Technical reference manual
RXHB 411 and RAHB 411
Compact breaker failure relay and protection assemblies

About this manual

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Chapter 1 Introduction

About this chapter

This chapter introduces the user to the content in the manual. The intended use of the manual and the intended audience is described. The introduction chapter also contains references to other documents.

1 Introduction to the technical reference manual

1.1 About this manual

The technical reference manual describes how the relay can be applied and used for different purposes. The manual is intended to be used when calculating how the relay could be configured to suit different networks and systems. The technical reference manual is also intended to be used for reference purposes when knowledge in how the relay is designed and the theories of operation is needed. The technical reference manual does not contain any instructions, only technical descriptions about the relay and the protection assemblies.

The technical reference manual contains the following chapters:

- The *overview* chapter gives a brief overview over the application and design of the protection.
- The *application* chapter describes the application possibilities for the various protection functions available in the relay.
- The *requirements* chapter contains descriptions concerning the different requirements that have to be fulfilled in order to achieve reliable operation of the protection.
- The *functional description* chapter contains description about the theories of operation for the protection.
- The *design description* chapter contains description about the different parts that constitutes the protection assembly.
- The *technical data* chapter contains technical data presented in tables.
- The *ordering* chapter contains ordering tables which could be used when ordering.

1.2 Intended audience

1.2.1 General

The intended audience is the system engineer responsible for calculating how the relay should be set and configured.

1.2.2 Requirements

The intended audience is supposed to have good knowledge in protection systems for transmission and distribution electrical systems in order to understand the content in this manual.

1.3 Related documents

Document related to COMBIFLEX© assemblies	Identity number
Buyer's guide, Connection and installation components in COMBIFLEX©	1MRK 513 003-BEN
Buyer's guide, Panel mounting cases for COMBIFLEX© relays	1MRK 513 013-BEN
Buyer's guide, Relay accessories and components	1MRK 513 004-BEN
Buyer's guide, Test system COMBITEST	1MRK 512 001-BEN
Buyer's guide, DC-DC converter	1MRK 513 001-BEN
Buyer's guide, Auxiliary relays	1MRK 508 015-BEN

Documents related to RXHB 411 and RAHB 411	Identity number
Technical overview brochure	1MRK 509 070-BEN
Connection and setting guide (only RXHB 411)	1MRK 509 070-WEN
Operator's manual	1MRK 509 071-UEN
Technical reference manual	1MRK 509 072-UEN
Installation and commissioning manual	1MRK 509 073-UEN

1.4 Revisions

Revision	Description
-	Initial version

Chapter 2 Overview

About this chapter

This chapter introduces the user to the measuring relay. The features are presented and the application and the design for each protection function is given as a summary. By reading this chapter the user will gain an overview over the functionality of the relay.

1 Features

- **Three-phase compact numerical breaker failure relay**

- **Single- and three-phase breaker failure protection**
  - Single-phase, three-phase and three-phase unconditional start
  - Selectable current detection criteria
  - A patented adaptable current detector principle improves time coordination
  - Single-phase, three-phase and three-phase unconditional relay functions, all have different settable time delays for different types of faults
  - Re-trip function for faulted circuit-breaker
  - Instantaneous back-up trip is enabled when protected circuit-breaker is out-of-order
  - Additional back-up trip stage
  - Suitable for one and a half breaker systems

- **Pole-disagreement protection**
  - Phase current measuring, under and overcurrent detection levels
  - External blocking via binary input
  - Internal blocking during single-phase reclosing

- **General relay characteristics**
  - Setting parameters settable and readable via HMI
  - English or Swedish dialog
  - Two binary inputs for selected functions
  - Five binary output relays
  - Service values (primary/secondary) and disturbance information
  - Service value recording
  - Start and trip presentation via HMI and LED’s
  - Self-supervision with output error signal
  - Testing of output relays and operation of binary inputs via HMI
  - RAHB 411 can serve as a cost effective back-up protection to a REL 5xx line terminal in transmission systems
  - RAHB 411 can replace earlier breaker failure relays for example RAICA

- **Options**
  - Phase overcurrent protection with two stages and definite time delay. Possibility to use different delays for single- and multi-phase faults
  - Earth-fault protection with two stages and definite time delay
  - 4 additional inputs and 4 additional outputs

2 General

2.1 Compact breaker failure relay RXHB 411

The compact breaker failure relay RXHB 411 has a wide application range as an important part of the back-up protection for feeders and lines, transformers, capacitor banks, electric boilers as well as for generators and motors.

