

Feeder Protection Relay REF610

Technical Reference Manual



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1. Introduction

1.1. This manual

This manual provides thorough information on the protection relay REF610 and its applications, focusing on giving a technical description of the relay.

Refer to the Operator's Manual for instructions on how to use the human-machine interface (HMI) of the relay, also known as the man-machine interface (MMI), and to the Installation Manual for installation of the relay.

1.2. Use of symbols

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



The electrical warning icon indicates the presence of a hazard which could result in electrical shock.



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



The caution icon indicates important information or warning related to the concept discussed in the text. It might indicate the presence of a hazard which could result in corruption of software or damage to equipment or property.



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



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

Although warning hazards are related to personal injury, it should be understood that operation of damaged equipment could, under certain operational conditions, result in degraded process performance leading to personal injury or death. Therefore, comply fully with all warning and caution notices.

1.3. Intended audience

This manual is intended for operators and engineers to support normal use of as well as configuration of the product.

1.4. Product documentation

In addition to the relay and this manual, the delivery contains the following relay-specific documentation:

Table 1.4.-1 REF610 product documentation

Name	Document ID
Installation Manual	1MRS752265-MUM
Technical Reference Manual	1MRS755310
Operator's Manual	1MRS755311

1.5. Document conventions

The following conventions are used for the presentation of material:

- Push button navigation in the human-machine interface (HMI) menu structure is presented by using the push button icons, for example:

To navigate between the options, use ▲ and ▼.

- HMI menu paths are presented as follows:

Use the arrow buttons to select CONFIGURATION\ COMMUNICATION\ SPA SETTINGS\ PASSWORD SPA.

- Parameter names, menu names, relay indication messages and relay's HMI views are shown in a Courier font, for example:

Use the arrow buttons to monitor other measured values in the menus DEMAND VALUES and HISTORY DATA.

- HMI messages are shown inside quotation marks when it is good to point out them for the user, for example:

When you store a new password, the relay confirms the storage by flashing “- - -” once on the display.

1.6. Document revisions

Version	IED Revision	Date	History
A	A	05.10.2004	Document created. Version A2 includes only a minor layout change.
B	A	12.09.2005	Content updated
C	A	25.01.2006	Minor layout update.
D	C	30.11.2006	Content updated
E	C	01.10.2007	Content updated
F	C	12.12.2007	Added information related to ordering parts and accessories.
G	C	20.05.2009	Content updated
H	C	18.11.2011	Language sets updated.

2. Safety information



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

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

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

National and local electrical safety regulations must always be followed.

The frame of the device has to be carefully earthed.

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



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

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

3. Product overview

3.1. Use of the relay

The feeder protection relay REF610 is a versatile multifunction protection relay mainly designed to protect incoming and outgoing feeders in a wide range of feeder applications.

The relay is based on a microprocessor environment. A self-supervision system continuously monitors the operation of the relay.

The HMI includes a liquid crystal display (LCD) which makes the local use of the relay safe and easy.

Local control of the relay via serial communication can be carried out with a computer connected to the front communication port. Remote control can be carried out via the rear connector connected to the control and monitoring system through the serial communication bus.

3.2. Features

- Three-phase non-directional overcurrent protection with definite-time or IDMT characteristic, low-set stage.
- Three-phase non-directional overcurrent protection, high-set stage
- Three-phase non-directional overcurrent protection, instantaneous stage
- Non-directional earth-fault protection with definite-time or IDMT characteristic, low-set stage
- Non-directional earth-fault protection, high-set stage.
- Phase discontinuity protection
- Three-phase thermal overload protection for cables
- Arc protection:
 - Two lens sensors for arc detection (optional)
 - Automatic reference level adjustment based on backlight intensity
 - Arc detection via a remote light signal
- Automatic reclosing 1...3 shots
- Circuit-breaker failure protection
- Trip counters for circuit-breaker condition monitoring
- Trip-circuit supervision with possibility to route the warning signal to a signal output
- Trip lockout function
- Four accurate current inputs
- User-selectable rated frequency 50/60 Hz
- Three normally open power output contacts
- Two change-over signal output contacts and three additional change-over signal output contacts on the optional I/O module
- Output contact functions freely configurable for wanted operation

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- Two galvanically isolated digital inputs and three additional galvanically isolated digital inputs on the optional I/O module
- Disturbance recorder:
 - Recording time up to 80 seconds
 - Triggering by one or several internal or digital input signals
 - Records four analog channels and up to eight user-selectable digital channels
 - Adjustable sampling rate
- Non-volatile memory for:
 - Up to 100 event codes with time stamp
 - Setting values
 - Disturbance recorder data
 - Recorded data of the five last events with time stamp
 - Number of AR shots and starts/trips for protection stages
 - Operation indication messages and LEDs showing the status at the moment of power failure
- HMI with an alphanumeric LCD and navigation buttons
 - Eight programmable LEDs
- Multi-language support
- User-selectable password protection for the HMI
- Display of primary current values
- Demand values
- All settings can be modified with a PC
- Optical front communication connection: wirelessly or via cable
- Optional rear communication module with plastic fibre-optic, combined fibre-optic (plastic and glass) or RS-485 connection for system communication using the SPA-bus, IEC 60870-5-103 or Modbus (RTU and ASCII) communication protocol
- Optional DNP 3.0 rear communication module with RS-485 connection for system communication using the DNP 3.0 communication protocol
- Battery back-up for real-time clock
- Battery charge supervision
- Continuous self-supervision of electronics and software
- Detachable plug-in unit

4. Application

REF610 is a versatile multifunction protection relay mainly designed for protection of incoming and outgoing feeders in MV distribution substations. The relay can also be used as back-up protection for motors, transformers and generators, in industrial as well as in utility applications.

The large number of integrated protection functions, including three-stage overcurrent protection, two-stage, non-directional earth-fault protection as well as thermal protection, makes the relay a complete protection against overcurrent and earth faults.

The optional arc protection for detection of arc situations in air insulated metal-clad switchgears and the auto-reclose function for automatic clearing of overhead line faults increase the range of applications further.

The large number of digital inputs and output contacts allows a wide range of applications.

4.1. Requirements

To secure correct and safe operation of the relay, preventive maintenance is recommended to be performed every five years when the relay is operating under the specified conditions; see Table 4.1.-1 and Section 5.2.4. Technical data.

When being used for real-time clock or recorded data functions, the battery should be changed every five years.

Table 4.1.-1 Environmental conditions

Recommended temperature range (continuous)	-10...+55°C
Limit temperature range (short-term)	-40...+70°C
Temperature influence on the operation accuracy of the protection relay within the specified service temperature range	0.1%/°C
Transport and storage temperature range	-40...+85°C

4.2. Configuration

The appropriate configuration of the output contact matrix enables the use of the signals from the protection stages as contact functions. The start signals can be used for blocking co-operating protection relays and signalling.

The figures below represent the relay with the default configuration: all trip signals are routed to trip the circuit breaker.

In the first example Fig. 4.2.-1, the residual current is measured via a core-balance current transformer and the output contacts are connected to enable the use of the auto-reclose function. In the second example Fig. 4.2.-2, the residual current is measured via a summation connection of the phase current transformers and the output contacts are connected to enable the use of the trip lockout function with an external reset switch.

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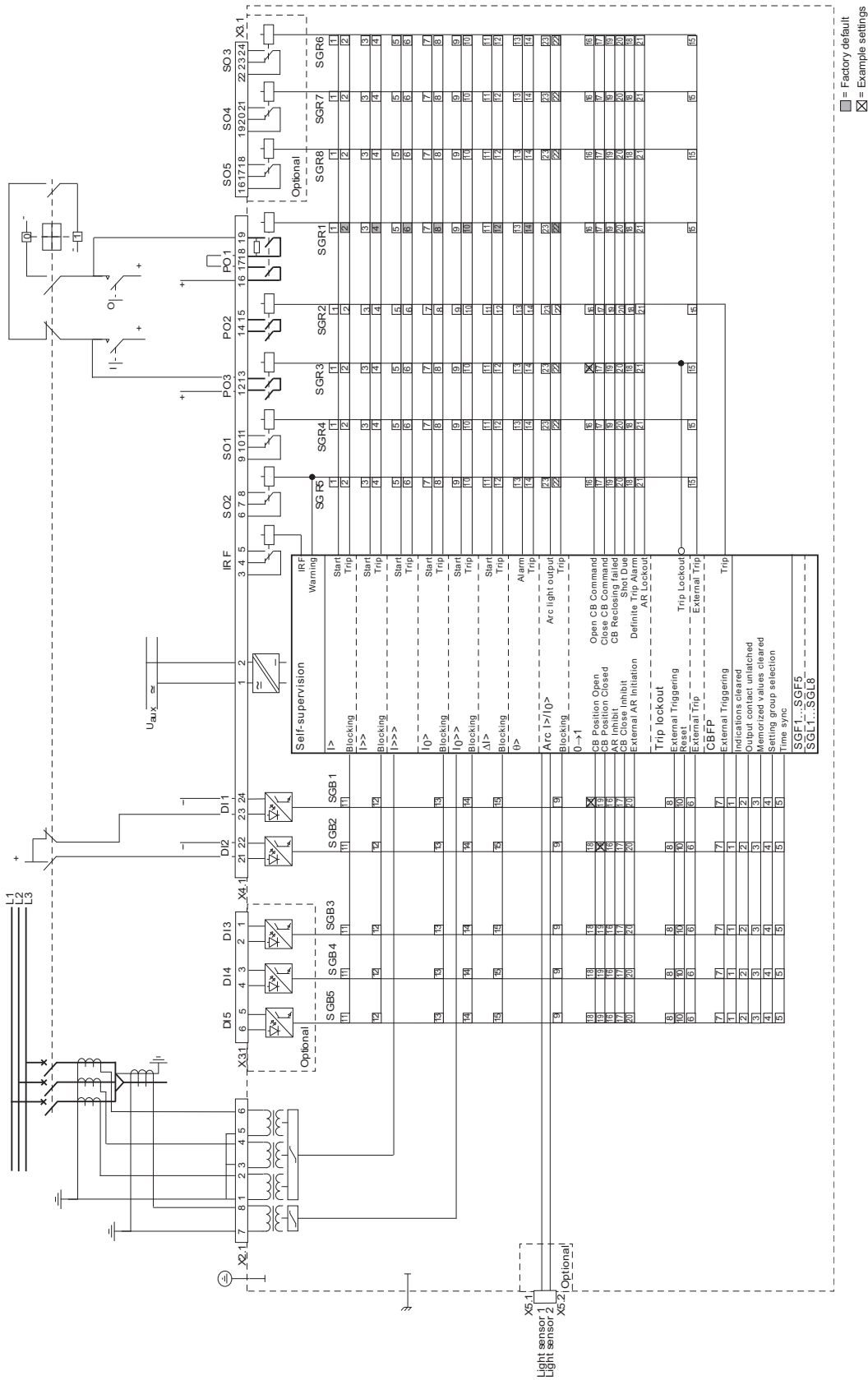


Fig. 4.2.-1 Connection diagram, example 1

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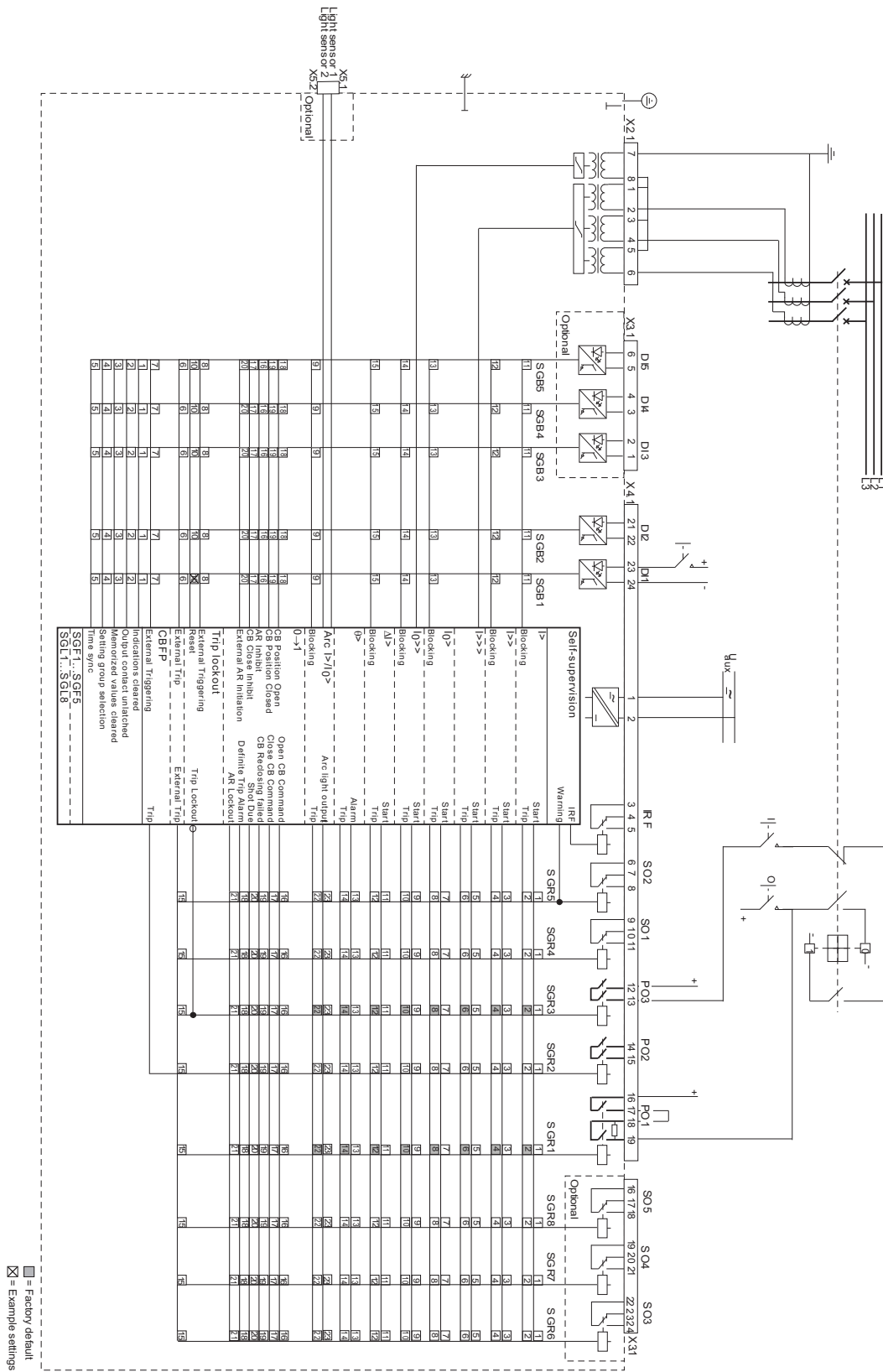


Fig. 4.2.-2 Connection diagram, example 2

5. Technical description

5.1. Functional description

5.1.1. Product functions

5.1.1.1. Protection functions

The protection functions of REF610 with their IEC symbols and IEEE device numbers are presented in the table below:

Table 5.1.1.1.-1 IEC symbols and IEEE device numbers

Function description	IEC symbol	IEEE Device No.
Three-phase non-directional overcurrent protection, low-set stage	$I>$	51
Three-phase non-directional overcurrent protection, high-set stage	$I>>$	50/51
Three-phase non-directional overcurrent protection, instantaneous stage	$I>>>$	50
Phase discontinuity protection	$\Delta I>$	46
Three-phase thermal overload protection for cables	$\theta>$	49
Non-directional earth-fault protection, low-set stage	$I_0>$	51N
Non-directional earth-fault protection, high-set stage	$I_0>>$	50N/51N
Arc protection	ARC	50/50NL
Circuit-breaker failure protection	CBFP	62BF
Automatic reclosing	$0 \rightarrow 1$	79
Lockout relay		86

For descriptions of the protection functions, refer to Section 5.1.4.11. Technical data on protection functions.

5.1.1.2. Inputs

The relay is provided with four energizing inputs, two optional light sensor inputs, two digital inputs and three optional digital inputs controlled by an external voltage. Three of the energizing inputs are for the phase currents and one for the earth-fault current.

The functions of the digital inputs are determined with the SGB switches. For details, refer to Section 5.2.1. Input/output connections and Table 5.1.4.10.-7, Table 5.2.1.-1 and Table 5.2.1.-5.

5.1.1.3. Outputs

The relay is provided with:

- Three power output contacts PO1, PO2 and PO3
- Two signal output contacts SO1 and SO2
- Three optional signal output contacts SO3, SO4 and SO5

Switchgroups SGR1...8 are used for routing internal signals from the protection stages, the external trip signal and signals from the auto-reclose function to the wanted signal or power output contact. The minimum pulse length can be configured to be 40 or 80 ms and the power output contacts can be configured to be latched.

5.1.1.4. Disturbance recorder

The relay includes an internal disturbance recorder which records the momentary measured values or the RMS curves of the measured signals, and up to eight user-selectable digital signals: the digital input signals and the internal signals from the protection stages. Any digital signal can be set to trigger the recorder on either the falling or rising edge.

5.1.1.5. Front panel

The front panel of the relay contains:

- Alphanumeric 2 × 16 characters' LCD with backlight and automatic contrast control
- Three indicator LEDs (green, yellow, red) with fixed functionality
- Eight programmable indicator LEDs (red)
- HMI push-button section with four arrow buttons and buttons for clear/cancel and enter, used in navigating in the menu structure and in adjusting setting values
- Optically isolated serial communication port with an indicator LED.

There are two levels of HMI passwords; main HMI setting password for all settings and HMI communication password for communication settings only.

The HMI passwords can be set to protect all user-changeable values from being changed by an unauthorized person. Both the HMI setting password and the HMI communication password remain inactive and are not required for altering parameter values until the default HMI password is replaced.



Entering the HMI setting or communication password successfully can be selected to generate an event code. This feature can be used to indicate interaction activities via the local HMI.

For further information on the HMI, refer to the Operator's Manual.

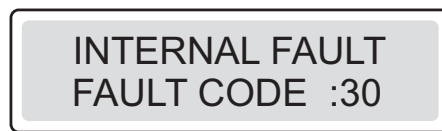
5.1.1.6. Non-volatile memory

The relay can be configured to store various data in a non-volatile memory, which retains its data also in case of loss of auxiliary voltage (provided that the battery has been inserted and is charged). Operation indication messages and LEDs, disturbance recorder data, event codes and recorded data can all be configured to be stored in the non-volatile memory whereas setting values are always stored in the EEPROM. The EEPROM does not require battery backup.

5.1.1.7. Self-supervision

The self-supervision system of the relay manages run-time fault situations and informs the user about an existing fault. There are two types of fault indications: internal relay fault (IRF) indications and warnings.

When the self-supervision system detects a permanent internal relay fault, which prevents relay operation, the green indicator LED (ready) will blink. At the same time, the IRF contact (also referred to as the IRF relay), which is normally picked up, drops off and a fault code appears on the LCD. The fault code is numerical and identifies the fault type.



A040278

Fig. 5.1.1.7.-1 Permanent IRF

In case of a warning, the relay continues to operate with full or reduced functionality and the green indicator LED (ready) remains lit as during normal operation. A fault indication message (see Fig. 5.1.1.7.-2), with a possible fault code (see Fig. 5.1.1.7.-3), appears on the LCD indicating the type of fault. In case of a warning due to an external fault in the trip circuit detected by the trip-circuit supervision, or due to continuous light on the light sensor inputs, SO2 is activated (if SGF1/8=1).



A040279

Fig. 5.1.1.7.-2 Warning with text message



A040280

Fig. 5.1.1.7.-3 Warning with numeric code

For fault codes, refer to Section 5.1.18. Self-supervision (IRF) system.

5.1.1.8.

Time synchronization

Time synchronization of the relay's real-time clock can be realized in two different ways: via serial communication using a communication protocol or via a digital input.

When time synchronization is realized via serial communication, the time is written directly to the relay's real-time clock.

Any digital input can be configured for time synchronization and used for either minute-pulse or second-pulse synchronization. The synchronization pulse is automatically selected and depends on the time range within which the pulse occurs. Two detected pulses within acceptable time range are required before the relay activates pulse synchronization. Respectively, if the synchronization pulses disappear, the relay takes time that corresponds to the time range of four pulses before de-activating pulse synchronization. The time must be set once, either via serial communication or manually via the HMI.

When the time is set via serial communication and minute-pulse synchronization is used, only year-month-day-hour-minute is written to the relay's real-time clock, and when second-pulse synchronization is used, only year-month-day-hour-minute-second is written. The relay's real-time clock will be rounded to the nearest whole second or minute, depending on whether second- or minute-pulse synchronization is used. When the time is set via the HMI, the entire time is written to the relay's real-time clock.

If the synchronization pulse differs more than ± 0.05 seconds for second-pulse or ± 2 seconds for minute-pulse synchronization from the relay's real-time clock, the synchronization pulse is rejected.

Time synchronization is always triggered on the rising edge of the digital input signal. The time is adjusted by accelerating or decelerating the relay's clock. By this way the clock neither stops nor makes sudden jumps during the time adjustment. The typical accuracy achievable with time synchronization via a digital input is ± 2.5 milliseconds for second-pulse and ± 5 milliseconds for minute-pulse synchronization.



The pulse length of the digital input signal does not affect time synchronization.



If time synchronization messages are received from a communication protocol as well, they have to be synchronized within ± 0.5 minutes at minute-pulse or ± 0.5 seconds at second-pulse synchronization. Otherwise the time difference may appear as rounding errors. If it is possible that the synchronization messages from the communication protocol are delayed more than 0.5 seconds, minute-pulse synchronization must be used.

When the minute-pulse synchronization is active and long time format is sent via a communication protocol, the protocol's second and millisecond part is ignored. The protocol's minute part is rounded to the nearest minute. Short time format is ignored altogether.

When the second-pulse synchronization is active and long or short time format is sent via a communication protocol, the protocol's millisecond part is ignored. The protocol's second-part is rounded to the nearest second.

5.1.2.

Measurements

The table below presents the measured values which can be accessed through the HMI.

Table 5.1.2.-1 *Measured values*

Indicator	Description
L1	Current measured on phase L1
L2	Current measured on phase L2
L3	Current measured on phase L3
I_0	Measured earth-fault current
ΔI	Calculated phase unbalance
θ	Calculated thermal level
$I_{1 \text{ minute}}$	The average current of the three phase-to-phase currents during one minute
$I_{n \text{ minute}}$	The average current of the three phase-to-phase currents during the specified time range
Max I	The maximum of one-minute average current of the I_{n_min}

5.1.3.

Configuration

The Fig. 5.1.3.-1 illustrates how the internal and digital input signals can be configured to obtain the required protection functionality.

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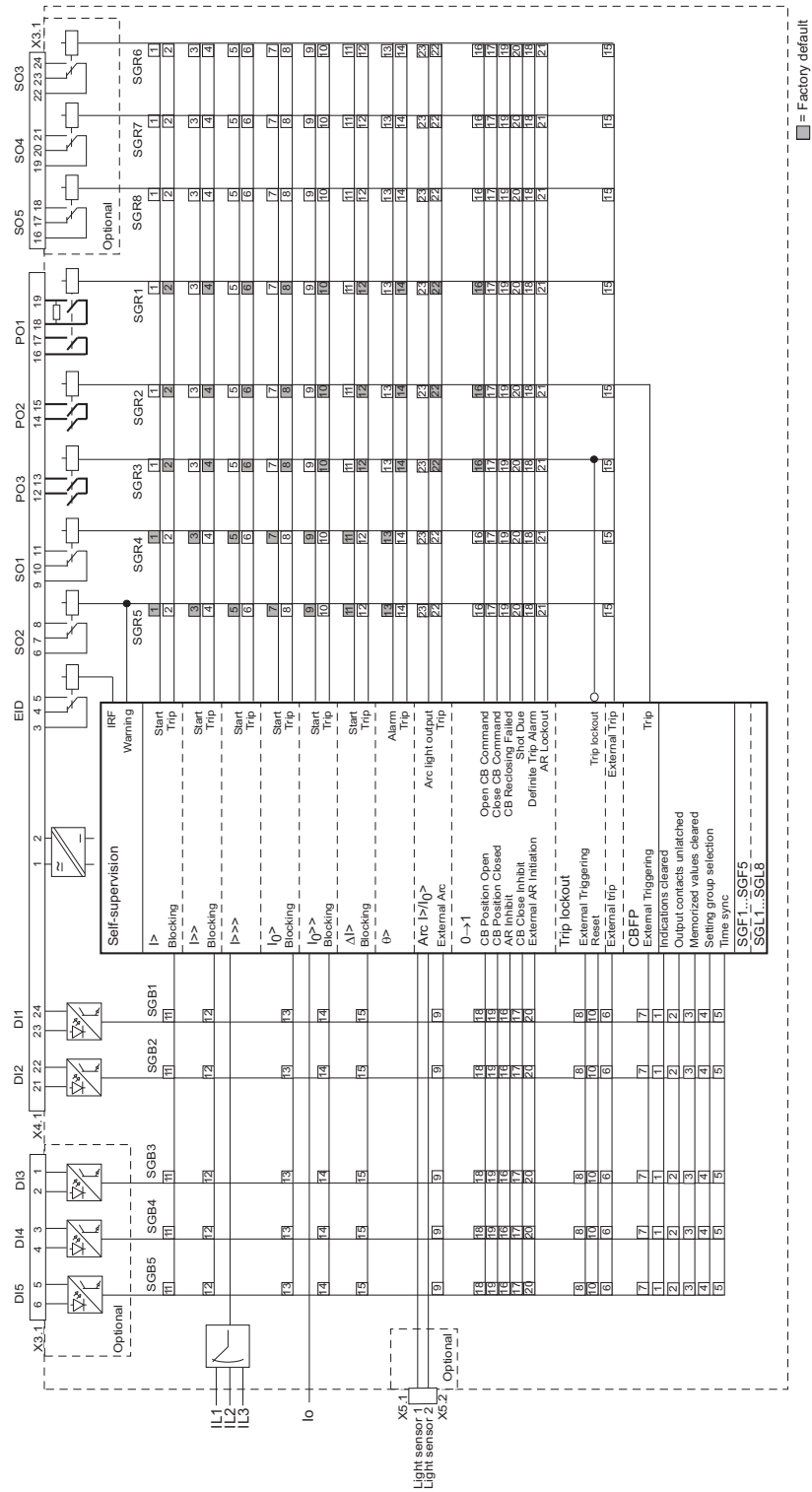


Fig. 5.1.3.-1 Signal diagram

The functions of the relay are selected with the switches of switchgroups SGF, SGB, SGR and SGL. The checksums of the switchgroups are found under SETTINGS in the HMI menu. The functions of the switches are explained in detail in the corresponding SG_ tables.

5.1.4. Protection

5.1.4.1. Block diagram

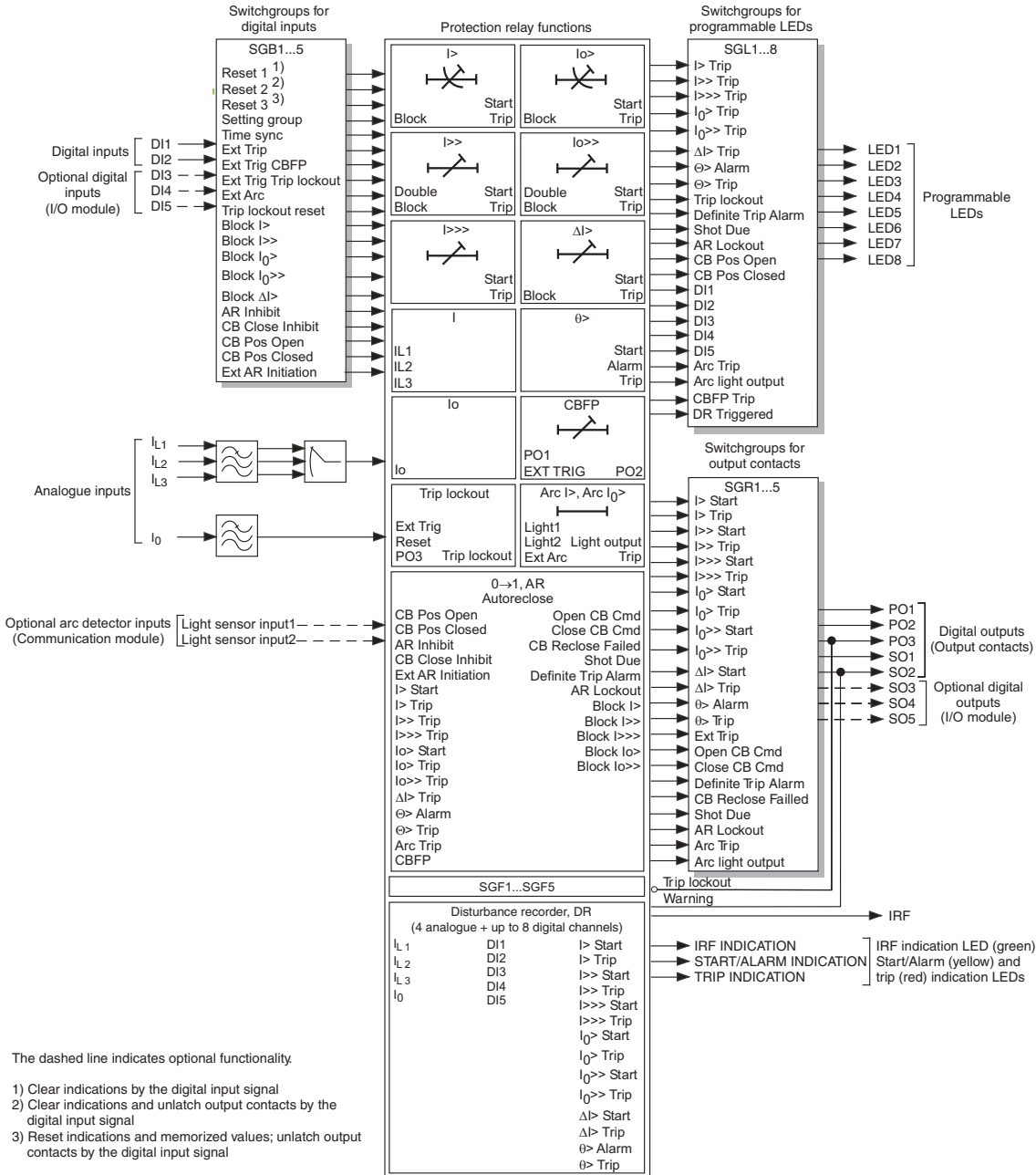


Fig. 5.1.4.1.-1 Block diagram

5.1.4.2. Overcurrent protection

The non-directional overcurrent protection detects overcurrent caused by phase-to-phase and phase-to-earth short circuits.

When one or several phase currents exceed the set start value of the low-set stage, $I_{>}$, the stage will generate a start signal after a ~ 55 ms' start time. When the set operate time at definite-time characteristic or the calculated operate time at IDMT characteristic elapses, the stage will generate a trip signal.

Stage $I_{>}$ has a settable resetting time (both at definite-time and IDMT characteristics), $t_{r>}$, for reset coordination with existing electromechanical relays or for reducing fault clearance times of recurring, transient faults. If stage $I_{>}$ has started and the phase currents fall below the set start value of the stage, the start of the stage will remain active for the set resetting time. If the phase currents exceed the set start value again, while the timer is being reset, the start of the stage will remain active. Consequently, the set resetting time ensures that when the stage starts because of current spikes, it will not be immediately reset. However, if stage $I_{>}$ has already tripped, the stage will be reset in 50 ms after all three phase currents have fallen below 0.5 times the set start value of the stage.

The inverse-time function of stage $I_{>}$ can be set to be inhibited when stage $I_{>>}$ and/or $I_{>>>}$ starts. In this case, the operate time will be determined by stage $I_{>>}$ and/or $I_{>>>}$. The selection is made in SGF4.

It is possible to block the tripping of the low-set overcurrent stage by applying a digital input signal to the relay.

When one or several phase currents exceed the set start value of the high-set stage, $I_{>>}$, the stage will generate a start signal after a ~ 30 ms' start time. When the set operate time at definite-time characteristic elapses, the stage will generate a trip signal. Stage $I_{>>}$ can be given an instantaneous characteristic by setting the operate time to the minimum, i.e. 0.04 s.

The set start value of stage $I_{>>}$ can be set to be automatically doubled in a start situation, i.e. when the object to be protected is being connected to a network. Consequently, a set start value below the connection inrush current level can be selected for stage $I_{>>}$. A start situation is defined as a situation where the maximum phase current rises from a value below $0.12 \times I_{>}$ to a value above $1.5 \times I_{>}$ within less than 60 ms. The start situation ends when all phase currents fall below $1.25 \times I_{>}$ and remain below for at least 200 ms. The selection is made in SGF4.

It is possible to block the tripping of the high-set overcurrent stage by applying a digital input signal to the relay.

Stage $I_{>>}$ can be set out of operation in SGF3. This state will be indicated by dashes on the LCD and by "999" when the set start value is read via serial communication.

When one or several phase currents exceed the set start value of the instantaneous stage, $I_{>>>}$, the stage will generate a start signal after a ~ 30 ms' start time. When the set operate time at definite-time characteristic elapses, the stage will generate a trip signal. Stage $I_{>>>}$ can be given an instantaneous characteristic by setting the operate time to the minimum, i.e. 0.04 s.

Stage I>>> can be set out of operation in SGF3. This state will be indicated by dashes on the LCD and by “999” when the set start value is read via serial communication.

Stages I>> and I>>> will be reset in 50 ms after all three phase currents have fallen below the set start value of the stage.



Stages I> and I>> can be set to be blocked by the auto-reclose function.

5.1.4.3.

Earth-fault protection

The non-directional earth-fault current protection detects phase-to-earth currents, caused by insulation failure due to ageing and thermal cycling, for instance.

When the earth-fault current exceeds the set start value of the low-set stage, $I_{0>}$, the stage will generate a start signal after a ~ 60 ms' start time. When the set operate time at definite-time characteristic or the calculated operate time at IDMT characteristic elapses, the stage will generate a trip signal. The low-set stage can be given an instantaneous characteristic by setting the operate time to the minimum, i.e. 0.05 s.

Stage $I_{0>}$ has a settable resetting time (both at definite-time and IDMT characteristics), $t_{0r>}$, for reset coordination with existing electromechanical relays or for reducing fault clearance times of recurring, transient faults. If stage $I_{0>}$ has started and the earth-fault current falls below the set start value of the stage, the start of the stage will remain active for the set resetting time. If the earth-fault current exceeds the set start value again, while the timer is being reset, the start of the stage will remain active. Consequently, the set resetting time ensures that when the stage starts because of current spikes, it will not be immediately reset. However, if stage $I_{0>}$ has already tripped, the stage will be reset in 50 ms after the earth-fault current has fallen below 0.5 times the set start value of the stage.

The inverse-time function of stage $I_{0>}$ can be set to be inhibited when stage $I_{0>>>}$ starts. In this case, the operate time will be determined by stage $I_{0>>>}$. The selection is made in SGF4.

When the earth-fault current exceeds the set start value of the high-set stage, $I_{0>>>}$, the stage will generate a start signal after a ~ 40 ms' start time. When the set operate time at definite-time characteristic elapses, the stage will generate a trip signal. The high-set stage can be given an instantaneous characteristic by setting the operate time to the minimum, i.e. 0.05 s. The stage will be reset in 50 ms after the earth-fault current has fallen below the set start value of the stage.

The set start value of stage $I_{0>>>}$ can be set to be automatically doubled in a start situation, i.e. when the object to be protected is being connected to a network. Consequently, a set start value below the connection inrush current level can be selected for the stage. A start situation is defined as a situation where the earth-fault

current rises from a value below $0.12 \times I_{0>}$ to a value above $1.5 \times I_{0>}$ within less than 60 ms. The start situation ends when the current falls below $1.25 \times I_{0>}$ and remain below for at least 200 ms. The selection is made in SGF4.



Consider carefully when using the automatically doubled setting for the set start value of stage $I_{0>>}$.

Stage $I_{0>>}$ can be set out of operation in SGF3. This state will be indicated by dashes on the LCD and by “999” when the set start value is read via serial communication. It is possible to block the tripping of an earth-fault stage by applying a digital input signal to the relay.



Stages $I_{0>}$ and $I_{0>>}$ can be set to be blocked by the auto-reclose function.

5.1.4.4.

Thermal protection for cables

The thermal protection detects long-time overloads during normal operation. Prolonged overloading results in the thermal stress capacity of the cable being exceeded, which degrades the insulation of the cable, which in turn may cause a short circuit or an earth fault. The heating up of the cable follows an exponential curve, the levelled-out value of which is determined by the squared value of the load current. The thermal protection may equally well be used to protect dry-type transformers, capacitor banks, busbars and overhead lines, for instance.

The thermal protection stage continuously calculates the thermal capacity used as a percentage of the cable's total thermal capacity. The thermal capacity is calculated as follows:

$$\theta = \left(\frac{I}{1.05 \times I_{\theta}} \right)^2 \times (1 - e^{-t/\tau}) \times 100\% \quad (1)$$

θ	= thermal capacity
I	= phase current value
I_{θ}	= set full load current
t	= time (in minutes)
τ	= time constant (in minutes)

When one or several phase currents exceed the set full load current, I_{θ} , stage $\theta>$ will start. At the same time, the thermal capacity will start to increase at a rate depending on the current amplitude and the prior load of the cable.

When the thermal capacity, influenced by the thermal history of the cable, exceeds the set alarm level, $\theta_{a>}$, the stage will generate an alarm signal. The thermal alarm can be used to avoid unnecessary tripping due to a beginning overload. The thermal level at various constant currents are presented in the table below:

Table 5.1.4.4.-1 Thermal level at constant currents

I/I_0	Thermal level (%)
1.0	90.7
0.9	73.5
0.8	58
0.7	44.4
0.5	22.7
0.3	8.2
0	0

When the thermal capacity exceeds the trip level, $\theta_t >$, the stage will generate a trip signal. The operate time, i.e. the time from when the stage starts until it trips, is determined by the time constant, τ , and depends on the cable (cable cross section area and cable rated voltage). The time constant is provided by the cable manufacturer. For a 22 kV cable, the typical time constant is 20 minutes. For operate times, see Fig. 5.1.4.4.-1...Fig. 5.1.4.4.-3. The operate time is calculated as follows:

$$t = \tau \times \ln \left\{ \frac{(I/I_0)^2 - (I_p/I_0)^2}{(I/I_0)^2 - 1.1025} \right\} \quad (2)$$

- I = phase current value
- I_0 = set full load current
- I_p = prior load current
- t = operate time (in minutes)
- τ = time constant (in minutes)
- \ln = natural logarithm

At power up, the thermal level will be set to 75 percent of the thermal capacity of the cable. This will ensure that the stage will trip within a safe time span in case of an overload. The calculated thermal level will approach the thermal level of the cable.

Stage $\theta >$ can be set out of operation in SGF3. This state will be indicated by dashes on the LCD and by “999” when the set full load current is read via serial communication.



At an alarm level below 75 percent, connecting the auxiliary supply to the relay will cause a thermal alarm due to the initialization of the thermal level to 75 percent of the thermal capacity of the cable. The thermal level can be reset via the HMI during power up.



The thermal level can be reset or changed via serial communication, which will generate an event code.

