr>
<tr><td>Max. number of disturbance reports</td><td>10</td></tr>
</table>

Table 66: FLOC - Fault locator

<table>
<tr><th colspan="3">Function</th><th>Setting range</th><th>Accuracy</th></tr>
<tr><td rowspan="3">Distance to fault locator</td><td rowspan="2">Reach for I_r =1 A</td><td>Resistive direction</td><td>(0 - 1500) ohm/ phase</td><td rowspan="3">+/- 2.5 % (typical)</td></tr>
<tr><td>Reactive direction</td><td>(0 - 1500) ohm/ phase</td></tr>
<tr><td colspan="2">Phase selection</td><td>According to input signals</td></tr>
</table>

Table 67: Mean values (AC-monitoring)

Function	Nominal range	Accuracy
Frequency	(0.95 - 1.05) x f_r	+/- 0.2 Hz
Voltage (RMS) Ph-Ph	(0.1 - 1.5) x U_r	+/- 2.5% of U_r, at $U \leq U_r$ +/- 2.5% of U, at $U > U_r$
Current (RMS)	(0.2 - 4) x I_r	+/- 2.5% of I_r, at $I \leq I_r$ +/- 2.5% of I, at $I > I_r$
Active power*)	at $\lvert\cos\varphi\rvert \geq 0.9$	+/- 5%
Reactive power*)	at $\lvert\cos\varphi\rvert \leq 0.8$	+/- 7.5%
*) Measured at U_r and 20% of I_r		

Table 68: MIM - mA measuring function

Function	Setting range	Accuracy
mA measuring function	+/- 5, +/- 10, +/- 20 mA 0-5, 0-10, 0-20, 4-20 mA	+/- 0.1 % of set value +/-0.005 mA
Max current of transducer to input	(-25.00 to +25.00) mA in steps of 0.01	
Min current of transducer to input	(-25.00 to +25.00) mA in steps of 0.01	
High alarm level for input	(-25.00 to +25.00) mA in steps of 0.01	
High warning level for input	(-25.00 to +25.00) mA in steps of 0.01	
Low warning level for input	(-25.00 to +25.00) mA in steps of 0.01	
Low alarm level for input	(-25.00 to +25.00) mA in steps of 0.01	
Alarm hysteresis for input	(0-20) mA in steps of 1	
Amplitude dead band for input	(0-20) mA in steps of 1	
Integrating dead band for input	(0.00-1000.00) mA in steps of 0.01	

Table 69: Mean values with increased accuracy (AC-monitoring)

Function	Nominal range	Accuracy
Frequency	(0.95 - 1.05) x f_r	+/- 0.2 Hz
Voltage (RMS) Ph-Ph	(0.8 - 1.2) x U_r	+/- 0.25% of U_r, at $U <= U_r$ +/- 0.25% of U, at $U > U_r$
Current (RMS)	(0.2 - 2) x I_r	+/- 0.25% of I_r, at $I <= I_r$ +/- 0.25% of I, at $I > I_r$
Active power	$0.8 \times U_r < U < 1.2 \times U_r$ $0.2 \times I_r < I < 2 \times I_r$ Active power, $\lvert\cos\varphi\rvert >= 0.9$	+/- 0.5% of P_r at $P <= P_r$ *), +/- 0.5% of P at $P > P_r$ *),
*) P_r: Active power at $U = U_r$, I = Ir and $\lvert\cos\varphi\rvert = 1$		

Metering

Table 70: PC - Pulse counter logic function

Function	Setting range	Accuracy
Input frequency	See Binary Input Module (BIM)	-
Cycle time for pulse counter	30 s, 1 min, 1 min 30 s, 2 min, 2 min 30 s, 3 min, 4 min, 5 min, 6 min, 7 min 30s, 10 min, 12 min, 15 min, 20 min, 30 min, 60 min	+/- 0,1% of set value