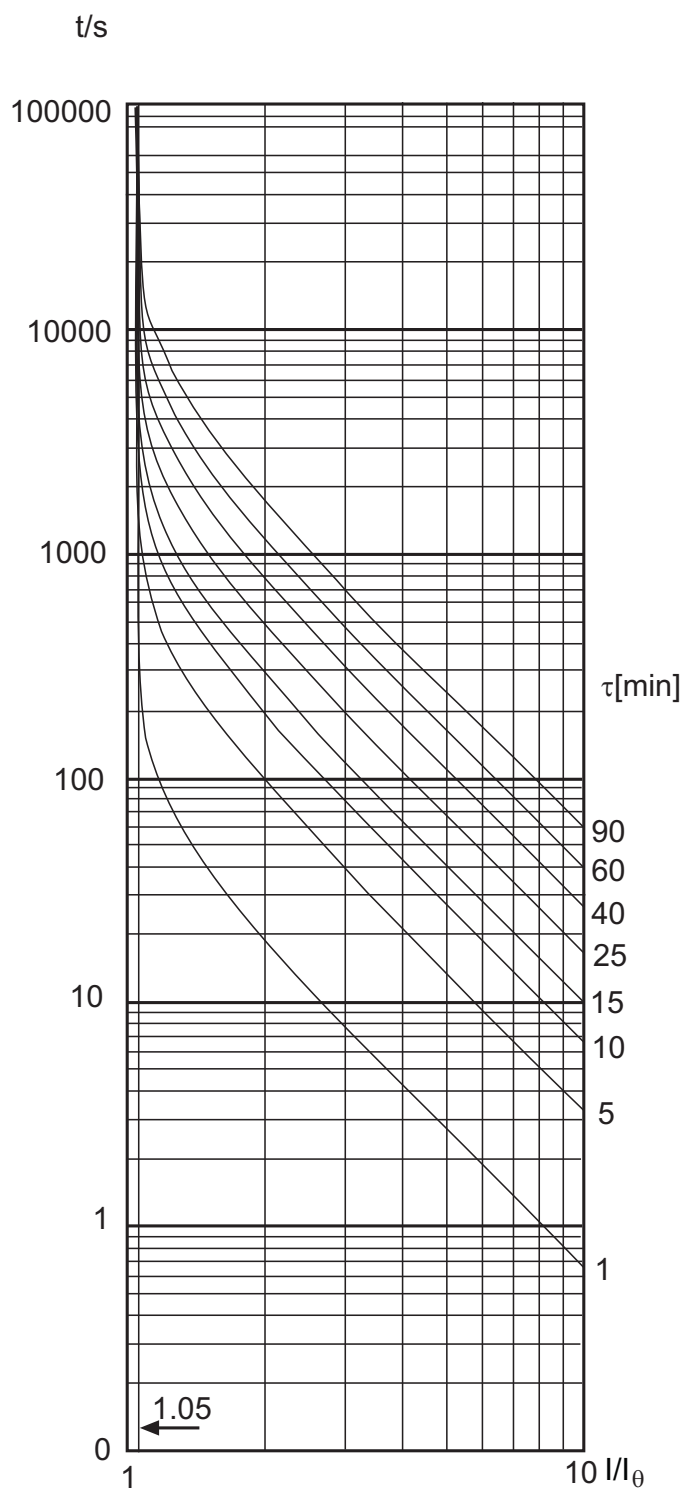


Fig. 5.1.4.4.-1 Trip curves when no prior load

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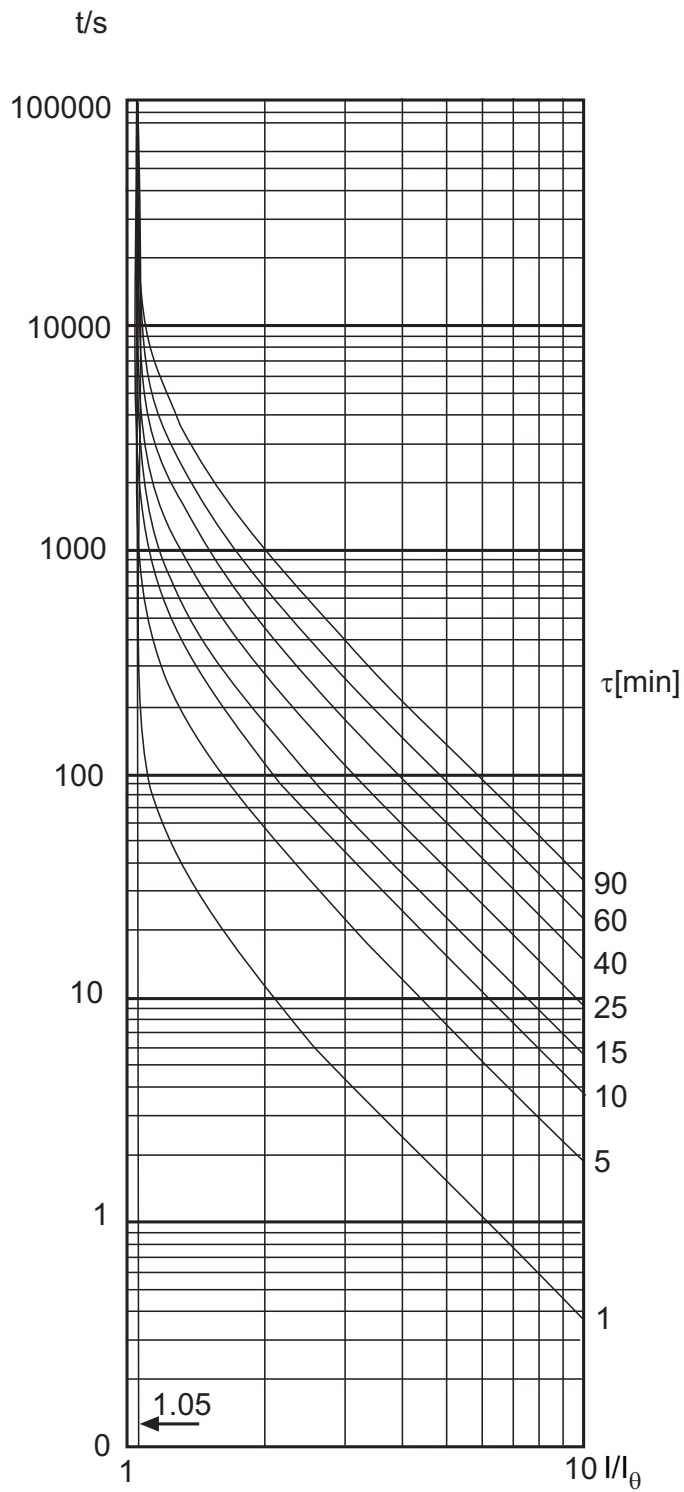


Fig. 5.1.4.4.-2 Trip curves at prior load $0.7 \times I_\theta$

A040314

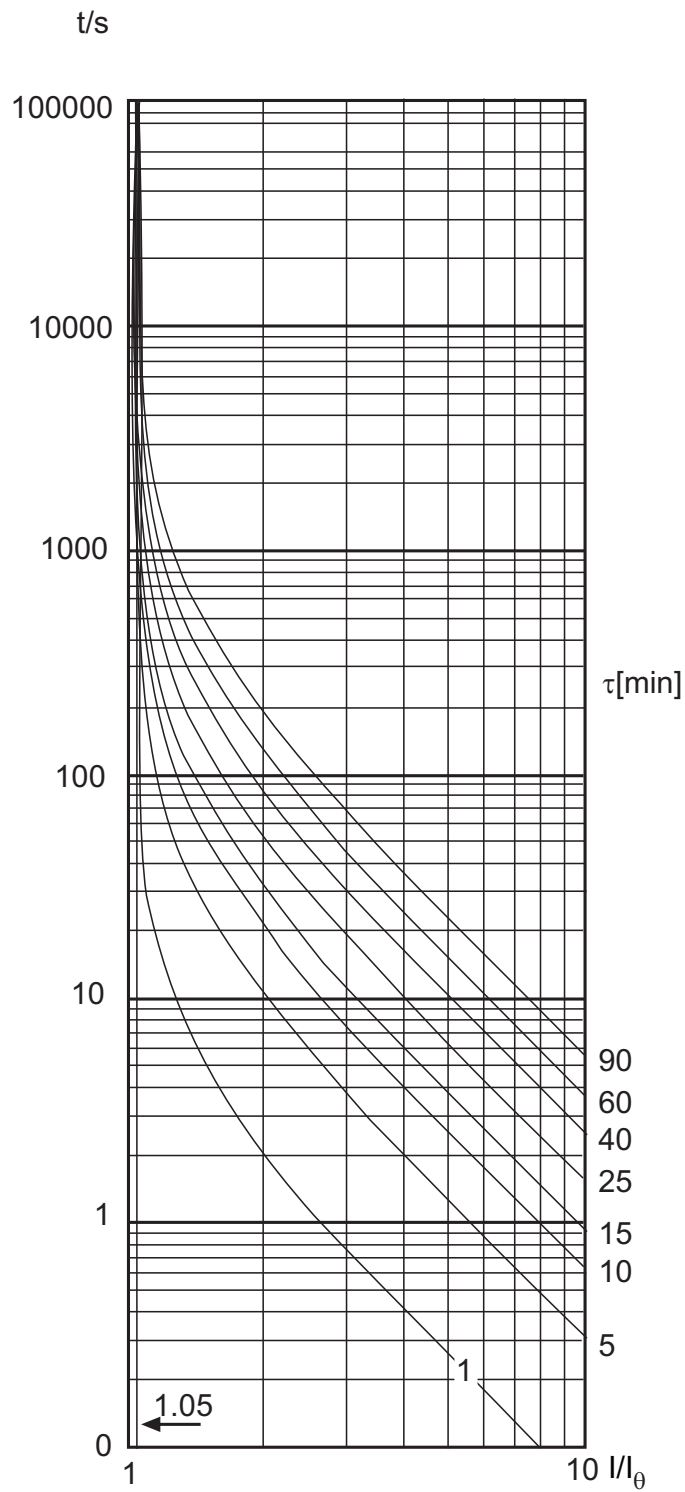


Fig. 5.1.4.4.-3 Trip curves at prior load $I \times I_{\theta}$

A040315

5.1.4.5. Phase discontinuity protection

The phase discontinuity protection detects phase unbalance between phases I_{L1} , I_{L2} and I_{L3} , caused by a broken conductor, for instance. The difference between the minimum and maximum phase currents is calculated as follows:

$$\Delta I = \frac{(I_{\max} - I_{\min})}{I_{\max}} \times 100\% \quad (3)$$

When the current difference exceeds the set start value of the phase discontinuity stage, $\Delta I >$, the stage will generate a start signal after a ~100 ms' start time. When the set operate time at definite-time characteristic elapses, the stage will generate a trip signal. The stage will be reset in 70 ms after the current difference has fallen below the set start value of the stage.

The phase discontinuity protection will be inhibited when all phase currents fall below $0.1 \times I_n$.

It is possible to block the tripping of the phase discontinuity stage by applying a digital input signal to the relay.

Stage $\Delta I >$ can be set out of operation in SGF3. This state will be indicated by dashes on the LCD and by "999" when the set start value is read via serial communication.

5.1.4.6. Circuit-breaker failure protection

The circuit-breaker failure protection (CBFP) detects situations where the trip remains active although the circuit breaker should have operated.

If a trip signal generated via output PO1 is still active and the current has not been cut off on expiration of the CBFP set operate time, the CBFP generates a trip signal via output PO2.

The CBFP is not triggered in case of:

- Thermal alarm
- Thermal trip
- External trip

The CBFP can also be selected to be triggered externally by applying a digital input signal to the relay. In this case, the CBFP generates a trip signal via output PO2 if the current has not been cut off on expiration of the set operate time.

External triggering is inhibited when all phase currents fall below 12 percent of the rated current, I_n .

Internal triggering is selected by activating the CBFP in SGF and external triggering by activating the CBFP in SGB. Both triggering options can be selected at the same time.

Normally, the CBFP controls the upstream circuit breaker. However, it can also be used for tripping via redundant trip circuits of the same circuit breaker.

5.1.4.7. Arc protection

The arc protection detects arc situations in air insulated metal-clad switchgears, caused by human error during maintenance or poor contact in the cable connections, for instance. Local light detection requires the optional arc light detection hardware.

The arc protection can be realized as a stand-alone function in a single REF610 or as a station-wide arc protection including several REF610 protection relays. If realized as a station-wide arc protection, different tripping schemes can be selected for the operation of the circuit breakers of the incoming and outgoing feeders.

Consequently, the REF610 relays in the station can, for instance, be set to trip the circuit breaker of either the incoming or the outgoing feeder depending on the fault location in the switchgear. For maximum safety, the REF610 relays can be set to always trip both the circuit breaker of the incoming feeder and that of the outgoing feeder.

The arc protection consists of:

- Optional arc light detection hardware with automatic backlight compensation for two lens sensors
- A light signal output for routing the locally detected light signal to another relay
- The protection stage ARC with phase- and earth-fault current measurement.

The light from an arc is detected either locally or via a remote light signal. Locally, the light is detected by lens sensors connected to inputs Light sensor 1 and Light sensor 2 on the serial communication module of the relay. The lens sensors can be placed, for instance, in the busbar compartment and the cable compartment of the metal-clad cubicle.

The light detected by the lens sensors is compared to an automatically adjusted reference level. Inputs Light sensor 1 and Light sensor 2 have their own reference levels. When the reference level of either or both inputs is exceeded, an arc has been detected locally. When light has been detected locally or remotely and one or several phase currents exceed the set current limit $\text{ArcI}_>$, or the earth-fault current the set current limit $\text{ArcI}_0>$, the arc protection stage (ARC) will generate a trip signal in less than 15 ms. The stage will be reset in 30 ms after all three phase currents and the earth-fault current have fallen below the set current limits.

The light signal output, $L>$, can be configured to be activated either immediately upon detection of light in all situations, or only when the arc has not been extinguished by the time the trip signal is generated. The selection is made in SGF4. By routing the light signal output to an output contact connected to a digital input of another REF610 relay, a station-wide arc protection is realized.

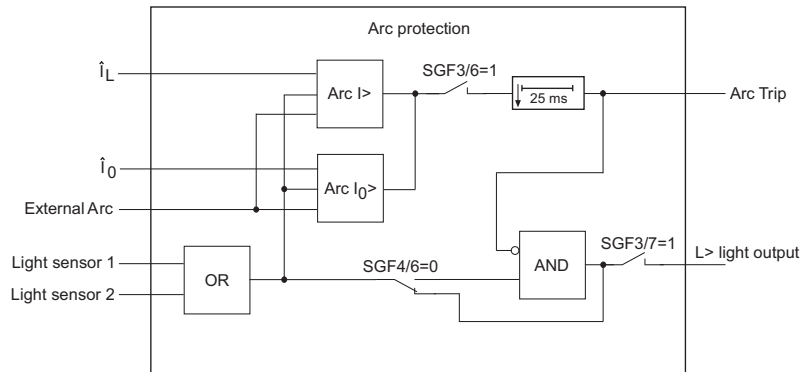
stage ARC and the light signal output can be set out of operation in SGF3.



Inputs not in use should be covered with dust caps.



The warning signal generated in case of continuous light on the light sensor inputs can be routed to SO2 by setting switch SGF1/8 to 1.



A040316_2

Fig. 5.1.4.7.-1 Block diagram of the arc protection

5.1.4.8. Auto-reclose function

The vast majority of MV overhead line faults are transient and automatically cleared by momentarily de-energizing the line. De-energizing of the fault location for a selected time period is implemented through automatic reclosing, during which most faults can be cleared.

At a permanent fault, auto-reclosing is followed by definite tripping. A permanent fault must be located and cleared before the fault location can be re-energized.

The auto-reclose (AR) function of REF610 can be used with any circuit breaker suitable for auto-reclosing. The AR function provides three programmable auto-reclose shots and can thus be set to perform one to three successive auto-reclosures of desired type and duration, one high-speed and one delayed, for instance.

The AR function can be initiated by pickup and trip signals from certain overcurrent and earth-fault protection stages. Consequently, tripping of the arc protection stage, for instance, does not initiate the AR function. Initiation is also possible from an external device via a digital input.

The AR function can be inhibited (AR inhibit) by trip signals from certain protection stages or via a digital input. Inhibition is advantageous with tripping faults as this type of fault cannot be cleared during an auto-reclose sequence. Tripping faults are detected by the CBFP, for instance. Inhibition will also interrupt any ongoing shot.

The initiation of one or several auto-reclose shots can be set to be blocked by trip signals from certain protection stages. Blocking is also possible via a digital input. Blocking can be used to limit the number of shots in an auto-reclose sequence, which may be advantageous with certain types of faults. In case of shot initiation while a blocking is active, the next shot will be initiated.

The AR function monitors the position and status of the circuit breaker. Information on the circuit-breaker position is always required whereas circuit-breaker status is optional. For safety reasons, shot initiation is not possible when the circuit breaker is open. If the circuit breaker is not ready, due to an discharged spring, for instance, reclosing can be inhibited via a digital input (CB Close inhibit). Inhibition of reclosing is checked only when necessary and can therefore not be used to prevent initiation or progression of a shot.

For co-ordination of the other protection devices in the network, such as downstream fuses, the AR function supports optional blocking of selectable overcurrent and earth-fault protection stages (refer to section Blocking of protection stages). By setting a stage with a short operate time to trip and initiate only the first auto-reclose shot, fast tripping and shot initiation will be achieved. After this, the stage will be blocked to allow selective delayed tripping of another stage in accordance with the time-grading plan of the system.

The typical auto-reclose sequence is as follows: the overcurrent or earth-fault protection detects a network fault, trips the circuit breaker and initiates the first auto-reclose shot. At the time of shot initiation, the set dead time for shot 1 will start. When the set dead time elapses, the blocking of selected protection stages will be activated and the AR function will issue a reclosing command (Close CB Command) to the circuit breaker, the duration of which is settable. In addition, the set reclaim time and set cutout time will start when the set dead time elapses. The blocking of protection stages will be reset on expiration of the cutout time. For the cutout time, refer to section Fast tripping and initiation of shot 1 using two protection stages.

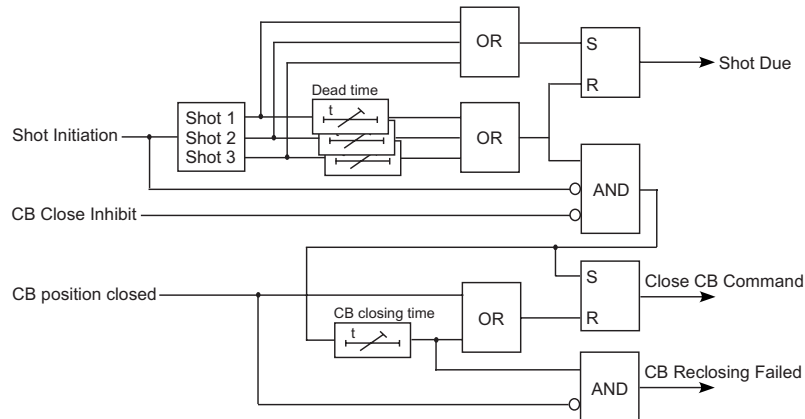
If the network fault is cleared, i.e. the auto-reclosure is successful, the set reclaim time will expire and the AR function will be automatically reset to the quiescent condition.

However, if the network fault is not cleared, i.e. the auto-reclosure is unsuccessful, and the protection trips the circuit breaker before expiration of the set reclaim time, the next shot will be initiated (provided that a further auto-reclosure is allowed). At the time of shot initiation, the set dead time for shot 2 will start. When the set dead time elapses, the blocking of selected protection stages (may differ from shot 1) will be activated and the AR function will issue a reclosing command to the circuit breaker. In addition, the set reclaim time and set cutout time will start when the set dead time elapses. The blocking of protection stages will be reset on expiration of the set cutout time.

If the network fault is cleared, the AR function will be automatically reset after the reclaim time. However, if the fault is not cleared and the protection trips the circuit breaker before expiration of the reclaim time, the next shot will be initiated (provided that a further auto-reclosure is allowed). At the time of shot initiation, the set dead time for shot 3 will start. When the set dead time elapses, the blocking of selected protection stages (the same as for shot 2) will be activated and the AR function will issue a reclosing command to the circuit breaker. In addition, the set reclaim time and set cutout time will start when the set dead time elapses. The blocking of protection stages will be reset on expiration of the set cutout time.

If the network fault has still not been cleared, i.e. all selected auto-reclose shots have been unsuccessful, and the protection trips the circuit breaker before expiration of the set reclaim time, the AR function will generate a definite trip alarm. The circuit breaker will now remain open and the AR function will be locked out.

As default, the AR function is not in use (number of auto-reclose shots = 0). The AR function can be activated either via the HMI or with SPA parameter S25 by setting the number of auto-reclose shots to 1, 2 or 3.



A040317

Fig. 5.1.4.8.-1 Simplified shot logic diagram

Shot initiation

The AR function can be initiated by any of the following signals:

- External AR initiation signal
- Start signal from stages I_> and I_{0>}
- Trip signal from stages I_>, I_{>>}, I_{0>} and I_{0>>}

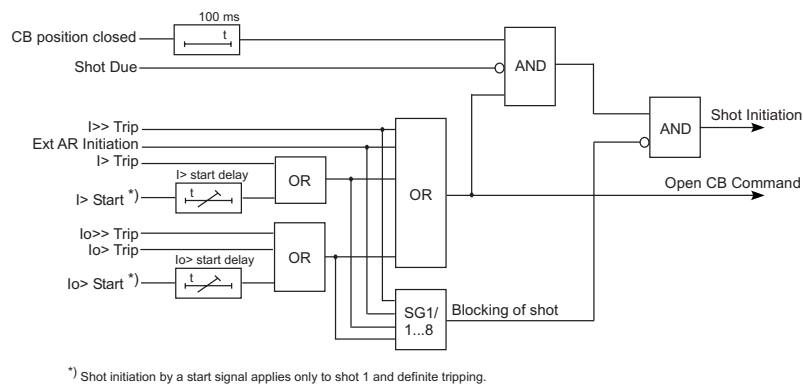
The start signal from stages I_>, and I_{0>} will initiate a shot on expiration of a settable start delay for the respective stage. At the factory default delay of 300 s, the start signal will, in practice, not be used for shot initiation. External AR initiation by the digital input signal is selected in SGB.



Shot initiation by a start signal applies only to shot 1 and definite tripping.



The AR function will issue an opening command to the circuit breaker at shot initiation by a start or a trip signal.



A040318

Fig. 5.1.4.8.-2 Simplified shot initiation logic diagram

Blocking of shot initiation

The initiation of one or several auto-reclose shots can be set to be blocked by any of the following signals:

- External AR initiation signal
- Trip signal from overcurrent stages I> and I>>
- Trip signal from earth-fault stages I₀> and I₀>>

The selection is made in SG1 (see Table 5.1.4.10.-10).

Blocking of shot initiation can also be used to skip the entire shot sequence (by blocking the initiation of all three shots), and go directly to definite tripping. Further, it can be used, for instance, to allow shot initiation by the trip signal from stage I>, but to go directly to definite tripping in case of shot initiation by the trip signal from stage I>>.



Activation of any above-mentioned signal will always cause the AR function to issue an opening command to the circuit breaker. If the signal used for blocking is not simultaneously used for initiation of the next shot, the AR function will generate a definite trip alarm and be locked out.



Shot initiation is blocked only for as long as the blocking signal is active.



In case of shot initiation while a blocking is active, the next shot (if such has been selected and not blocked) will be initiated. This can be used to skip Shot 1, for instance.

Inhibition of the auto-reclose function

The AR function can be inhibited (AR inhibit) by any of the following signals:

- external AR inhibit signal
- trip signal from the arc protection stage, ARC
- trip signal from the thermal protection stage, $\theta>$
- trip signal from the CBFP
- alarm signal from the thermal protection stage, $\theta>$
- trip signal from overcurrent stage $I>>>$
- trip signal from earth-fault stage $I_0>>$
- trip signal from the phase discontinuity stage, $\Delta I>$

The trip signals from stages ARC and $\theta>$ and from the CBFP are fixed and will thus always inhibit the AR function. External CBFP inhibition by the digital input signal is selected in SGB, and the alarm signal from stage $\theta>$ and the trip signals from stages $I>>>$, $I_0>>$ and $\Delta I>$ in SG3 (see Table 5.1.4.10.-12).



The AR function will remain inhibited after all inhibition signals have been reset for a time equal in length to the set reclaim time.



Inhibition will always also interrupt any ongoing shot.

Information on the circuit-breaker position

The AR function requires information on the circuit-breaker position. Any digital input can be selected for the information on the circuit breaker being open (CB Position Open) and closed (CB Position Closed) in SGB. Normally, two digital inputs is recommended although either one is enough for the AR function.

Information on the circuit-breaker position is used in the following situations:

- At manual circuit-breaker closing, the AR function will be inhibited for the reclaim time.
- At manual circuit-breaker closing during an ongoing shot, the shot will be interrupted and the AR function inhibited during the reclaim time.
- Shot initiation is allowed only when the circuit breaker is closed.
- Reclosing of the circuit breaker is ended immediately after the AR function has received information that the circuit breaker has been closed.

Circuit-breaker closing

When the set dead time elapses, the AR function will issue a reclosing command to the circuit breaker (Close CB Command). Reclosing can be inhibited via a digital input (CB Close inhibit). External inhibition of reclosing by the digital input signal is selected in SGB.

When reclosing is inhibited, or the circuit breaker does not close before expiration of the set CB closing time, the circuit breaker will remain open and the AR function will generate a CB Reclosing Failed signal.

Reclosing is inhibited and the CB Reclosing Failed signal generated also if an AR initiation signal is active, i.e. the fault has not been cleared, when reclosing begins.

The duration of the reclosing command is settable (CB closing time). However, reclosing of the circuit breaker will end immediately after the AR function has received information that the circuit breaker has been closed, or if a protection trips the circuit breaker again.

Blocking of protection elements

In several applications, such as fuse-saving (refer to 6.1.1. Fast tripping and initiation of shot 1 using two protection stages), the aim is at fast tripping and initiation of shot 1 and delayed tripping and initiation of shot 2 and 3. Consequently, if two protection s are used, one fast and the other one delayed, the fast stage should be set to be blocked by the AR function during shot 2 and 3.

The protection stages can be set to be blocked at shot 1 and/or shot 2 and 3. The selection is made in SG2 (see Table 5.1.4.10.-11).

Definite trip alarm

The AR function generates a definite trip alarm signal after an unsuccessful auto-reclose sequence, i.e. when no more auto-reclose shots are allowed but the network fault has not be cleared, the circuit breaker is open and there is no ongoing shot. The definite trip alarm signal is also be generated in case a protection trips the circuit breaker while the AR function is inhibited.



The definite trip alarm signal is active for 1 second.



The definite trip alarm signal will not be generated if the AR function has been set out of operation.

Lockout of the auto-reclose function

The lockout signal indicates whether the AR function is ready for shot initiation. The AR function will be locked out in any of the following situations:

- The AR function generates a definite trip alarm
- The AR function is inhibited
- Circuit-breaker closing fails
- Manual circuit-breaker closing is detected

The lockout signal is reset and the AR function ready for shot initiation on expiration of the set reclaim time. The set reclaim time starts when the definite trip alarm signal, the AR inhibition signal or the CB reclosing failed signal has been reset or the circuit breaker closed, depending on the reason for the AR function being locked.

5.1.4.9.

Inverse definite minimum time characteristics

The low-set overcurrent and earth-fault stages can be given an inverse definite minimum time (IDMT) characteristic. At IDMT characteristic, the operate time of the stage is dependent on the current value: the higher the current value, the shorter the operate time.

The relay provides nine IDMT characteristics, of which four comply with the IEC 60255-3 and three with the IEEE C37.112 standard. Two are special characteristics according to ABB praxis and are referred to as RI and RD.

The time/current characteristics can be selected either via the HMI or the SPA bus as follows:

Table 5.1.4.9.-1 *Time/current characteristic settings*

Value	Time/current characteristic
0	Definite time
1	IEC Extremely inverse
2	IEC Very inverse
3	IEC Normal inverse
4	IEC Long-time inverse
5	RI-type
6	IEEE Extremely inverse
7	IEEE Very inverse
8	IEEE inverse
9	RD-type (RXIDG)

IDMT characteristics according to IEC 60255-3

The relay provides four time/current curve groups which comply with the IEC 60255-3 standard: normal inverse, very inverse, extremely inverse and long-time inverse. The relationship between time and current is expressed as follows:

$$t[s] = \left(\frac{\beta}{\frac{I}{I_0}^\alpha - 1} \right) \times k \tag{4}$$

- t = operate time
- I = phase (or earth-fault) current value
- k (or k₀) = time multiplier
- I₀ (or I₀>) = set start value



The actual operate time of the relay (see Fig. 5.1.4.9.-1...Fig. 5.1.4.9.-4) includes an additional filter and detection time and the operate time of the trip output contact. When the operate time of the relay is calculated as above, approximately 30 ms should be added to the result t.

Table 5.1.4.9.-2 Values of constants α and β

Time/current curve group	α	β
Normal inverse	0.02	0.14
Very inverse	1.0	13.5
Extremely inverse	2.0	80.0
Long-time inverse	1.0	120

According to the standard, the normal current range is 2...20 times the set start value at normal inverse, very inverse or extremely inverse characteristic. The relay is to start before the current exceeds the set start value by 1.3 times. At long-time inverse characteristic, the normal current range is specified to be 2...7 times the set start value, and the relay is to start before the current exceeds the set start value by 1.1 times

Table 5.1.4.9.-3 Operate time tolerances specified by the standard

I/I ₀ ^{a)}	Normal ^{b)}	Very ^{b)}	Extremely ^{b)}	Long time ^{b)}
2	2.22E	2.34E	2.44E	2.34E
5	1.13E	1.26E	1.48E	1.26E
7	-	-	-	1.00E
10	1.01E	1.01E	1.02E	-
20	1.00E	1.00E	1.00E	-

^{a)} or I₀/I₀>
^{b)} E = accuracy in percent; - = not specified

Within the normal current range the inverse-time stage fulfills the tolerance requirements of class 5 or ±25 ms at all degrees of inversivity.

The time/current curve groups based on the IEC standard are illustrated in Fig. 5.1.4.9.-1...Fig. 5.1.4.9.-4.



If the ratio between the current and the set start value is higher than 20, the operate time is the same as when the ratio is 20.

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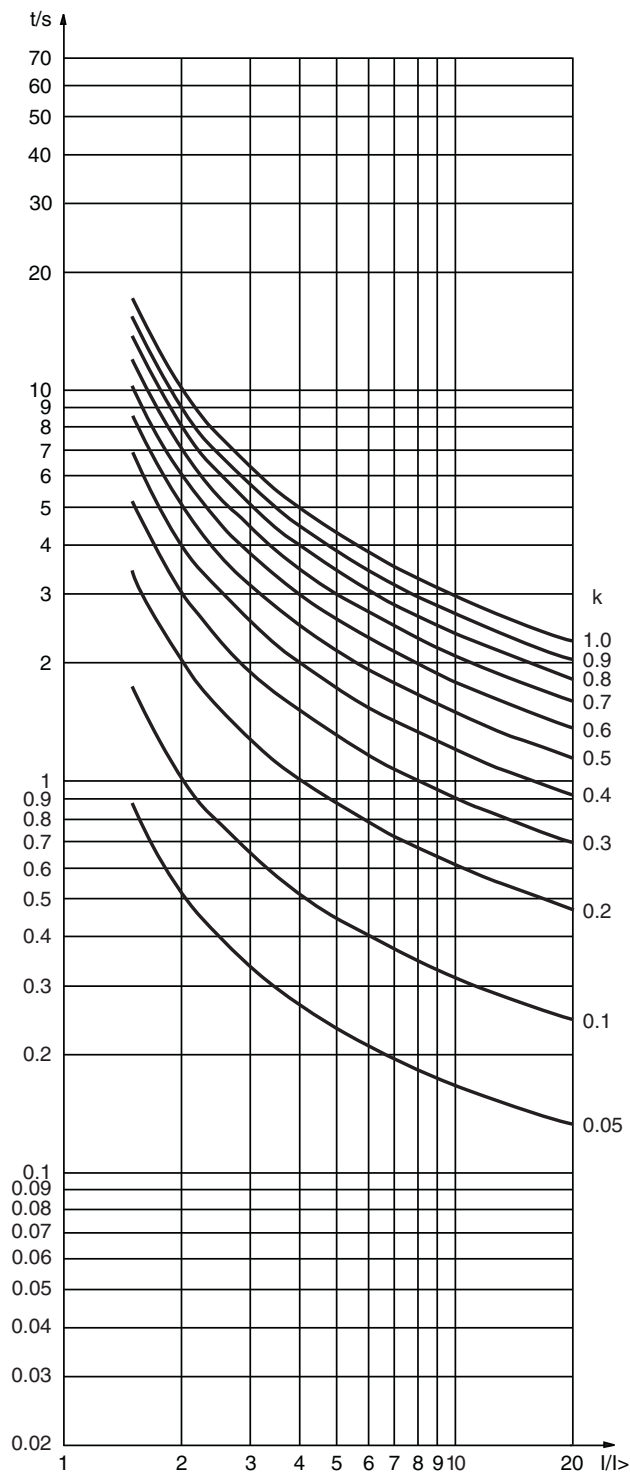


Fig. 5.1.4.9.-1 Normal inverse-time characteristic

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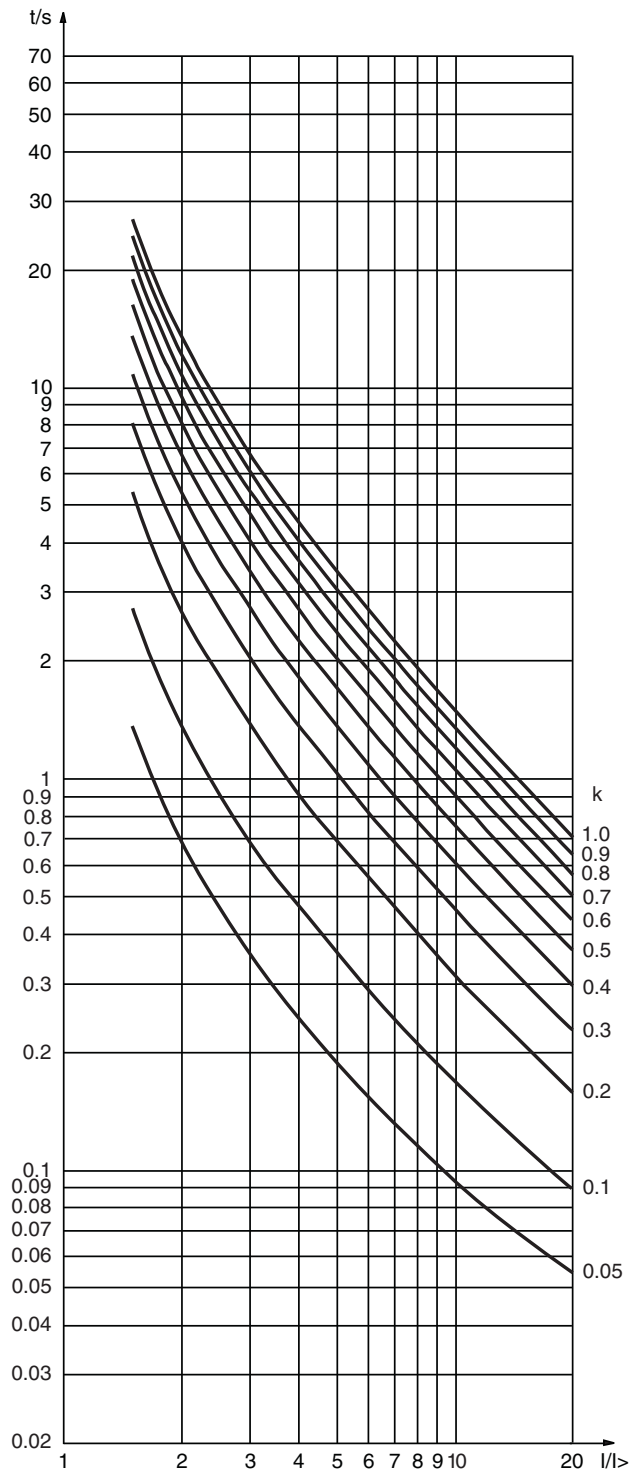


Fig. 5.1.4.9.-2 Very inverse-time characteristic

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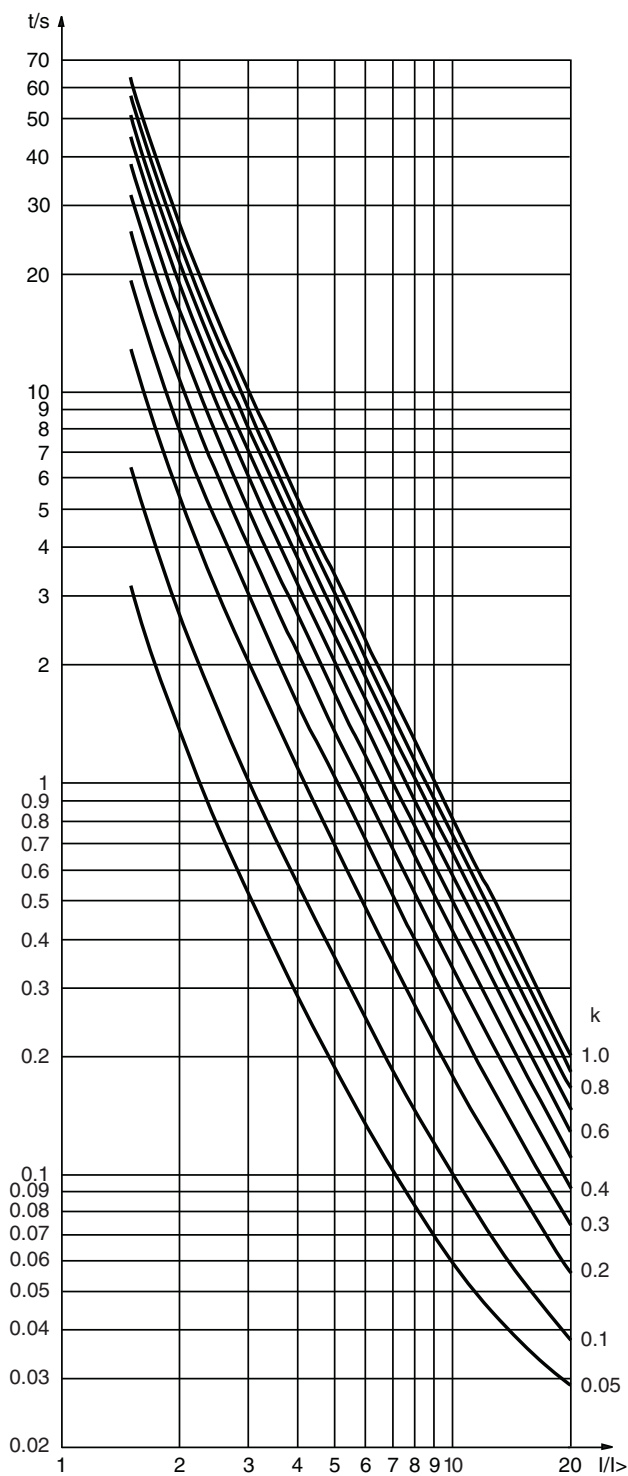


Fig. 5.1.4.9.-3 Extremely inverse-time characteristic

A040321

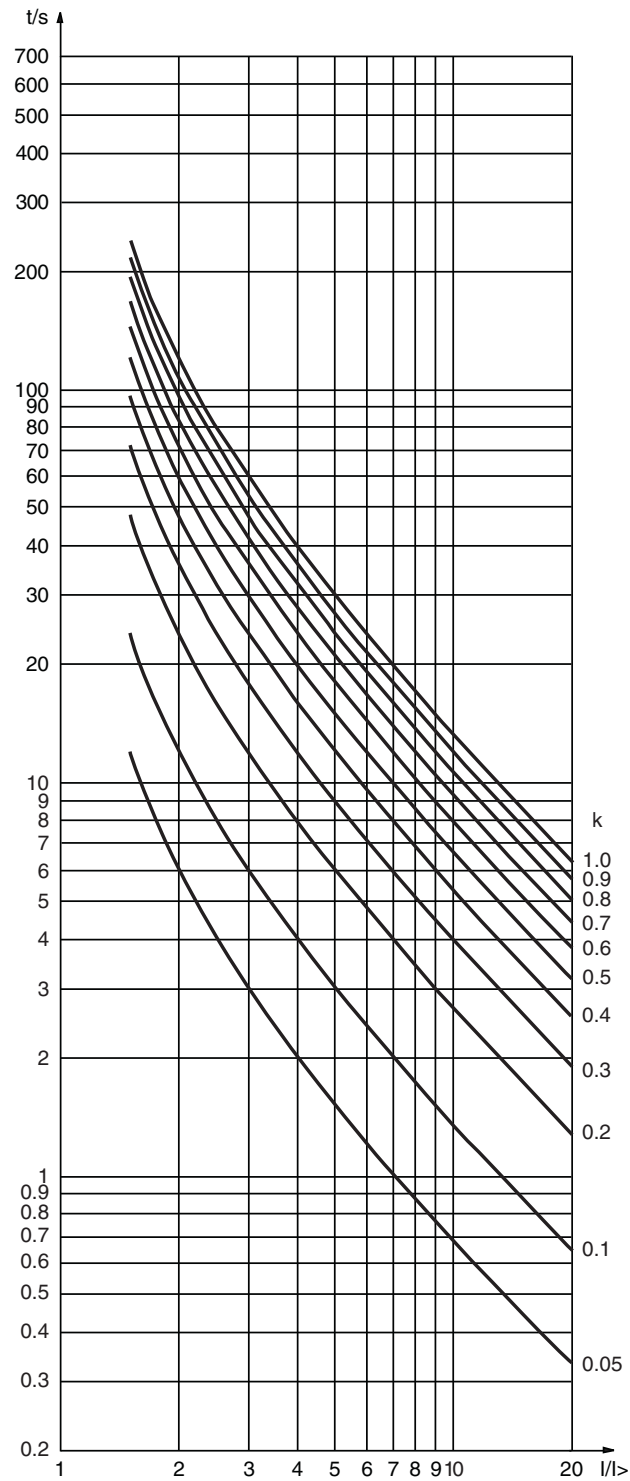


Fig. 5.1.4.9.-4 Long-time inverse-time characteristic

A040322

IDMT characteristics according to the IEEE C37.112

REF610 provides three time/current curve groups which comply with the IEEE C37.112 standard: extremely inverse, very inverse and inverse. The relationship between time and current is expressed as follows:

$$t[s] = \left(\frac{A}{\left(\frac{I}{I_{>}} \right)^P - 1} + B \right) \times n \tag{5}$$

- t = operate time
- I = phase (or earth-fault) current value
- n (or n₀) = time multiplier
- I> (or I₀>) = set start value



The actual operate time of the relay (see Fig. 5.1.4.9.-5...Fig. 5.1.4.9.-7) includes an additional filter and detection time and the operate time of the trip output contact. When the operate time of the relay is calculated as above, approximately 30 ms should be added to the result t.

Table 5.1.4.9.-4 Values of constants A, B and P

Time/current curve group	A	B	P
Extremely inverse	6.407	0.025	2.0
Very inverse	2.855	0.0712	2.0
Inverse	0.0086	0.0185	0.02

The time/current curve groups based on the IEEE standard are illustrated in Fig. 5.1.4.9.-5...Fig. 5.1.4.9.-7.

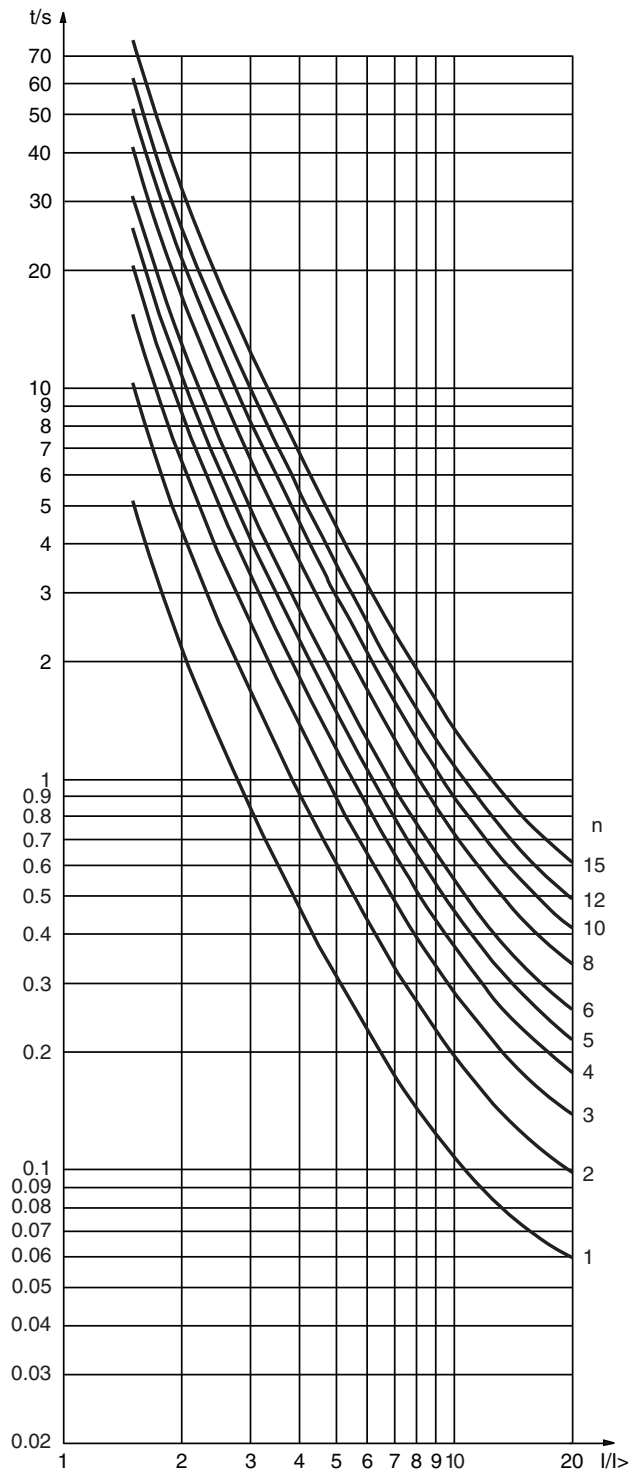


Fig. 5.1.4.9.-5 Extremely inverse-time characteristic

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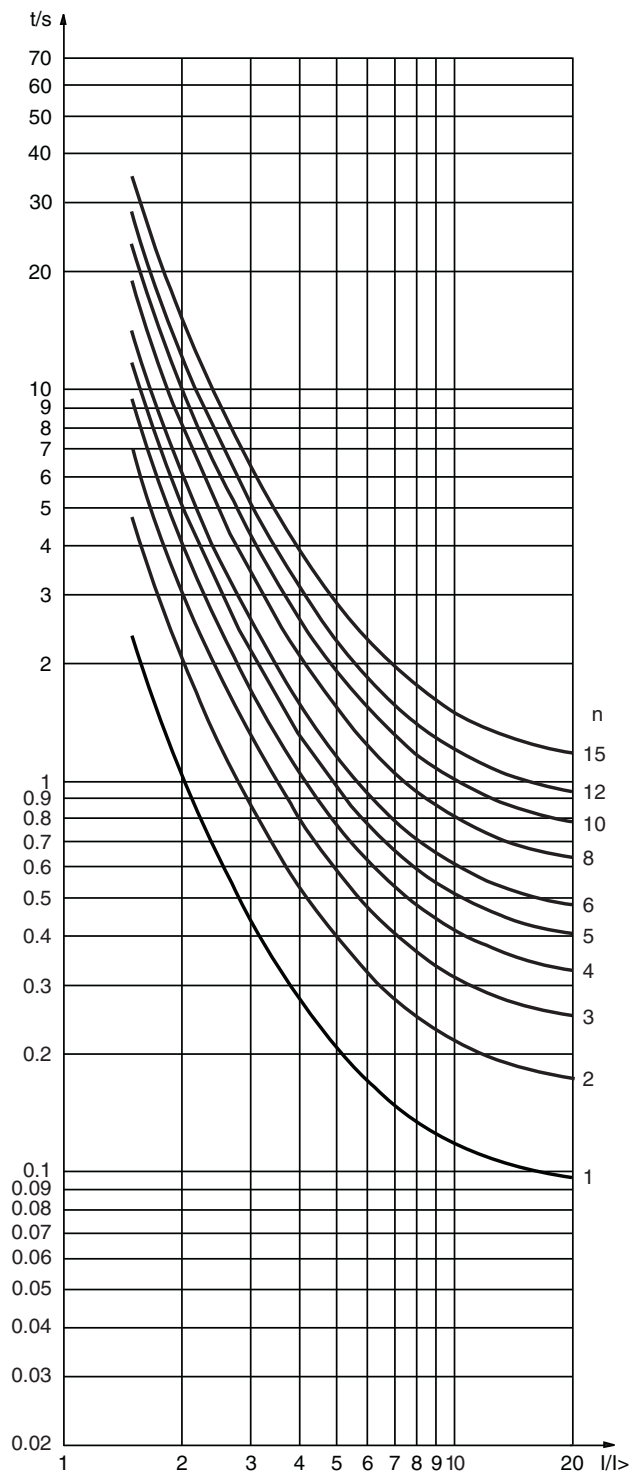


Fig. 5.1.4.9.-6 Very inverse-time characteristic

A040324

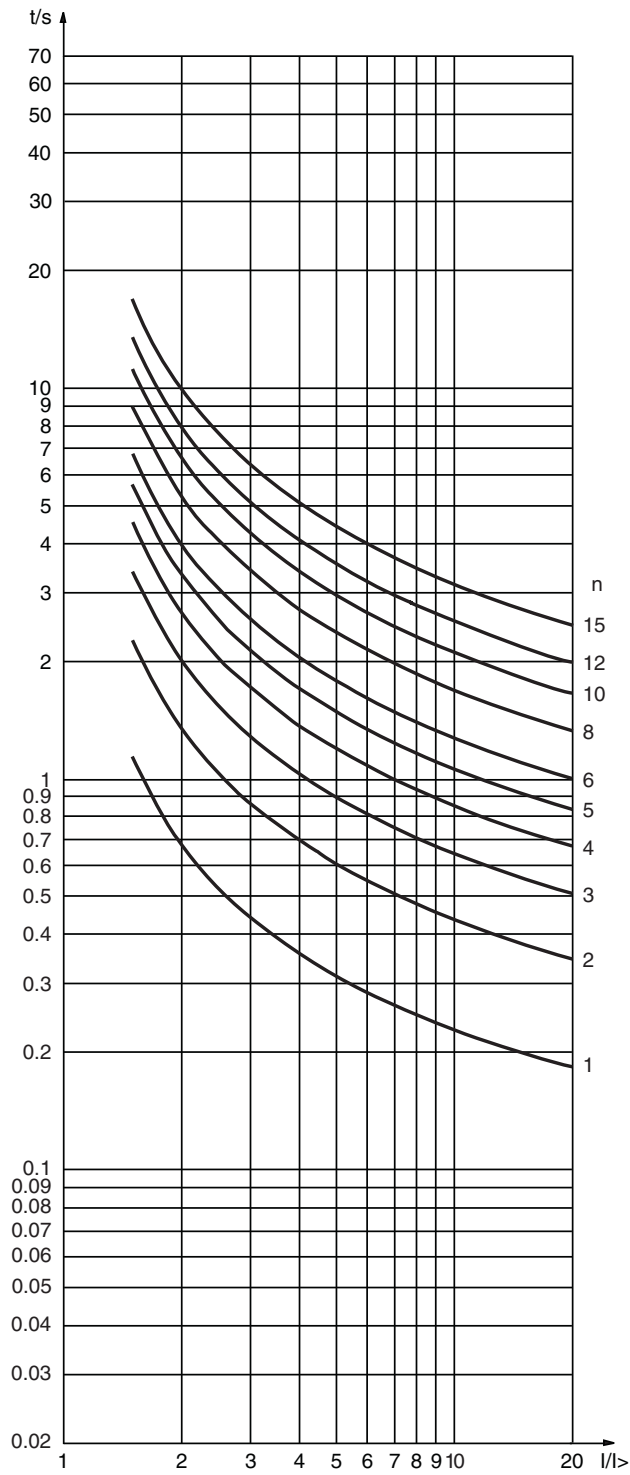


Fig. 5.1.4.9.-7 Inverse-time characteristic

A040325

RI-type characteristic

The RI-type characteristic is a special characteristic which is principally used for obtaining time grading with mechanical relays. The relationship between time and current is expressed as follows:

$$t[s] = \frac{k}{0.339 - 0.236 \times \frac{I_{>}}{I}} \quad (6)$$

t	= operate time
I	= phase (or earth-fault) current value
k (or k ₀)	= time multiplier
I> (or I ₀ >)	= set start value



The actual operate time of the relay (see Fig. 5.1.4.9.-8) includes an additional filter and detection time and the operate time of the trip output contact. When the operate time of the relay is calculated as above, approximately 30 ms should be added to the result t.

The RI-type characteristic is illustrated in Fig. 5.1.4.9.-8.

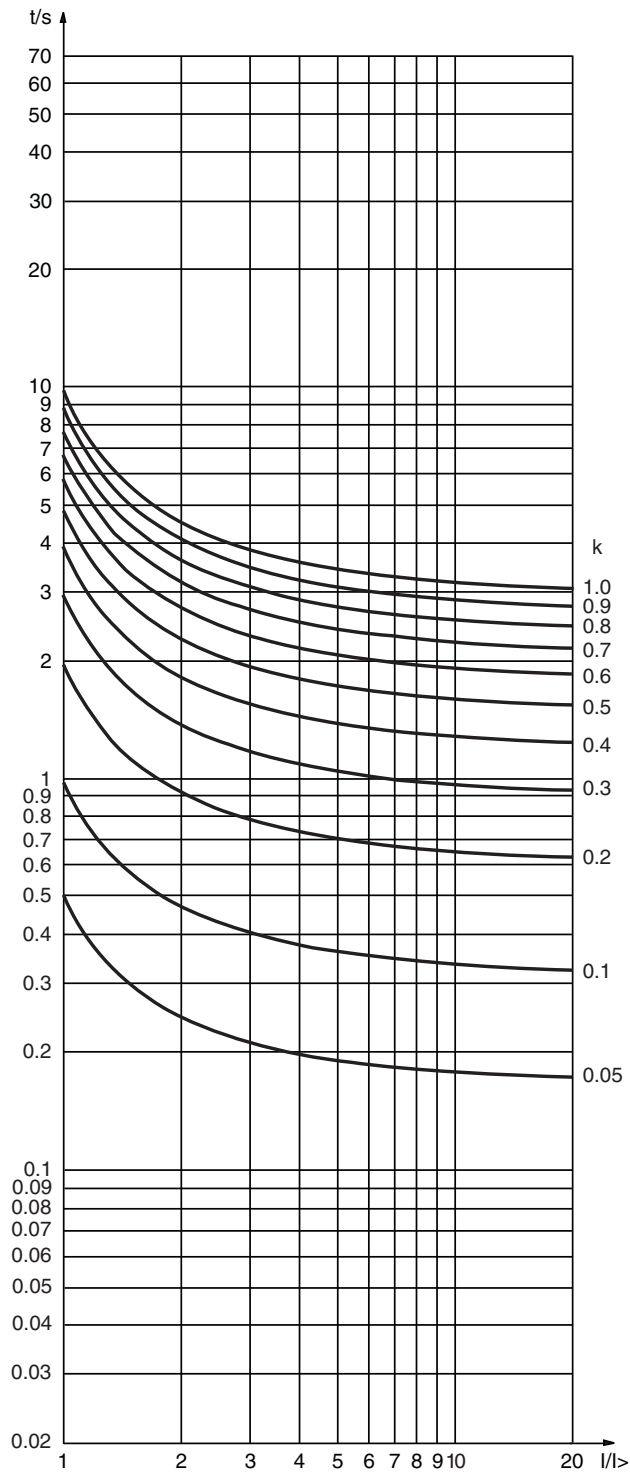


Fig. 5.1.4.9.-8 RI-type characteristic

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RD-type characteristic (RXIDG)

The RD-type characteristic is a special characteristic, which is principally used in earth-fault protection and which requires a high degree of selectivity even at high resistance faults. The protection can operate in a selective way even if it is not directional. Mathematically, the time/current characteristic can be expressed as follows:

$$t[s] = 5.8 - 1.35 \times \log_e \left(\frac{I}{k \times I_0} \right) \quad (7)$$

t	= operate time
I	= phase (or earth-fault) current value
k (or k ₀)	= time multiplier
I ₀ (or I _{0>})	= set start value

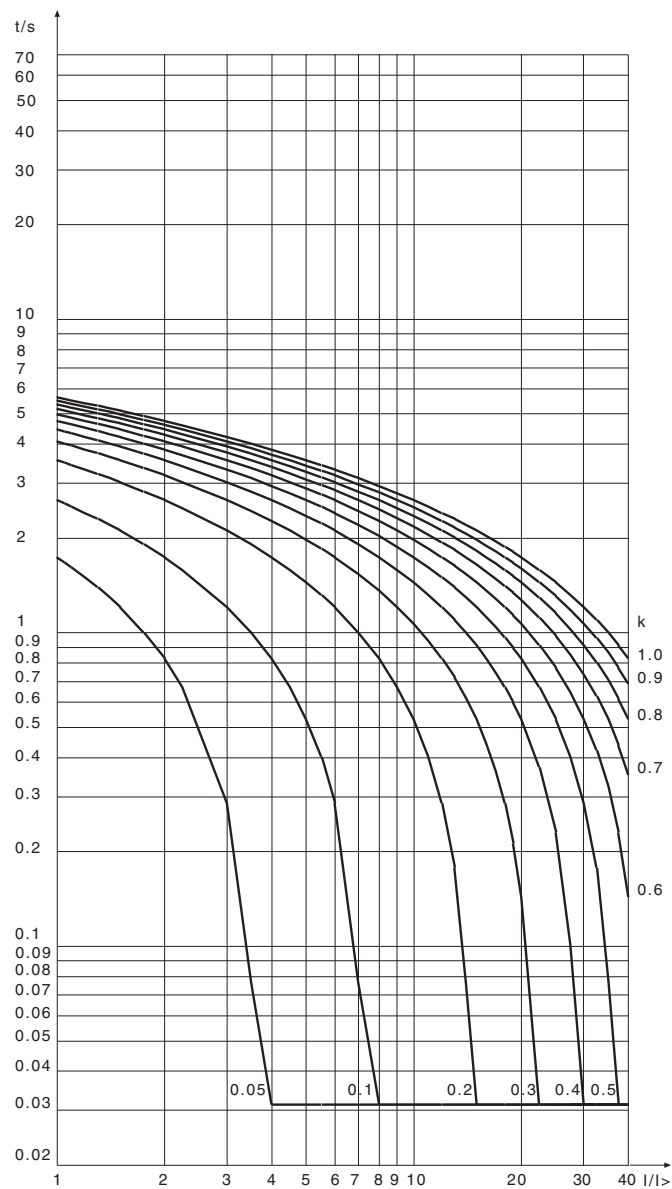


The actual operate time of the relay includes an additional filter and detection time and the operate time of the trip output contact. When the operate time of the relay is calculated as above, approximately 30 ms should be added to the result t.



If the ratio between the current and the set start value is higher than 40, the operate time will be the same as when the ratio is 40.

The RD-type characteristic is illustrated in Fig. 5.1.4.9.-9.



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Fig. 5.1.4.9.-9 RD-type inverse-time characteristic

5.1.4.10.

Settings

There are two alternative setting groups available, setting groups 1 and 2. Either of these setting groups can be used as the actual settings, one at a time. Both groups have their related registers. By switching between the setting groups, a whole group of settings can be changed at the same time. This can be done in any of the following ways:

- Via the HMI
- Entering SPA parameter V150 via serial communication
- Via a digital input



Switching between setting groups via a digital input has a higher priority than via the HMI or with the parameter V150.

The setting values can be altered via the HMI or with a PC provided with Relay Setting Tool.

Before the relay is connected to a system it must be assured that the relay has been given the correct settings. If there is any doubt, the setting values should be read with the relay trip circuits disconnected or tested with current injection; refer to Section 8. Check lists for additional information.

Table 5.1.4.10.-1 Setting values

Setting	Description	Setting range	Default setting
$I>/I_n$	Start value of stage I>	$0.30...5.00 \times I_n$	$0.30 \times I_n$
$t>$	Operate time of stage I>	0.05...300 s	0.05 s
IDMT I>	Time/current characteristic for stage I>	0...9	0
k	Time multiplier k	0.05...1.00	0.05
n	Time multiplier n	1.0...15.0	1.0
$t_r>$	Resetting time of stage I>	0.05...2.50 s	0.05 s
$I>>/I_n$	Start value of stage I>>	$0.50...35.0 \times I_n$	$0.50 \times I_n$
$t>>$	Operate time of stage I>>	0.04...300 s	0.04 s
$I>>>/I_n$	Start value of stage I>>>	$0.50...35.0 \times I_n$	$0.50 \times I_n$
$t>>>$	Operate time of stage I>>>	0.04...30.0 s	0.04 s
$I_0>/I_n$	Start value of stage I ₀ >	$1.0...100\% I_n$	$1.0\% I_n$
$t_0>$	Operate time of stage I ₀ >	0.05...300 s	0.05 s
IDMT I ₀ >	Time/current characteristic for stage I ₀ >	0...9	0
k_0	Time multiplier k_0	0.05...1.00	0.05
n_0	Time multiplier n_0	1.0...15.0	1.0
$t_{0r}>$	Resetting time of stage I ₀ >	0.05...2.50 s	0.05 s
$I_0>>/I_n$	Start value of stage I ₀ >>	$5.0...800\% I_n$	$5.0\% I_n$
$t_0>>$	Operate time of stage I ₀ >>	0.05...300 s	0.05 s
$\Delta I>$	Start value of stage $\Delta I>$	10...100%	100 %
$t_{\Delta}>$	Operate time of stage $\Delta I>$	1...300 s	60 s
I_{θ}	Full load current	$0.30...1.50 \times I_n$	$0.30 \times I_n$
T	Time constant of stage $\theta>$	1...200 min	1 min
$\theta_a>$	Alarm level of stage $\theta>$	$50...100\% \theta_t>$	$95\% \theta_t>$
CBFP	Operate time of CBFP	0.10...60.0 s	0.10 s
0→1	Number of AR shots	0 = AR is not in use 1 = shot 1 2 = shot 1 and 2 3 = shot 1, 2 and 3	0
Arcl>	Current limit Arcl> of stage ARC	$0.50...35.0 \times I_n$	$2.50 \times I_n$
Arcl ₀ >	Current limit Arcl ₀ > of stage ARC	$5.0...800\% I_n$	$20.0\% I_n$

Switchgroups and parameter masks

The settings can be altered and the functions of the relay selected in the SG_ selector switchgroups. The switchgroups are software based and thus not physical switches to be found in the hardware of the relay.

A checksum is used for verifying that the switches have been properly set. The Fig. 5.1.4.10.-1 shows an example of manual checksum calculation.

Switch number	Position		Weighting factor		Value
1	1	x	1	=	1
2	0	x	2	=	0
3	1	x	4	=	4
4	0	x	8	=	0
5	1	x	16	=	16
6	0	x	32	=	0
7	1	x	64	=	64
8	0	x	128	=	0
9	1	x	256	=	256
10	0	x	512	=	0
11	1	x	1024	=	1024
12	0	x	2048	=	0
13	1	x	4096	=	4096
14	0	x	8192	=	0
15	1	x	16384	=	16384
16	0	x	32768	=	0
17	1	x	65536	=	65536
18	0	x	131072	=	0
19	1	x	262144	=	262144
20	0	x	524288	=	0
21	1	x	1048576	=	1048576
22	0	x	2097152	=	0
23	1	x	4194304	=	4194304
checksum			SG_ Σ	=	5505024

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Fig. 5.1.4.10.-1 Example of calculating the checksum of a SG_ selector switchgroup

When the checksum, calculated according to the example above, equals the checksum of the switchgroup, the switches in the switchgroup are properly set.

The factory default settings of the switches and the corresponding checksums are presented in the following tables.

SGF1...SGF5

Switchgroups SGF1...SGF5 are used for configuring the wanted function as follows:

Table 5.1.4.10.-2 SGF1


Switch	Function	Default setting
SGF1/1	Selection of the latching feature for PO1	0
SGF1/2	Selection of the latching feature for PO2	0
SGF1/3	Selection of the latching feature for PO3 <ul style="list-style-type: none"> When the switch is in position 0 and the measuring signal which caused the trip falls below the set start value, the output contact returns to its initial state. When the switch is in position 1, the output contact remains active although the measuring signal which caused the trip falls below the set start value. <p>A latched output contact can be unlatched either via the HMI, a digital input or the serial bus.</p>	0
SGF1/4	Minimum pulse length for SO1 and SO2 and optional SO3, SO4 and SO5 <ul style="list-style-type: none"> 0 = 80 ms 1 = 40 ms 	0
SGF1/5	Minimum pulse length for PO1, PO2 and PO3 <ul style="list-style-type: none"> 0 = 80 ms 1 = 40 ms <div style="display: flex; align-items: center;">  <p>The latching feature being selected for PO1, PO2 and PO3 overrides this function.</p> </div>	0
SGF1/6	CBFP <ul style="list-style-type: none"> 0 = CBFP is not in use 1 = the signal to PO1 starts a timer which generates a delayed signal to PO2, provided that the fault is not cleared before the CBFP operate time has elapsed 	0
SGF1/7	Trip lockout function <ul style="list-style-type: none"> 0 = the trip lockout function is not in use. PO3 works as a normal power output relay. 1 = the trip lockout function is in use. PO3 is dedicated to this function. 	0
SGF1/8	External fault warning <ul style="list-style-type: none"> When the switch is in position 1, the warning signal from the trip-circuit supervision or generated in case of continuous light on light sensor inputs is routed to SO2. 	0
ΣSGF1		0

Table 5.1.4.10.-3 SGF2

Switch	Function	Default setting
SGF2/1	Operation mode of the start indication of stage I> ^{a)}	0
SGF2/2	Operation mode of the start indication of stage I>>	0
SGF2/3	Operation mode of the start indication of stage I>>> ^{a)}	0
SGF2/4	Operation mode of the start indication of stage I ₀ >	0
SGF2/5	Operation mode of the start indication of stage I ₀ >> ^{a)}	0
SGF2/6	Operation mode of the start indication of stage ΔI>	0
SGF2/7	Operation mode of the alarm indication of stage θ> ^{a)} <ul style="list-style-type: none"> 0 = the start indication is automatically cleared after the fault has disappeared 1 = latching. The start indication remains active although the fault has disappeared. 	0
ΣSGF2		0

^{a)} When the switch is on, the phase(s) that caused the start are shown on LCD.

Table 5.1.4.10.-4 SGF3

Switch	Function	Default setting
SGF3/1	Inhibition of stage I>>	0
SGF3/2	Inhibition of stage I>>>	0
SGF3/3	Inhibition of stage I ₀ >>	0
SGF3/4	Inhibition of stage ΔI>	1
SGF3/5	Inhibition of stage θ>	1
SGF3/6	Inhibition of stage ARC <ul style="list-style-type: none"> When the switch is in position 1, the stage is inhibited. 	1
SGF3/7	Inhibition of light signal output <ul style="list-style-type: none"> When the switch is in position 1, the output is inhibited. 	1
ΣSGF3		120

Table 5.1.4.10.-5 SGF4


Switch	Function	Default setting
SGF4/1	Automatic doubling of the start value of stage I>> <ul style="list-style-type: none"> When the switch is in position 1, the set start value of the stage is automatically doubled at high inrush situations. 	0
SGF4/2	Inverse-time operation of stage I> inhibited by the start of stage I>>	0
SGF4/3	Inverse-time operation of stage I> inhibited by the start of stage I>>> <ul style="list-style-type: none"> When the switch is in position 1, inverse-time operation is inhibited. 	0
SGF4/4	Automatic doubling of the start value of stage I ₀ >> <ul style="list-style-type: none"> When the switch is in position 1, the set start value of the stage is automatically doubled at high inrush situations. <div style="display: flex; align-items: center; margin-top: 10px;">  <p>Consider carefully when using this function!</p> </div>	0
SGF4/5	Inverse-time operation of stage I ₀ > inhibited by the start of stage I ₀ >> <ul style="list-style-type: none"> When the switch is in position 1, inverse-time operation is inhibited. 	0
SGF4/6	Operation mode of light signal output <ul style="list-style-type: none"> When the switch is in position 1, the light signal output is blocked by the trip signal from stage ARC. 	0
ΣSGF4		0

Table 5.1.4.10.-6 SGF5

Switch	Function	Default setting
SGF5/1	Selection of the latching feature for programmable LED1	0
SGF5/2	Selection of the latching feature for programmable LED2	0
SGF5/3	Selection of the latching feature for programmable LED3	0
SGF5/4	Selection of the latching feature for programmable LED4	0
SGF5/5	Selection of the latching feature for programmable LED5	0
SGF5/6	Selection of the latching feature for programmable LED6	0


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Switch	Function	Default setting
SGF5/7	Selection of the latching feature for programmable LED7	0
SGF5/8	Selection of the latching feature for programmable LED8 <ul style="list-style-type: none"> When the switch is in position 0 and the signal routed to the LED is reset, the programmable LED is cleared. When the switch is in position 1, the programmable LED remains lit although the signal routed to the LED is reset. A latched programmable LED can be cleared either via the HMI, a digital input or the serial bus.	0
ΣSGF5		0

SGB1...SGB5

The DI1 signal is routed to the functions below with the switches of switchgroup SGB1, the DI2 signal with those of SGB2, and so forth.

Table 5.1.4.10-7 SGB1...SGB5

Switch	Function	Default setting
SGB1...5/1	<ul style="list-style-type: none"> 0 = indications are not cleared by the digital input signal 1 = indications are cleared by the digital input signal 	0
SGB1...5/2	<ul style="list-style-type: none"> 0 = indications are not cleared and latched output contacts are not unlatched by the digital input signal 1 = indications are cleared and latched output contacts are unlatched by the digital input signal 	0
SGB1...5/3	<ul style="list-style-type: none"> 0 = indications and memorized values are not cleared and latched output contacts are not unlatched by the digital input signal 1 = indications and memorized values are cleared and latched output contacts are unlatched by the digital input signal 	0
SGB1...5/4	Switching between setting groups 1 and 2 by using the digital input <ul style="list-style-type: none"> 0 = the setting group cannot be changed using the digital input 1 = the setting group is changed by using the digital input. When the digital input is energized, setting group 2 is activated, if not, setting group 1 is activated.  When SGB1...5/4 is set to 1, it is important that the switch has the same setting in both setting groups.	0
SGB1...5/5	Time synchronization by the digital input signal	0
SGB1...5/6	External tripping by the digital input signal	0
SGB1...5/7	External triggering of the CBFP by the digital input signal	0
SGB1...5/8	External triggering of the trip lockout by the digital input signal	0
SGB1...5/9	External arc signalling by the digital input signal	0
SGB1...5/10	Resetting of the trip lockout by the digital input signal	0
SGB1...5/11	Blocking of tripping of stage I> by the digital input signal	0
SGB1...5/12	Blocking of tripping of stage I>> by the digital input signal	0
SGB1...5/13	Blocking of tripping of stage I ₀ > by the digital input signal	0
SGB1...5/14	Blocking of tripping of stage I ₀ >> by the digital input signal	0
SGB1...5/15	Blocking of tripping of stage ΔI> by the digital input signal	0
SGB1...5/16	External AR inhibition by the digital input signal	0
SGB1...5/17	External inhibition of CB reclosing by the digital input signal	0

Switch	Function	Default setting
SGB1...5/18	CB position open	0
SGB1...5/19	CB position closed	0
SGB1...5/20	External AR initiation by the digital input signal	0
Σ SGB1...5		0

SGR1...SGR8

The start, trip and alarm signals from the protection stages, the signals from the auto-reclose function, and the external trip signal are routed to the output contacts with the switches of switchgroups SGR1...SGR8.

The signals are routed to PO1...PO3 with the switches of switchgroup SGR1...SGR3 and to SO1...SO5 with those of SGR4...SGR8.

The matrix below can be of help when making the wanted selections. The start, trip and alarm signals from the protection stages and the external trip signal are combined with the output contacts by encircling the wanted intersection point. Each intersection point is marked with a switch number, and the corresponding weighting factor of the switch is shown to the right in the matrix. The switchgroup checksum is obtained by vertically adding the weighting factors of all the selected switches of the switchgroup.



The trip lockout signal is always routed to PO3.



The trip signal from CBFP is always routed to PO2.



The external fault warning is always routed to SO2.

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	PO1	PO2	PO3	SO1	SO2	SO3	SO4	SO5	Weighting factor
SGR1...8/1	1	1	1	1	1	1	1	1	1
SGR1...8/2	2	2	2	2	2	2	2	2	2
SGR1...8/3	3	3	3	3	3	3	3	3	4
SGR1...8/4	4	4	4	4	4	4	4	4	8
SGR1...8/5	5	5	5	5	5	5	5	5	16
SGR1...8/6	6	6	6	6	6	6	6	6	32
SGR1...8/7	7	7	7	7	7	7	7	7	64
SGR1...8/8	8	8	8	8	8	8	8	8	128
SGR1...8/9	9	9	9	9	9	9	9	9	256
SGR1...8/10	10	10	10	10	10	10	10	10	512
SGR1...8/11	11	11	11	11	11	11	11	11	1024
SGR1...8/12	12	12	12	12	12	12	12	12	2048
SGR1...8/13	13	13	13	13	13	13	13	13	4096
SGR1...8/14	14	14	14	14	14	14	14	14	8192
SGR1...8/15	15	15	15	15	15	15	15	15	16384
SGR1...8/16	16	16	16	16	16	16	16	16	32768
SGR1...8/17	17	17	17	17	17	17	17	17	65536
SGR1...8/18	18	18	18	18	18	18	18	18	131072
SGR1...8/19	19	19	19	19	19	19	19	19	262144
SGR1...8/20	20	20	20	20	20	20	20	20	524288
SGR1...8/21	21	21	21	21	21	21	21	21	1048576
SGR1...8/22	22	22	22	22	22	22	22	22	2097152
SGR1...8/23	23	23	23	23	23	23	23	23	4194304
Checksum	ΣSGR1	ΣSGR2	ΣSGR3	ΣSGR4	ΣSGR5	ΣSGR6	ΣSGR7	ΣSGR8	

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Fig. 5.1.4.10.-2 Output signal matrix

Table 5.1.4.10-8 SGR1...SGR8

Switch	Function	Default setting		
		SGR1...SGR3	SGR4...SGR5	SGR6...SGR8 ^{a)}
SGR1...8/1	Start signal from stage I>	0	1	0
SGR1...8/2	Trip signal from stage I>	1	0	0
SGR1...8/3	Start signal from stage I>>	0	1	0
SGR1...8/4	Trip signal from stage I>>	1	0	0
SGR1...8/5	Start signal from stage I>>>	0	1	0
SGR1...8/6	Trip signal from stage I>>>	1	0	0
SGR1...8/7	Start signal from stage I ₀ >	0	1	0
SGR1...8/8	Trip signal from stage I ₀ >	1	0	0
SGR1...8/9	Start signal from stage I ₀ >>	0	1	0
SGR1...8/10	Trip signal from stage I ₀ >>	1	0	0
SGR1...8/11	Start signal from stage ΔI>	0	1	0
SGR1...8/12	Trip signal from stage ΔI>	1	0	0

Switch	Function	Default setting		
		SGR1...SGR3	SGR4...SGR5	SGR6...SGR8
SGR1...8/13	Alarm signal from stage θ >	0	0	0
SGR1...8/14	Trip signal from stage θ >	1	0	0
SGR1...8/15	External trip signal	0	0	0
SGR1...8/16	Open CB command from AR	0	0	0
SGR1...8/17	Close CB command from AR	0	0	0
SGR1...8/18	Definite trip alarm signal from AR	0	0	0
SGR1...8/19	CB reclosing failed signal from AR	0	0	0
SGR1...8/20	Shot due signal from AR	0	0	0
SGR1...8/21	Lockout signal from AR	0	0	0
SGR1...8/22	Trip signal from stage ARC	1	0	0
SGR1...8/23	Light signal output	0	0	0
Σ SGR1...8		2108074	5461	0

^{a)} If the optional I/O module has not been installed, dashes are shown on the LCD and "9999" when the parameter is read via the SPA bus.

SGL1...SGL8

The signals are routed to LED1 with the switches of switchgroup SGL1, to LED2 with those of SGL2, and so forth.

Table 5.1.4.10.-9 SGL1...SGL8

Switch	Function	Default setting
SGL1...8/1	Trip signal from stage I>	0
SGL1...8/2	Trip signal from stage I>>	0
SGL1...8/3	Trip signal from stage I>>>	0
SGL1...8/4	Trip signal from stage I ₀ >	0
SGL1...8/5	Trip signal from stage I ₀ >>	0
SGL1...8/6	Trip signal from stage Δ I>	0
SGL1...8/7	Alarm signal from stage θ >	0
SGL1...8/8	Trip signal from stage θ >	0
SGL1...8/9	Trip lockout signal	0
SGL1...8/10	Definite trip alarm signal from AR	0
SGL1...8/11	Shot due signal from AR	0
SGL1...8/12	Lockout signal from AR	0
SGL1...8/13	CB position open	0
SGL1...8/14	CB position closed	0
SGL1...8/15	DI1 signal	0
SGL1...8/16	DI2 signal	0
SGL1...8/17	DI3 signal	0
SGL1...8/18	DI4 signal	0
SGL1...8/19	DI5 signal	0
SGL1...8/20	Trip signal from stage ARC	0
SGL1...8/21	Light signal output	0
SGL1...8/22	Trip signal from CBFP	0

Switch	Function	Default setting
SGL1...8/23	Disturbance recorder triggered	0
ΣSGL1...SGL8		0

Auto-reclose SG1...SG3

Switchgroup SG1 is used for blocking the initiation of one or several auto-reclose shots, SG2 for blocking of protection stages at one or several auto-reclose shots, and SG3 for inhibiting the AR function as follows:

Table 5.1.4.10.-10 SG1

Switch	Function	Default setting
SG1/1	Blocking of initiation of shot 1 by the trip signal from stage I>>	0
SG1/2	Blocking of initiation of shot 1 by the external AR initiation signal	0
SG1/3	Blocking of initiation of shot 1 by the trip or delayed start signal from stage I>	0
SG1/4	Blocking of initiation of shot 1 by the trip or delayed start signal from stage I ₀ > or the trip signal from stage I ₀ >>	0
SG1/5	Blocking of initiation of shot 2 and 3 by the trip signal from stage I>>	0
SG1/6	Blocking of initiation of shot 2 and 3 by the external AR initiation signal	0
SG1/7	Blocking of initiation of shot 2 and 3 by the trip or delayed start signal from stage I>	0
SG1/8	Blocking of initiation of shot 2 and 3 by the trip or delayed start signal from stage I ₀ > or the trip signal from stage I ₀ >> • When the switch is in position 1, shot initiation is blocked.	0
ΣSG1		0

Table 5.1.4.10.-11 SG2

Switch	Function ^{a)}	Default setting
SG2/1	Blocking of tripping of stage I> at shot 1	0
SG2/2	Blocking of tripping of stage I>> at shot 1	0
SG2/3	Blocking of tripping of stage I>>> at shot 1	0
SG2/4	Blocking of tripping of stage I ₀ > at shot 1	0
SG2/5	Blocking of tripping of stage I ₀ >> at shot 1	0
SG2/6	Blocking of tripping of stage I> at shots 2 and 3	0
SG2/7	Blocking of tripping of stage I>> at shots 2 and 3	0
SG2/8	Blocking of tripping of stage I>>>; at shots 2 and 3	0
SG2/9	Blocking of tripping of stage I ₀ > at shots 2 and 3	0
SG2/10	Blocking of tripping of stage I ₀ >> at shots 2 and 3 • When the switch is in position 1, the stage is blocked.	0
ΣSG2		0

^{a)} The blocking is active until the set cutout time or the set reclaim time elapses or the AR function is locked out.

Table 5.1.4.10.-12 SG3

Switch	Function	Default setting
SG3/1	Inhibition of the AR function by the trip signal from stage I>>>	1
SG3/2	Inhibition of the AR function by the trip signal from stage I ₀ >>	1
SG3/3	Inhibition of the AR function by the alarm signal from stage θ>	1
SG3/4	Inhibition of the AR function by the trip signal from stage ΔI> • When the switch is in position 1, the AR function is inhibited.	1
SG3/5	Resetting indications at CB reclosing • When the switch is in position 1, indications are reset when the AR function issues a reclosing command to the circuit breaker.	0
ΣSG3		15

New trip indication timer

The new trip indication timer can be configured to allow a second trip indication on the LCD. When several protection stages trip, the first trip indication is displayed until the time, as specified by the `NEW TRIP IND.` setting value, has expired. After this, a new trip indication can displace the old one. The basic protection functions are not affected by the `NEW TRIP IND.` setting.

Table 5.1.4.10.-13 New trip indication timer

Setting	Description	Setting range	Default setting
New trip indication	New trip indication timer in minutes	0...998	60
	No new trip indication allowed until the previous one has been manually cleared.	999	-

Non-volatile memory settings



Non-volatile memory is backed up by a battery; the battery must be inserted and charged.

The table below presents data which can be configured to be stored in the non-volatile memory. All of the functions mentioned below can be selected separately with switches 1...5 either via the HMI or the SPA bus.

Table 5.1.4.10.-14 Memory settings

Setting	Switch	Function	Default setting
Non-volatile memory settings	1	• 0 = operation indication messages and LEDs are cleared • 1 = operation indication messages and LEDs are retained ^{a)}	1
	2	• 1 = disturbance recorder data is retained ^{a)}	1
	3	• 1 = event codes are retained ^{a)}	1

Setting	Switch	Function	Default setting
	4	<ul style="list-style-type: none"> 1 = recorded data and information on the number of starts of the protection stages are retained^{a)} 	1
	5	<ul style="list-style-type: none"> 1 = the real-time clock is running also during loss of auxiliary voltage^{a)} 	1
	Σ		31

^{a)} The prerequisite is that the battery has been inserted and is charged.



When all switches are set to zero, the battery supervision is disabled.

5.1.4.11.

Technical data on protection functions

Table 5.1.4.11.-1 Stages I>, I>> and I>>>

Feature	Stage I>	Stage I>>	Stage I>>>
Set start value, I>, I>> and I>>>			
<ul style="list-style-type: none"> at definite-time characteristic at IDMT characteristic 	0.30...5.00 x I _n 0.30...2.50 x I _n ^{a)}	0.50...35.0 x I _n	0.50...35.0 x I _n
Start time, typical	55 ms	30 ms	30 ms
Time/current characteristic			
<ul style="list-style-type: none"> definite-time operate time, t>, t>> and t>>>	0.05...300 s	0.04...300 s	0.04...300 s
<ul style="list-style-type: none"> IDMT according to IEC 60255-3 time multiplier, k	Extremely inverse Very inverse Normal inverse Long-time inverse 0.05...1.00		
<ul style="list-style-type: none"> Special type of IDMT characteristic time multiplier, k	RI-type inverse RD-type inverse (RXIDG) 0.05...1.00		
<ul style="list-style-type: none"> IDMT according to IEEE C37.112 time dial, n	Extremely inverse Very inverse Inverse 1...15		
Resetting time, maximum	50 ms ^{b)}	50 ms	50 ms
Retardation time, typical	30 ms	30 ms	30 ms
Set resetting time, t _{r>}	0.05...2.50 s		
Drop-off/pick-up ratio, typical	0.96	0.96	0.96
Operate time accuracy			

Feature	Stage I>	Stage I>>	Stage I>>>
<ul style="list-style-type: none"> at definite-time characteristic at IDMT characteristic according to IEC 60255-3: accuracy class index E at IDMT characteristic according to IEEE C37.112 at RI-type characteristic at RD-type characteristic (RXIDG) 	<ul style="list-style-type: none"> ±2% of the set operate time or ±25 ms 5 or ±25 ms ±7% of the calculated operate time or ±25 ms ±7% of the calculated operate time or ±25 ms ±7% of the calculated operate time or ±25 ms 	<ul style="list-style-type: none"> ±2% of the set operate time or ±25 ms 	<ul style="list-style-type: none"> ±2% of the set operate time or ±25 ms
Operation accuracy <ul style="list-style-type: none"> 0.3...0.5 x I_n 0.5...5.0 x I_n 5.0...35.0 x I_n 	<ul style="list-style-type: none"> ±5% of the set start value ±3% of the set start value 	<ul style="list-style-type: none"> ±3% of the set start value ±3% of the set start value 	<ul style="list-style-type: none"> ±3% of the set start value ±3% of the set start value

a) Because of the maximum measured current (50 × I_n), the setting value 2.5 is used for the IDMT calculation if the set value is greater than 2.5. This makes the operate time faster than the theoretical IDMT curve. However, the stage always starts according to the set value.

b) Resetting time of the trip signal.