Hardware modules

Table 71: Binary inputs

Inputs	RL24	RL48	RL110	RL220
Binary inputs	BIM: 16, IOM: 8, PSM: 4			
Debounce frequency	5 Hz (BIM), 1 Hz (IOM)			
Oscillating signal discrimi-nator.*	Blocking and release settable between 1-40 Hz			
Binary input voltage RL	24/30 VDC +/-20%	48/60 VDC +/-20%	110/125 VDC +/-20%	220/250 VDC +/-20%
Power consumption (max.)	0.05 W/input	0.1 W/input	0.2 W/input	0.4 W/input
*) Only available for BIM				

Table 72: Binary outputs

Function or quantity		Trip and Signal relays	Fast signal relays
Binary outputs		BOM: 24, IOM: 10, PSM: 4	IOM: 2
Max system voltage		250 V AC, DC	250 V AC, DC
Test voltage across open contact, 1 min		1000 V rms	800 V DC
Current carrying capacity	Continuous	8 A	8 A
	1 s	10 A	10 A
Making capacity at inductive load with L/R>10 ms	0.2 s	30 A	0.4 A
	1.0 s	10 A	0.4 A
Breaking capacity for AC, cos φ>0.4		250 V/8.0 A	250 V/8.0 A
Breaking capacity for DC with L/R<40ms		48 V/1 A	48 V/1 A
		110 V/0.4 A	110 V/0.4 A
		220 V/0.2 A	220 V/0.2 A
		250 V/0.15 A	250 V/0.15 A
Maximum capacitive load		-	10 nF

Table 73: MIM - Energizing quantities, rated values and limits

<table>
<tr><th colspan="3">Quantity</th><th>Rated value</th><th>Nominal range</th></tr>
<tr><td rowspan="4">mA input module</td><td colspan="2">input range</td><td>+/- 20 mA</td><td>-</td></tr>
<tr><td colspan="2">input resistance</td><td>R_{in} = 194 ohm</td><td>-</td></tr>
<tr><td rowspan="2">power consumption</td><td>each mA-module</td><td>≤ 4 W</td><td>-</td></tr>
<tr><td>each mA-input</td><td>≤ 0.1 W</td><td>-</td></tr>
</table>

Table 74: SMS communication via front

Function	Value
Protocol	SPA
Communication speed for the terminals	300, 1200, 2400, 4800, 9600 Kbaud
Slave number	1 to 899
Change of active group allowed	Yes
Change of settings allowed	Yes

Table 75: Optical receiver module, ORM

Function	Type
Optical connector	Type ST

Table 76: Cable connection requirements for SPA/IEC connection

	Glass fibre	Plastic fibre
Cable connector	ST connector	HFBR, Snap-in connector
Fibre diameter	62.5/125 µm 50/125 µm	1 mm
Max. cable length	500 m	30 m

Table 77: LON - Cable connection requirements for LON bus connection

	Glass fibre	Plastic fibre
Cable connector	ST-connector	HFBR, Snap-in connector
Fibre diameter	62.5/125 µm 50/125 µm	1 mm
Max. cable length	1000 m	30 m

Table 78: Galvanic data communication module

Interface type	According to standard	Connector type
V.36/V11 Co-directional (on request)	ITU (CCITT)	D-sub 25 pins
V.36/V11 Contra-directional	ITU (CCITT)	D-sub 25 pins
X.21/X27	ITU (CCITT)	D-sub 15 pins
RS530/RS422 Co-directional (on request)	EIA	D-sub 25 pins
RS530/RS422 Contra-directional	EIA	D-sub 25 pins
G.703 Co-directional	ITU (CCITT)	Screw

Table 79: Short-range galvanic module

Data transmission	Synchronous, full duplex
Transmission rate	64 kbit/s (256 kBaud; code transparent)
Clock source	Internal or derived from received signal
Range	max 4 km
Line interface	Balanced symmetrical three-state current loop (4 wires)
Connector	5-pin divisible connector with screw connection
Insulation	2,5 kV 1 min. Opto couplers and insulating DC/DC-converter
	15 kV with additional insulating transformer