Table 5.1.4.11-2 Stages I₀> and I₀>>

Feature	Stage I ₀ >	Stage I ₀ >>
Set start value, I ₀ > and I ₀ >> <ul style="list-style-type: none"> at definite-time characteristic at IDMT characteristic 	<ul style="list-style-type: none"> 1.0...100% I_n 1.0...100% I_n^{a)} 	<ul style="list-style-type: none"> 5.0...800% I_n
Start time, typical	60 ms	50 ms
Time/current characteristic <ul style="list-style-type: none"> definite time operate time, 51N TDLY and 50N TDLY IDMT according to IEC 60255-3 	<ul style="list-style-type: none"> 0.05...300 s Extremely inverse Very inverse Normal inverse Long-time inverse 	<ul style="list-style-type: none"> 0.05...300 s
time multiplier, k ₀ <ul style="list-style-type: none"> Special type of IDMT characteristic 	<ul style="list-style-type: none"> 0.05...1.00 RI-type inverse RD-type inverse 	
time multiplier, k ₀ <ul style="list-style-type: none"> IDMT according to IEEE C37.112 	<ul style="list-style-type: none"> 0.05...1.00 Extremely inverse Very inverse Inverse 	

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Feature	Stage I _{0>}	Stage I _{0>>}
time dial, n	1...15	
Resetting time, maximum	50 ms ^{b)}	50 ms
Retardation time, typical	30 ms	30 ms
Set resetting time, t _{0r>}	0.05...2.50 s	
Drop-off/pick-up ratio, typical	0.96	0.96
Operate time accuracy <ul style="list-style-type: none"> at definite-time characteristic at IDMT characteristic according to IEC 60255-3: accuracy class index E at IDMT characteristic according to IEEE C37.112 at RI-type characteristic at RD-type characteristic (RXIDG) 	±2% of the set operate time or ±25 ms 5 or ±25 ms ±7% of the calculated operate time or ±25 ms ±7% of the calculated operate time or ±25 ms ±7% of the calculated operate time or ±25 ms	±2% of the set operate time or ±25 ms
Operation accuracy <ul style="list-style-type: none"> 1.0...10.0% I_n 10.0...100% I_n 100...800% I_n 	±5% of the set start value + 0.05% I _n ±3% of the set start value	±5% of the set start value + 0.05% I _n ±3% of the set start value ±3% of the set start value

^{a)} In REF610 revision A and B, the setting value 40% I_n is used for the IDMT calculation, if the set value is greater than 40% I_n. In revision C (or later), the full setting range is used for the IDMT calculation.

^{b)} Resetting time of the trip signal.

Table 5.1.4.11.-3 Stage θ>

Feature	Value
Set full load current, I _θ	0.30...1.50 x I _n
Set alarm level, θ _{a>}	50...100%
Trip level, θ _{t>}	100 %
Time constant, τ	1...200 min
Operate time accuracy I/I _θ > 1.2	±2% of the set operate time or ±1 s

Table 5.1.4.11.-4 Stage ΔI>

Feature	Value
Set pickup value, ΔI> at definite-time characteristic	10...100%
Start time, typical	100 ms
Time/current characteristics definite time operate time, t _{ΔI>}	1...300 s
Resetting time, maximum	70 ms
Drop-off/pick-up ratio, typical	0.90
Operate time accuracy <ul style="list-style-type: none"> at definite-time characteristic 	±2% of the set operate time or ±100 ms

Feature	Value
Operation accuracy	±3% of the set start value and ±1 unit
• 10...100%	

Table 5.1.4.11.-5 Stage ARC and L>

Feature	Value
Stage ARC	
Set trip value $Arcl>$	$0.5...35.0 \times I_n$
Operate time	$< 15 \text{ ms}^a$
$Arcl_0>$	$5.0...800\% I_n$
Operate time	$< 17 \text{ ms}^a$
Resetting time	30 ms
Operation accuracy	±7% of the set start value
L>	
Activation time of L>	$< 15 \text{ ms}$
Resetting time	20 ms

^{a)} Applies only if a signal output contact (SO1...5) is used. If a power output contact (PO1...3) is used, 2...3 ms will be added.

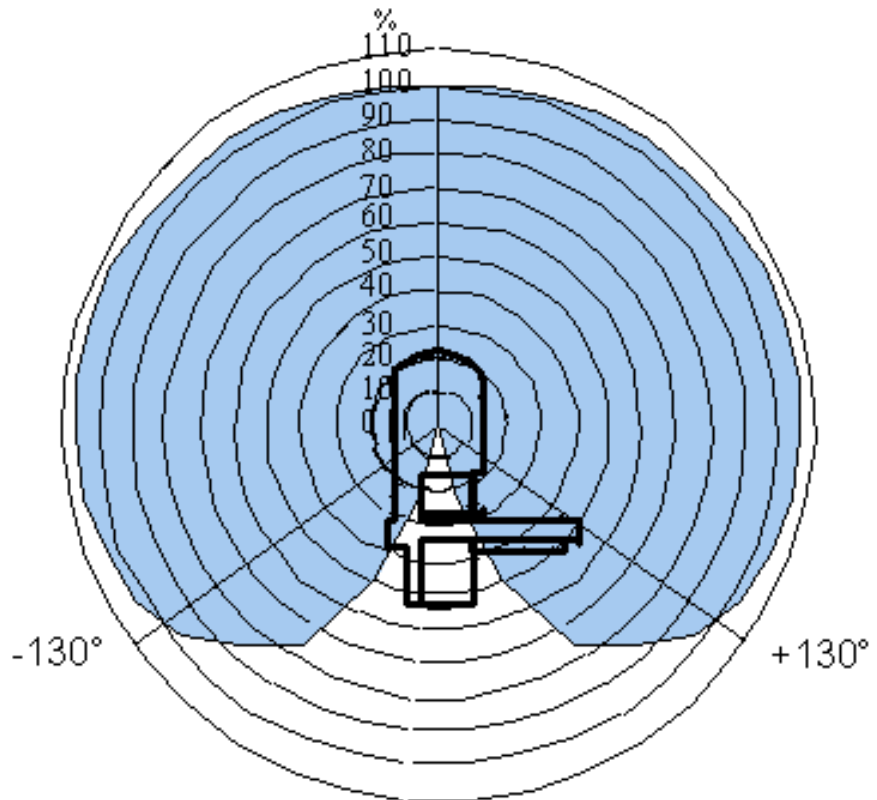


Fig. 5.1.4.11.-1 Relative sensitivity of lens sensors

Table 5.1.4.11-6 Auto-reclose function

Feature	Value
Number of shots	0...3
CB Closing time	0.1...10 s
Start delay of stage I>	0...300 s
Start delay of stage I ₀ >	0...300 s
Reset time	3...300 s
Cutout time	0.1...300 s
Dead time of shot 1	0.1...300 s
Dead time of shot 2	0.1...300 s
Dead time of shot 3	0.1...300 s
Operate time accuracy	±2% of the set time and ±25 ms

Table 5.1.4.11-7 CBFP

Feature	Value
Set operate time	0.10...60.0 s
Phase-current threshold for external triggering of the CBFP	
• pick-up/drop-off	0.08/0.04 x I _n

5.1.5.

Trip-circuit supervision

The trip-circuit supervision (TCS) detects open circuits, both when the circuit breaker is open and closed, and trip-circuit supply failure.

The trip-circuit supervision is based on a constant current injection principle: by applying an external voltage, a constant current is forced to flow through the external trip circuit. If the resistance of the trip circuit exceeds a certain limit, due to oxidation or a bad contact, for instance, the trip-circuit supervision is activated and a warning appears on the LCD together with a fault code. The warning signal from the trip-circuit supervision can also be routed to SO2 by setting switch SGF1/8 to 1.

Under normal operating conditions, the applied external voltage is divided between the relay's internal circuit and the external trip circuit so that at least 20 V remains over the relay's internal circuit. If the external trip circuit's resistance is too high or the internal circuit's too low, due to welded relay contacts, for instance, the voltage over the relay's internal circuit falls below 20 V (15...20 V), which activates the trip-circuit supervision.

The operation condition is:

$$U_c - (R_{ext} + R_{int} + R_s) \times I_c \geq 20 \text{ V ac/dc} \quad (8)$$

- U_c = operating voltage over the supervised trip circuit
- I_c = current flowing through the trip circuit, ~1.5 mA
- R_{ext} = external shunt resistor
- R_{int} = internal shunt resistor, 1 kΩ
- R_s = trip coil resistance

The external shunt resistor is used to enable trip-circuit supervision also when the circuit breaker is open.

The resistance of the external shunt resistor is to be calculated so that it does not cause malfunction of the trip-circuit supervision or affect the operation of the trip coil. Too high resistance causes too high voltage drop, which in turn results in the operation conditions not being fulfilled, whereas too low resistance may cause faulty operation of the trip coil.

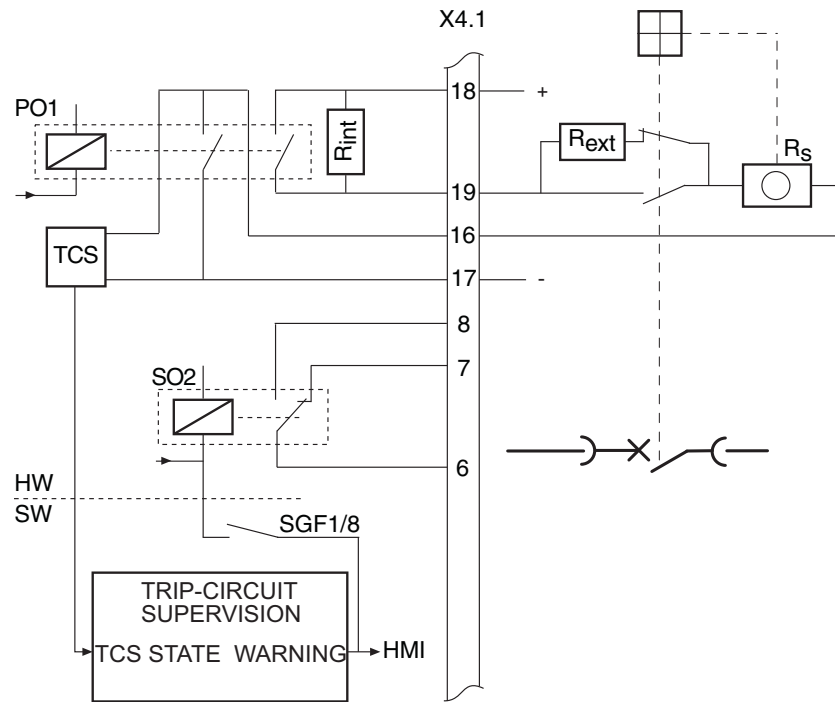
The following values are recommended for the external resistor, R_{ext} :

Table 5.1.5.-1 Recommended values for R_{ext}

Operating voltage, U_c	Shunt resistor R_{ext}
48 V DC	1.2 k Ω , 5 W
60 V DC	5.6 k Ω , 5 W
110 V DC	22 k Ω , 5 W
220 V DC	33 k Ω , 5 W

The circuit breaker is to be provided with two external contacts, one opening and one closing contact. The closing contact is to be connected in parallel with the external shunt resistor, which enables trip-circuit supervision when the circuit breaker is closed. The opening contact, on the contrary, is to be connected in series with the external shunt resistor, which enables trip-circuit supervision when the circuit breaker is open; see Fig. 5.1.5.-1.

Trip-circuit supervision can be selected either via the HMI or with SPA parameter V113.



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Fig. 5.1.5.-1 Connecting the trip-circuit supervision using two external contacts and the external resistor in the trip circuit

5.1.6. Trip lockout function

The trip lockout function is used to prevent accidental closing of the circuit breaker after a trip. The trip lockout function must be locally reset with a separate reset command before the circuit breaker can be closed again. This function is useful when the trip output contact of the relay is latched or the open circuit of the circuit breaker remains activated.

The trip lockout function is selected in SGF1. When selected, PO3 is dedicated to this function. As long as no trip occurs, PO3 is closed.

Every signal which has been routed to PO3 via the output signal matrix activates the trip lockout function and opens the contacts of PO3. When the contacts have opened, they are locked into the open state.

The trip lockout function can also be activated externally, via a digital input. The trip lockout function can be reset via a digital input, the HMI or SPA parameter V103, but not before the signal which activated the function has been reset.

In case of loss of auxiliary power when the trip lockout function is in use, the contacts of PO3 return to the same state as before the loss, provided that the battery has been inserted and is charged. If no battery has been inserted, the trip lockout function is activated and the contacts of PO3 remain open when the auxiliary power is switched on again.

5.1.7. Trip counters for circuit-breaker condition monitoring

The trip counters for circuit-breaker condition monitoring provide history data, which can be used for circuit-breaker service scheduling. With this information, the service cycle can be estimated for the future.

The monitoring function consists of four counters, which count the number of trip signals generated to the circuit breaker by the relay. Every time a stage generates a trip signal, the corresponding counter value is increased by one. The number of trips is stored in the non-volatile EEPROM memory.

There are separate counters for the different protection stages because breaking the current in different fault situations wears the circuit breaker differently. Each overcurrent stage ($I>$, $I>>$ and $I>>>$) has its own trip counter, whereas there is a common trip counter for stages $I_{0>}$, $I_{0>>}$, $\Delta I>$, $\theta>$, ARC and the external trip.

The counters can be read via the HMI or SPA parameters V9...V12 and cleared via SPA parameter V166. When a counter reaches its maximum value, it rolls over.



In case several stages trip during the same fault sequence, only the counter of the stage which tripped first is increased by one.

5.1.8. Indicator LEDs and operation indication messages

The operation of the relay can be monitored via the HMI by means of LED indications and text messages on the LCD. On the front panel of the relay there are three indicator LEDs with fixed functionality:

- Green indicator LED (ready)
- Yellow indicator LED (start/alarm)
- Red indicator LED (trip)

In addition, there are eight programmable LEDs and an indicator LED for front communication. Refer to the Operator's Manual for a more thorough presentation.

The indication messages on the LCD have a certain priority order. If different types of indications are activated simultaneously, the message with the highest priority appears on the LCD.

The priority order of the operation indication messages:

1. CBFP
2. Trip
3. Start/Alarm

5.1.9. Demand values

The relay provides three different kinds of demand values.

The first value shows the average current of all three phases measured during one minute. The value is updated once a minute.

The second value shows the average current during an adjustable time range, ranging from 0 to 999 minutes, with an accuracy of one minute. This value is updated at the expiration of each time range.

The third value shows the highest one-minute average current value measured during the previous time range. However, if the time range is set to zero, only the one-minute and the maximum demand value is shown. The maximum value is the highest one-minute mean value since the last reset.

The demand values can be set to zero through serial communication using SPA parameter V102. The average values are also reset if SPA parameter V105 is changed or the relay is reset.

5.1.10. **Commissioning tests**

The following two product functions can be used during the commissioning of the relay: function test and digital input test.

The function test is used for testing the configuration as well as the connections from the relay. By selecting this test, the internal signals from the protection stages, the motor start-up signal, the external trip signal and the IRF function can be activated one by one. Provided that the signals have been set to be routed to the output contacts (PO1...PO3 and SO1...SO5) with the switches of SGR1...SGR8, the output contacts are activated and their corresponding event codes are generated when the test is run. However, activation of the internal signals from the protection stages, the signals from the auto-reclose function, the external trip signal and the IRF function do not generate an event code.

The digital input test is used for testing the connections to the relay. The state of the digital inputs can be monitored via the HMI.

Refer to the Operator's Manual for instructions on how to perform the tests.

5.1.11. **Disturbance recorder**

5.1.11.1. **Function**

The relay features an integrated disturbance recorder which continuously captures the curve forms of the currents as well as the status of both internal signals and digital input signals and stores these in the memory.

Triggering of the recorder generates an event code. After the recorder has been triggered, it continues to record data for a pre-defined post-triggering time. An asterisk is shown on the LCD on completion of the recording. The status of the recording can also be viewed using SPA parameter V246.

As soon as the recorder has been triggered and the recording has finished, the recording can be uploaded and analyzed by means of a PC provided with a special program.

5.1.11.2. Disturbance recorder data

One recording contains data from the four analog channels and up to eight digital channels. The analog channels, whose data is stored either as RMS curves or as momentary measured values, are the currents measured by the relay. The digital channels, referred to as digital signals, are start and trip signals from the protection stages, the alarm signal from stage 0>, the signals from the auto-reclose function and the digital input signals linked to the relay.

The user can select up to eight digital signals to be recorded. If more than eight signals are selected, the first eight signals are stored, beginning with the internal signals followed by the digital input signals.

The digital signals to be stored are selected with parameters V238 and V243; see Table 5.1.17.-6 and Table 5.1.17.-7.

The recording length varies according to the selected sampling frequency. The RMS curve is recorded by selecting the sampling frequency to be the same as the nominal frequency of the relay. The sampling frequency is selected with SPA parameter M15; see the table below for details.

Table 5.1.11.2.-1 Sampling frequency

Nominal frequency Hz	Sampling frequency Hz	Cycles
50	800	250
	400	500
	50 ^{a)}	4000
60	960	250
	480	500
	60 ^{a)}	4000

^{a)} RMS curve.

Recording length:

$$[s] = \frac{\text{Cycles}}{\text{Nominal frequency [Hz]}} \quad (9)$$

Changing the setting values of parameters M15, V238 and V243 is allowed only when the recorder is not triggered.

The post-triggering recording length defines the time during which the recorder continues to store data after it has been triggered. The length can be changed with SPA parameter V240. If the post-triggering recording length is defined to be the same as the total recording length, no data stored prior to the triggering is retained in the memory. By the time the post-triggering recording finishes, a complete recording is created.

Triggering of the recorder immediately after it has been cleared or the auxiliary voltage connected may result in a shortened total recording length. Disconnection of the auxiliary voltage after the recorder has been triggered, but before the recording has finished, on the other hand, may result in a shortened post-triggering recording length. This, however, does not affect the total recording length.

At a power reset, triggered recorder data is retained in the memory provided that it has been defined non-volatile.

5.1.11.3.

Control and indication of disturbance recorder status

It is possible to control and monitor the recording status of the disturbance recorder by writing to and reading SPA parameters M1, M2 and V246. Reading SPA parameter V246 returns either the value 0 or 1, indicating whether the recorder has not been triggered or triggered and ready to be uploaded. Event code E31 is generated the moment the disturbance recorder is triggered. If the recorder is ready to be uploaded, this is also indicated by an asterisk shown in the lower right-hand corner of the LCD when it is in the idle mode. Indication can also be routed to programmable LEDs.

Writing the value 1 to SPA parameter M2 clears the recorder memory and enables the triggering of the recorder. Recorder data can be cleared by performing a master reset, that is, clearing indications and memorized values and unlatching output contacts.

Writing the value 2 to SPA parameter V246 restarts the unloading process by setting the time stamp and the first data ready to be read.

5.1.11.4.

Triggering

The user can select one or several internal or digital input signals to trigger the disturbance recorder, either on the rising or falling edge of the signal(s). Triggering on the rising edge means that the post-triggering recording sequence starts when the signal is activated. Correspondingly, triggering on the falling edge means that the post-triggering recording sequence starts when the active signal is reset.

The trigger signal(s) and the edge are selected with SPA parameters V236...V237 and V241...V242; see Table 5.1.17.-6 and Table 5.1.17.-7. The recorder can also be triggered manually with SPA parameter M1.

Triggering of the disturbance recorder is only possible if the recorder is not already triggered.

5.1.11.5.

Settings and unloading

The setting parameters for the disturbance recorder are V parameters V236...V238, V240...V243 and V246, and M parameters M15, M18, M20 and M80...M83.

Unloading correct information from the recorder requires that M80 and M83 have been set. Unloading is done by using a PC application. The uploaded recorder data is stored in separate files defined by the comtrade® format.

5.1.11.6. **Event code of the disturbance recorder**

The disturbance recorder generates an event code on triggering (E31) and clearing (E32) the recorder. The event mask is determined using SPA parameter V155.

5.1.12. **Recorded data of the last events**

The relay records up to five events. This enables the user to analyze the last five fault conditions in the electrical power network. Each event includes the measured currents, start durations and time stamp, for instance. Additionally, information on the number of starts of the stages, trips and auto-reclose shots is provided.

Recorded data is non-volatile by default, provided that the battery has been inserted and is charged. A master reset, that is, clearing of indications and memorized values and unlatching of output contacts, erases the contents of the stored events and the number of starts of the stages.



The number of trips and auto-reclose shots is stored in the non-volatile memory (EEPROM) and is thereby not cleared when performing a master reset. The number of trips can be erased by entering the value 1 and the number of auto-reclose shots by entering the value 2 into parameter V166.

The relay collects data during fault conditions. When all start or thermal alarm signals have been reset or a stage trips, the collected data and time stamp is stored as EVENT1 and the previously stored events move one step forward. When a sixth event is stored, the oldest event is cleared.

Table 5.1.12.-1 Recorded data

REGISTER	Data description
EVENT1	<ul style="list-style-type: none"> • Phase current L1, measured as a multiple of the rated current, I_n, is displayed in two registers: the main register and the sub register. When a stage starts but does not trip, the maximum fault current during the start period will be stored in both the main register and the sub register. When a stage trips, the fault current at the time of the trip will be stored in the main register and the maximum fault current during the start period in the sub register. The same applies to phase currents L2, L3 and I_0. • The phase unbalance, ΔI, as a percentage of the maximum phase current value. When the stage starts but does not trip, the maximum phase unbalance value during the start period will be stored. When the stage trips, the fault unbalance at the time of the trip will be stored. • Thermal level, as a percentage of the maximum thermal level of the cable, at activation of a start or alarm signal. If the thermal protection stage has been set out of operation, dashes will be shown on the LCD and "999" when read via serial communication. • The maximum thermal level during the time the start or alarm signal was active, as a percentage of the maximum thermal level of the cable, or in case of a trip, the thermal level, as a percentage of the maximum thermal level of the cable, at activation of a trip signal. If the thermal protection stage has been set out of operation, dashes will be shown on the LCD and "999" when read via serial communication. • Duration of the starts of stages $I>$, $I>>$, $I>>>$, ΔI, $I_0>$ and $I_0>>$, the trip of stage ARC (local), the trip of stage ARC (remote), and of the external trip. A value other than zero indicates that the corresponding stage has started whereas the value 100% indicates that the operate time of the stage has elapsed, i.e. the stage has tripped. If the operate time of a stage has elapsed but the stage is blocked, the value will be 99% of the set or calculated operate time. • Trip number in the auto-reclose sequence. The number 1...20 indicates the order of the trip in the AR sequence. The value 1 indicates the first trip in the AR sequence, the value 2 the second trip, and so forth. On expiration of the set reclaim time, the value will start from 1 again. If the AR function has been set out of operation, the value will always be 1. • Time stamp for the event. The time when the collected data was stored. The time stamp is displayed in two registers, one including the date expressed as yy-mm-dd, and the other including the time expressed as HH.MM; SS.sss.
EVENT 2	Same as EVENT 1.
EVENT 3	Same as EVENT 1.
EVENT 4	Same as EVENT 1.
EVENT 5	Same as EVENT 1.

REGISTER	Data description
Number of starts	The number of times each protection stage, I>, I>>, I>>>, ΔI, I ₀ > and I ₀ >>, has started, counting up to 999.
Number of trips	<ul style="list-style-type: none"> The number of times each protection stage, I>, I>>, I>>>, has tripped. When the counters reach their maximum values (65535), it will roll over. The number of times protection stages, I₀> and I₀>>, θ> and ARC has tripped and external trips. When the counter reaches its maximum value (65535), it will roll over.
Number of AR shots	<ul style="list-style-type: none"> Number of AR shots (shot 1) initiated by the trip signal from stage I>>, counting up to 255 Number of AR shots (shot 1) initiated by the digital input signal, counting up to 255 Number of AR shots (shot 1) initiated by the start or trip signal from stage I>, counting up to 255 Number of AR shots (shot 1) initiated by the pickup or trip signal from stage I₀>, counting up to 255 Number of AR shots (shot 2) initiated by the trip signal from stage I>>, counting up to 255 Number of AR shots (shot 2) initiated by the digital input signal, counting up to 255 Number of AR shots (shot 2) initiated by the start or trip signal from stage I>, counting up to 255 Number of AR shots (shot 2) initiated by the start or trip signal from stage I₀>, counting up to 255 Number of AR shots (shot 3) initiated by the trip signal from stage I>>, counting up to 255 Number of AR shots (shot 3) initiated by the digital input signal, counting up to 255 Number of AR shots (shot 3) initiated by the start or trip signal from stage I>, counting up to 255 Number of AR shots (shot 3) initiated by the start or trip signal from stage I₀>, counting up to 255

5.1.13.

Communication ports

The relay is provided with an optical communication port (infrared) on the front panel. Rear communication is optional and requires a communication module, which can be provided with either a plastic fibre-optic, combined fibre-optic (plastic and glass) or RS-485 connection. The relay is connected to an automation system via the rear connection. The optional rear communication module allows the use of either the SPA bus, IEC 60870-5-103 or Modbus communication protocol.

For connection to the DNP 3.0 communication system, the relay can be provided with an optional DNP 3.0 rear communication module with RS-485 connection. For further information on optional rear communication module connections, refer to Section 5.2.3. Serial communication connections.



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Fig. 5.1.13.-1 Communication port

1) Front connection for local communication

The relay is connected to a PC used for local parameterization via the infrared port on the front panel. The front connection allows the use of the SPA bus protocol only.

The optical front connection galvanically isolates the PC from the relay. The front connection can be used in two different ways: wirelessly using a PC compatible to the IrDA[®], Standard specifications or using a specific front communication cable (refer to Section 7. Ordering information). The cable is connected to the serial RS-232 port of the PC. The optical stage of the cable is powered by RS-232 control signals. The cable has a fixed baud rate of 9.6 kbps.

The following serial communication parameters are to be set for RS-232:

- Number of data bits: 7
- Number of stop bits: 1
- Parity: even
- Baud rate: 9.6 kbps

Relay data such as events, setting values and all input data and memorized values can be read via the front communication port.

When setting values are altered via the front communication port, the relay checks that the entered parameter values are within the permitted setting range. If an entered value is too high or too low, the setting value remains unchanged.

The relay has a counter which can be accessed via `CONFIGURATION \COMMUNICATION` in the HMI menu. The counter value is set to zero when the relay receives a valid message.

5.1.14.

IEC 60870-5-103 remote communication protocol

The relay supports the IEC 60870-5-103 remote communication protocol in the unbalanced transmission mode. The IEC 60870-5-103 protocol is used to transfer measurand and status data from the slave to the master. However, the IEC 60870-5-103 protocol cannot be used to transfer disturbance recorder data.

The IEC 60870-5-103 protocol can be used only through the rear connection of the relay on the optional communication module. Connecting the relay to a fibre-optic communication bus requires a fibre-optic communication module. The line-idle state of the fibre-optic communication module can be selected either via the HMI or the SPA bus. According to the IEC 60870-5-103 standard, the line-idle state is “light on”. To ensure communication, the line-idle state should be the same for both the master and the slave device. The connection topology can be selected to be either loop or star, the default being loop, and either via the HMI or the SPA bus. The selected line-idle state and connection topology apply irrespective of which rear communication protocol is active.

The relay uses the SPA bus protocol as default when the optional communication module is in use. The protocol selection is memorized and is therefore always activated when the rear connection is in use. The baud rate can be selected either via the HMI or the SPA bus. According to the IEC 60870-5-103 standard, the baud rate is 9.6 kbps. When the IEC 60870-5-103 protocol is active, event masks are not in use. Consequently, all events in the selected configuration set are included in the event reporting.

The relay is provided with two different selectable configuration sets, of which configuration set 1 is used by default.

Configuration set 1 is intended to be used when the optional I/O module is not installed. Configuration set 2 includes additional information, for example output contact events 6...8 (SO3...SO5) and digital input events 3...5 (DI3...DI5), provided that the optional I/O module is installed.

Function type and information number are mapped into configuration sets according to the IEC 60870-5-103 standard to the extent that these have been defined by the standard. If not defined by the standard, the type of function and/or the information number are/is mapped into a private range.

The tables below indicate the information mapping of the corresponding configuration sets. The column GI indicates whether the status of the specified information object is transmitted within the general interrogation cycle. The relative time in messages with the type identification 2 is calculated as a time difference between the occurred event and the event specified in the column Relative time. The measurand multiplied by the normalize factor is proportional to the rated value. Therefore, the maximum value of each measurand is the normalize factor multiplied by the rated value.

Table 5.1.14.-1 Information mapping of configuration set 1 and 2

Event reason	Event code	Configuration set 1	Configuration set 2	Function type	Information number	GI	Relative time	Type identification
Disturbance recorder Triggered/Cleared	0E31/ 0E32	X	X	178	100	-	-	1
HMI Setting password Opened/Closed	0E33/ 0E34	X	X	178	101	-	-	1
HMI Communication password Opened/Closed	0E35/ 0E36	X	X	178	102	-	-	1
I> Start/Reset	1E1/ 1E2	X	X	160	84	X	1E1	2
I> Trip/Reset	1E3/ 1E4	X	X	160	90	-	1E1	2
I>> Start/Reset	1E5/ 1E6	X	X	162	94	X	1E5	2
I>> Trip/Reset	1E7/ 1E8	X	X	160	91	-	1E5	2
I>>> Start/Reset	1E9/ 1E10	X	X	162	96	X	1E9	2
I>>> Trip/Reset	1E11/ 1E12	X	X	162	98	-	1E9	2
I ₀ > Start/Reset	1E13/ 1E14	X	X	160	67	X	1E13	2
I ₀ > Trip/Reset	1E15/ 1E16	X	X	160	92	-	1E13	2
I ₀ >> Start/Reset	1E17/ 1E18	X	X	162	95	X	1E17	2
I ₀ >> Trip/Reset	1E19/ 1E20	X	X	160	93	-	1E17	2
ΔI> Start/Reset	1E21/ 1E22	X	X	173	84	X	1E21	2
ΔI> Trip/Reset	1E23/ 1E24	X	X	173	90	-	1E21	2
θ> Start/Reset	1E25/ 1E26	X	X	184	84	X	1E25	2
θ> Alarm/Reset	1E27/ 1E28	X	X	184	11	X	-	1
θ> Trip/Reset	1E29/ 1E30	X	X	184	90	-	1E25	2
ARC (light and current) Trip/Reset	1E31/ 1E32	X	X	100	90	-	1E31	2
ARC (DI and current) Trip/Reset	1E33/ 1E34	X	X	100	50	-	1E33	2
Arc light signal output Activated/Reset	1E35/ 1E36	X	X	100	20	-	-	1

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Event reason	Event code	Configuration set 1	Configuration set 2	Function type	Information number	GI	Relative time	Type identification
Trip lockout Activated/Reset	1E37/ 1E38	X	X	10	223	X	-	1
External Trip/Reset	1E39/ 1E40	X	X	10	222	-	-	1
CBFP Activated/Reset	1E41/ 1E42	X	X	160	85	-	-	1
PO1 Activated/Reset	2E1/ 2E2	X	X	251	27	X	-	1
PO2 Activated/Reset	2E3/ 2E4	X	X	251	28	X	-	1
PO3 Activated/Reset	2E5/ 2E6	X	X	251	29	X	-	1
SO1 Activated/Reset	2E7/ 2E8	X	X	251	30	X	-	1
SO2 Activated/Reset	2E9/ 2E10	X	X	251	31	X	-	1
SO3 Activated/Reset	2E11/ 2E12	-	X	251	32	X	-	1
SO4 Activated/Reset	2E13/ 2E14	-	X	251	33	X	-	1
SO5 Activated/Reset	2E15/ 2E16	-	X	251	34	X	-	1
DI1 Activated/Deactivated	2E17/ 2E18	X	X	249	231	X	-	1
DI2 Activated/Deactivated	2E19/ 2E20	X	X	249	232	X	-	1
DI3 Activated/Deactivated	2E21/ 2E22	-	X	249	233	X	-	1
DI4 Activated/Deactivated	2E23/ 2E24	-	X	249	234	X	-	1
DI5 Activated/Deactivated	2E25/ 2E26	-	X	249	235	X	-	1
Shot 1 Initiated/Ended	3E1/ 3E2	X	X	169	101	-	-	1
Shot 2 Initiated/Ended	3E3/ 3E4	X	X	169	102	-	-	1
Shot 3 Initiated/Ended	3E5/ 3E6	X	X	169	103	-	-	1
CB Position Open/Closed	3E7/ 3E8	X	X	240	160	-	-	1
Definite Trip Alarm/Reset	3E9/ 3E10	X	X	169	150	-	-	1
AR Lockout/Reset	3E11/ 3E12	X	X	169	164	-	-	1

Event reason	Event code	Configuration set 1	Configuration set 2	Function type	Information number	GI	Relative time	Type identification
Open CB Command/Reset	3E13/ 3E14	X	X	169	127	-	-	1
Close CB Command/Reset	3E15/ 3E16	X	X	169	128	-	-	1
CB Reclosing Failed/Reset	3E17/ 3E18	X	X	169	163	-	-	1
CB Reclosing inhibited/Reset	3E19/ 3E20	X	X	169	162	-	-	1
AR Cancelled/Reset	3E21/ 3E22	X	X	169	130	-	-	1

Table 5.1.14.-2 Information mapping of configuration set 1 and 2

Measurand	Normalize factor	Rated value	Configuration set 1	Configuration set 2	Function type	Information number	Type identification
Current I_{L1}	2.4	I_n	X	X	135	140	9
Current I_{L2}	2.4	I_n	X	X			
Current I_{L3}	2.4	I_n	X	X			
Current I_0	2.4	I_n	X	X			

5.1.15.

Modbus remote communication protocol

The master/slave protocol Modbus was first introduced by Modicon Inc. and is widely accepted as a communication standard for industrial device controllers and PLCs. For the protocol definition, refer to Section 1.4. Product documentation.

The implementation of the Modbus protocol in the relay supports both the RTU and the ASCII link mode. Both the link mode and the line setting parameters are user-configurable. The character codings of the link modes follow the protocol definition. The RTU character format is presented in Table 5.1.15.-1 and the ASCII character format in Table 5.1.15.-2:

Table 5.1.15.-1 RTU character format

Coding system	8-bit binary
Bits per character	1 start bit 8 data bits, the least significant bit is sent first 1 bit for even/odd parity; no bit if parity is not used 1 stop bit if parity is used; 2 stop bits if parity is not used

Table 5.1.15.-2 ASCII character format

Coding system	Two ASCII characters representing a hexadecimal number
Bits per character	1 start bit 7 data bits, the least significant bit is sent first 1 bit for even/odd parity; no bit if parity is not used 1 stop bit if parity is used; 2 stop bits if parity is not used



The turnaround time (response time) of the relay depends on the amount of data requested in a query. Therefore, the turnaround time can vary between approximately 20 and 100 ms. However, a turnaround timeout no lower than 150 ms is recommended for the Modbus master.



The data address range in the Modbus network follows the protocol definition and starts from 0. Consequently, the data addresses in Table 5.1.15.1.-5...Table 5.1.15.1.-13 are decreased by one when transferred over the network.



The Modbus data type digital input (DI) is commonly also referred to as 1X, coils as 0X, input register (IR) as 3X and holding register (HR) as 4X, of which the former is used here. Thus, HR 123, for instance, can also be referred to as register 400123.

5.1.15.1.

Profile of Modbus

The Modbus protocol (ASCII or RTU) is selected via the HMI and can be used only through the rear connection of the relay on the optional communication module. Modbus line settings, that is, parity, CRC byte order and baud rate, can be adjusted either via the HMI or the SPA bus.

The implementation of the Modbus protocol in REF610 supports the following functions:

Table 5.1.15.1-1 Supported application functions

Function code	Function description
01	Read coil status Reads the status of discrete outputs.
02	Read digital input status Reads the status of discrete inputs.
03	Read holding registers Reads the contents of output registers.
04	Read input registers Reads the contents of input registers.
05	Force single coil Sets the status of a discrete output.
06	Preset single register Sets the value of a holding register.
08	Diagnostics Checks the communication system between the master and the slave.
15	Force multiple coils Sets the status of multiple discrete outputs.
16	Preset multiple registers Sets the value of multiple holding registers.
23	Read/write holding registers Exchanges holding registers in one query.

Table 5.1.15.1-2 Supported diagnostic subfunctions

Code	Name	Description
00	Return query data	The data in the query data field is returned (looped back) in the response. The entire response is to be identical to the query.
01	Restart communication option	The slave's peripheral port is initialized and restarted and the communication event counters are cleared. Before this, a normal response will be sent provided that the port is not in the listen only mode. However, if the port is in the listen only mode, no response will be sent.
04	Force listen only mode	The slave is forced to enter the listen only mode for Modbus communication.
10	Clear counters and diagnostic register	All counters and the diagnostic register are cleared.
11	Return bus message count	The number of messages in the communications system detected by the slave since its last restart, clear counters operation or power up is returned in the response.
12	Return bus communication error count	The number of CRC errors encountered by the slave since its last restart, clear counters operation or power up is returned in the response.
13	Return bus exception error count	The number of Modbus exception responses sent by the slave since its last restart, clear counters operation or power up is returned in the response.
14	Return slave message count	The number of messages addressed to the slave or broadcast which the slave has processed since its last restart, clear counters operation or power up is returned in the response.

Code	Name	Description
15	Return slave no response count	The number of messages addressed to the slave for which a response (neither a normal response nor an exception response) has not been sent since its last restart, clear counters operation or power up is returned in the response.
16	Return slave NACK response count	The number of messages addressed to the slave for which a NACK response has been sent is returned in the response.
18	Return bus character overrun count	The number of messages addressed to the slave for which it has not been able to send a response due to a character overrun since its last restart, clear counters operation or power up is returned in the response.



Sending other subfunction codes than those listed above cause an Illegal data value response.

The Modbus protocol provides the following diagnostic counters:

Table 5.1.15.1.-3 Diagnostic counters

Name	Description
Bus message count	The number of messages in the communications system detected by the slave since its last restart, clear counters operation or power up.
Bus communication error count	The number of CRC or LRC errors encountered by the slave since its last restart, clear counters operation or power up.
Bus exception error count	The number of Modbus exception responses sent by the slave since its last restart, clear counters operation or power up.
Slave message count	The number of messages addressed to the slave or broadcast which the slave has processed since its last restart, clear counters operation or power up.
Slave no response count	The number of messages addressed to the slave for which a response (neither a normal response nor an exception response) has not been sent since its last restart, clear counters operation or power up.
Slave NACK response count	The number of messages addressed to the slave for which a NACK response has been sent.
Bus character overrun count	The number of messages addressed to the slave for which it has not been able to send a response due to a character overrun since its last restart, clear counters operation or power up.

The following exception codes may be generated by the Modbus protocol:

Table 5.1.15.1.-4 Possible exception codes

Code	Name	Description
01	Illegal function	The slave does not support the requested function.
02	Illegal data address	The slave does not support the data address or the number of items in the query is incorrect.
03	Illegal data value	A value contained in the query data field is out of range.
04	Slave device failure	An unrecoverable error has occurred while the slave was attempting to perform the requested task.



If an `Illegal data value` exception response is generated when attempting to preset multiple registers, the contents of the register to which an illegal value has been imposed and of the following registers is not changed. Registers which have already been preset are not restored.

User-defined registers

Reading of unwanted data in a data block wastes bandwidth and complicates data interpretation. For optimum efficiency in Modbus communication, data has therefore been organized into consecutive blocks. In addition, a set of programmable user-defined registers (UDR) has been defined in the holding register area.

The first sixteen holding registers, that is, HR1...16, are user-defined registers. The UDRs can be linked to any holding register, except for HR721...727, using SPA parameters 504V1...504V16. However, one UDR cannot be linked to another, that is, linking cannot be nested. Each parameter contains the address of the holding register to which the UDR is linked.

If a UDR is linked to a non-existent holding register, reading from the register fails and an `Illegal address` exception response is sent. Giving the link address the value 0 disables the UDR. If the master reads from a disabled UDR, the value 0 is returned.

The UDRs are mirrored in HR385...400.

Fault records

The data recorded during a fault sequence is called a fault record (FR). The slave stores the five latest fault records. When a sixth record is stored, the oldest record is deleted.

To read a fault record:

1. Write a preset single register command (function 06) to HR601 using a selection code as data value.
2. Read the selected fault record (function 04) from HR601, register count 28.

Alternatively, a fault record can be read using one command (function 23) only.

Selection code 1: the master reads the oldest unread record

Status register 3 (HR403) informs whether there are unread fault records (see Fig. 5.1.15.1.-2). If there is one or several unread fault records, the master can read the contents using selection code 1.

The fault record contains a sequence number which makes it possible for the master to determine whether one or several unread fault records have been deleted due to overflow. The master compares the sequence number to that of the previously read fault record.

The slave keeps track of which fault record is currently the oldest unread. The master can continue reading fault records for as long as Status register 3 indicates that there are unread records.