Table 80: Fibre optical communication module

Optical interface		
Type of fibre	Graded-index multimode 50/125µm or 62,5/125µm	Single mode 9/125 µm
Wave length	1300 nm	1300 nm
Optical transmitter injected power	LED -17 dBm	LED -22 dBm
Optical receiver sensitivity	PIN diode -38 dBm	PIN diode -38 dBm
Optical budget	21 dB	16 dB
Transmission distance	typical 15-20 km [a)]	typical 30-70 km [a)]
Optical connector	Type FC-PC	Type FC-PC
Protocol	ABB specific	ABB specific
Data transmission	Synchronous, full duplex	Synchronous, full duplex
Transmission rate	64 kbit/s	64 kbit/s
Clock source	Internal or derived from received signal	Internal or derived from received signal
[a)] depending on optical budget calculation		

Table 81: Short-range fibre optical module

Data transmission	Synchronous, full duplex
Transmission rate	64 kbit/s
Clock source	Internal or derived from received signal
Optical fibre	Graded-index multimode 50/125µm or 62,5/125µm
Wave length	850 nm
Optical connectors	ST
Optical budget	15 dB
Transmission distance	max 3,5 km
Protocol	FIBERDATA specific

Ordering

Guidelines

Carefully read and follow the set of rules to ensure problem-free order management. Be aware that certain functions can only be ordered in combination with other functions and that some functions require specific hardware selections.

Basic hardware and functions

Platform and basic functionality

Basic REx 5xx platform and common functions housed in selected casing

Manuals on CD

Operator’s manual (English)

Installation and commissioning manual (English)

Technical reference manual (English)

Application manual (English)

Binary I/O capabilities

Binary I/O resided on power supply module

Measuring capabilities

A/D module

Transformer module

Line impedance

3 zones phase-to-phase protection *(ZM1, ZM2, ZM3)*

3 zones phase-to-ground protection *(ZM1, ZM2, ZM3)*

Phase selection logic *(PHS)*

Scheme communication logic *(ZCOM)*

Current reversal and weak end infeed logic *(ZCAL)*

Local acceleration logic *(ZCLC)*

Current

Instantaneous overcurrent protection *(IOC)*

- Phase element
- Residual element

Time delayed overcurrent protection *(TOC)*

- Phase element
- Residual element

Power system supervision

Dead line detection *(DLD)*

Logic

Trip logic *(TR)*

- Three pole tripping

High speed binary output logic *(HSBO)*

Monitoring

Event recorder

Analog AC monitor software

Analog DC monitor software (Requires optional mA-transducer module, MIM)

Product specification

REL 521	Quantity:	☐	1MRK 002 494-AC

Default:

The terminal is delivered without loaded configuration.

Use the configuration and programming tool (CAP 540) to build a configuration from start or to make an example configuration complete.

Option:

Customer specific configuration	On request

Rule: Select only one alternative.

Engergizing quantities for binary inputs on power supply module	24/30 V	☐	1MRK 002 238-AA
	48/60 V	☐	1MRK 002 238-BA
	110/125 V	☐	1MRK 002 238-CA
	220/250 V	☐	1MRK 002 238-DA

Note: Auxiliary dc voltage EL, connected to the power supply module, is (48-250) V.

Measuring capabilities

Add measuring capabilities by selecting input energizing options from the following tables.

Rule: If optical measuring transformers is used and connected to an OITP (Optical Instrument Transformer Platform), omit the steps where measuring input energizing quantities are selected.

Optical receiver module (ORM)	☐	1MRK 002 216-AA

Rule: Select only one alternative. If sensitive earth fault functionality should be used, select from next table.

Rated measuring input energizing quantities	1 A, 110 V	☐	1MRK 000 157-MB
	1 A, 220 V	☐	1MRK 000 157-VB
	5 A, 110 V	☐	1MRK 000 157-NB
	5 A, 220 V	☐	1MRK 000 157-WB

Rule: Select only one alternative. Also select the corresponding sensitive earth fault function(s) from the optional protection functions.

Rated measuring input energizing quantities for sensitive earth fault functions	I1-I4	1 A	☐	1MRK 000 157-XB
	I5	0.1 A		
	U1-U5	110 V		
	I1-I4	5 A	☐	1MRK 000 157-RB
	I5	0.5 A		
	U1-U5	110 V		

Optional functions

Line impedance

Simplified impedance settings	☐	1MRK 001 459-UA
Full scheme distance protection		
Additional impedance zone 4 *(ZM4)*	☐	1MRK 001 456-FA
Additional impedance zone 5 *(ZM5)*	☐	1MRK 001 456-GA
Power swing detection *(PSD)*	☐	1MRK 001 456-LA
Power swing logic *(PSL)*	☐	1MRK 001 456-SA
Pole slip protection *(PSP)*	☐	1MRK 001 457-SA
Radial feeder protection *(PAP)*	☐	1MRK 001 455-SA
Automatic switch onto fault logic *(SOTF)*	☐	1MRK 001 456-RA

Current

Two step time delayed phase overcurrent protection *(TOC2)*	☐	1MRK 001 459-LA
Two step time delayed directional phase overcurrent protection *(TOC3)*	☐	1MRK 001 457-CA
Thermal phase overload protection *(THOL)*	☐	1MRK 001 457-DA
Stub protection *(STUB)*	☐	1MRK 001 457-TA
Breaker failure protection *(BFP)*	☐	1MRK 001 458-AA

Rule: Four step residual overcurrent protection (EF4) or Definite and inverse time delayed residual overcurrent protection (TEF) can only be selected separately, never together.

Scheme communication logic (EFC) and Current reversal and weak end infeed logic for residual overcurrent protection (EFCA) are automatically added when Four step residual overcurrent protection (EF4) is selected.

Four step residual overcurrent protection *(EF4)*	☐	1MRK 001 459-HA
Definite and inverse time delayed residual overcurrent protection *(TEF)*		

Rule: If Scheme communication logic (ZCOM) or Current reversal and weak end infeed logic for residual overcurrent protection (EFCA) is to be used, only the directional element may be selected		
Nondirectional element	☐	1MRK 001 456-YA
Directional element	☐	1MRK 001 459-ZA
Scheme communication logic *(EFC)*	☐	1MRK 001 455-UA
Current reversal and weak end infeed logic for residual overcurrent protection *(EFCA)*	☐	1MRK 001 455-VA
Rule: The sensitive protection functions demands that the corresponding rated measuring input energizing quantities are selected.		
Sensitive directional residual overcurrent protection *(WEF1)*	☐	1MRK 001 457-PA
Sensitive directional residual power protection *(WEF2)*	☐	1MRK 001 459-TA

Voltage

Time delayed phase undervoltage protection *(TUV)*	☐	1MRK 001 457-RA
Time delayed overvoltage protection *(TOV)*		
Phase element	☐	1MRK 001 457-GA
Residual element	☐	1MRK 001 459-FA

Power system supervision

Broken conductor check *(BRC)*	☐	1MRK 001 457-UA
Loss of voltage check *(LOV)*	☐	1MRK 001 457-VA
Overload supervision *(OVLD)*	☐	1MRK 001 457-FA

Secondary system supervision

Current circuit supervision, current based *(CTSU)*	☐	1MRK 001 457-XA
Fuse failure *(FUSE)*		
Rule: If du/dt and di/dt based option is selected Zero sequence option must be ordered		
Zero sequence	☐	1MRK 001 457-ZA
du/dt and di/dt based	☐	1MRK 001 459-YA
Voltage transformer supervision *(TCT)*	☐	1MRK 001455-TA

Control

Single command *(CD)*	☐	1MRK 001 458-EA
Synchrocheck *(SYN)*		
For single CB, including energizing check	☐	1MRK 001 458-GA
For double CBs, including energizing check	☐	1MRK 001 458-FA
For double CBs, including phasing and energizing check	☐	1MRK 001 457-HA
For single CB, including phasing and energizing check	☐	1MRK 001 458-KA
Automatic reclosing function *(AR)*		