- Special case 1: If there are no unread fault records, the contents of the last read record is returned. If the buffer is empty, however, the registers contain only zeros. This is the only time when sequence number zero appears.
- Special case 2: If the master tries to read the next unread fault record without entering selection code 1 again, the contents of the last read record will be returned.

Selection code 2: the master reads the oldest stored record

By resetting the read pointer using selection code 2, the master can read the oldest stored fault record. After this, the master can continue reading the following records using selection code 1, irrespective of whether they have been read before.



Resetting the read pointer does not affect the sequence number of the fault record.



A master reset, that is, clearing of indications and memorized values and unlatching of output contacts, clears the fault records, after which the sequence number starts from 1 again.

Event records

Modbus events are derived from SPA events. With a few exceptions, SPA events update binary points in the DI and the packed HR area. Simultaneously, a corresponding Modbus event record is generated. The event record contains the

Modbus DI/CO data point address and the value to which the point has changed (0 or 1). SPA events lacking a corresponding DI/CO data point are shown as SPA channel and event code (informative event) in the event record. The maximum capacity of the Modbus event buffer is 99 events. The time stamp of Modbus events is extended to contain complete information, from date to millisecond.

To read an event record:

1. Write a preset single register command (function 06) to HR671 using a selection code as data value.
2. Read the selected fault record (function 04) from HR672, register count 8.

Alternatively, a fault record can be read using one command (function 23) only.

Selection code 1: reading the oldest unread record

Status register 3 (HR403) informs whether there are unread event records (see Fig. 5.1.15.1.-2). If there is one or several unread event records, the master can read the contents using selection code 1.

The event record contains a sequence number which makes it possible for the master to determine whether one or several unread event records have been deleted due to overflow by comparing it to the sequence number of the previously read event record.

The slave keeps track of which event record is currently the oldest unread. The master can continue reading event records for as long as Status register 3 indicates that there are unread records.

- Special case 1: If there are no unread event records, the contents of the last read record is returned. If the buffer is empty, however, the registers contain only zeros. This is the only time when sequence number zero appears.
- Special case 2: If the master tries to read the next unread event record without entering selection code 1 again, the contents of the last read record is returned.

Selection code 2: reading the oldest stored record

By resetting the read pointer using selection code 2, the master can read the oldest stored event record. After this, the master can continue reading the following records using selection code 1, irrespective of whether they have been read before.



Resetting the read pointer does not affect the sequence number of the event record.

Selection code -1...-99

With selection code -1...-99, the master can move backwards from the newest event as many events as defined by the selection code and read that specific event record. After this, the master can continue reading the following records using selection code 1, irrespective of whether they have been read before.

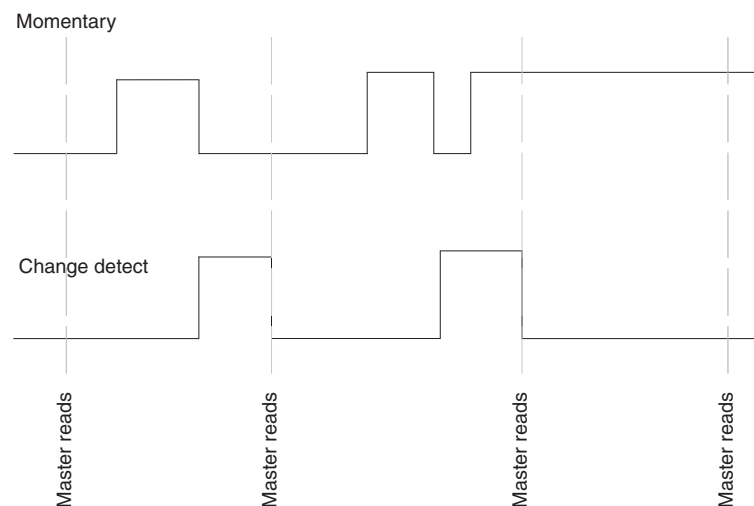
- Special case: If there is not as many events in the buffer as specified by the selection code, the oldest stored event is read.

Selection code 3

The Modbus event buffer is cleared with selection code 3. Clearing the buffer does not require any read operation to follow.

Digital inputs

As the master may not detect the state changes of all digital signals when scanning, an additional change detect (CD) indication bit is created for every momentary indication point; see the example below.



A040332

Fig. 5.1.15.1.-1 Change detection bit

If the momentary value of an indication bit has changed two or more times since the master last read it, the CD bit is set to one. When the CD bit has been read, it is set to zero.

The momentary and the CD bit of a certain indication point always occur as a pair in the Modbus memory map.

Modbus data mapping

There are two types of monitoring data: digital indications and measurands. For convenience and efficiency, the same data can be read from different data areas. Measurands and other 16-bit values can be read either from the IR or HR (read-only) area and digital indication values from either the DI or coil (read-only) area. It is also possible to read the status of the DIs as packed 16-bit registers from both the IR and the HR area.

Consequently, all monitoring data can be read as consecutive blocks of data from the IR or HR area.

The register and bit addresses are presented in the tables below. Some register structures are presented in separate sections below.



The HR and IR values are unsigned 16-bit integers unless otherwise specified.

Table 5.1.15.1.-5 Mapping of Modbus data: user-defined registers

Description	HR/IR address (.bit)	DI/Coil bit address	Writeable	Value range	Comment
UDR 1	1 or 385				
UDR 2	2 or 386				
UDR 3	3 or 387				
UDR 4	4 or 388				
UDR 5	5 or 389				
UDR 6	6 or 390				
UDR 7	7 or 391				
UDR 8	8 or 392				
UDR 9	9 or 393				
UDR 10	10 or 394				
UDR 11	11 or 395				
UDR 12	12 or 396				
UDR 13	13 or 397				
UDR 14	14 or 398				
UDR 15	15 or 399				
UDR 16	16 or 400				

Table 5.1.15.1.-6 Mapping of Modbus data: status registers

Description	HR/IR address (.bit)	DI/Coil bit address	Writeable	Value range	Comment
Status register 1	401			IRF code	See Structure 1
Status register 2	402			Warning codes	See Structure 1
Status register 3	403				See Structure 1

Table 5.1.15.1-7 Mapping of Modbus data: analog data

Description	HR/IR address (.bit)	DI/Coil bit address	Writeable	Value range	Comment
Phase current $I_{L1} \times I_n$	404			0...5000	$0...50 \times I_n$
Phase current $I_{L2} \times I_n$	405			0...5000	$0...50 \times I_n$
Phase current $I_{L3} \times I_n$	406			0...5000	$0...50 \times I_n$
Earth-fault current $\times I_n$	407			0...20000	$0...2000\% I_n$
Phase unbalance ΔI	408			0...100	$0...100\%$

Table 5.1.15.1-8 Mapping of Modbus data: digital data

Description	HR/IR address (.bit)	DI/Coil bit address	Writeable	Value range	Comment
Start signal from stage I>	409.00	1		0/1	1 = activated
Start signal from stage I> CD	409.01	2			
Trip signal from stage I>	409.02	3		0/1	1 = activated
Trip signal from stage I> CD	409.03	4			
Start signal from stage I>>	409.04	5		0/1	1 = activated
Start signal from stage I>> CD	409.05	6			
Trip signal from stage I>>	409.06	7		0/1	1 = activated
Trip signal from stage I>> CD	409.07	8			
Start signal from stage I>>>	409.08	9		0/1	1 = activated
Start signal from stage I>>> CD	409.09	10			
Trip signal from stage I>>>	409.10	11		0/1	1 = activated
Trip signal from stage I>>> CD	409.11	12			
Start signal from stage I ₀ >	409.12	13		0/1	1 = activated
Start signal from stage I ₀ > CD	409.13	14			
Trip signal from stage I ₀ >	409.14	15		0/1	1 = activated
Trip signal from stage I ₀ > CD	409.15	16			
Start signal from stage I ₀ >>	410.00	17		0/1	1 = activated
Start signal from stage I ₀ >> CD	410.01	18			
Trip signal from stage I ₀ >>	410.02	19		0/1	1 = activated
Trip signal from stage I ₀ >> CD	410.03	20			
Start signal from stage ΔI >	410.04	21		0/1	1 = activated
Start signal from stage ΔI > CD	410.05	22			
Trip signal from stage ΔI >	410.06	23		0/1	1 = activated
Trip signal from stage ΔI > CD	410.07	24			
Start signal from stage θ >	410.08	25		0/1	1 = activated
Start signal from stage θ > CD	410.09	26			
Alarm signal from stage θ >	410.10	27		0/1	1 = activated
Alarm signal from stage θ > CD	410.11	28			
Trip signal from stage θ >	410.12	29		0/1	1 = activated
Trip signal from stage θ > CD	410.13	30			
Trip signal from stage ARC (light and current)	410.14	31		0/1	1 = activated
Trip signal from stage ARC (light and current) CD	410.15	32			

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Description	HR/IR address (.bit)	DI/Coil bit address	Writeable	Value range	Comment
Trip signal from stage ARC (light and DI)	411.00	33		0/1	1 = activated
Trip signal from stage ARC (light and DI) CD	411.01	34			
Light signal output	411.02	35		0/1	1 = activated
Light signal output CD	411.03	36			
Trip lockout signal	411.04	37		0/1	1 = activated
Trip lockout signal CD	411.05	38			
External trip signal	411.06	39		0/1	1 = activated
External trip signal CD	411.07	40			
CBFP	411.08	41		0/1	1 = failure
CBFP CD	411.09	42			
Shot 1	411.10	43		0/1	1 = initiated
Shot 1 CD	411.11	44			
Shot 2	411.12	45		0/1	1 = initiated
Shot 2 CD	411.13	46			
Shot 3	411.14	47		0/1	1 = initiated
Shot 3 CD	411.15	48			
CB position	412.00	49		0/1	1 =closed 0 = open
CB position CD	412.01	50			
Definite trip alarm signal	412.02	51		0/1	1 = activated
Definite trip alarm signal CD	412.03	52			
AR lockout signal	412.04	53		0/1	1 = activated
AR lockout signal CD	412.05	54			
Open CB command	412.06	55		0/1	1 = activated
Open CB command CD	412.07	56			
Close CB command	412.08	57		0/1	1 = activated
Close CB command CD	412.09	58			
CB reclosing failed signal	412.10	59		0/1	1 = activated
CB reclosing failed signal CD	412.11	60			
CB reclosing inhibited	412.12	61		0/1	1 = activated
CB reclosing inhibited CD	412.13	62			
AR cancelled	412.14	63		0/1	1 = activated
AR cancelled CD	412.15	64			
PO1	413.00	65		0/1	1 = activated
PO1 CD	413.01	66			
PO2	413.02	67		0/1	1 = activated
PO2 CD	413.03	68			
PO3	413.04	69		0/1	1 = activated
PO3 CD	413.05	70			
SO1	413.06	71		0/1	1 = activated
SO1 CD	413.07	72			
SO2	413.08	73		0/1	1 = activated

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Description	HR/IR address (.bit)	DI/Coil bit address	Writeable	Value range	Comment
SO2 CD	413.09	74			
SO3	413.10	75		0/1	1 = activated
SO3 CD	413.11	76			
SO4	413.12	77		0/1	1 = activated
SO4 CD	413.13	78			
SO5	413.14	79		0/1	1 = activated
O5 CD	413.15	80			
D11	414.00	81		0/1	1 = activated
D11 CD	414.01	82			
D12	414.02	83		0/1	1 = activated
D12 CD	414.03	84			
D13	414.04	85		0/1	1 = activated
D13 CD	414.05	86			
D14	414.06	87		0/1	1 = activated
D14 CD	414.07	88			
D15	414.08	89		0/1	1 = activated
D15 CD	414.09	90			
Disturbance recorder	414.10	91		0/1	1 = triggered 0 = cleared
Disturbance recorder CD	414.11	92			
HMI Setting password	414.12	93		0/1	1 = opened 0 = closed
HMI Setting password CD	414.13	94			
IRF	414.14	95		0/1	1 = activated
IRF CD	414.15	96			
Warning	415.00	97		0/1	1 = activated
Warning CD	415.01	98			
SPA event overflow	415.02	99			
SPA event overflow CD	415.03	100			Only the CD bit will be activated in case of overflow.
HMI Communication password	415.04	101		0/1	1 = opened 0 = closed
HMI Communication password CD	415.05	102			

Table 5.1.15.1.-9 Mapping of Modbus data: recorded data

Description	HR/IR address (.bit)	DI/Coil bit address	Writeable	Value range	Comment
Fault record	601...628				See Structure 2
Event record	671...679				See Structure 3

Table 5.1.15.1.-10 Mapping of Modbus data: relay identification

Description	HR/IR address (.bit)	DI/Coil bit address	Writeable	Value range	Comment
Type designation of the relay	701...708				ASCII chars, 2 chars/register

Table 5.1.15.1.-11 Mapping of Modbus data: real-time clock

Description	HR/IR address (.bit)	DI/Coil bit address	Writeable	Value range	Comment
Time reading and setting	721...727		W		See Structure 4

Table 5.1.15.1.-12 Mapping of Modbus data: additional analog data

Description	HR/IR address (.bit)	DI/Coil bit address	Writeable	Value range	Comment
Thermal level	801			0...106	%
One-minute demand value	802			0...5000	$0...50 \times I_n$
Demand value during the specified time range	803			0...5000	$0...50 \times I_n$
Maximum one-minute demand value during the specified time range	804			0...5000	$0...50 \times I_n$
Stage/phase which caused the trip	805 HI word 806 LO word			0...131071	See Table 5.1.17.-3
Trip indication code	807			0...21	See Table 5.1.17.-3
Number of starts of stage I>	808			0...999	Counter
Number of starts of stage I>>	809			0...999	Counter
Number of starts of stage I>>>	810			0...999	Counter
Number of starts of stage I ₀ >	811			0...999	Counter
Number of starts of stage I ₀ >>	812			0...999	Counter
Number of starts of stage ΔI>	813			0...999	Counter
Number of trips of stage I>	814			0...65535	Counter
Number of trips of stage I>>	815			0...65535	Counter
Number of trips of stage I>>>	816			0...65535	Counter
Number of trips of other stages	817			0...65535	Counter
Number of AR shots (shot 1) initiated by the trip signal from stage I>>	818			0...255	Counter
Number of AR shots (shot 1) initiated by the digital input signal	819			0...255	Counter
Number of AR shots (shot 1) initiated by the start or trip signal from stage I>	820			0...255	Counter
Number of AR shots (shot 1) initiated by the start or trip signal from stage I ₀ >	821			0...255	Counter
Number of AR shots (shot 2) initiated by the trip signal from stage I>>	822			0...255	Counter
Number of AR shots (shot 2) initiated by the digital input signal	823			0...255	Counter
Number of AR shots (shot 2) initiated by the start or trip signal from stage I>	824			0...255	Counter

Description	HR/IR address (.bit)	DI/Coil bit address	Writeable	Value range	Comment
Number of AR shots (shot 2) initiated by the start or trip signal from stage I ₀ >	825			0...255	Counter
Number of AR shots (shot 3) initiated by the trip signal from stage I>>	826			0...255	Counter
Number of AR shots (shot 3) initiated by the digital input signal	827			0...255	Counter
Number of AR shots (shot 3) initiated by the start or trip signal from stage I>	828			0...255	Counter
Number of AR shots (shot 3) initiated by the start or trip signal from stage I ₀ >	829			0...255	Counter

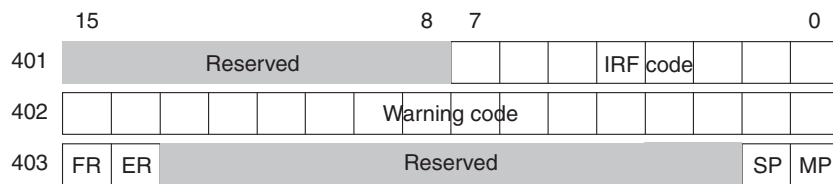
Table 5.1.15.1.-13 Mapping of Modbus data: control points

Description	HR/IR address (.bit)	DI/Coil bit address	Writeable	Value range	Comment
LED reset		501	W	1	1 = LED reset ^{a)}

^{a)} Coil area, only writeable.

Structure 1

The status registers contain information on unread fault and event records, and relay status. The registers are arranged as in Fig. 5.1.15.1.-2 below.



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Fig. 5.1.15.1.-2 Status registers

When the value of the FR/ER bit is 1, there is one or several unread fault/event records. If time synchronization is realized via a digital input, either the SP (second-pulse) or MP (minute-pulse) bit will be activated.

Refer to Table 5.1.18.-1 for IRF codes and Table 5.1.18.-2 for warning codes.

Structure 2

This structure contains data recorded during a fault sequence. Refer to Fault records earlier in this section for the reading method.

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Table 5.1.15.1.-14 Fault record

Address	Signal name	Range	Comment
601	Latest selection code ^{a)}	1...2	1 = read oldest unread record 2 = read oldest stored record
602	Sequence number	1...255	
603	Unread records left	0...6	
604	Time stamp of the recorded data, date		2 bytes: YY.MM
605	Time stamp of the recorded data, date and time		2 bytes: DD.HH
606	Time stamp of the recorded data, time		2 bytes: MM.SS
607	Time stamp of the recorded data, time	0...999	0...999 ms
608	Phase current I_{L1}	0...5000	0...50 x I_n
609	Phase current I_{L2}	0...5000	0...50 x I_n
610	Phase current I_{L3}	0...5000	0...50 x I_n
611	Earth-fault current	0...20000	0...2000% I_n
612	Phase discontinuity	0...100	0...100%
613	Thermal level at start	0...106	0...106%
614	Thermal level at trip	0...106	0...106%
615	Maximum pickup phase current I_{L1}	0...5000	0...50 x I_n
616	Maximum pickup phase current I_{L2}	0...5000	0...50 x I_n
617	Maximum pickup phase current I_{L3}	0...5000	0...50 x I_n
618	Maximum pickup earth-fault current	0...20000	0...2000% I_n
619	Start duration of stage I>	0...100	0...100%
620	Start duration of stage I>>	0...100	0...100%
621	Start duration of stage I>>>	0...100	0...100%
622	Start duration of stage I ₀ >	0...100	0...100%
623	Start duration of stage I ₀ >>	0...100	0...100%
624	Start duration of stage ΔI>	0...100	0...100%
625	Start duration of external trip	0/100	0/100%
626	Trip number of AR sequence	0...255	
627	Start duration of stage ARC (local)	0/100	0/100%
628	Start duration of stage ARC (remote)	0/100	0/100%

^{a)} Readable and writeable register.

Structure 3

This structure contains Modbus event records. Refer to Event records earlier in this section for the reading method.

Table 5.1.15.1.-15 Event record

Address	Signal name	Range	Comment
671	Latest selection code ^{a)}	1...3 -1...-99	1 = read oldest unread record 2 = read oldest stored record 3 = clear Modbus event buffer -1...-99 = move to the nth newest record
672	Sequence number	1...255	

Address	Signal name	Range	Comment
673	Unread records left	0...99	
674	Time stamp of the event, date		2 bytes: YY.MM
675	Time stamp of the event, date and time		2 bytes: DD.HH
676	Time stamp of the event, time		2 bytes: MM.SS
677	Time stamp of the event, time	0...999	0...999 ms
678	Modbus DI point or informative event (SPA channel) • DI event • Informative event	0/1 0 1	When MSB = 0, bits 14...0 indicate the DI point. When MSB = 1, bits 14...0 indicate the SPA channel.
679	DI value or SPA event code • DI event • Informative event	0/1 0...63	In case of a DI event, the register will contain the DI value. In case of an informative event, the register will contain the SPA event code.

^{a)} Readable and writeable register.

Structure 4

The relay's real-time clock is stored in this structure. It can be updated by presetting the whole register structure in one Modbus transaction.

Table 5.1.15.1-16 Real-time clock structure

Address	Description	Range
721	Year	0...99
722	Month	1...12
723	Day	1...31
724	Hour	0...23
725	Minute	0...59
726	Second	0...59
727	Hundredth of a second	0...99

5.1.16.

DNP 3.0 remote communication protocol

The DNP 3.0 protocol was developed by Harris Control based on the early versions of the IEC 60870-5 standard telecontrol protocol specifications. Today, the DNP protocol specifications are controlled by the DNP Users Group.

The DNP protocol supports the ISO OSI (Open System Interconnection) based model, which only specifies physical, data link and application layers. This reduced protocol stack is referred to as Enhanced Performance Architecture (EPA). To support advanced RTU functions and messages larger than the maximum frame length as defined in the IEC 60870-1, the DNP 3.0 Data Link is to be used with a transport pseudo-layer. As a minimum, the transport pseudo-layer implements message assembly and disassembly services.

5.1.16.1. Protocol parameters

The DNP parameters can all be adjusted using Relay Setting Tool. For the DNP parameters, refer to Table 5.1.17.-14.

Storing DNP 3.0 parameters

All DNP parameters are stored on the external DNP 3.0 module. After parameterization with Relay Setting Tool, REF610 must be switched to the rear communication mode for at least 10 seconds in order for the DNP parameters to be replicated and stored onto the DNP module. However, this is necessary only if the DNP parameters have been altered.

5.1.16.2. DNP 3.0 point list

The DNP data points (binary, analog and counters) of the relay, presented in Table 5.1.16.2.-1...Table 5.1.16.2.-3, are all in use as default.

The default class settings of the DNP points within the different event object groups are:

- Binary inputs change events: class 1
- Analog inputs change events: class 2
- Counter change events: class 3

All static data points belong to class 0.

Unsolicited reporting is enabled for all event objects as default. However, the point-specific enable/disable parameters are meaningless unless unsolicited reporting has been enabled with SPA parameter 503V24.

The pointers to the scaling factors for analog objects are all 0 as default. Consequently, the DNP and Modbus analog values of the relay are identical as default.

All DNP process points can be edited using Relay Setting Tool. Editing features include:

- Re-organizing, adding and removing DNP points
- Assigning event classes to specific DNP points
- DNP point-specific enabling/disabling of unsolicited reporting
- Defining deadbands for event reporting
- Defining scaling factors for analog values

Table 5.1.16.2.-1 Binary data

Description	DNP point address	Event class	UR enable	Value range	Comment
Start signal from stage I>	0	1	1	0/1	1 = activated
Trip signal from stage I>	1	1	1	0/1	1 = activated
Start signal from stage I>>	2	1	1	0/1	1 = activated
Trip signal from stage I>>	3	1	1	0/1	1 = activated
Start signal from stage I>>>	4	1	1	0/1	1 = activated
Trip signal from stage I>>>	5	1	1	0/1	1 = activated
Start signal from stage I ₀ >	6	1	1	0/1	1 = activated
Trip signal from stage I ₀ >	7	1	1	0/1	1 = activated
Start signal from stage I ₀ >>	8	1	1	0/1	1 = activated
Trip signal from stage I ₀ >>	9	1	1	0/1	1 = activated
Start signal from stage ΔI>	10	1	1	0/1	1 = activated
Trip signal from stage ΔI>	11	1	1	0/1	1 = activated
Start signal from stage θ>	12	1	1	0/1	1 = activated
Alarm signal from stage θ>	13	1	1	0/1	1 = activated
Trip signal from stage θ>	14	1	1	0/1	1 = activated
Trip signal from stage ARC (light and current)	15	1	1	0/1	1 = activated
Trip signal from stage ARC (DI and current)	16	1	1	0/1	1 = activated
Light signal output	17	1	1	0/1	1 = detected
Trip lockout signal	18	1	1	0/1	1 = activated
External trip signal	19	1	1	0/1	1 = activated
CBFP	20	1	1	0/1	1 = failure
Shot 1	21	1	1	0/1	1 = initiated
Shot 2	22	1	1	0/1	1 = initiated
Shot 3	23	1	1	0/1	1 = initiated
CB position	24	1	1	0/1	1 = closed
Definite trip alarm signal	25	1	1	0/1	1 = activated
AR lockout signal	26	1	1	0/1	1 = activated
Open CB command	27	1	1	0/1	1 = activated
Close CB command	28	1	1	0/1	1 = activated
CB reclosing failed signal	29	1	1	0/1	1 = activated
CB reclosing inhibited	30	1	1	0/1	1 = activated
AR cancelled	31	1	1	0/1	1 = activated
PO1	32	1	1	0/1	1 = activated
PO2	33	1	1	0/1	1 = activated
PO3	34	1	1	0/1	1 = activated
SO1	35	1	1	0/1	1 = activated
SO2	36	1	1	0/1	1 = activated
SO3	37	1	1	0/1	1 = activated
SO4	38	1	1	0/1	1 = activated
SO5	39	1	1	0/1	1 = activated
DI1	40	1	1	0/1	1 = activated

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Description	DNP point address	Event class	UR enable	Value range	Comment
DI2	41	1	1	0/1	1 = activated
DI3	42	1	1	0/1	1 = activated
DI4	43	1	1	0/1	1 = activated
DI5	44	1	1	0/1	1 = activated
Disturbance recorder	45	1	1	0/1	1 = triggered 0 = cleared
HMI Setting password	46	1	1	0/1	1 = opened 0 = closed
IRF	47	1	1	0/1	1 = activated
Warning	48	1	1	0/1	1 = activated
SPA event overflow	49	1	1	0/1	1 = activated
HMI Communication password	50	1	1	0/1	1 = opened 0 = closed

Table 5.1.16.2-2 Analog data

Description	DNP point address	Event class	UR enable	Deadband	Value range	Internal scaling factor (ix = 0)
Phase current $I_{L1} \times I_n$	0	2	1	1	0...5000	100
Phase current $I_{L2} \times I_n$	1	2	1	1	0...5000	100
Phase current $I_{L3} \times I_n$	2	2	1	1	0...5000	100
Earth-fault current $x I_n$	3	2	1	1	0...20000	10
Phase unbalance	4	2	1	1	0...100	100
Thermal level	5	2	1	1	0...106	100
One-minute demand value	6	2	1	1	0...5000	100
Demand value during the specified time range	7	2	1	1	0...5000	100
Maximum one-minute demand value during the specified time range	8	2	1	1	0...5000	100

Table 5.1.16.2-3 Counters

Description	DNP point address	Event class	UR enable	Deadband	Value range
Number of starts of stage I>	0	3	1	1	0...999
Number of starts of stage I>>	1	3	1	1	0...999
Number of starts of stage I>>>	2	3	1	1	0...999
Number of starts of stage I ₀ >	3	3	1	1	0...999
Number of starts of stage I ₀ >>	4	3	1	1	0...999
Number of starts of stage ΔI>	5	3	1	1	0...999
Number of trips of stage I>	6	3	1	1	0...65535
Number of trips of stage I>>	7	3	1	1	0...65535
Number of trips of stage I>>>	8	3	1	1	0...65535
Number of trips of other stages	9	3	1	1	0...65535
Number of AR shots (shot 1) initiated by the trip signal from stage I>>	10	3	1	1	0...255

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Description	DNP point address	Event class	UR enable	Deadband	Value range
Number of AR shots (shot 1) initiated by the digital input signal	11	3	1	1	0...255
Number of AR shots (shot 1) initiated by the start or trip signal from stage I>	12	3	1	1	0...255
Number of AR shots (shot 1) initiated by the start or trip signal from stage I ₀ >	13	3	1	1	0...255
Number of AR shots (shot 2) initiated by the trip signal from stage I>>	14	3	1	1	0...255
Number of AR shots (shot 2) initiated by the digital input signal	15	3	1	1	0...255
Number of AR shots (shot 2) initiated by the start or trip signal from stage I>	16	3	1	1	0...255
Number of AR shots (shot 2) initiated by the start or trip signal from stage I ₀ >	17	3	1	1	0...255
Number of AR shots (shot 3) initiated by the trip signal from stage I>>	18	3	1	1	0...255
Number of AR shots (shot 3) initiated by the digital input signal	19	3	1	1	0...255
Number of AR shots (shot 3) initiated by the start or trip signal from stage I>	20	3	1	1	0...255
Number of AR shots (shot 3) initiated by the start or trip signal from stage I ₀ >	21	3	1	1	0...255

5.1.16.3.

DNP 3.0 device profile

DNP V3.00	
DEVICE PROFILE DOCUMENT	
Vendor Name: ABB Oy, Distribution Automation, Vaasa, Finland	
Device Name: REF610	
Highest DNP Level Supported For Requests L ₂	Device Function <input checked="" type="checkbox"/> Slave
For Responses L ₂	
Notable objects, functions, and/or qualifiers supported in addition to the Highest DNP Levels Supported (the complete list is described in the attached table): Additions to level 2 are marked as shaded in the implementation table	
Maximum Data Link Frame Size (octets) Transmitted 292 Received 292	Maximum Application Fragment Size (octets) Transmitted 2048 Received 2048
Maximum Data Link Re-tries: Configurable, range from 0 to 255 with primary data link layer retransmission count	Maximum Application Layer Re-tries: Configurable, range from 0 to 255 with application layer retransmission count
Requires Data Link Layer Confirmation: Configurable, with confirmation type selector, default NO ACK	
Requires Application Layer Confirmation <input checked="" type="checkbox"/> Configurable with confirmation type selector when reporting Event Data (Slave devices only) <input checked="" type="checkbox"/> Always after response to reset request	

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<input type="checkbox"/> Always when sending multi-fragment responses (Slave devices only) <input checked="" type="checkbox"/> Configurable, with confirmation type selector																					
Timeouts while waiting for: <table border="0"> <tr> <td>Data Link Confirm</td> <td>Configurable with primary data link layer timeout, not relevant when NO ACK</td> </tr> <tr> <td>Complete Appl. Fragment</td> <td>No, multi-fragment application frames not supported</td> </tr> <tr> <td>Application Confirm</td> <td>Configurable with application layer timeout</td> </tr> <tr> <td>Complete Appl. Response</td> <td>No, not relevant in slave</td> </tr> </table>		Data Link Confirm	Configurable with primary data link layer timeout, not relevant when NO ACK	Complete Appl. Fragment	No, multi-fragment application frames not supported	Application Confirm	Configurable with application layer timeout	Complete Appl. Response	No, not relevant in slave												
Data Link Confirm	Configurable with primary data link layer timeout, not relevant when NO ACK																				
Complete Appl. Fragment	No, multi-fragment application frames not supported																				
Application Confirm	Configurable with application layer timeout																				
Complete Appl. Response	No, not relevant in slave																				
Sends/Executes Control Operations <table border="0"> <tr><td>WRITE Binary Outputs</td><td><input checked="" type="checkbox"/> Never</td></tr> <tr><td>SELECT/OPERATE</td><td><input checked="" type="checkbox"/> Never</td></tr> <tr><td>DIRECT OPERATE</td><td><input checked="" type="checkbox"/> Never</td></tr> <tr><td>DIRECT OPERATE - NO ACK</td><td><input checked="" type="checkbox"/> Never</td></tr> <tr><td>Count</td><td><input checked="" type="checkbox"/> Never</td></tr> <tr><td>Code</td><td><input checked="" type="checkbox"/> Never</td></tr> <tr><td>Trip/Close</td><td><input checked="" type="checkbox"/> Never</td></tr> <tr><td>Pulse On</td><td><input checked="" type="checkbox"/> Never</td></tr> <tr><td>Queue</td><td><input checked="" type="checkbox"/> Never</td></tr> <tr><td>Clear Queue</td><td><input checked="" type="checkbox"/> Never</td></tr> </table>		WRITE Binary Outputs	<input checked="" type="checkbox"/> Never	SELECT/OPERATE	<input checked="" type="checkbox"/> Never	DIRECT OPERATE	<input checked="" type="checkbox"/> Never	DIRECT OPERATE - NO ACK	<input checked="" type="checkbox"/> Never	Count	<input checked="" type="checkbox"/> Never	Code	<input checked="" type="checkbox"/> Never	Trip/Close	<input checked="" type="checkbox"/> Never	Pulse On	<input checked="" type="checkbox"/> Never	Queue	<input checked="" type="checkbox"/> Never	Clear Queue	<input checked="" type="checkbox"/> Never
WRITE Binary Outputs	<input checked="" type="checkbox"/> Never																				
SELECT/OPERATE	<input checked="" type="checkbox"/> Never																				
DIRECT OPERATE	<input checked="" type="checkbox"/> Never																				
DIRECT OPERATE - NO ACK	<input checked="" type="checkbox"/> Never																				
Count	<input checked="" type="checkbox"/> Never																				
Code	<input checked="" type="checkbox"/> Never																				
Trip/Close	<input checked="" type="checkbox"/> Never																				
Pulse On	<input checked="" type="checkbox"/> Never																				
Queue	<input checked="" type="checkbox"/> Never																				
Clear Queue	<input checked="" type="checkbox"/> Never																				
FILL OUT THE FOLLOWING ITEMS FOR SLAVE DEVICES ONLY:																					
Reports Digital Input Change Events when no specific variation requested <input type="checkbox"/> Never <input type="checkbox"/> Only time-tagged <input type="checkbox"/> Only non-time-tagged <input checked="" type="checkbox"/> Configurable to send both, one or the other (depends on default variation)	Reports time-tagged Digital Input Change Events when no specific variation requested <input type="checkbox"/> Never <input checked="" type="checkbox"/> Binary Input Change With Time <input type="checkbox"/> Binary Input Change With Relative Time <input type="checkbox"/> Configurable, depends on objects basic variation (variation used at initialization)																				
Sends Unsolicited Responses <input type="checkbox"/> Never <input checked="" type="checkbox"/> Configurable <input type="checkbox"/> Only certain objects <input type="checkbox"/> Sometimes (attach explanation) <input checked="" type="checkbox"/> ENABLE/DISABLE UNSOLICITED Function codes supported	Sends Static Data in Unsolicited Responses <input checked="" type="checkbox"/> Never <input type="checkbox"/> When Device Restarts <input type="checkbox"/> When Status Flags Change No other options are permitted.																				
Default Counter Object/Variation <input type="checkbox"/> No Counters Reported <input type="checkbox"/> Configurable, default object and variation <input checked="" type="checkbox"/> Default Object 20 Default Variation 2 <input type="checkbox"/> Point-by-point list attached	Counters Roll Over at <input type="checkbox"/> No Counters Reported <input type="checkbox"/> Configurable (attach explanation) <input checked="" type="checkbox"/> 16 Bits (Counters 6...9) <input type="checkbox"/> 32 Bits, but roll-over bits not used																				

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	<input checked="" type="checkbox"/> Other value: 999 (Counters 0...5) and 255 (Counters 10...21) <input type="checkbox"/> Point-by-point list attached
Sends Multi-Fragment Responses	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No

Table 5.1.16.3.-1 Supported function codes

Code	Function	Description	Supported
Transfer Function Codes			
0	Confirm	Message fragment confirmation No response	Yes
1	Read	Request objects from outstation Respond with requested objects	Yes
2	Write	Store specified objects to outstation Respond with status of operation	Yes
Control Function Codes			
3	Select	Select output point of outstation Respond with status of control point	No
4	Operate	Set previously selected output Respond with status of control point	No
5	Direct operate	Set output directly Respond with status of control point	No
6	Direct operate NO ACK	Set output directly No response	No
Freeze Function Codes			
7	Immediate Freeze	Copy specified objects to freeze buffer Respond with status of operation	Yes
8	Immediate Freeze NO ACK	Copy specified objects to freeze buffer No response	Yes
9	Freeze and Clear	Copy specified objects to freeze buffer and clear objects Respond with status of operation	Yes ^{a)}
10	Freeze and Clear NO ACK	Copy specified objects to freeze buffer and clear objects No response	Yes ^{a)}
11	Freeze with time	Copy specified objects to freeze buffer at specified time Respond with status of operation	No
12	Freeze with time NO ACK	Copy specified objects to freeze buffer at specified time No response	No
Application Control Function Codes			
13	Cold Restart	Perform desired reset sequence Respond with a time object	Yes
14	Warm Restart	Perform desired partial reset operation Respond with a time object	Yes
15	Initialize Data to Defaults	Initialize the specified data to default Respond with status of operation	No
16	Initialize Application	Set the specified application ready to be run Respond with status of operation	No
17	Start Application	Start the specified application to run Respond with status of operation	Yes
18	Stop Application	Stop the specified application to run Respond with status of operation	Yes
Configuration Function Codes			

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Code	Function	Description	Supported
19	Save configuration	Save configuration Respond with status of operation	No
20	Enable Unsolicited Messages	Enable Unsolicited Messages Respond with status of operation	Yes
21	Disable Unsolicited Messages	Disable Unsolicited Messages Respond with status of operation	Yes
22	Assign Class	Assign specified objects to a class Respond with status of operation	Yes
Time Synchronization Function Codes			
23	Delay Measurement	Perform propagation delay measurement	Yes
Response Function Codes			
0	Confirm	Message fragment confirmation	Yes
129	Response	Response to request message	Yes
130	Unsolicited Message	Spontaneous message without request	Yes

a) Counters of the relay cannot be cleared by using the DNP 3.0 protocol.

Table 5.1.16.3.-2 Supported objects

OBJECT			REQUEST (slave must parse)		RESPONSE (master must parse)	
Object group	Variation	Description	Function codes (dec)	Qualifier codes (hex)	Function codes (dec)	Qualifier codes (hex)
1	0	Binary Input, all variations	1, 20, 21, 22	00, 01, 06, 07, 08, 17, 28	129	00, 01, 17, 28
1	1	Binary Input	1, 20, 21, 22	00, 01, 06, 07, 08, 17, 28	129	00, 01, 17, 28
1	2	Binary Input with Status	1, 20, 21, 22,	00, 01, 06, 07, 08 17, 28	129	00, 01, 17, 28
2	0	Binary Input Change, all variation	1	06, 07, 08		
2	1	Binary Input Change without Time	1	06, 07, 08	129, 130	17, 28
2	2	Binary Input Change with Time	1	06, 07, 08	129, 130	17, 28
2	3	Binary Input Change with Relative Time				
10	0	Binary Output, all variations				
10	1	Binary Output				
10	2	Binary Output with Status				
12	0	Control Block, all variations				
12	1	Control Relay Output Block				
12	2	Pattern Control Block				
12	3	Pattern Mask				
20	0	Binary Counter, all variations	1, 7, 8, 20, 21, 22	00, 01, 06, 07, 08, 17, 28	129	00, 01, 17, 28
20	1	32-Bit Binary Counter	1, 7, 8, 20, 21, 22	00, 01, 06, 07, 08, 17, 28	129	00, 01, 17, 28
20	2	16-Bit Binary Counter	1, 7, 8, 20, 21, 22	00, 01, 06, 07, 08, 17, 28	129	00, 01, 17, 28
20	3	32-Bit Delta Counter				
20	4	16-Bit Delta Counter				

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OBJECT			REQUEST (slave must parse)		RESPONSE (master must parse)	
Object group	Variation	Description	Function codes (dec)	Qualifier codes (hex)	Function codes (dec)	Qualifier codes (hex)
20	5	32-Bit Binary Counter without Flag				
20	6	16-Bit Binary Counter without Flag				
20	7	32-Bit Delta Counter without Flag				
20	8	16-Bit Delta Counter without Flag				
21	0	Frozen Counter, all variations	1	00, 01, 06, 07, 08, 17, 28	129	00, 01, 17, 28
21	1	32-Bit Frozen Counter	1	00, 01, 06, 07, 08, 17, 28	129	00, 01, 17, 28
21	2	16-Bit Frozen Counter	1	00, 01, 06, 07, 08, 17, 28	129	00, 01, 17, 28
21	3	32-Bit Frozen Delta Counter				
21	4	16-Bit Frozen Delta Counter				
21	5	32-Bit Frozen Counter with Time of Freeze	1	00, 01, 06, 07, 08, 17, 28	129	00, 01, 17, 28
21	6	16-Bit Frozen Counter with Time of Freeze	1	00, 01, 06, 07, 08, 17, 28	129	00, 01, 17, 28
21	7	32-Bit Frozen Delta Counter with Time of Freeze				
21	8	16-Bit Frozen Delta Counter with Time of Freeze				
21	9	32-Bit Frozen Counter without Flag				
21	10	16-Bit Frozen Counter without Flag				
21	11	32-Bit Frozen Delta Counter without Flag				
21	12	16-Bit Frozen Delta Counter without Flag				
22	0	Counter Change Event, all variations	1	06, 07, 08	129, 130	17, 28
22	1	32-Bit Counter Change Event without Time	1	06, 07, 08	129, 130	17, 28
22	2	16-Bit Counter Change Event without Time	1	06, 07, 08	129, 130	17, 28
22	3	32-Bit Delta Counter Change Event without Time				
22	4	16-Bit Delta Counter Change Event without Time				
22	5	32-Bit Counter Change Event with Time	1	06, 07, 08	129, 130	17, 28
22	6	16-Bit Counter Change Event with Time	1	06, 07, 08	129, 130	17, 28
22	7	32-Bit Delta Counter Change Event with Time				
22	8	16-Bit Delta Counter Change Event with Time				
23	0	Frozen Counter Event, all variations				

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OBJECT			REQUEST (slave must parse)		RESPONSE (master must parse)	
Object group	Variation	Description	Function codes (dec)	Qualifier codes (hex)	Function codes (dec)	Qualifier codes (hex)
23	1	32-Bit Frozen Counter Event without Time				
23	2	16-Bit Frozen Counter Event without Time				
23	3	32-Bit Frozen Delta Counter Event without Time				
23	4	16-Bit Frozen Delta Counter Event without Time				
23	5	32-Bit Frozen Counter Event with Time				
23	6	16-Bit Frozen Counter Event with Time				
23	7	32-Bit Frozen Delta Counter Event with Time				
23	8	16-Bit Frozen Delta Counter Event with Time				
30	0	Analog Input, all variations	1, 20, 21, 22	00, 01, 06, 07, 08 17, 28	129	00, 01, 17, 28
30	1	32-Bit Analog Input	1, 20, 21, 22	00, 01, 06, 07, 08 17, 28	129	00, 01, 17, 28
30	2	16-Bit Analog Input	1, 20, 21, 22	00, 01, 06, 07, 08 17, 28	129	00, 01, 17, 28
30	3	32-Bit Analog Input without Flag	1, 20, 21, 22	00, 01, 06, 07, 08 17, 28	129	00, 01, 17, 28
30	4	16-Bit Analog Input without Flag	1, 20, 21, 22	00, 01, 06, 07, 08 17, 28	129	00, 01, 17, 28
31	0	Frozen Analog Input, all variations				
31	1	32-Bit Frozen Analog Input				
31	2	16-Bit Frozen Analog Input				
31	3	32-Bit Frozen Analog Input with Time of Freeze				
31	4	16-Bit Frozen Analog Input with Time of Freeze				
31	5	32-Bit Frozen Analog Input without Flag				
31	6	16-Bit Frozen Analog Input without Flag				
32	0	Analog Change Event, all variations	1	06, 07, 08	129, 130	17, 28
32	1	32-Bit Analog Change Event without Time	1	06, 07, 08	129, 130	17, 28
32	2	16-Bit Analog Change Event without Time	1	06, 07, 08	129, 130	17, 28
32	3	32-Bit Analog Change Event with Time	1	06, 07, 08	129, 130	17, 28
32	4	16-Bit Analog Change Event with Time	1	06, 07, 08	129, 130	17, 28

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OBJECT			REQUEST (slave must parse)		RESPONSE (master must parse)	
Object group	Variation	Description	Function codes (dec)	Qualifier codes (hex)	Function codes (dec)	Qualifier codes (hex)
33	0	Frozen Analog Event, all variations				
33	1	32-Bit Frozen Analog Event without Time				
33	2	16-Bit Frozen Analog Event without Time				
33	3	32-Bit Frozen Analog Event with Time				
33	4	16-Bit Frozen Analog Event with Time				
40	0	Analog Output Status, all variations				
40	1	32-Bit Analog Output Status				
40	2	16-Bit Analog Output Status				
41	0	Analog Output Block, all variations				
41	1	32-Bit Analog Output Block				
41	2	16-Bit Analog Output Block				
50	0	Time and Date, all variations	1	06, 07, 08	129	17, 28
50	1 (def)	Time and Date	1	06, 07, 08	129	17, 28
50	1 (def)	Time and Date	2	06, 07, 08	129	
50	2	Time and Date with Interval				
51	0	Time and Date CTO, all variations				
51	1	Time and Date CTO				
51	2	Unsynchronized Time and Date CTO				
52	0	Time Delay, all variations				
52	1	Time Delay Coarse				
52	2	Time Delay Fine	23	7	129	7
60	0	All classes	1	6	129	28
60	1	Class 0 Data	1	06, 07, 08	129	17, 28
60	2	Class 1 Data	1	06, 07, 08	129	17, 28
60	3	Class 2 Data	1	06, 07, 08	129	17, 28
60	4	Class 3 Data	1	06, 07, 08	129	17, 28
70	1	File Identifier				
80	1	Internal Indications	2	00	129	
81	1	Storage Object				
82	1	Device Profile				
83	1	Private Registration Object				
83	2	Private Registration Object Descriptor				
90	1	Application Identifier				
100	1	Short Floating Point				
100	2	Long Floating Point				

OBJECT			REQUEST (slave must parse)		RESPONSE (master must parse)	
Object group	Variation	Description	Function codes (dec)	Qualifier codes (hex)	Function codes (dec)	Qualifier codes (hex)
100	3	Extended Floating Point				
101	1	Small Packed Binary-Coded Decimal				
101	2	Medium Packed Binary-Coded Decimal				
101	3	Large Packed Binary-Coded Decimal				
		No Object	13, 14			

5.1.16.4. Specific DNP features

Time synchronization

If time synchronization (minute-pulse or second-pulse) of the relay’s real-time clock is realized via a digital input, the following applies to the DNP interface of the relay:

- Depending on the pulse type, either the date-to-minute or the date-to-second information of the DNP time synchronization message is used.
- The relay sends only one request for time synchronization to the DNP master, which is at power up.