For single CB, one and/or three phase reclosing	☐	1MRK 001 458-LA
For double CBs, one and/or three phase reclosing	☐	1MRK 001 457-KA
For single CB, three phase reclosing	☐	1MRK 001 458-MA
For double CBs, three phase reclosing	☐	1MRK 001 457-LA

Logic

Trip logic *(TR)*		
Single, two and/or three pole trip logic, replacing the default three pole trip logic function	☐	1MRK 001 458-XA
One additional trip logic function block		
Three pole trip	☐	1MRK 001 459-VA
Single, two and/or three pole trip	☐	1MRK 001 459-XA
Pole discordance logic, contact based *(PD)*	☐	1MRK 001 458-UA
Communication channel test logic *(CCHT)*	☐	1MRK 001 459-NA

Monitoring

Disturbance recorder	☐	1MRK 001 458-NA
Fault locator *(FLOC)*	☐	1MRK 001 458-RA
Trip value recorder	☐	1MRK 001 458-SA
Increased measuring accuracy for U, I, P, Q	☐	1MRK 000 597-PA

Metering capabilities

Note: The binary input module (BIM) with enhanced pulse counting capabilities is needed for pulse counting

Pulse counting	☐	1MRK 001 458-TA
Event counting	☐	1MRK 001 445-CA

Additional logic function block

Additional gates, pulse timers and registers	☐	1MRK 001 457-MA

Additional HMI language

Note: Only one alternative is possible

Second language beside English	German	☐	1MRK 001 459-AA
	Russian	☐	1MRK 001 459-BA
	French	☐	1MRK 001 459-CA
	Spanish	☐	1MRK 001 459-DA
	Italian	☐	1MRK 001 459-EA
Customer specific language	Contact your local ABB representative for availability		

Interbay communication capabilities

Note: The LON based SCS communication capability option is necessary

Binary signal interbay communication *(CM)*

One fast communication block (16 signals)	☐	1MRK 001 455-RA
79 medium speed communication block instances (79*16 signals)	☐	1MRK 001 458-YA

Communication functions for remote terminal communication

Rule: If Binary signal transfer to remote end (RTC) is selected Communication interfaces for remote terminal communication must be ordered

Binary signal transfer to remote end	☐	1MRK 001 458-ZA

Hardware

Extended indication capabilities

LED indication module (18 LEDs)	☐	1MRK 000 008-DA

Communication interfaces for remote terminal communication

Rule: If Communication interfaces for remote terminal communication is selected Binary signal transfer to remote end (RTC) must be ordered.

Co-directional V.36/V.35 galvanic interface	☐	On request
Contra-directional V.36/V.35 galvanic interface	☐	1MRK 000 185-BA
Co-directional RS530/RS422 galvanic interface	☐	On request
X.21 galvanic interface	☐	1MRK 000 185-CA
Contra-directional RS530/RS422 galvanic interface	☐	1MRK 000 185-EA
Fiber optical modem	☐	1MRK 000 195-AA
Short range galvanic modem	☐	1MRK 001 370-AA
Short range fiber optical modem	☐	1MRK 001 370-DA
Co-directional G.703 galvanic interface	☐	1MRK 001 370-CA

Additional binary I/O capabilities

Rule: The number of binary I/O modules (IOM) and binary output modules (BOM) together in a terminal may not exceed a total of 4.

Binary I/O module, IOM (8 inputs, 10 outputs, 2 high-speed outputs)

24/30 V	Quantity:		1MRK 000 173-GB
48/60 V	Quantity:		1MRK 000 173-AC
110/125 V	Quantity:		1MRK 000 173-BC
220/250 V	Quantity:		1MRK 000 173-CC

Binary input module, BIM (16 inputs)

24/30 V	Quantity:	☐	1MRK 000 508-DB
48/60 V	Quantity:	☐	1MRK 000 508-AB
110/125 V	Quantity:	☐	1MRK 000 508-BB
220/250 V	Quantity:	☐	1MRK 000 508-CB

Binary input module, BIM, with enhanced pulse counting capabilities (16 inputs)

Rule: Can only be ordered together with the pulse counter logic (PC) optional function

24/30 V	Quantity:	☐	1MRK 000 508-HA
48/60 V	Quantity:	☐	1MRK 000 508-EA
110/125 V	Quantity:	☐	1MRK 000 508-FA
220/250 V	Quantity:	☐	1MRK 000 508-GA

Rule: The number of binary output modules (BOM) and binary I/O modules (IOM) together in a terminal may not exceed a total of 4.