Unsolicited reporting start up

Due to implementation differences in DNP master devices, the following alternative unsolicited reporting (SPA parameter 503V24) start ups are available in the relay:

- 1 = Unsolicited reporting starts immediately, without permission from the master.
- 2 = The relay sends an empty unsolicited response message when communication begins, which the master confirms. After this, the relay starts to send unsolicited responses.
- 3 = The relay sends an empty unsolicited response message when communication begins, which the master confirms. After this, the master enables unsolicited reporting for certain or all classes using function 20. Classes which are not enabled remain disabled.



Only the last alternative is compliant with the DNP 3.0 standard.

Event handling

The maximum capacity of the DNP event buffer is 100 events. When unsolicited reporting has been enabled (SPA parameter 503V24), the event reporting uses the following SPA parameters, called send throttle parameters:

503V18	Class 1 Event delay
503V19	Class 1 Event count
503V20	Class 2 Event delay
503V21	Class 2 Event count
503V22	Class 3 Event delay
503V23	Class 3 Event count

Example:

(class 1)

The events are reported when the event delay (SPA parameter 503V18) has elapsed or the defined amount of events (SPA parameter 503V19) are generated for class 1.

If send throttles are not wanted, the event delay should be set to 0 and the event count to 1. In this case, the class events are sent to the host immediately as they occur.

Event buffer overflow

DNP 3.0 event buffer overflow is indicated with the internal indication IIN2.3, as defined by the standard. IIN2.3 can also indicate event buffer overflow in the internal communication between the DNP3.0 module and the main CPU module of the relay. In this case, the relay automatically activates and resets the IIN2.3 bit.

As events have been lost in both cases, the DNP 3.0 master should perform an integrity scan after the IIN2.3 bit has been reset.

DNP counters and frozen counters

DNP counters in use have a corresponding frozen counter. The frozen counters in object group 21 have the same DNP point index as the ordinary DNP counters. Further, frozen counters can only be read as static objects, and frozen counter events (object group 23) are not supported.

Collision avoidance and detection

The relay supports both collision avoidance and detection. Collision detection can be enabled or disabled with SPA parameter 503V235. Collision avoidance occurs before message transmission. When preparing to transmit and the link is busy, the relay first waits until the link becomes idle. After this, a backoff time starts. When the backoff time elapses, the relay checks the link again. If the link is not busy, the relay starts the transmission. The backoff time is calculated as follows:

backoff time = silent interval + random delay

The silent interval is set with SPA parameter 503V232 and the maximum random delay with SPA parameters 503V233 (the width of a single time slot in milliseconds) and 503V234 (the maximum number of time slots). By setting the time-slot width to 10 milliseconds and the maximum number of time slots to 10, for instance, the maximum random delay is 100 milliseconds.



In a network consisting of several slaves, the priority between the devices are defined with SPA parameters 503V233 and 503V234. A device with shorter silent interval and maximum random delay has higher sending priority than a device with longer silent interval and maximum random delay.

Collision detection is always active during transmission (provided that it has been enabled). While sending a message, the relay supervises collisions on the link. If a collision is detected, the transmission is immediately cancelled. After this, the relay tries to transmit the message again, using collision avoidance before sending the message.

Scaling DNP analog values

The DNP analog values can be scaled using either an internal (fixed) or a user-defined scaling factor. If the scaling factor index for a certain analog value is set to 0, the internal scaling factor is used. If set to 1...5, the user-defined scaling factor of the corresponding scaling factor parameter, SPA parameter 503V (100+index), is used:

503V101	Scaling factor 1
503V102	Scaling factor 2
503V103	Scaling factor 3
503V104	Scaling factor 4
503V105	Scaling factor 5

Example:

Phase current I_{L1}	$0.00...50.0 \times I_n$
Internal scaling factor	100
Default DNP range	0...5000

To show the analog value in primary units, and if $I_n = 300$ A and the accuracy of the analog value = 1 A:

1. Take any unused scaling factor and set it to 300.
2. Set the scaling index pointer of the analog value to point at the scaling factor.
3. The value range is now $0.00 \times 300...50.0 \times 300 = 0...15000$ A.

DNP analog values deadband

The deadband is always defined in units of the original value when scaled using the internal (fixed) scaling factor, irrespective of whether the internal scaling factor is used for value presentation or not.

Example:

For a deadband of 2% I_n when the internal scaling factor is 100, the deadband value is set as follows: $0.02 \times 100 = 2$. If the scaling factor is set to 300 A, the scaled deadband is $300 \text{ A} \times 0.02 = 6 \text{ A}$.

5.1.17. SPA bus communication protocol parameters

Altering parameter values via serial communication requires the use of the SPA password in some cases. The password is a user-defined number within the range 1...999, the default value being 001. SPA parameters are found on channels 0...5, 503...504, 507 and 601...603.

To enter the setting mode, enter the password into parameter V160. To exit the setting mode, enter the same password into parameter V161. The password protection is also reactivated in case of loss of auxiliary voltage.

The password can be changed with parameter V162, but it is not possible to read the password via this parameter. Abbreviations used in the following tables:

- R = readable data
- W = writeable data
- P = password protected writeable data

Settings

Table 5.1.17.-1 Settings

Variable	Actual settings (R), channel 0	Group/Channel 1 (R, W, P)	Group/Channel 2 (R, W, P)	Setting range
Start value of stage I>	S1	1S1	2S1	$0.30 \dots 5.00 \times I_n$
Operate time of stage I>	S2	1S2	2S2	0.05...300 s
Time/current characteristic for stage I>	S3	1S3	2S3	0...9
Time multiplier k	S4	1S4	2S4	0.05...1.00
Time multiplier n	S5	1S5	2S5	1.0...15.0
Resetting time of stage I>	S6	1S6	2S6	0.05...2.50 s
Start value of stage I>>	S7 ^{a)}	1S7	2S7	$0.50 \dots 35.0 \times I_n$
Operate time of stage I>>	S8	1S8	2S8	0.04...300 s
Start value of stage I>>>	S9 ^{a)}	1S9	2S9	$0.50 \dots 35.0 \times I_n$
Operate time of stage I>>>	S10	1S10	2S10	0.04...30.0 s
Start value of stage I ₀ >	S11	1S11	2S11	$1.0 \dots 100\% I_n$
Operate time of stage I ₀ >	S12	1S12	2S12	0.05...300 s
Time/current characteristic for stage I ₀ >	S13	1S13	2S13	0...9

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Variable	Actual settings (R), channel 0	Group/Channel 1 (R, W, P)	Group/Channel 2 (R, W, P)	Setting range
Time multiplier k_0	S14	1S14	2S14	0.05...1.00 s
Time multiplier n_0	S15	1S15	2S15	1.0...15.0
Resetting time of stage $I_0>$	S16	1S16	2S16	0.05...2.50
Start value of stage $I_0>>$	S17 ^{a)}	1S17	2S17	5.0...800% I_n
Operate time of stage $I_0>>$	S18	1S18	2S18	0.05...300 s
Start value of value of stage $\Delta I>$	S19 ^{a)}	1S19	2S19	10...100%
Operate time of stage $\Delta I>$	S20	1S20	2S20	1...300 s
Full load current	S21 ^{a)}	1S21	2S21	0.30...1.50 x I_n
Time constant of stage $\theta>$	S22	1S22	2S22	1...200 min
Alarm level of stage $\theta>$	S23	1S23	2S23	50...100% $\theta_t>$
Operate time of CBFP	S24	1S24	2S24	0.10...60.0 s
Number of AR shots	S25	1S25	2S25	0 = AR is not in use 1 = shot 1 2 = shot 1 and 2 3 = shot 1, 2 and 3
Current limit Arc $I>$ of stage ARC	S26 ^{a)b)}	1S26	2S26	0.50...35.0 x I_n
Current limit Arc $I_0>$ of stage ARC	S27 ^{a)b)}	1S27	2S27	5.0...800% I_n
Checksum, SGF 1	S61	1S61	2S61	0...255
Checksum, SGF 2	S62	1S62	2S62	0...127
Checksum, SGF 3	S63	1S63	2S63	0...127
Checksum, SGF 4	S64	1S64	2S64	0...63
Checksum, SGF 5	S65	1S65	2S65	0...255
Checksum, SGB 1	S71	1S71	2S71	0...1048575
Checksum, SGB 2	S72	1S72	2S72	0...1048575
Checksum, SGB 3	S73 ^{c)}	1S73	2S73	0...1048575
Checksum, SGB 4	S74 ^{c)}	1S74	2S74	0...1048575
Checksum, SGB 5	S75 ^{c)}	1S75	2S75	0...1048575
Checksum, SGR 1	S81	1S81	2S81	0...8388607
Checksum, SGR 2	S82	1S82	2S82	0...8388607
Checksum, SGR 3	S83	1S83	2S83	0...8388607
Checksum, SGR 4	S84	1S84	2S84	0...8388607
Checksum, SGR 5	S85	1S85	2S85	0...8388607
Checksum, SGR 6	S86 ^{c)}	1S86	2S86	0...8388607
Checksum, SGR 7	S87 ^{c)}	1S87	2S87	0...8388607
Checksum, SGR 8	S88 ^{c)}	1S88	2S88	0...8388607
Checksum, SGL 1	S91	1S91	2S91	0...8388607
Checksum, SGL 2	S92	1S92	2S92	0...8388607
Checksum, SGL 3	S93	1S93	2S93	0...8388607
Checksum, SGL 4	S94	1S94	2S94	0...8388607
Checksum, SGL 5	S95	1S95	2S95	0...8388607

Variable	Actual settings (R), channel 0	Group/Channel 1 (R, W, P)	Group/Channel 2 (R, W, P)	Setting range
Checksum, SGL 6	S96	1S96	2S96	0...8388607
Checksum, SGL 7	S97	1S97	2S97	0...8388607
Checksum, SGL 8	S98	1S98	2S98	0...8388607

a) If the protection stage is out of operation, the number indicating the currently used value will be displaced by "999" when the parameter is read via the SPA bus and by dashes on the LCD.

b) If the optional/O module has not been installed, a dash will be shown on the LCD and "999" when the parameter is read via the SPA bus.

c) If the optional/O module has not been installed, a dash will be shown on the LCD and "9999999" when the parameter is read via the SPA bus.

Auto-reclose parameters

Table 5.1.17.-2 Auto-reclose parameters

Description	Parameter (R, W, P), channel 0	Value
CB Closing time	V121	0.1...10 s
Start delay of stage I>	V122	0...300 s
Start delay of stage I ₀ >	V123	0...300 s
Reclaim time	V124	3...300 s
Cutout time	V125	0.1...300 s
Dead time of shot 1	V126	0.1...300 s
Dead time of shot 2	V127	0.1...300 s
Dead time of shot 3	V128	0.1...300 s
SG1	V129	0...255
SG2	V130	0...1023
SG3	V131	0...31

The AR function can be activated either via the or with SPA parameter S25 by setting the number of auto-reclose shots to 1, 2 or 3.

Recorded data

Parameter V1 shows the stage and phase which caused the trip. Parameter V2 shows the trip indication code.

Parameters V3...V8 show the number of starts of the protection stages, parameters V9...V12 the number of trips of the protection stages, and parameters V13...V24 the number of initiated auto-reclose shots.

Table 5.1.17.-3 Recorded data: Channel 0

Recorded data	Parameter (R)	Value
Stage/phase which caused the trip	V1	1=I _{L3} > 2=I _{L2} > 4=I _{L1} > 8=I ₀ > 16=I _{L3} >> 32=I _{L2} >>

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Recorded data	Parameter (R)	Value
		64= $I_{L1}>>$ 128= $I_0>>$ 256= $I_{L3}>>>$ 512= $I_{L2}>>>$ 1024= $I_{L1}>>>$ 2048= $\Delta I>$ 4096= $\theta>$ 8192=external trip 16384=AR 32768=trip of stage ARC (local) 65536=trip of stage ARC (remote)
Trip indication code	V2	0 = — 1=start of stage $I>$ 2=trip of stage $I>$ 3=start of stage $I>>$ 4=trip of stage $I>>$ 5=start of stage $I>>>$ 6=trip of stage $I>>>$ 7=start of stage $I_0>$ 8=trip of stage $I_0>$ 9=start of stage $I_0>>$ 10=trip of stage $I_0>>$ 11=start of stage $\Delta I>$ 12=trip of stage $\Delta I>$ 13=alarm of stage $\theta>$ 14=trip of stage $\theta>$ 15=external trip 16=definite trip alarm 17=CB reclosing failed
		18=AR shot due 19=AR lockout 20=trip of stage ARC 21=CBFP
Number of starts of stage $I>$	V3	0...999
Number of starts of stage $I>>$	V4	0...999
Number of starts of stage $I>>>$	V5	0...999
Number of starts of stage $I_0>$	V6	0...999
Number of starts of stage $I_0>>$	V7	0...999

Recorded data	Parameter (R)	Value
Number of starts of stage ΔI>	V8	0...999
Number of trips of stage I>	V9	0...65535
Number of trips of stage I>>	V10	0...65535
Number of trips of stage I>>>	V11	0...65535
Number of trips of other stages	V12	0...65535
Number of AR shots (shot 1) initiated by the trip signal from stage I>>	V13	0...255
Number of AR shots (shot 1) initiated by the digital input signal	V14	0...255
Number of AR shots (shot 1) initiated by the start or trip signal from stage I>	V15	0...255
Number of AR shots (shot 1) initiated by the start or trip signal from stage I ₀ >	V16	0...255
Number of AR shots (shot 2) initiated by the trip signal from stage I>>	V17	0...255
Number of AR shots (shot 2) initiated by the digital input signal	V18	0...255
Number of AR shots (shot 2) initiated by the start or trip signal from stage I>	V19	0...255
Number of AR shots (shot 2) initiated by the start or trip signal from stage I ₀ >	V20	0...255
Number of AR shots (shot 3) initiated by the trip signal from stage I>>	V21	0...255

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Recorded data	Parameter (R)	Value
Number of AR shots (shot 3) initiated by the digital input signal	V22	0...255
Number of AR shots (shot 3) initiated by the start or trip signal from stage I>	V23	0...255
Number of AR shots (shot 3) initiated by the start or trip signal from stage I ₀ >	V24	0...255

The last five recorded values can be read with parameters V1...V23 on channels 1...5. Event n denotes the last recorded value, n-1 the next one, and so forth.

Table 5.1.17.-4 Recorded data: Channels 1...5

Recorded data	Event (R)					Value
	n Channel 1	n-1 Channel 2	n-2 Channel 3	n-3 Channel 4	n-4 Channel 5	
Phase current I _{L1}	1V1	2V1	3V1	4V1	5V1	0...50 x I _n
Phase current I _{L2}	1V2	2V2	3V2	4V2	5V2	0...50 x I _n
Phase current I _{L3}	1V3	2V3	3V3	4V3	5V3	0...50 x I _n
Earth-fault current	1V4	2V4	3V4	4V4	5V4	0...2000% I _n
Phase discontinuity	1V5	2V5	3V5	4V5	5V5	0...100%
Thermal level at start	1V6	2V6	3V6	4V6	5V6	0...106% ^{a)}
Thermal level at trip	1V7	2V7	3V7	4V7	5V7	0...106% ^{a)}
Maximum pickup phase current I _{L1}	1V8	2V8	3V8	4V8	5V8	0...50 x I _n
Maximum pickup phase current I _{L2}	1V9	2V9	3V9	4V9	5V9	0...50 x I _n
Maximum pickup phase current I _{L3}	1V10	2V10	3V10	4V10	5V10	0...50 x I _n
Maximum pickup earth-fault current	1V11	2V11	3V11	4V11	5V11	0...2000%
Start Pickup duration of stage I>	1V12	2V12	3V12	4V12	5V12	0...100%
Start duration of stage I>>	1V13	2V13	3V13	4V13	5V13	0...100%
Start duration of stage I>>>	1V14	2V14	3V14	4V14	5V14	0...100%
Start duration of stage I ₀ >	1V15	2V15	3V15	4V15	5V15	0...100%
Start duration of stage I ₀ >>	1V16	2V16	3V16	4V16	5V16	0...100%
Start duration of stage ΔI>	1V17	2V17	3V17	4V17	5V17	0...100%
Start duration of external trip	1V18	2V18	3V18	4V18	5V18	0/100%

Recorded data	Event (R)					Value
	n Channel 1	n-1 Channel 2	n-2 Channel 3	n-3 Channel 4	n-4 Channel 5	
Trip number of AR sequence	1V19	2V19	3V19	4V19	5V19	0...255
Start duration of stage ARC (local)	1V20	2V20	3V20	4V20	5V20	0/100%
Start duration of stage ARC (remote)	1V21	2V21	3V21	4V21	5V21	0/100%
Time stamp of the recorded data, date	1V22	2V22	3V22	4V22	5V22	YY-MM-DD
Time stamp of the recorded data, time	1V23	2V23	3V23	4V23	5V23	HH.MM; SS.sss

^{a)} If the thermal protection has been set out of operation (SGF3/5), dashes will be shown on the LCD and "999" when the parameter is read via the SPA bus.

Disturbance recorder

Table 5.1.17.-5 Parameters for the disturbance recorder

Description	Parameter (channel 0)	R, W	Value
Remote triggering	M1 ^{a)}	W	1
Clear recorder memory	M2	W	1
Sampling rate	M15 ^{b)}	R, W	800/960 Hz 400/480 Hz 50/60 Hz
Station identification/unit number	M18	R, W	0...9999
Rated frequency	M19	R	50 or 60 Hz
Name of the feeder	M20	R, W	Max 16 characters
Digital channel texts	M40...M47	R	-
Analog channel texts	M60...M63	R	-
Analog channel conversion factor and unit for I_{L1} , I_{L2} and I_{L3}	M80 ^{c)d)}	R, W	Factor 0...65535, unit (A, kA), e.g. 10,kA
	M81 and M82	R R	
Analog channel conversion factor and unit for the earth-fault current	M83 ^{c)}	R, W	Factor 0...65535, unit (A, kA), e.g. 10,kA
Internal trigger signals' checksum	V236	R, W	0...16383
Internal trigger signal's edge	V237	R, W	0...16383
Checksum of internal signal storing mask	V238 ^{b)}	R, W	0...16383
Post-triggering recording length	V240	R, W	0...100%
External trigger signal's checksum	V241	R, W	0...31

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Description	Parameter (channel 0)	R, W	Value
External trigger signal's edge	V242	R, W	0...31
Checksum of external signal storing mask	V243 ^{b)}	R, W	0...31
Triggering state, clearing and restart	V246	R, W	R: 0 = Recorder not triggered 1 = Recorder triggered and recording stored in the memory W: 0 = Clear recorder memory 2 = Download restart; sets the first information and the time stamp for triggering ready to be read 4 = Manual triggering

^{a)} M1 can be used for broadcast triggering by using the unit address "900".

^{b)} Parameters can be written if the recorder has not been triggered.

^{c)} The disturbance recorder requires this parameter to be set. The conversion factor is the transformation ratio multiplied by the rated current voltage of the relay. If value 0 is given to this parameter, dashes are shown on the LCD instead of the primary values and the recorded data will be redundant.

^{d)} This value is copied to parameters M81 and M82.

Table 5.1.17.-6 Disturbance recorder internal triggering and storing

Event	Weighting factor	Default value of triggering mask, V236	Default value of triggering edge, V237 ^{a)}	Default value of storing mask, V238
Start of stage I>	1	0	0	1
Trip of stage I>	2	1	0	1
Start of stage I>>	4	0	0	1
Trip of stage I>>	8	1	0	1
Start of stage I>>>	16	0	0	0
Trip of stage I>>>	32	1	0	1
Start of stage I ₀ >	64	0	0	1
Trip of stage I ₀ >	128	1	0	1
Start of stage I ₀ >>	256	0	0	0
Trip of stage I ₀ >>	512	1	0	1
Start of stage ΔI>	1024	0	0	0
Trip of stage ΔI>	2048	0	0	0
Alarm of stage θ>	4096	0	0	0
Trip of stage θ>	8192	0	0	0
Σ		682	0	751

^{a)} 0 = rising edge; 1 = falling edge.

Table 5.1.17.-7 Disturbance recorder external triggering and storing

Event	Weighting factor	Default value of triggering mask, V241	Default value of triggering edge, V242 ^{a)}	Default value of storing mask, V243
DI1	1	0	0	0
DI2	2	0	0	0
DI3	4	0	0	0
DI4	8	0	0	0
DI5	16	0	0	0
Σ		0	0	0

^{a)} 0 = rising edge; 1 = falling edge.

Table 5.1.17.-8 Control parameters

Description	Parameter	R, W, P	Value
Reading of the event buffer	L	R	Time, channel number and event code
Re-reading of the event buffer	B	R	Time, channel number and event code
Reading of relay state data	C	R	0 = Normal state 1 = The relay has been subject to an automatic reset 2 = Overflow of the event buffer 3 = Both 1 and 2
Resetting of relay state data	C	W	0 = Reset E50 and E51 1 = Reset only E50 2 = Reset only E51 4 = Reset all events including E51 except for E50
Time reading and setting	T	R, W	SS.sss
Date and time reading and setting	D	R, W	YY-MM-DD HH.MM;SS.sss
Type designation of the relay	F	R	REF610
Unlatching output contacts	V101	W	1 = Unlatch
Clearing indications and memorized values and unlatching contacts (master reset)	V102	W	1 = Clear and unlatch
Resetting of trip lockout	V103	W	1 = Reset
Rated frequency	V104	R, W (P)	50 or 60 Hz
Time setting range for demand values in minutes	V105	R, W	0...999 min
Non-volatile memory settings	V106	R, W	0...31
Time setting for disabling new trip indications on the LCD	V108	R, W (P)	0...999 min
Testing the self-supervision	V109	W (P)	1 = Self-supervision output contact is activated and the READY indicator LED starts to blink 0 = Normal operation
LED test for start and trip indicators	V110	W (P)	0 = Start and trip LEDs off 1 = Trip LED on, start LED off 2 = Start LED on, trip LED off 3 = Start and trip LEDs on
LED test for programmable LEDs	V111	W (P)	0...255
Trip-circuit supervision	V113	R, W	0 = Not in use 1 = In use

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Description	Parameter	R, W, P	Value
Store counter ^{a)}	V114	R	0...65535
Remote control of setting group	V150	R, W	0 = Setting group 1 1 = Setting group 2
Entering the SPA password for settings	V160	W	1...999
Changing the SPA password or taking the password protection into use	V161	W (P)	1...999
Changing the HMI Setting password	V162	W	1...999
Changing the HMI Communication password	V163	W	1...999
Clearing trip counters or AR counter	V166	W (P)	1 = Clear trip counters 2 = Clear AR counters
Restoring factory settings	V167	W (P)	2 = Restore factory settings for CPU 3 = Restore factory settings for DNP
Warning code	V168	R	0...63 ^{b)}
IRF code	V169	R	0...255 ^{b)}
Unit address of the relay	V200	R, W	1...254
Data transfer rate (SPA), kbps	V201	R, W	9.6/4.8
Rear communication	V202	W	1 = Rear connector activated
Rear communication protocol	V203 ^{c)}	R, W	0 = SPA 1 = IEC_103 2 = Modbus RTU 3 = Modbus ASCII 4 = DNP 3.0 (read-only)
Connection type	V204	R, W	0 = Loop 1 = Star
Line-idle state	V205	R, W	0 = Light off 1 = Light on
Optional communication module	V206	R, W (P)	0 = Not in use 1 = In use ^{d)}
CPU software number	V227	R	1MRS118512
CPU software revision	V228	R	A...Z
CPU build number	V229	R	XXX
DNP protocol name	2V226	R	DNP 3.0
DNP software number	2V227	R	1MRS118531
DNP software revision	2V228	R	A...Z
DNP build number	2V229	R	XXX
Relay serial number	V230	R	BAxxxxxx
CPU serial number	V231	R	ACxxxxxx
DNP serial number	V232	R	AKxxxxxx
Test date	V235	R	YYMMDD
Date reading and setting (RED500 format)	V250	R, W	YY-MM-DD
Time reading and setting (RED500 format)	V251	R, W	HH.MM;SS.sss

^{a)} The store counter can be used for monitoring parameter changes, for instance. The store counter is incremented by one on each parameter change via the HMI or serial communication. When the counter reaches its maximum value, it will roll over. If the factory settings are restored, the counter is cleared.

^{b)} In case of a warning, the value 255 is stored in V169. This enables the master to continuously read only V169.

Table footnotes from previous page

^{c)} If the optional DNP 3.0 module has been installed, the DNP 3.0 communication protocol is automatically selected.

^{d)} If the optional communication module is not installed, a warning of a faulty communication module appears on the LCD together with the fault code.

The measured currents can be read with parameters I1...I4, the calculated phase discontinuity value with parameter I5, the status of light detection with parameter I6, the CB position with parameter I7 and the status of the digital inputs with parameters I8...I12.

Table 5.1.17.-9 Input signals

Description	Channel	Parameter (R)	Value
Current measured on phase I _{L1}	0	I1	0...50 x I _n
Current measured on phase I _{L2}	0	I2	0...50 x I _n
Current measured on phase I _{L3}	0	I3	0...50 x I _n
Measured earth-fault current	0	I4	0...2000% I _n
Calculated phase discontinuity value	0	I5	0...100%
Light detected (arc)	0	I6	0/1
CB position	0,3	I7	0 = undefined 1 = closed 2 = open 3 = undefined
DI1 status	0,2	I8	0/1 ^{a)}
DI2 status	0,2	I9	0/1 ^{a)}
DI3 status	0,2	I10	0/1 ^{a)}
DI4 status	0,2	I11	0/1 ^{a)}
DI5 status	0,2	I12	0/1 ^{a)}

^{a)} When the value is 1, the digital input is energized.

Each protection stage has its internal output signal. These signals can be read with parameters O1...O26 and the recorded functions with parameters O61...O86. The state of the output contacts can be read or changed with parameters O41...O49 and the recorded functions read with parameters O101...O109.

Table 5.1.17.-10 Output signals

Status of the protection stages	Channel	State of stage (R)	Recorded functions (R)	Value
Start of stage I>	0,1	O1	O61	0/1
Trip of stage	0,1	O2	O62	0/1
Start of stage I>>	0,1	O3	O63	0/1
Trip of stage stage I>>	0,1	O4	O64	0/1
Start of stage I>>>	0,1	O5	O65	0/1
Trip of stage I>>>	0,1	O6	O66	0/1 ;
Start of stage I ₀ >	0,1	O7	O67	0/1

Status of the protection stages	Channel	State of stage (R)	Recorded functions (R)	Value
Trip of stage $I_0 >$	0,1	O8	O68	0/1
Start of stage $I_0 >>$	0,1	O9	O69	0/1
Trip of stage $I_0 >>$	0,1	O10	O70	0/1
Start of stage $\Delta I >$	0,1	O11	O71	0/1
Trip of stage $\Delta I >$	0,1	O12	O72	0/1
Start of stage $\theta >$	0,1	O13	O73	0/1
Alarm of stage $\theta >$	0,1	O14	O74	0/1
Trip of stage $\theta >$	0,1	O15	O75	0/1
External trip	0,1	O16	O76	0/1
Trip lockout	0,1	O17	O77	0/1
CBFP Trip	0,1	O18	O78	0/1
Trip of stage ARC	0,1	O19	O79	0/1
Light signal output	0,1	O20	O80	0/1
Open CB command	0,3	O21	O81	0/1
Close CB command	0,3	O22	O82	0/1
Definite trip alarm	0,3	O23	O83	0/1
CB reclosing failed	0,3	O24	O84	0/1
Shot due	0,3	O25	O85	0/1
AR Lockout	0,3	O26	O86	0/1

Table 5.1.17.-11 Outputs

Operation of output contact	Channel	State of output (R, W, P)	Recorded functions (R)	Value
Output PO1	0,2	O41	O101	0/1
Output PO2	0,2	O42	O102	0/1
Output PO3 ^{a)}	0,2	O43	O103	0/1 ^{b)}
Output SO1	0,2	O44	O104	0/1
Output SO2	0,2	O45	O105	0/1
Output PO3 (trip lockout) ^{c)}	0,2	O46	-	0/1 ^{b)}
Output SO3	0,2	O47	O107	0/1 ^{d)}

Operation of output contact	Channel	State of output (R, W, P)	Recorded functions (R)	Value
Output SO4	0,2	O48	O108	0/1 ^{d)}
Output SO5	0,2	O49	O109	0/1 ^{d)}
Enabling activation of output contacts PO1, PO2, PO3, SO1, SO2, SO3, SO4 and SO5 via the SPA bus	0,2	O51	-	0/1

^{a)} State of output when the trip lockout function is not in use.

^{b)} Either O43/O103 or O46 is to be used at a time.

^{c)} State of output when the trip lockout function is in use.



Parameters O41...O49 and O51 control the physical output contacts which can be connected to circuit breakers, for instance.

Parameters for IEC 60870-5-103 remote communication protocol

Table 5.1.17.-12 Settings

Description	Parameter (channel 507)	R, W, P	Value
Unit address of the relay	507V200	R, W	1...254
Data transfer rate (IEC 60870-5-103), kbps	507V201	R, W (P)	9.6/4.8

Parameters for Modbus remote communication protocol

Table 5.1.17.-13 Settings

Description	Parameter (channel 504)	R, W, P	Value
User-defined register 1	504V1	R, W	0...65535 ^{a)}
User-defined register 2	504V2	R, W	0...65535 ^{a)}
User-defined register 3	504V3	R, W	0...65535 ^{a)}
User-defined register 4	504V4	R, W	0...65535 ^{a)}
User-defined register 5	504V5	R, W	0...65535 ^{a)}
User-defined register 6	504V6	R, W	0...65535 ^{a)}
User-defined register 7	504V7	R, W	0...65535 ^{a)}
User-defined register 8	504V8	R, W	0...65535 ^{a)}
User-defined register 9	504V9	R, W	0...65535 ^{a)}
User-defined register 10	504V10	R, W	0...65535 ^{a)}
User-defined register 11	504V11	R, W	0...65535 ^{a)}

Description	Parameter (channel 504)	R, W, P	Value
User-defined register 12	504V12	R, W	0...65535 ^{a)}
User-defined register 13	504V13	R, W	0...65535 ^{a)}
User-defined register 14	504V14	R, W	0...65535 ^{a)}
User-defined register 15	504V15	R, W	0...65535 ^{a)}
User-defined register 16	504V16	R, W	0...65535 ^{a)}
Unit address of the relay	504V200	R, W	1...254
Data transfer rate (Modbus), kbps	504V201	R, W	9.6/4.8/2.4/1.2/0.3
Modbus link parity	504V220	R, W	0 = even 1 = odd 2 = no parity
CRC order of Modbus RTU link	504V221	R, W	0 = low/high 1 = high/low

^{a)} The default value is 0.

Parameters for DNP 3.0 remote communication protocol

Table 5.1.17.-14 Settings

Description	SPA parameter (channel 503)	R, W	Value range	Default	Explanation
Unit address	503V1	R, W	0...65532	1	Address of the relay in the DNP 3.0 network
Master address	503V2	R, W	0...65532	2	Address of the master station (destination address for unsolicited responses)
Primary data link timeout	503V3	R, W	0 = no data link timeout used 1...65535 ms	0	Used when the relay sends data using service 3
Primary data link layer retransmission count	503V4	R, W	0...255	0	Number of retransmissions on data link layer
Application layer confirmation timeout	503V6	R, W	0...65535 ms	5000	Used when the relay sends messages with confirmation request
Application layer retransmission count	503V7	R, W	0...255	0	Number of retransmissions on the application layer when the relay sends messages with confirmation request
Confirmation on application layer	503V9	R, W	0 = enabled only for event messages 1 = enabled for all messages	0	Used to enforce inclusion of confirmation request in all application messages (DNP 3.0 standard requires inclusion of confirmation request in event messages only)
Default variation of binary input objects	503V10	R, W	1...2	2	
Default variation of binary input change event objects	503V11	R, W	1...2	2	
Default variation of analog input objects	503V15	R, W	1...4	2	
Default variation of analog input change event objects	503V16	R, W	1...4	2	

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Description	SPA parameter (channel 503)	R, W	Value range	Default	Explanation
Default variation of counter objects	503V13	R, W	1...2	2	
Default variation of counter change event objects	503V14	R, W	1, 2, 5, 6	2	
Default variation of frozen counter objects	503V30	R, W	1, 2, 5, 6	2	
Class 1 event delay	503V18	R, W	0...255 s	0	
Class 1 event count	503V19	R, W	0...255	1	
Class 2 event delay	503V20	R, W	0...255 s	0	
Class 2 event count	503V21	R, W	0...255	1	
Class 3 event delay	503V22	R, W	0...255 s	0	
Class 3 event count	503V23	R, W	0...255	1	
Unsolicited reporting mode	503V24	R, W	0 = UR disabled 1 = immediate 2 = empty UR 3 = empty UR and enable UR	0	Refer to Unsolicited reporting start up in Section 5.1.16.4. Specific DNP features.
Scaling factor 1	503V101	R, W	0...4294967295	1	
Scaling factor 2	503V102	R, W	0...4294967295	1	
Scaling factor 3	503V103	R, W	0...4294967295	1	
Scaling factor 4	503V104	R, W	0...4294967295	1	
Scaling factor 5	503V105	R, W	0...4294967295	1	
Baud rate	503V211	R, W	4.8/9.6/19.2/38.4	9.6	
Number of stop bits	503V212	R, W	1...2	1	
Parity	503V230	R, W	0 = no parity 1 = odd 2 = even	0	
Silent interval	503V232	R, W	0...65535 ms	20	
Time slot width	503V233	R, W	0...255 ms	10	
Number of time slots	503V234	R, W	0...255	8	
Collision detection enabled	503V235	R, W	0 = disabled 1 = enabled	0	
DNP module warning register	503V168	R	Bit coded 0 = OK		
DNP module status register	503V169	R	Bit coded 0 = OK		

Measurements

Table 5.1.17.-15 Measured values

Description	Parameter (channel 0)	R, W, P	Value
Thermal level	V60	R, W (P)	0...106% ^{a)b)}
One-minute average current value	V61	R	0...50 x I _n ^{c)}
Average current value during the specified time range	V62	R	0...50 x I _n ^{c)}
Maximum one-minute average current value during the specified time range	V63	R	0...50 x I _n ^{c)}

^{a)} Changing the thermal level via serial communication will generate an event code.

^{b)} If the thermal protection has been set out of operation, the parameter cannot be written to, and dashes will be shown on the LCD and "999" when the thermal level is read via the SPA bus.

^{c)} If the demand value is reset and the specified time has not elapsed, dashes are shown on the LCD and "999" when the parameter is read via the SPA bus.

5.1.17.1.

Event codes

Special codes are determined to represent certain events, such as start and tripping of protection stages and different states of output signals.

The events are stored in the event buffer of the relay. The maximum capacity of the buffer is 100 events. Under normal conditions the buffer is empty.

The contents of the buffer can be read using the L command, 5 events at a time. Using the L command erases the previously read events from the buffer, with the exception of events E50 and E51 which have to be reset by using the C command. If a fault occurs and reading fails for example in data communication, the events can be re-read by using the B command. If needed, the B command can also be repeated.

Events to be included in the event reporting are marked with the multiplier 1. The event mask is formed by the sum of the weighting factors of all those events which are to be included in event reporting.

Table 5.1.17.1.-1 Event masks

Event mask	Code	Setting range	Default setting
V155	E31...E36	0...63	1
1V155	1E1...1E12	0...4095	1365
1V156	1E13...1E24	0...4095	1365
1V157	1E25...1E42	0...262143	4180
2V155	2E1...2E16	0...65535	3
2V156	2E17...2E26	0...1023	0
3V155	3E1...3E12	0...4095	1023
3V156	3E13...3E22	0...1023	1008

Channel 0

Events always included in the event reporting:

Table 5.1.17.1.-2 Event codes E1...E4 and E7

Channel	Event	Description
0	E1	IRF
0	E2	IRF disappeared
0	E3	Warning
0	E4	Warning disappeared
0	E7	The thermal level has been changed via serial communication

Table 5.1.17.1.-3 Event codes E50...E51

Channel	Event	Description
0	E50	Relay restart
0	E51	Event buffer overflow

Events possible to mask out:

Table 5.1.17.1.-4 Event codes E31...E36

Channel	Event	Description	Weighting factor	Default value
0	E31	Disturbance recorder triggered	1	1
0	E32	Disturbance recorder memory cleared	2	0
0	E33	HMI Setting password opened	4	0
0	E34	HMI Setting password closed	8	0
0	E35	HMI Communication password opened	16	0
0	E36	HMI Communication password closed	32	0
Default value of event mask V155				1

Channel 1

Table 5.1.17.1.-5 Event codes E1...E12

Channel	Event	Description	Weighting factor	Default value
1	E1	Start signal from stage I> activated	1	1
1	E2	Start signal from stage I> reset	2	0
1	E3	Trip signal from stage I> activated	4	1
1	E4	Trip signal from stage I> reset	8	0
1	E5	Start signal from stage I>> activated	16	1
1	E6	Start signal from stage I>> reset	32	0
1	E7	Trip signal from stage I>> activated	64	1
1	E8	Trip signal from stage I>> reset	128	0
1	E9	Start signal from stage I>>> activated	256	1
1	E10	Start signal from stage I>>> reset	512	0
1	E11	Trip signal from stage I>>> activated	1024	1
1	E12	Trip signal from stage I>>> reset	2048	0
Default value of event mask 1V155				1365

Table 5.1.17.1-6 Event codes E13...E24

Channel	Event	Description	Weighting factor	Default value
1	E13	Start signal from stage I ₀ > activated	1	1
1	E14	Start signal from stage I ₀ > reset	2	0
1	E15	Trip signal from stage I ₀ > activated	4	1
1	E16	Trip signal from stage I ₀ > reset	8	0
1	E17	Start signal from stage I ₀ >> activated	16	1
1	E18	Start signal from stage I ₀ >> reset	32	0
1	E19	Trip signal from stage I ₀ >> activated	64	1
1	E20	Trip signal from stage I ₀ >> reset	128	0
1	E21	Start signal from stage ΔI> activated	256	1
1	E22	Start signal from stage ΔI> reset	512	0
1	E23	Trip signal from stage ΔI> activated	1024	1
1	E24	Trip signal from stage ΔI> reset	2048	0
Default value of event mask 1V156				1365

Table 5.1.17.1-7 Event codes E25...E42

Channel	Event	Description	Weighting factor	Default value
1	E25	Start signal from stage θ> activated	1	0
1	E26	Start signal from stage θ> reset	2	0
1	E27	Alarm signal from stage θ> activated	4	1
1	E28	Alarm signal from stage θ> reset	8	0
1	E29	Trip signal from stage θ> activated	16	1
1	E30	Trip signal from stage θ> reset	32	0
1	E31	Trip signal from stage ARC (light and current) activated	64	1
1	E32	Trip signal from stage ARC (light and current) reset	128	0
1	E33	Trip signal from stage ARC (DI and current) activated	256	0
1	E34	Trip signal from stage ARC (DI and current) reset	512	0
1	E35	Light signal output activated	1024	0
1	E36	Light signal output reset	2048	0
1	E37	Trip lockout signal activated	4096	1
1	E38	Trip lockout signal reset	8192	0
1	E39	External trip signal activated	16384	0
1	E40	External trip signal reset	32768	0
1	E41	CBFP activated	65536	0
1	E42	CBFP reset	131072	0
Default value of event mask 1V157				4180

Channel 2

Table 5.1.17.1-8 Event codes E1...E16

Channel	Event	Description	Weighting factor	Default value
2	E1	PO1 activated	1	1
2	E2	PO1 reset	2	1
2	E3	PO2 activated	4	0
2	E4	PO2 reset	8	0
2	E5	PO3 activated	16	0
2	E6	PO3 reset	32	0
2	E7	SO1 activated	64	0
2	E8	SO1 reset	128	0
2	E9	SO2 activated	256	0
2	E10	SO2 reset	512	0
2	E11	SO3 activated	1024	0
2	E12	SO3 reset	2048	0
2	E13	SO4 activated	4096	0
2	E14	SO4 reset	8192	0
2	E15	SO5 activated	16384	0
2	E16	SO5 reset	32768	0
Default value of event mask 2V155				3

Table 5.1.17.1-9 Event codes E17...E26

Channel	Event	Description	Weighting factor	Default value
2	E17	DI1 activated	1	0
2	E18	DI1 deactivated	2	0
2	E19	DI2 activated	4	0
2	E20	DI2 deactivated	8	0
2	E21	DI3 activated	16	0
2	E22	DI3 deactivated	32	0
2	E23	DI4 activated	64	0
2	E24	DI4 deactivated	128	0
2	E25	DI5 activated	256	0
2	E26	DI5 deactivated	512	0
Default value of event mask 2V156				0

Channel 3

Table 5.1.17.1.-10 Event codes E1...E12

Channel	Event	Description	Weighting factor	Default value
3	E1	Shot 1 initiated	1	1
3	E2	Shot 1 ended	2	1
3	E3	Shot 2 Initiated	4	1
3	E4	Shot 2 ended	8	1
3	E5	Shot 3 initiated	16	1
3	E6	Shot 3 ended	32	1
3	E7	CB position open	64	1
3	E8	CB position closed	128	1
3	E9	Definite trip alarm signal activated	256	1
3	E10	Definite trip alarm signal reset	512	1
3	E11	AR lockout signal activated	1024	0
3	E12	AR lockout signal reset	2048	0
Default value of event mask 3V155				1023

Table 5.1.17.1.-11 E13...E22

Channel	Event	Description	Weighting factor	Default value
3	E13	Open CB command activated	1	0
3	E14	Open CB command reset	2	0
3	E15	Close CB command activated	4	0
3	E16	Close CB command reset	8	0
3	E17	CB reclosing failed signal activated	16	1
3	E18	CB reclosing failed signal reset	32	1
3	E19	CB reclosing inhibited	64	1
3	E20	CB reclosing inhibited reset	128	1
3	E21	AR cancelled	256	1
3	E22	AR cancelled reset	512	1
Default value of event mask 3V156				1008

5.1.18.

Self-supervision (IRF) system

The relay is provided with an extensive self-supervision system which continuously supervises the software and the electronics of the relay. It handles run-time fault situations and informs the user about an existing fault via a LED on the HMI and a text message on the LCD. There are two types of fault indications: IRF indications and warnings.

Internal relay fault

When an internal relay fault preventing relay operation is detected, the relay first tries to eliminate the fault by restarting. Only after the fault is found to be permanent, the green indicator LED (ready) begins to blink and the self-supervision output contact is activated. All other output contacts are returned to the initial state and locked for the internal relay fault. Further, a fault indication message appears on the LCD, including a fault code.

IRF indications have the highest priority on the HMI. None of the other HMI indications can override the IRF indication. As long as the green indicator LED (ready) is blinking, the fault indication cannot be cleared. In case an internal fault disappears, the green indicator LED (ready) stops blinking and the relay is returned to the normal service state, but the fault indication message remains on the LCD until manually cleared.

The IRF code indicates the type of internal relay fault. When a fault appears, the code is to be recorded and stated when ordering service. The fault codes are listed in the following table:

Table 5.1.18.-1 IRF codes

Fault code	Type of fault
4	Error in output relay PO1
5	Error in output relay PO2
6	Error in output relay PO3
7	Error in output relay SO1
8	Error in output relay SO2
9	Error in the enable signal for output relay PO1, PO2, SO1 or SO2
10, 11, 12	Error in the feedback, enable signal or output relay PO1, PO2, SO1 or SO2
13	Error in optional output relay SO3
14	Error in optional output relay SO4
15	Error in optional output relay SO5
16	Error in the enable signal for optional output relay SO3, SO4 or SO5
17, 18, 19	Error in the feedback, enable signal or optional output relay SO3, SO4 or SO5
20, 21	Auxiliary voltage dip
30	Faulty program memory
50, 59	Faulty work memory
51, 52, 53 ^{a)} , 54, 56	Faulty parameter memory ^{b)}
55	Faulty parameter memory, calibration parameters
80	Optional I/O module missing
81	Optional I/O module unknown
82	Optional I/O module configuration error
85	Power supply module faulty
86	Power supply module unknown
90	Hardware configuration error
95	Communication module unknown

Fault code	Type of fault
104	Faulty configuration set (for IEC 60870-5-103)
131, 139, 195, 203, 222, 223	Internal reference voltage error
240	Faulty input, Light sensor 2
241	Faulty input, Light sensor 1
253	Error in the measuring unit

^{a)} Can be corrected by restoring factory settings for CPU.
^{b)} All settings will be zero during the fault.

For further information on internal relay faults, refer to the Operator’s Manual.

Warnings

In case of a warning, the relay continues to operate except for those protection functions possibly affected by the fault, and the green indicator LED (ready) remains lit as during normal operation. Further, a fault indication message, which depending on the type of fault includes a fault code, appears on the LCD. If more than one type of fault occur at the same time, one single numeric code which indicates all the faults is displayed. The fault indication message cannot be manually cleared but it disappears with the fault.

When a fault appears, the fault indication message is to be recorded and stated when ordering service. The fault codes are listed in the following table:

Table 5.1.18.-2 Warning codes

Fault	Weight value
Battery low	1
Trip-circuit supervision ^{a)}	2
Power supply module temperature high	4
Communication module faulty or missing	8
DNP 3.0 configuration error ^{b)}	16
DNP 3.0 module faulty	32
Continuous light detected by Light sensor 1 or 2 ^{a)}	64
Σ	127

^{a)} The external fault warning can be routed to SO2 with SGF1/8.
^{b)} Can be corrected by restoring factory settings for DNP

For further information on warnings, refer to the Operator’s Manual.

5.1.19. Relay parameterization

The parameters of the relay can be set either locally via the HMI or externally via serial communication with Relay Setting Tool.

Local parameterization

When the parameters are set locally, the setting parameters can be chosen via the hierarchical menu structure. The wanted language can be selected for parameter descriptions. Refer to the Operator's Manual for further information.

External parameterization

Relay Setting Tool is used for parameterizing the relay units. Adjusting the parameter values using Relay Setting Tool is done off-line, after which the parameters can be downloaded to the relay via a communication port.

5.2.

Design description

5.2.1.

Input/output connections

All external circuits are connected to the terminals on the rear panel of the relay.

- Terminals X2.1- are dimensioned for one 0.5...6.0 mm² (20-8) wire or two max 2.5 mm² (24-12) wires
- Terminals X3.1- and X4.1- are dimensioned for one 0.2...2.5 mm² wire or two 0.2...1.0 mm² (24-16) wires.

The energizing phase currents of the relay are connected to terminals:

- X2.1/1-2
- X2.1/3-4
- X2.1/5-6

For inputs for phase and earth-fault currents, refer to Table 5.2.1.-1.



The relay can also be used in single or two-phase applications by leaving one or two energizing inputs unoccupied. However, at least terminals X2.1/1-2 must be connected.

The energizing earth-fault current of the relay is connected to terminals X2.1/7-8, see Table 5.2.1.-1.

The input terminals of the optional I/O module are located on connection socket X3.1, see Table 5.2.1.-4 and Table 5.2.1.-5.



When connection socket X3.1 is used, the optional I/O module must be installed.

Terminals X4.1/21-24 and X3.1/1-6 (optional) are digital input terminals, see Table 5.2.1.-5. The digital inputs can be used to generate a blocking signal, to unlatch output contacts or for remote control of relay settings, for instance. The

requested functions are selected separately for each input in switchgroups SGB1...5. The digital inputs can also be used to trigger the disturbance recorder; this function is selected with SPA parameter V243.

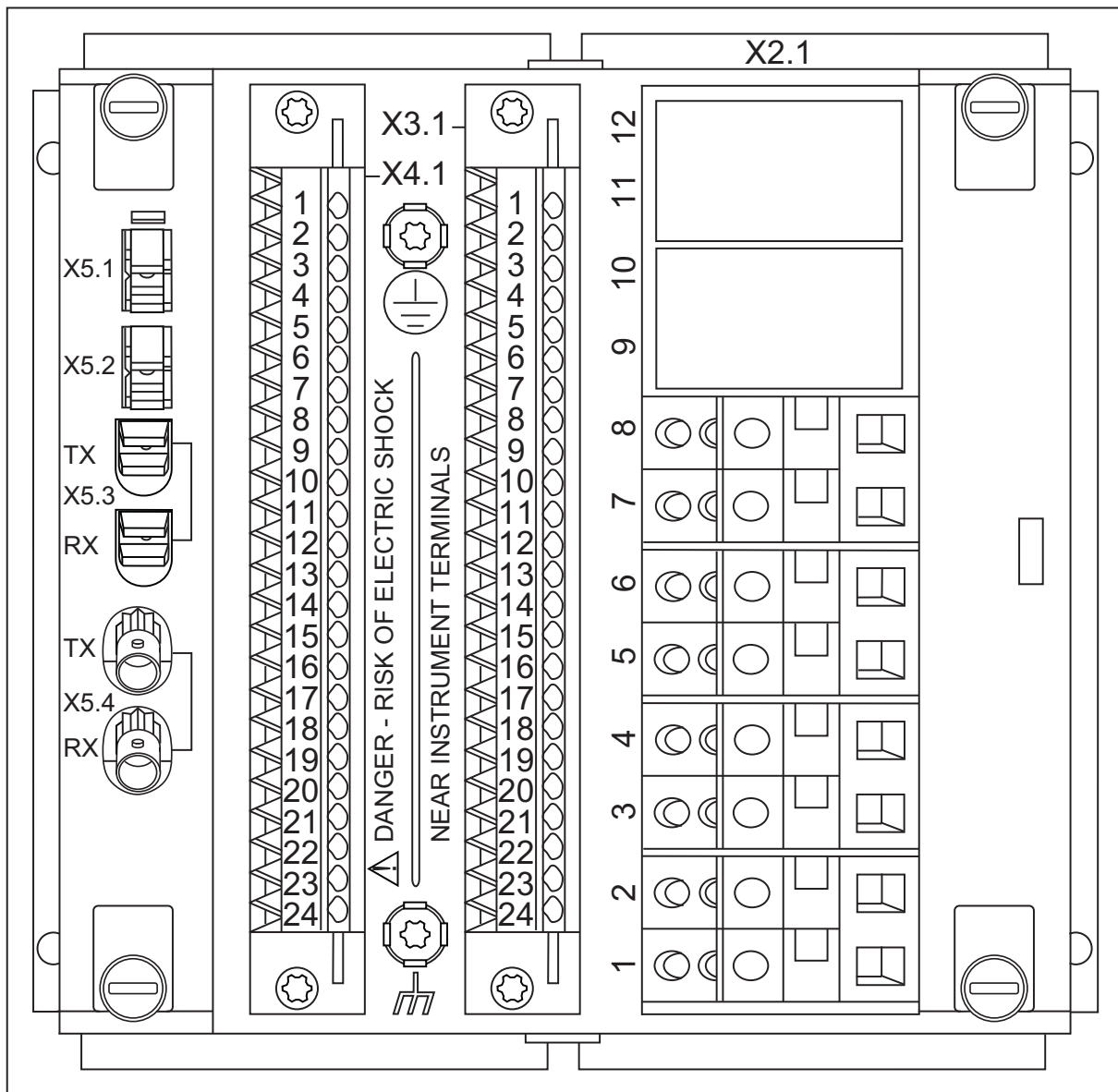
The auxiliary voltage of the relay is connected to terminals X4.1/1-2, see Table 5.2.1.-2. At DC supply, the positive lead is connected to terminal X4.1/1. The permitted auxiliary voltage range of the relay is marked on the front panel of the relay under the handle of the plug-in unit.

Output contacts PO1, PO2 and PO3 are heavy-duty trip contacts capable of controlling most circuit breakers, see Table 5.2.1.-4. The signals to be routed to PO1...PO3 are selected with the switches of switchgroups SGR1...SGR3. On delivery from the factory, the trip signals from all the protection stages are routed to PO1, PO2 and PO3.

Output contacts SO1...SO5 can be used for signalling on start and tripping of the relay, see Table 5.2.1.-4. Output contacts SO3...SO5 are optional and available only if the optional I/O module has been installed. The signals to be routed to SO1...SO5 are selected with the switches of switchgroups SGR4...SGR8. On delivery from the factory, the start and alarm signals from all the protection stages are routed to SO1 and SO2.

The IRF contact functions as an output contact for the self-supervision system of the protection relay, see Table 5.2.1.-3. Under normal operating conditions, the relay is energized and the contact is closed (X4.1/3-5). When a fault is detected by the self-supervision system or the auxiliary voltage is disconnected, the output contact drops off and the contact closes (X4.1/3-4).

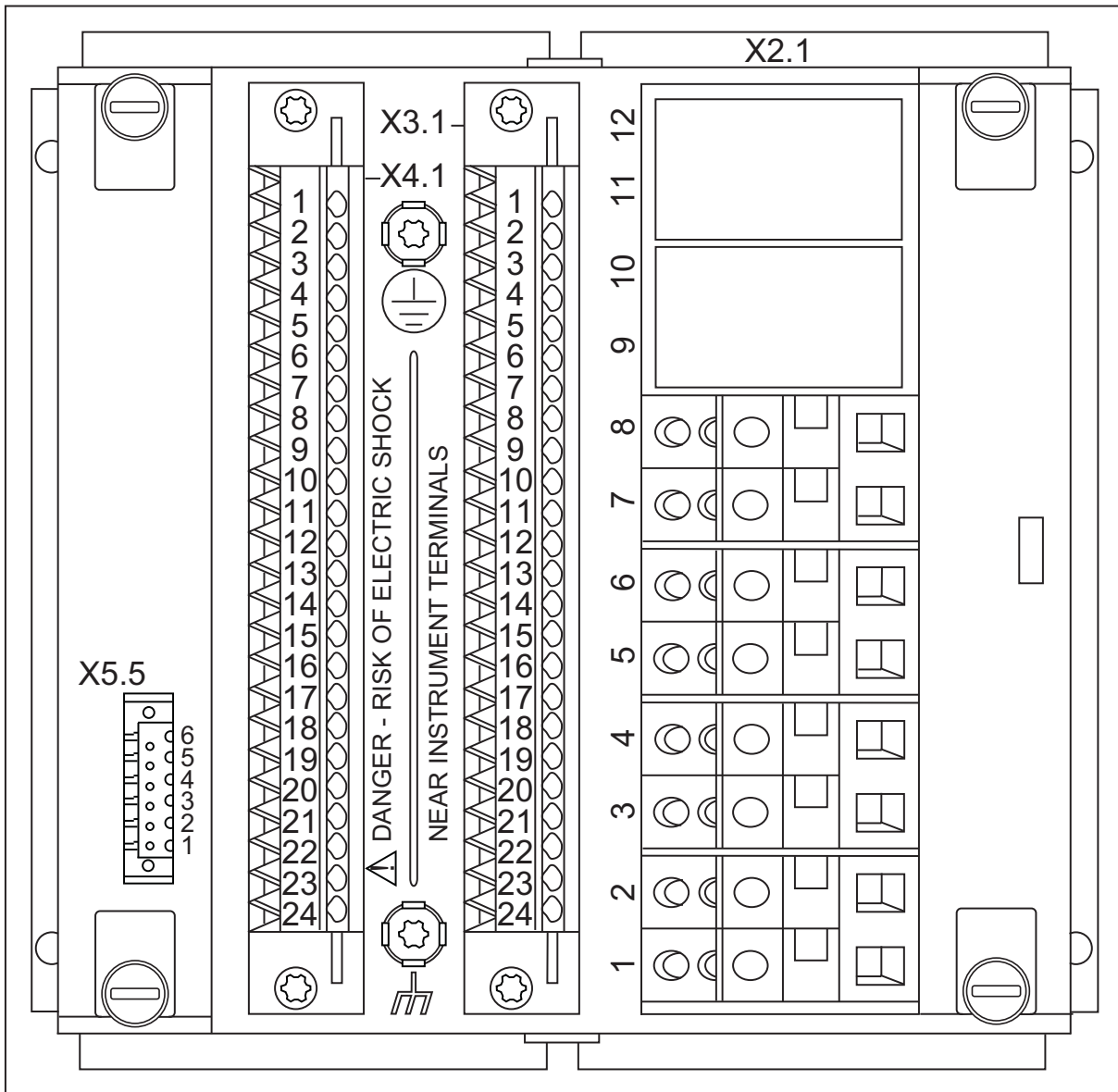
Fig. 5.2.1.-1...Fig. 5.2.1.-3 present a rear view of the relay, showing four connecting sockets: one for measuring transformers, one for the optional I/O module, one for power supply and one for optional serial communication.



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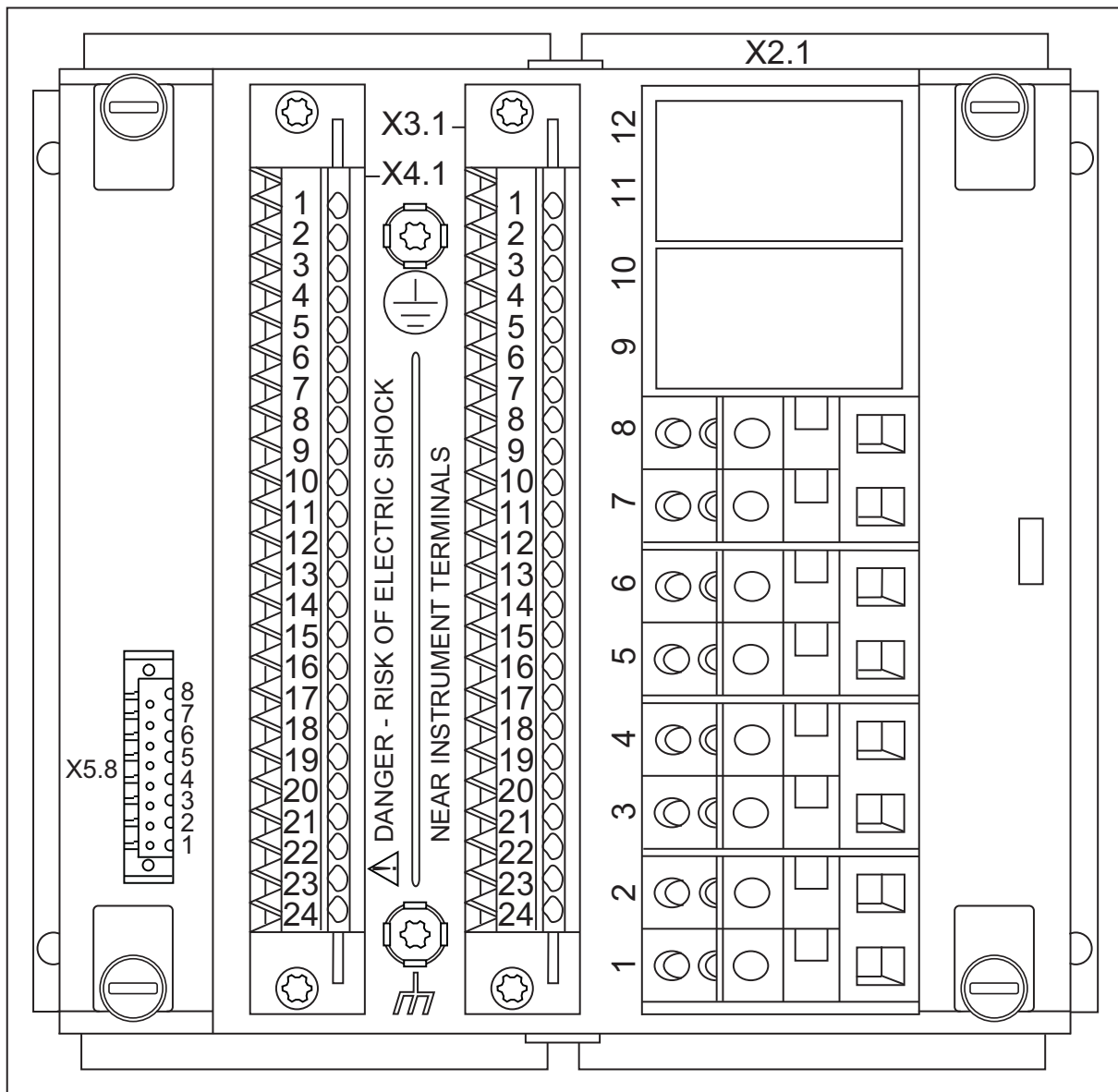
Fig. 5.2.1.-1 Rear view of the relay with the fibre-optic communication module for plastic and glass fibre with light sensor inputs

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Fig. 5.2.1.-2 Rear view of the relay with the RS-485 communication module



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Fig. 5.2.1.-3 Rear view of the relay with the DNP 3.0 communication module for RS-485

Table 5.2.1.-1 Inputs for phase and earth-fault currents

Terminal	Function ^{a)}					
	REF610A11xxxx	REF610A12xxxx	REF610A15xxxx	REF610A51xxxx	REF610A52xxxx	REF610A55xxxx
X2.1-1 X2.1-2	I _{L1} 1 A	I _{L1} 1 A	I _{L1} 1 A	I _{L1} 5 A	I _{L1} 5 A	I _{L1} 5 A
X2.1-3 X2.1-4	I _{L2} 1 A	I _{L2} 1 A	I _{L2} 1 A	I _{L2} 5 A	I _{L2} 5 A	I _{L2} 5 A
X2.1-5 X2.1-6	I _{L3} 1 A	I _{L3} 1 A	I _{L3} 1 A	I _{L3} 5 A	I _{L3} 5 A	I _{L3} 5 A

Terminal	Function					
	REF610A11xxxx	REF610A12xxxx	REF610A15xxxx	REF610A51xxxx	REF610A52xxxx	REF610A55xxxx
X2.1-7 X2.1-8	I_0 1 A	I_0 0.2 A	I_0 5 A	I_0 1 A	I_0 0.2 A	I_0 5 A
X2.1-9	-		-	-		-
X2.1-10	-		-	-		-
X2.1-11	-		-	-		-
X2.1-12	-		-	-		-

^{a)} The value denotes the rated current for each input.

Table 5.2.1.-2 Auxiliary supply voltage

Terminal	Function
X4.1-1	Input, +
X4.1-2	Input, -

Table 5.2.1.-3 IRF contact

Terminal	Function
X4.1-3	IRF, common
X4.1-4	Closed; IRF, or U_{aux} disconnected
X4.1-5	Closed; no IRF, and U_{aux} connected

Table 5.2.1.-4 Output contacts

Terminal	Function
X3.1-16	SO5, common ^{a)}
X3.1-17	SO5, NC ^{a)}
X3.1-18	SO5, NO ^{a)}
X3.1-19	SO4, common ^{a)}
X3.1-20	SO4, NC ^{a)}
X3.1-21	SO4, NO ^{a)}
X3.1-22	SO3, common ^{a)}
X3.1-23	SO3, NC ^{a)}
X3.1-24	SO3, NO ^{a)}
X4.1-6	SO2, common
X4.1-7	SO2, NC
X4.1-8	SO2, NO
X4.1-9	SO1, common
X4.1-10	SO1, NC
X4.1-11	SO1, NO
X4.1-12	PO3 (trip lockout relay), NO
X4.1-13	
X4.1-14	PO2, NO
X4.1-15	

Terminal	Function
X4.1-16	PO1, NO
X4.1-17	
X4.1-18	PO1 (TCS), NO
X4.1-19	
X4.1-20	-

^{a)} Optional.

Table 5.2.1.-5 Digital inputs

Terminal	Function
X4.1-23	DI1
X4.1-24	
X4.1-21	DI2
X4.1-22	
X3.1-1	DI3 ^{a)}
X3.1-2	
X3.1-3	DI4 ^{a)}
X3.1-4	
X3.1-5	DI5 ^{a)}
X3.1-6	

^{a)} Optional.

5.2.2. Light sensor input connections

If REF610 is provided with the optional communication module with light sensor inputs, the pre-manufactured lens-sensor fibres are connected to inputs X5.1 and X5.2 (see 5.2.2.-1 and). For further information on the arc protection, refer to 5.1.4.7. Arc protection.



REF610 is provided with connection sockets X5.1 and X5.2 only if the optional communication module with light sensor inputs has been installed (refer to section Ordering information).

Table 5.2.2.-1 Light sensor input connectors

Terminal	Function
X5.1	Input Light sensor 1
X5.2	Input Light sensor 2

5.2.3. Serial communication connections

The optical front connection of the relay is used to connect the relay to the SPA bus via the front communication cable, refer to Section 7. Ordering information. If a PC compatible to the IrDA® Standard specifications is used, wireless communication is possible as well. The maximum wireless operating distance depends on the transceiver of the PC.

Rear communication of the relay is optional and the physical connection varies with the communication option.

Plastic fibre-optic connection

If the relay is provided with the optional fibre-optic communication module for plastic fibre, the fibre-optic cables are connected to terminals as follows:

Table 5.2.3.-1 Plastic fibre-optic rear connection

Terminal	Function
X5.3-TX	Transmitter
X5.3-RX	Receiver

RS-485 connection

If the relay is provided with the optional RS-485 communication module, the cable is connected to terminals X5.5/1-2 and X5.5/4-6. The connection socket is a 6-pin header-type socket and the terminals are of screw compression type.

The RS-485 communication module follows the TIA/EIA-485 standard and is intended to be used in a daisy-chain bus wiring scheme with 2-wire, half-duplex, multi-point communication.



The maximum number of devices (nodes) connected to the bus where the relay is being used is 32, and the maximum length of the bus is 1200 meters.

When connecting the relay to the bus, a quality twisted pair shielded cable is to be used. The conductors of the pair are connected to A and B. If signal ground is being used for balancing potential differences between devices/nodes, a quality dual twisted pair shielded cable is to be used. In this case, one pair is connected to A and B, and one of the conductors of the other pair to signal ground. When connecting one device to another, A is connected to A and B to B.

The cable shield is to be connected directly to earth (shield GND) in one point/device of the bus. Other devices connected to the bus should have the cable shield connected to earth via a capacitor (shield GND via capacitor).



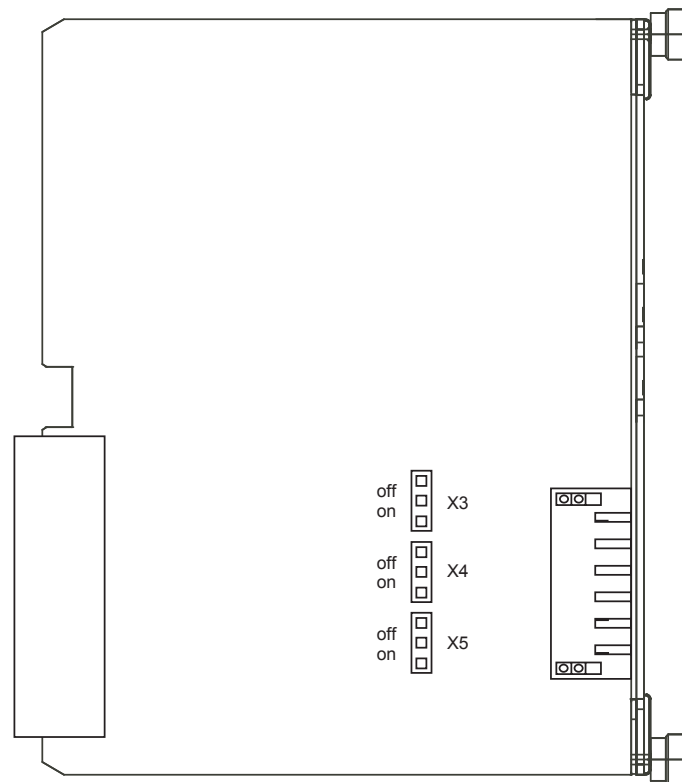
Signal ground can only be used for balancing potential differences between devices/nodes if all devices connected to the bus have isolated RS-485 interfaces.

The RS-485 communication module is provided with jumpers for setting bus termination and fail-safe biasing. The bus is to be terminated at both ends, which can be done by using the internal termination resistor on the communication

module. The termination resistor is selected by setting jumper X5 to the ON position. If the internal termination resistor of 120 Ω is used, the impedance of the cable should be the same.

The bus is to be biased at one end to ensure fail-safe operation, which can be done using the pull-up and pull-down resistors on the communication module. The pull-up and pull-down resistors are selected by setting jumpers X3 and X4 to the ON position.

The jumpers have been set to no termination (X5 in the OFF position) and no biasing (X3 and X4 in the OFF position) as default.



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Fig. 5.2.3.-1 Jumper location on the RS-485 communication module

Table 5.2.3.-2 RS-485 rear connector

Terminal	Function
X5.5-6	Data A (+)
X5.5-5	Data B (-)
X5.5-4	Signal GND (for potential balancing)
X5.5-3	-
X5.5-2	Shield GND (via capacitor)
X5.5-1	Shield GND

Combined fibre-optic connection (plastic and glass)

If the relay is provided with the optional fibre-optic communication module for plastic and glass fibre, the plastic fibre-optic cables are connected to terminals X5.3-RX (Receiver) and X5.3-TX (Transmitter) and the glass fibre-optic cables to terminals X5.4-RX (Receiver) and X5.4-TX (Transmitter).

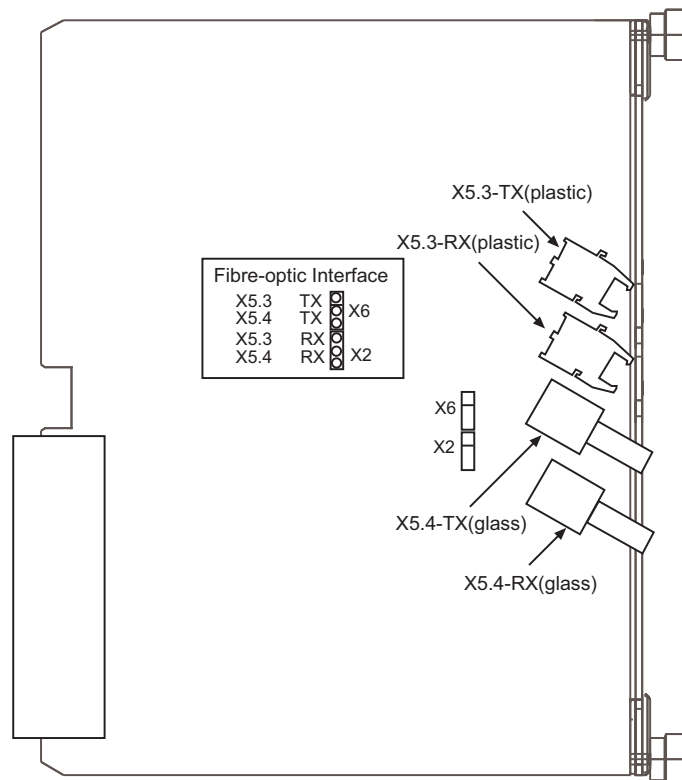
The fibre-optic interface is selected with jumpers X6 and X2 located on the PCB of the communication module (see Fig. 5.2.3.-2).

Table 5.2.3.-3 Transmitter selection

Transmitter	Position of jumper X6
Plastic	X5.3-TX
Glass	X5.4-TX

Table 5.2.3.-4 Receiver selection

Transmitter	Position of jumper X2
Plastic	X5.3-RX
Glass	X5.4-RX



A040335

Fig. 5.2.3.-2 Jumper location on the communication module for plastic and glass fibre

Table 5.2.3-5 Fibre-optic rear connectors (plastic and glass)

Terminal	Function
X5.3-TX	Transmitter for plastic fibre
X5.3-RX	Receiver for plastic fibre
X5.4-TX	Transmitter for glass fibre
X5.4-RX	Receiver for plastic fibre

RS-485 connection for the DNP 3.0 communication module

If the relay is provided with the optional DNP 3.0 communication module, the cable is connected to terminals X5.8/1-2 and X5.8/4-8. The connection socket is a 8-pin header-type socket and the terminals are of screw compression type.

The DNP communication module follows the DNP standard and is intended to be used in a daisy-chain bus wiring scheme with 2- or 4-wire, half-duplex, multi-point communication.



The maximum number of devices (nodes) connected to the bus where the relay is being used is 32, and the maximum length of the bus is 1200 meters in optimum conditions and with slow communication speed.

When connecting the relay to the bus, a quality twisted pair shielded cable is to be used. The conductors of the pair are connected to A and B. If signal ground is being used for balancing potential differences between devices/nodes, a quality dual twisted pair shielded cable is to be used. In this case, one pair is connected to A and B, and one of the conductors of the other pair to signal ground. When connecting one device to another, A is connected to A and B to B.

When using a 4-wire bus, one pair is connected to +RX and -RX and the other to +TX and -TX. If signal ground is being used, a quality cable with three or several pairs is to be used and one of the conductors of a pair connected to signal ground.

The cable shield is to be connected directly to earth (shield GND) in one point/ device of the bus. Other devices connected to the bus should have the cable shield connected to earth via a capacitor (shield GND via capacitor).



Signal ground can only be used for balancing potential differences between devices/nodes if all devices connected to the bus have isolated DNP interfaces.

The DNP communication module is provided with jumpers for setting bus termination and fail-safe biasing. The bus is to be terminated at both ends, which can be done by using the internal termination resistor on the DNP communication

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module. The termination resistor is selected by setting jumper X6 or/and X12 to the ON position. If the internal termination resistor of 120Ω is used, the impedance of the cable should be the same.

The bus is to be biased at one end to ensure fail-safe operation, which can be done using the pull-up and pull-down resistors on the communication module. The pull-up and pull-down resistors are selected by setting jumpers X8, X7, X13 and X11 to the ON position.

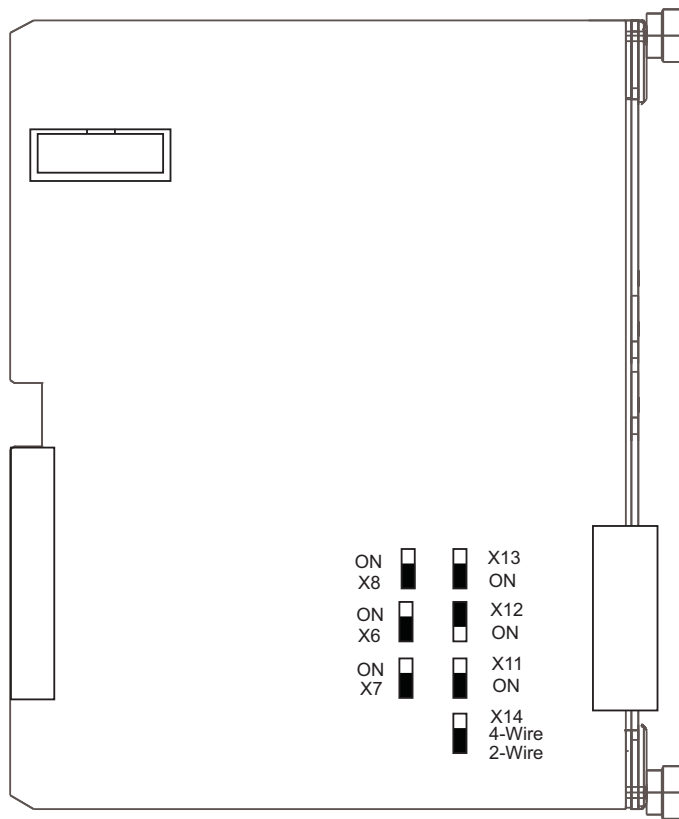
The 2-wire bus is selected by default (jumper X14) without termination or biasing. The jumpers X6, X7, X8 and X12 are in OFF position. The jumpers X11 and X13 are in ON position.

Table 5.2.3.-6 RS-485 rear connector (DNP 3.0)

Terminal	Function
X5.8-8	Data A (+ RX)
X5.8-7	Data B (- RX)
X5.8-6	Data A (+ TX)
X5.8-5	Data B (- TX)
X5.8-4	Signal GND (for potential balancing)
X5.8-3	-
X5.8-2	Shield GND (via capacitor)
X5.8-1	Shield GND

Table 5.2.3.-7 Jumper numbering

Terminal	Function	Signal
X8	Pull-up	Data A (+ TX)
X6	Termination	TX
X7	Pull-down	Data B (- TX)
X13	Pull-up	Data A (+ RX)
X12	Termination	RX
X11	Pull-down	Data B (- RX)
X14	4-wire/2-wire	-



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Fig. 5.2.3.-3 Jumper location on the DNP 3.0 communication module

5.2.4.