Binary output module, BOM (24 outputs in 12 groups)	Quantity:	☐	1MRK 000 614-AB
Milliampere input module *(MIM)*	Quantity:	☐	1MRK 000 284-AB

Case size

Compare the sum of the ordered quantities of I/O modules with the table below and select the case size which has the larger or equal number of slots available.

Seen from the front of the terminal the I/O modules will be placed from left to right in the order BIM, BOM, IOM, MIM, Communication interface.

Table 82: Maximum hardware configurations for I/O modules

Maximum number of modules	Case size	
	3/4 x 19” 1MRK 000 151-GC ☐	1/2 x 19” 1MRK 000 151-FC ☐
Binary input modules (BIM)	8	3
Binary output modules (BOM) and binary input/output modules (IOM)	4	3
mA input modules (MIM)	1	1
Communication interface for remote terminal communication	1	1
Total in case	*8*	*3*

SCS and SMS communication capabilities

SMS communication, only one alternative can be selected

SPA/IEC 60870-5-103 interface	Plastic fibers	☐	1MRK 000 168-FA
	Glass fibers	☐	1MRK 000 168-DA

SCS communication, only one alternative can be selected

LON interface	Plastic fibers	☐	1MRK 000 168-EA
	Glass fibers	☐	1MRK 000 168-DA

Test switch

Test switch module RTXP 24 mounted side-by-side to the terminal in RHGS case	☐	1MRK 000 371-CA
With internal earthing	☐	RK 926 215-BB
With external earthing	☐	RK 926 215-BC
On/off switch for the DC-supply	☐	RK 795 017-AA

Protection cover

Cover for rear area including fixing screws and assembly instruction	6U, 3/4 x 19”	☐	1MRK 000 020-AB
	6U, 1/2 x 19”	☐	1MRK 000 020-AC

Mounting accessories

19” rack mounting kit	☐	1MRK 000 020-BR
Wall mounting kit	☐	1MRK 000 020-DA
Flush mounting kit	☐	1MRK 000 020-Y
Semiflush mounting kit	☐	1MRK 000 020-BS
Additional mounting seal for IP54 protection of flush and semiflush mounted terminals	☐	1MKC 980 001-2
Side-by-side mounting kit	☐	1MRK 000 020-Z

Accessories

Converters

V.36 to G.703 converter with 48 VDC power supply	☐	1MRK 001 295-AA
V.35/V.36 converter for short range fiber optical modem	☐	1MRK 001 295-CA
X.21/G.703 converter for short range fiber optical modem	☐	1MRK 001 295-DA

Key switch

Key switch for setting lockout	Quantity:	☐	1MRK 000 611-A

Front communication cable

Front connection cable for PC (Opto/9-pole D-sub)	Quantity:	☐	1MKC 950 001-2

Manuals

One CD with Operator's manual, Technical reference manual, Installation and commissioning manual and Application manual is always included for each terminal.

Rule: Specify the number of extra CD's requested

CD with all manuals	Quantity:	☐	1MRK 002 241-AA

Rule: Specify the number of printed manuals requested

Operator's manual	Quantity:	☐	1MRK 506 068-UEN
Technical reference manual	Quantity:	☐	1MRK 506 069-UEN
Installation and commissioning manual	Quantity:	☐	1MRK 506 070-UEN
Application manual	Quantity:	☐	1MRK 506 111-UEN

Customer feedback

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

Technical overview brochure

Accessories for REx 5xx*2.3	1MRK 514 009-BEN
CAP 540*1.2	1MRK 511 112-BEN

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