Technical data

Table 5.2.4.-1 Dimensions (for dimension drawings, refer to the Installation Manual)

Width, frame 177 mm, case 164 mm
Height, frame 177 mm (4U), case 160 mm
Depth, case 149.3 mm
Weight of the relay ~3.5 kg
Weight of the spare unit ~1.8 kg

Table 5.2.4.-2 Power supply

<p>U_{aux} rated:</p> <p>-REF610CxxHxxx</p> <p>-REF610CxxLxxx</p>	<p>$U_r = 100/110/120/220/240$ V AC</p> <p>$U_r = 110/125/220/250$ V DC</p> <p>$U_r = 24/48/60$ V DC</p>
<p>U_{aux} variation (temporary):</p> <p>-REF610CxxHxxx</p> <p>-REF610CxxLxxx</p>	<p>85...110% of U_r (AC)</p> <p>80...120% of U_r (DC)</p> <p>80...120% of U_r (DC)</p>
<p>Burden of auxiliary voltage supply under quiescent (P_q)/operating condition</p>	<p><9 W/13 W</p>

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Ripple in the DC auxiliary voltage	Max 12% of the DC value (at frequency of 100 Hz)
Interruption time in the auxiliary DC voltage without resetting the relay	<50 ms at U_{aux} rated
Time to trip from switching on the auxiliary voltage	<350 ms
Internal over temperature limit	+100°C
Fuse type	T2A/250 V

Table 5.2.4.-3 Energizing inputs

Rated frequency	50/60 Hz \pm 5 Hz		
Rated current, $I_n()$	0.2 A	1 A	5 A
Thermal withstand capability:			
• continuously	1.5 A	4 A	20 A
• for 1 s	20 A	100 A	500 A
• for 10 s	5 A	25 A	100 A
Dynamic current withstand:			
• half-wave value	50 A	250 A	1250 A
Input impedance	<750 m Ω	<100 m Ω	<20 m Ω

Table 5.2.4.-4 Measuring range

Measured currents on phases I_{L1} , I_{L2} and I_{L3} as multiples of the rated currents of the energizing inputs	$0...50 \times I_n$
Earth-fault current as a multiple of the rated current of the energizing input	$0...20 \times I_n$

Table 5.2.4.-5 Digital inputs

Rated voltage:	DI1...DI2	DI3...DI5 (optional)
REF610CxxHxxx	110/125/220/250 V DC	
Activating threshold	Max. 88 V DC (110 V DC - 20%)	
REF610CxxLxxx	24/48/60/110/125/220/250 V DC	
Activating threshold	Max. 19,2 V DC (24 V DC - 20%)	
REF610CxxxxLx		24/48/60/110/125/220/250 V DC
Activating threshold		Max. 19,2 V DC (24 V DC -20%)
REF610CxxxxHx		110/125/220/250 V DC
Activating threshold		Max. 88 V DC (110 V DC -20%)
Operating range	\pm 20% of the rated voltage	
Current drain	2...18 mA	
Power consumption/input	\leq 0.9 W	

Table 5.2.4-6 Signal output SO1 and optional SO4 and SO5

Rated voltage	250 V AC/DC
Continuous carry	5 A
Make and carry for 3.0 s	15 A
Make and carry for 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R <40 ms, at 48/110/220 V DC	1 A/0.25 A/0.15 A (5 A/3 A/1 A for series connection of SO4 and SO5)
Minimum contact load	100 mA at 24 V AC/DC

Table 5.2.4-7 Signal output SO2, optional SO3, and IRF output

Rated voltage	250 V AC/DC
Continuous carry	5 A
Make and carry for 3.0 s	10 A
Make and carry for 0.5 s	15 A
Breaking capacity when the control-circuit time constant L/R <40 ms, at 48/110/220 V DC	1 A/0.25 A/0.15 A
Minimum contact load	100 mA at 24 V AC/DC

Table 5.2.4-8 Power outputs (PO1, PO2, PO3)

Rated voltage	250 V AC/DC
Continuous carry	5 A
Make and carry for 3.0 s	15 A
Make and carry for 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R <40 ms, at 48/110/220 V DC (PO1 with both contacts connected in series)	5 A/3 A/1 A
Minimum contact load	100 mA at 24 V AC/DC
Trip-circuit supervision (TCS):	
• Control voltage range	20...265 V AC/DC
• Current drain through the supervision circuit	~1.5 mA
• Minimum voltage over a contact	20 V AC/DC (15...20 V)

Table 5.2.4-9 Lens sensor and optic fibre for arc protection

Normal service temperature range	-40...+100 °C
Maximum service temperature range, max 1 h	+140°C
Minimum permissible bending radius of the connection fibre	100 mm

Table 5.2.4-10 Enclosure class of the flush-mounted relay

Front side	IP 54 Category 2
Rear side, top of the relay	IP 40
Rear side, connection terminals	IP 20

Table 5.2.4.-11 Environmental tests and conditions

Recommended service temperature range (continuous)	-10...+55°C
Humidity	< 95% RH
Limit temperature range (short-term)	-40...+70°C
Transport and storage temperature range	-40...+85°C according to IEC 60068-2-48
Dry heat test (humidity <50%)	According to IEC 60068-2-2
Dry cold test	According to IEC 60068-2-1
Damp heat test, cyclic (humidity >93%)	According to IEC 60068-2-30
Atmospheric pressure	86...106 kPa

Table 5.2.4.-12 Electromagnetic compatibility tests

EMC immunity test level meets the requirements listed below:	
1 MHz burst disturbance test, class III	According to IEC 60255-22-1, IEC 61000-4-18
<ul style="list-style-type: none"> • Common mode • Differential mode 	2.5 kV 1.0 kV
Electrostatic discharge test, class IV	According to IEC 61000-4-2, IEC 60255-22-2 and ANSI C37.90.3-2001
<ul style="list-style-type: none"> • For contact discharge • For air discharge 	8 kV 15 kV
Radio frequency interference tests:	
<ul style="list-style-type: none"> • Conducted, common mode 	According to IEC 61000-4-6 and IEC 60255-22-6 (2000) 10 V (rms), f = 150 kHz...80 MHz
<ul style="list-style-type: none"> • Radiated, amplitude-modulated 	According to IEC 61000-4-3 and IEC 60255-22-3 (2000) 10 V/m (rms), f = 80...1000 MHz
<ul style="list-style-type: none"> • Radiated, pulse-modulated 	According to the ENV 50204 and IEC 60255-22-3 (2000) 10 V/m, f = 900 MHz
Fast transient disturbance tests	According to IEC 60255-22-4 and IEC 61000-4-4
<ul style="list-style-type: none"> • Power outputs, energizing inputs, power supply • I/O ports 	4 kV 2 kV
Surge immunity test	According to IEC 61000-4-5 and IEC 60255-22-5
<ul style="list-style-type: none"> • Power outputs, energizing inputs, power supply • I/O ports 	4 kV, line-to-earth 2 kV, line-to-line 2 kV, line-to-earth 1 kV, line-to-line
Power frequency (50 Hz) magnetic field IEC 61000-4-8	300 A/m continuous
Power frequency immunity test:	According to IEC 60255-22-7 and IEC 61000-4-16
REF610CxxHxxx and REF610CxxxxHx	Class A
<ul style="list-style-type: none"> • Common mode • Differential mode 	300 V rms 150 V rms

REF610CxxLxxx and REF610CxxxxLx • Common mode • Differential mode	Class B 300 V rms 100 V rms
Voltage dips and short interruptions	According to IEC 61000-4-11 30%/10 ms 60%/100 ms 60%/1000 ms >95%/5000 ms
Electromagnetic emission tests	According to the EN 55011
• Conducted, RF-emission (Mains terminal) • Radiated RF-emission	EN 55011, class A, IEC 60255-25 EN 55011, class A, IEC 60255-25
CE approval	Complies with the EMC directive EMC 2004/108/EC and the LV directive LV 2006/95/EC

Table 5.2.4.-13 Standard tests

Insulation tests:	
Dielectric tests • Test voltage	According to IEC 60255-5 2 kV, 50 Hz, 1 min
Impulse voltage test • Test voltage	According to IEC 60255-5 5 kV, unipolar impulses, waveform 1.2/50 μ s, source energy 0.5 J
Insulation resistance measurements • Isolation resistance	According to IEC 60255-5 >100 M Ω , 500 V DC
Mechanical tests:	
Vibration tests (sinusoidal)	According to IEC 60255-21-1, class I
Shock and bump test	According to IEC 60255-21-2, class I

Table 5.2.4.-14 Data communication

Rear interface: • Fibre-optic or RS-485 connection • SPA bus, IEC 60870-5-103, DNP 3.0 or Modbus protocol • 9.6 or 4.8 kbps (additionally 2.4, 1.2 or 0.3 kbps for Modbus)
Front interface: • Optical connection (infrared): wirelessly or via the front communication cable (1MRS050698) • SPA bus protocol • 9.6 or 4.8 kbps (9.6 kbps with front communication cable)

Optional communication modules and protocols

- SPA-bus, IEC 60870-5-103, Modbus® (RTU and ASCII):
 - Plastic fibre
 - Plastic fibre with arc protection input
 - Plastic and glass fibre
 - Plastic and glass fibre with arc protection input
 - RS485
 - RS485 with arc protection input
- DNP 3.0:

- RS485 including DNP 3.0 protocol
- RS485 including DNP 3.0 protocol and arc protection input

Auxiliary voltage

The relay requires a secured auxiliary voltage supply to operate. The internal power supply of the relay forms the voltages required by the relay electronics. The power supply is a galvanically isolated (flyback-type) DC/DC converter. When the auxiliary voltage is connected, the green indicator LED (ready) on the front panel is lit. For detailed information on power supply, refer to Table 5.2.4.-2.

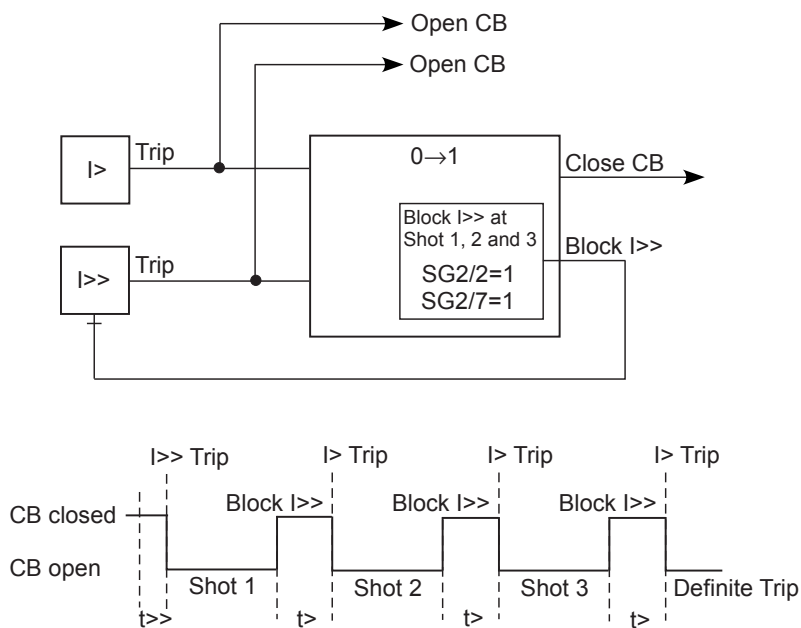
The primary side of the power supply is protected with a fuse located on the printed circuit board of the relay.

6. Application examples

6.1. Auto-reclose function

6.1.1. Fast tripping and initiation of shot 1 using two protection stages

In several applications, such as fuse-saving applications involving down-stream fuses, tripping and initiation of shot 1 should be fast (instantaneous or short-time delayed) and of shot 2 and 3, and definite tripping time delayed. In this example, two overcurrent stages are used, I> and I>>. Stage I>> is given an instantaneous characteristic and Stage I> a time delay. By setting SG2/2 to 1 and SG2/7 to 1, Stage I>> will be blocked by the AR function during shot 2 and 3.



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Fig. 6.1.1.-1 Fast initiation of shot 1 using one fast and one delayed stage

In case of a short-circuit in the network, stage I>> will trip the circuit breaker and initiate shot 1. At the time of shot initiation, the blocking of stage I>> will be activated. If the network fault is not cleared, stage I> will trip the circuit breaker and continue the auto-reclose sequence to shot 2, shot 3 and finally definite tripping.

As the set start value of stage I> in this example is higher than that of stage I>>, as sometimes is the case, it is possible that the current will not exceed the set start value of stage I> while the blocking of stage I>> is active. This will lead to a pumping effect when the AR function is reset (the blocking of stage I>> included), i.e. the AR sequence will start over and over again.

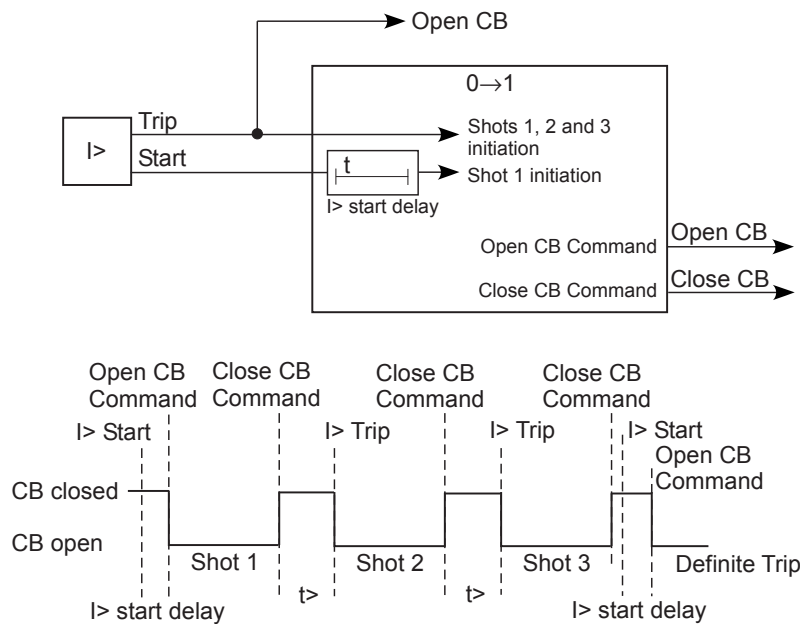
To avoid such a pumping effect, a cutout time is used. The cutout time, like the reclaim time, will start when the set dead time elapses and the AR function issues a reclosing command to the circuit breaker. By setting the cutout time to be shorter

than the reclaim time (e.g. half of the reclaim time), the blocking of stage I>> (in this case) will be reset before the AR function. Stage I>> will now be able to continue the AR sequence and the pumping effect will thus be avoided.

6.1.2. Fast tripping and initiation of shot 1 using start signals

An alternative way to achieve fast tripping and shot initiation (typical for certain countries, such as Finland), is to use start signals from protection stages for shot initiation. The AR function of REF610 can be initiated by the start signals from stages I> and I₀>.

The start time of stages I> and I₀> is very short but can be extended with the settings AR I> start Delay and AR I₀> start Delay of the AR function. When the set start delay elapses, the shot will be initiated and the AR function will trip the circuit breaker by issuing the Open CB Command.



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Fig. 6.1.2.-1 Fast initiation of shot 1 using start signals

Shot initiation by a start signal applies only to shot 1, and to definite tripping, i.e. when no more shots are allowed but the network fault has not been cleared. In this case, the AR function will trip the circuit breaker on expiration of AR I> start Delay and AR I₀> start Delay.



The signal Open CB Command must be routed to the output contact used for tripping the circuit breaker.



At the factory default delay of 300 s for AR I> start Delay and AR I₀> start Delay, the start signals will, in practise, not be used for shot initiation. However, if stages I> or I₀> have been given an IDMT characteristic, the factory default delay of 300 s will function as a trip time limiter. With small currents, the operate time at IDMT characteristic may be relatively long. However, since the start signals are always routed to the AR function, the circuit breaker will be tripped and a shot initiated (provided that the signal Open CB Command has been routed to the trip output contact) on expiration of the factory default delay.



When using AR I> start Delay and AR I₀> start Delay for shot initiation and the signal Open CB Command has been routed to the trip output contact, stages I> and I₀> should not be used for blocking of shot 1.

6.1.3.

Selecting adaptive sequence length

The auto-reclose sequence can be set to adapt to the fault current, either through blocking of shot initiation or inhibition of the AR function.

In the examples below, three overcurrent stages (I>, I>> and I>>>) are used and the number of shots of the AR sequence vary depending on which stages trips.

Example:

Start by checking that the switches have been properly set:

Settings	Function
SG1/1=1	Blocking of initiation of shot 1 by the trip signal from stage I>>
SG3/1=1	Inhibition of the AR function by the trip signal from stage I>>>

Number of shots = 3

If one or several phase currents

- exceed the set start value of stage I> but not of stages I>> and I>>>, the AR sequence will include shot 1, 2 and 3.
- exceed the set start value of stages I> and I>> but not of stage I>>>, the AR sequence will include shot 2 and 3.
- exceed the set start value of stages I>, I>> and I>>>, no shots will be performed (AR function inhibited).



Stage I>>> should have the shortest and stage I> the longest operate time.

Example:

Start by checking that the switches have been properly set:

Settings	Function
SG1/5=1	Blocking of initiation of shot 2 and 3 by the trip signal from stage I>>
SG3/1=1	Inhibition of the AR function by the trip signal from stage I>>>
Number of shots = 3	

If one or several phase currents

- exceed the set start value of stage I> but not of stages I>> and I>>>, the AR sequence will include shot 1, 2 and 3
- exceed the set start value of stages I> and I>> but not of stage I>>>, the AR sequence includes only shot 1
- exceed the set start value of stages I>, I>> and I>>>, no shots will be performed (AR function inhibited).



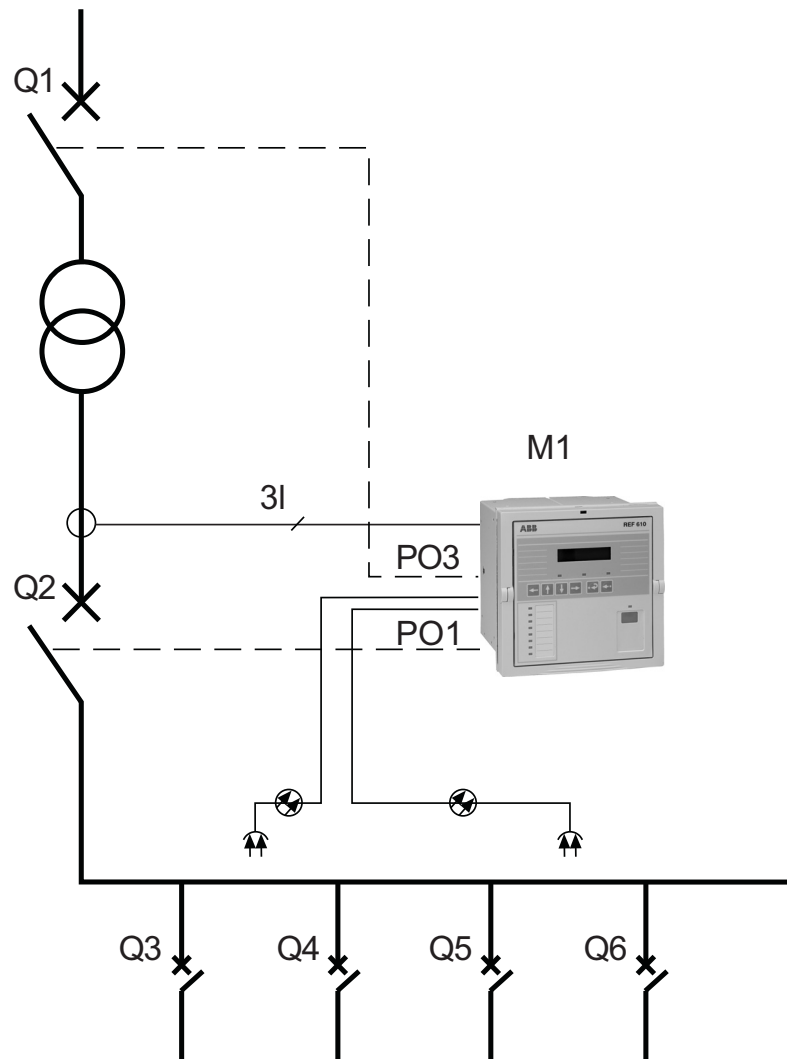
Stage I>>> should have the shortest and stage I> the longest operate time.

6.2. Arc protection

6.2.1. Arc protection with one REF610 relay

In installations with limited possibilities to realize signalling between relays protecting incoming and outgoing feeders, or if only the relay for the incoming feeder is to be exchanged, an arc protection with a lower protective level can be achieved with one protection relay.

An arc protection with one REF610 only (see Fig. 6.2.1.-1) is realized by installing two arc lens sensors, connected to the relay protecting the incoming feeder, to detect an arc on the busbar. On arc detection, the arc protection stage will trip the circuit breaker of the incoming feeder. The maximum recommended installation distance between the two lens sensors in the busbar area is 6 meters and the maximum distance from a lens sensor to the end of the busbar 3 meters.



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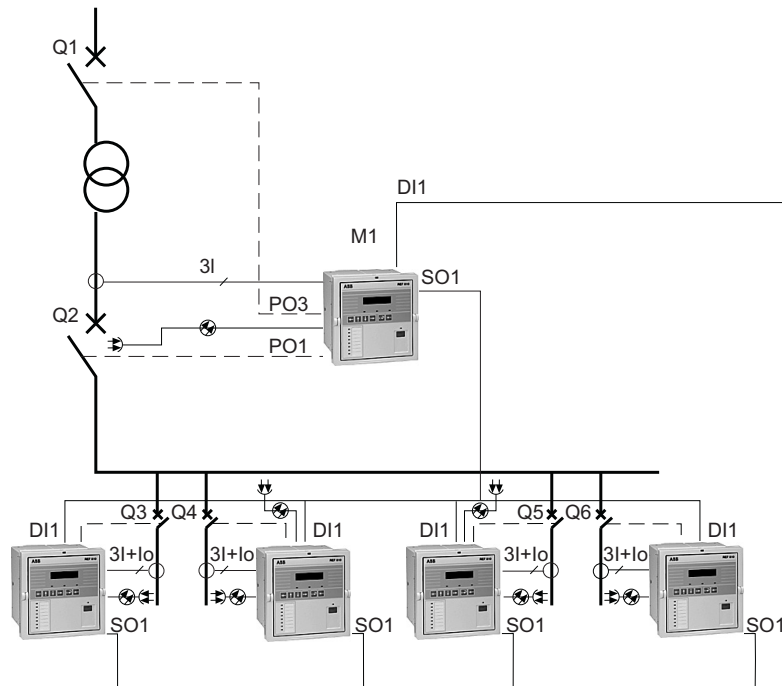
Fig. 6.2.1.-1 Arc protection with one REF610

6.2.2.

Arc protection with several REF610 relays

When using several REF610 relays (see Fig. 6.2.2.-1), a REF610 protecting an outgoing feeder will trip the circuit breaker of the outgoing feeder when detecting an arc at the cable terminations. If the REF610 protecting the outgoing feeder detects an arc on the busbar (via the other lens sensor), however, it will generate a signal to the REF610 protecting the incoming feeder. On detection of the signal, the REF610 protecting the incoming feeder will trip the circuit breaker of the incoming feeder and generate an external trip signal to all REF610 relays protecting outgoing feeders, which in turn will result in tripping of all circuit breakers of outgoing feeders.

For maximum safety, the REF610 relays can be configured to trip all circuit breakers, regardless of where the arc is detected.



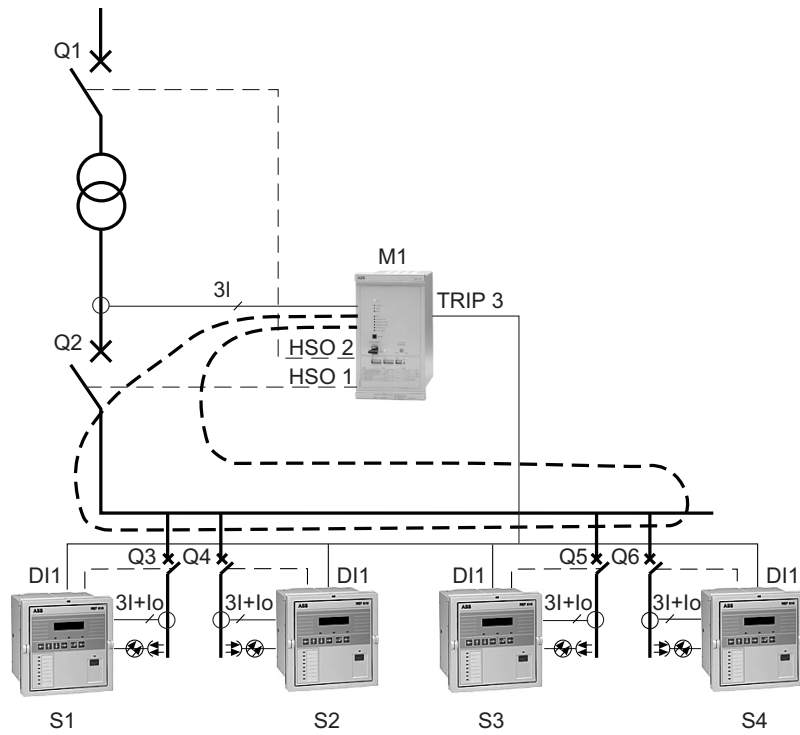
A040363

Fig. 6.2.2.-1 Arc protection with several REF610 relays

6.2.3. Arc protection with several REF610 relays and one REA101

When realizing an arc protection with both REF610 relays and an REA101 (see Fig. 6.2.3.-1), the cable terminations of outgoing feeders are protected by REF610 relays using one lens sensor for each relay. The busbar and the incoming feeder is protected by the sensor loop of the REA101.

On arc detection at the cable terminations, REF610 will trip the circuit breaker of the outgoing feeder. However, on detection of an arc on the busbar, REA101 will trip the circuit breaker of the incoming feeder and generate an external trip signal to all REF610 relays protecting outgoing feeders, which in turn will result in tripping of all circuit breakers of outgoing feeders.



A040364

Fig. 6.2.3.-1 Arc protection with REF610 and REA101

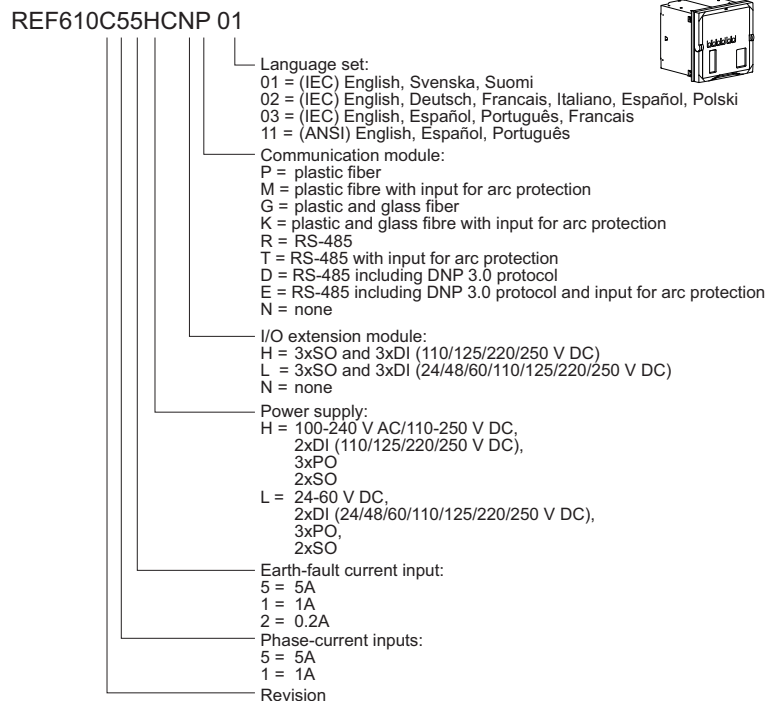
7. Ordering information

When ordering protection relays and/or accessories, specify the following:

- Order number
- HMI language set number
- Quantity

The order number identifies the protection relay type and hardware as described in the figures below and is labelled on the marking strip under the lower handle of the relay.

Use the ordering key information in Fig. 7-1 to generate the order number when ordering complete protection relays.

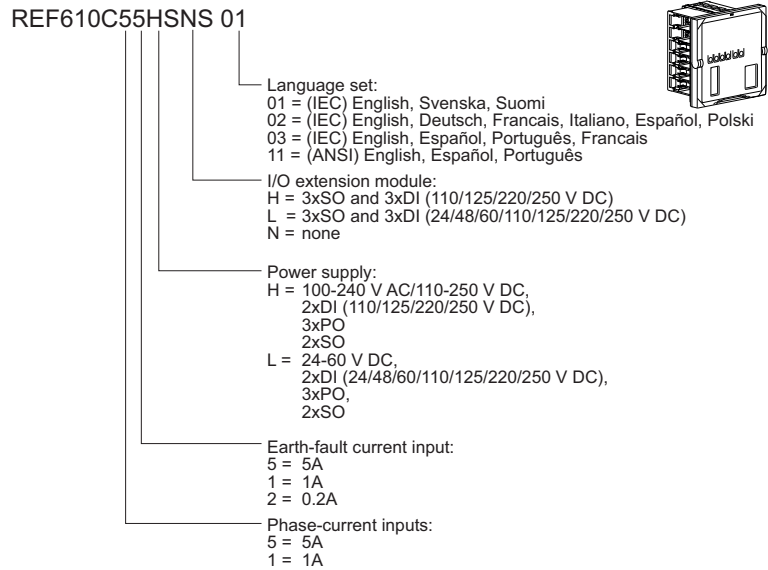


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Fig. 7-1 Ordering key for complete relays

Use the ordering key information in Fig. 7-2 to generate the order number when ordering spare units.

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Fig. 7.-2 Ordering key for spare units

The following accessories are available:

Item	Order number
Semi-flush mounting kit	1MRS050696
Inclined (/ 25°) semi-flush mounting kit	1MRS050831
Wall mounting kit	1MRS050697
19" Rack mounting kit, two relays side-by-side	1MRS050695
19" Rack mounting kit, single relay	1MRS050694
19" Rack mounting kit, single relay and RTXP18 (REF610)	1MRS090939
19" equipment frame mounting kit (Combiflex), single relay and RTXP18 (REF610)	1MRS090925
19" equipment frame mounting kit (Combiflex), single relay	1MRS050779
Pre-manufactured lens sensor and optic fibre for arc protection:	
• 1.5 m ±3%	1MRS120534-1.5
• 3 m ±3%	1MRS120534-3.0
• 5 m ±3%	1MRS120534-5.0
Front communication cable	1MRS050698
Communication modules:	
• Plastic fibre	1MRS050889
• Plastic fibre with input for arc protection	1MRS050890
• RS-485	1MRS050892
• RS-485 with input for arc protection	1MRS050888
• Plastic and glass fibre	1MRS050891
• Plastic and glass fibre with input for arc protection	1MRS050885
• RS-485 including DNP 3.0 protocol	1MRS050887
• RS-485 including DNP 3.0 protocol and input for arc protection	1MRS050886

8. Check lists

Table 8.-1 Setting group 1

Variable	Group/ Channel 1 (R, W, P)	Setting range	Default setting	Custom- er's setting
Start value of stage I>	1S1	0.30...5.0 x I _n	0.30 x I _n	
Operate time of stage I>	1S2	0.05...300 s	0.05 s	
Time/current characteristic for stage I>	1S3	0...9	0	
Time multiplier k	1S4	0.05...1.00	0.05	
Time multiplier n	1S5	1.0...15.0	1.0	
Resetting time of stage I>	1S6	0.05...2.50 s	0.05 s	
Start value of stage I>>	1S7	0.50...35.0 x I _n	0.50 x I _n	
Operate time of stage I>>	1S8	0.04...300 s	0.04 s	
Start value of stage I>>>	1S9	0.50...35.0 x I _n	0.50 x I _n	
Operate time of stage I>>>	1S10	0.04...30.0 s	0.04 s	
Start value of stage I ₀ >	1S11	1.0...100% I _n	1.0% I _n	
Operate time of stage I ₀ >	1S12	0.05...300 s	0.05 s	
Time/current characteristic for stage I ₀ >	1S13	0...9	0	
Time multiplier k ₀	1S14	0.05...1.00	0.05	
Time multiplier n ₀	1S15	1.0...15.0	1.0	
Resetting time of stage I ₀ >	1S16	0.05...2.50 s	0.05 s	
Start value of stage I ₀ >>	1S17	5.0...800% I _n	5.0% I _n	
Operate time of stage I ₀ >>	1S18	0.05...300 s	0.05 s	
Start value of stage ΔI>	1S19	10...100%	100 %	
Operate time of stage ΔI>	1S20	1...300 s	60 s	
Full load current	1S21	0.30...1.50 x I _n	0.30 x I _n	
Time constant of stage θ>	1S22	1...200 min	1 min	
Alarm level of stage θ>	1S23	50...100% θ _t >	95% θ _t >	
Operate time of CBFP	1S24	0.10...60.0 s	0.10 s	
Number of AR shots	1S25	0 = AR is not in use 1 = shot 1 2 = shot 1 and 2 3 = shot 1, 2 and 3	0	
Current limit ArcI> of stage ARC	1S26	0.50...35.0 x I _n	2.50 x I _n	
Current limit ArcI ₀ > of stage ARC	1S27	5.0...800% I _n	20% I _n	
Checksum, SGF 1	1S61	0...255	0	
Checksum, SGF 2	1S62	0...127	0	
Checksum, SGF 3	1S63	0...127	120	
Checksum, SGF 4	1S64	0...63	0	

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Variable	Group/ Channel 1 (R, W, P)	Setting range	Default setting	Custom- er's setting
Checksum, SGF 5	1S65	0...255	0	
Checksum, SGB 1	1S71	0...1048575	0	
Checksum, SGB 2	1S72	0...1048575	0	
Checksum, SGB 3	1S73	0...1048575	0	
Checksum, SGB 4	1S74	0...1048575	0	
Checksum, SGB 5	1S75	0...1048575	0	
Checksum, SGR 1	1S81	0...8388607	2108074	
Checksum, SGR 2	1S82	0...8388607	2108074	
Checksum, SGR 3	1S83	0...8388607	2108074	
Checksum, SGR 4	1S84	0...8388607	5461	
Checksum, SGR 5	1S85	0...8388607	5461	
Checksum, SGR 6	1S86	0...8388607	0	
Checksum, SGR 7	1S87	0...8388607	0	
Checksum, SGR 8	1S88	0...8388607	0	
Checksum, SGL 1	1S91	0...8388607	0	
Checksum, SGL 2	1S92	0...8388607	0	
Checksum, SGL 3	1S93	0...8388607	0	
Checksum, SGL 4	1S94	0...8388607	0	
Checksum, SGL 5	1S95	0...8388607	0	
Checksum, SGL 6	1S96	0...8388607	0	
Checksum, SGL 7	1S97	0...8388607	0	
Checksum, SGL 8	1S98	0...8388607	0	

Table 8.-2 Setting group 2

Variable	Group/ Channel 2 (R, W, P)	Setting range	Default setting	Custom- er's setting
Start value of stage I>	2S1	$0.30...5.0 \times I_n$	$0.30 \times I_n$	
Operate time of stage I>	2S2	0.05...300 s	0.05 s	
Time/current characteristic for stage I>	2S3	0...9	0	
Time multiplier k	2S4	0.05...1.00	0.05	
Time multiplier n	2S5	1.0...15.0	1.0	
Resetting time of stage I>	2S6	0.05...2.50 s	0.05 s	
Start value of stage I>>	2S7	$0.50...35.0 \times I_n$	$0.50 \times I_n$	
Operate time of stage I>>	2S8	0.04...300 s	0.04 s	
Start value of stage I>>>	2S9	$0.50...35.0 \times I_n$	$0.50 \times I_n$	
Operate time of stage I>>>	2S10	0.04...30.0 s	0.04 s	
Start value of stage I ₀ >	2S11	$1.0...100\% I_n$	$1.0\% I_n$	
Operate time of stage I ₀ >	2S12	0.05...300 s	0.05 s	
Time/current characteristic for stage I ₀ >	2S13	0...9	0	
Time multiplier k ₀	2S14	0.05...1.00	0.05	

Variable	Group/ Channel 2 (R, W, P)	Setting range	Default setting	Customer's setting
Time multiplier n_0	2S15	1.0...15.0	1.0	
Resetting time of stage $I_0>$	2S16	0.05...2.50 s	0.05 s	
Start value of stage $I_0>>$	2S17	5.0...800% I_n	5.0% I_n	
Operate time of stage $I_0>>$	2S18	0.05...300 s	0.05 s	
Start value of stage $\Delta I>$	2S19	10...100%	100 %	
Operate time of stage $\Delta I>$	2S20	1...300 s	60 s	
Full load current	2S21	0.30...1.50 x I_n	0.30 x I_n	
Time constant of stage $\theta>$	2S22	1...200 min	1 min	
Alarm level of stage $\theta>$	2S23	50...100% $\theta t>$	95% $\theta t>$	
Operate time of CBFP	2S24	0.10...60.0 s	0.10 s	
Number of AR shots	2S25	0 = AR is not in use 1 = shot 1 2 = shot 1 and 2 3 = shot 1, 2 and 3	0	
Current limit $Arcl>$ of stage ARC	2S26	0.50...35.0 x I_n	2.50 x I_n	
Current limit $Arcl_0>$ of stage ARC	2S27	5.0...800% I_n	20% I_n	
Checksum, SGF 1	2S61	0...255	0	
Checksum, SGF 2	2S62	0...127	0	
Checksum, SGF 3	2S63	0...127	120	
Checksum, SGF 4	2S64	0...63	0	
Checksum, SGF 5	2S65	0...255	0	
Checksum, SGB 1	2S71	0...1048575	0	
Checksum, SGB 2	2S72	0...1048575	0	
Checksum, SGB 3	2S73	0...1048575	0	
Checksum, SGB 4	2S74	0...1048575	0	
Checksum, SGB 5	2S75	0...1048575	0	
Checksum, SGR 1	2S81	0...8388607	10922	
Checksum, SGR 2	2S82	0...8388607	10922	
Checksum, SGR 3	2S83	0...8388607	10922	
Checksum, SGR 4	2S84	0...8388607	5461	
Checksum, SGR 5	2S85	0...8388607	5461	
Checksum, SGR 6	2S86	0...8388607	0	
Checksum, SGR 7	2S87	0...8388607	0	
Checksum, SGR 8	2S88	0...8388607	0	
Checksum, SGL 1	2S91	0...8388607	0	
Checksum, SGL 2	2S92	0...8388607	0	
Checksum, SGL 3	2S93	0...8388607	0	
Checksum, SGL 4	2S94	0...8388607	0	
Checksum, SGL 5	2S95	0...8388607	0	

Variable	Group/ Channel 2 (R, W, P)	Setting range	Default setting	Customer's setting
Checksum, SGL 6	2S96	0...8388607	0	
Checksum, SGL 7	2S97	0...8388607	0	
Checksum, SGL 8	2S98	0...8388607	0	

Table 8.-3 Control parameters

Description	Parameter (channel 0)	Setting range	Default setting	Customer's setting
Rated frequency	V104	50 or 60 Hz	50 Hz	
Time setting range for demand values in minutes	V105	0...999 min	10 min	
Non-volatile memory settings	V106	0...31	31	
Time setting for disabling new trip indications on the LCD	V108	0...999 min	60 min	
Trip-circuit supervision	V113	0 = not in use 1 = in use	0	
Remote control of settings	V150	0 = setting group 1 1 = setting group 2	0	
Unit address of the relay	V200	1...254	1	
Data transfer rate (SPA), kbps	V201	9.6/4.8	9.6	
Rear communication protocol	V203	0 = SPA 1 = IEC_103 2 = Modbus RTU 3 = Modbus ASCII	0	
Connection type	V204	0 = loop 1 = star	0	
Line-idle state	V205	0 = light off 1 = light on	0	
Optional communication module	V206	0 = not in use 1 = in use	0	

Table 8.-4 Parameters for the disturbance recorder

Description	Parameter (channel 0)	Setting range	Default setting	Customer's setting
Sampling rate	M15	800/960 Hz 400/480 Hz 50/60 Hz	800 Hz	
Station identification/unit number	M18	0...9999	0	
Name of the feeder	M20	Max 16 characters	- ABB -	

Description	Parameter (channel 0)	Setting range	Default setting	Customer's setting
Analogue channel conversion factor and unit for I_{L1} , I_{L2} and I_{L3}	M80, M81, M82	Factor 0...65535, unit (A, kA), e.g. 10, kA	00001, CT	
Analogue channel conversion factor and unit for the earth-fault current	M83	Factor 0...65535, unit (A, kA), e.g. 10, kA	00001, CT	
Internal trigger signals' checksum	V236	0...16383	682	
Internal trigger signal's edge	V237	0...16383	0	
Checksum of internal signal storing mask	V238	0...16383	751	
Post-triggering recording length	V240	0...100%	50 %	
External trigger signal's checksum	V241	0...31	0	
External trigger signal's edge	V242	0...31	0	
Checksum of external signal storing mask	V243	0...31	0	

Table 8-5 Auto-reclose parameters

Description	Parameter (channel 0)	Value	Default setting	Customer's setting
CB Closing time	V121	0.1...10 s	0.2 s	
Start delay of stage I>	V122	0...300 s	300 s	
Start delay of stage I0>	V123	0...300 s	300 s	
Reclaim time	V124	3...300 s	10 s	
Cutout time	V125	0.1...300 s	0.1 s	
Dead time of shot 1	V126	0.1...300 s	0.3 s	
Dead time of shot 2	V127	0.1...300 s	30 s	
Dead time of shot 3	V128	0.1...300 s	30 s	
SG1	V129	0...255	0	
SG2	V130	0...1023	0	
SG3	V131	0...31	15	

9. Abbreviations

Abbreviation	Description
AR	Autoreclosure
ASCII	American Standard Code for Information Interchange
CB	Circuit-breaker
CBFP	Circuit-breaker failure protection
CD	Change detect; compact disk
CPU	Central processing unit
CRC	Cyclical redundancy check
DI	Digital input
EEPROM	Electrically Erasable Programmable Read-Only Memory
EMC	Electromagnetic compatibility
EPA	Enhanced Performance Architecture
ER	Event records
FR	Fault record
GI	General interrogation
HMI	Human-machine interface
HR	Holding register
IDMT	Inverse definite minimum time characteristic
IEC	International Electrotechnical Commission
IEC_103	Standard IEC 60870-5-103
IED	Intelligent electronic device
IEEE	Institute of Electrical and Electronics Engineers, Inc.
IR	Input register
IRF	Internal relay fault
ISO	International Organization for Standardization
LCD	Liquid crystal display
LED	Light-emitting diode
LRC	Longitudinal redundancy check
MP	Minute-pulse
MSB	Most significant bit
MV	Medium voltage
NACK	Negative acknowledgments
NC	Normally closed
NO	Normally open
OSI	Open System Interconnection
PC	Personal computer
PCB	Printed circuit board
PLC	Programmable logical controller
PO	Power output, process object
RMS	Root mean square
RTU	Remote terminal unit

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SGB	Switchgroup for digital inputs
SGF	Switchgroup for functions
SGL	Switchgroup for LEDs
SGR	Switchgroup for output contacts
SO	Signal output
SP	Second-pulse
SPA	Data communication protocol developed by ABB
TCS	Trip-circuit supervision
UDR	User-defined register
UR	Unsolicited reporting



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