3 Functions

3.1 Breaker failure protection

3.1.1 Application

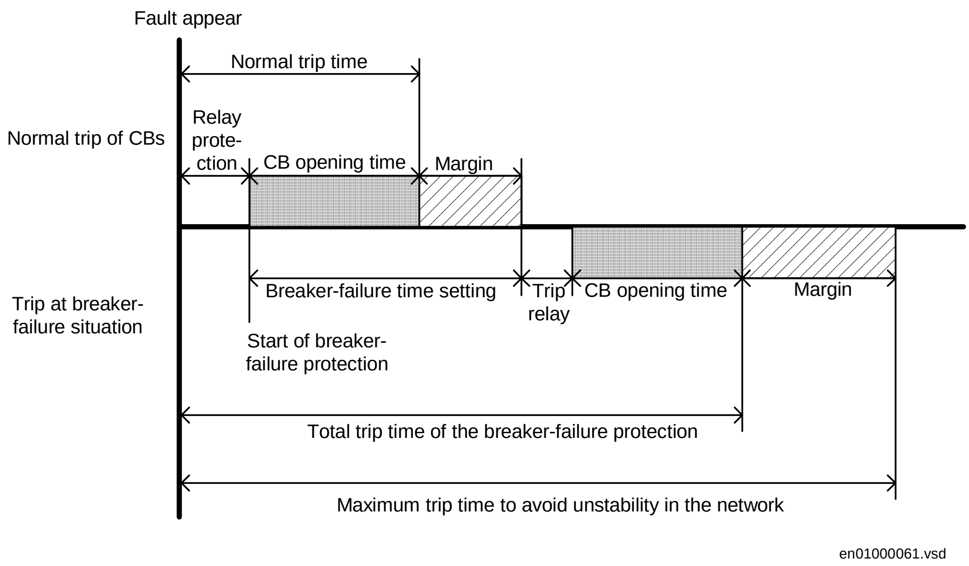


Figure 1: Operating diagram for the breaker failure situations.

Breaker failure protections are used in local back-up protection schemes. Breaker failure protection is required to give a rapid back-up protection when the primary circuit-breaker does not break properly at for example a short-circuit in the network. In such a case all adjacent circuit-breakers are tripped by the breaker failure protection. A simple and reliable way to secure the isolation of a fault is to check the appearance of fault current a selected time after the trip command. The time should be set long enough to permit the circuit-breaker to operate.

The timer setting of the back-up protection function should be selected with a certain margin to allow variation in the normal fault clearing time. The properties of the breaker failure protection allows the user to use smaller margins. Figure 1 shows the fault clearance time for the breaker failure situations.

3.1.2 Design

The breaker failure function can be activated from external protection functions via a binary input used for starting and seal-in of starting, as well as from internal protection functions trip. The breaker failure protection function may be one of the most important back-up protection functions in many cases and may be used separately or in combination with the phase and residual overcurrent functions. The combined breaker failure and overcurrent back-up protection RXHB 411 can therefor be used together with for example the 500 series products for an efficiently combined total protection terminal.

The operate values for the phase-current measuring elements and the neutral current element of the breaker failure function are separately set over the wide scale-range available. The use of the neutral current measuring element allows a more sensitive breaker failure setting for earth-faults. The phase-elements can also be set below rated current as they are not initiated during normal system operation. Thus a breaker failure relay operation can be obtained even though the fault current levels may be lower than rated line current during some fault conditions. The setting range is 0,1-1,0 times basic current. This basic current is settable between 1,0 - 10,0 times the rated current of the relay.

In case of a saturated current transformer there is a “false” DC-current in the secondary CT circuit. Also after a normal breaker trip operation there is a “false” DC-current in the secondary CT circuit. The measurement is therefor stabilised against the DC-transient that otherwise could cause unwanted operation. The use of a patented adaptable current detector reset function permits a short breaker failure margin time and a good critical system clearing time coordination. With the new technology used, the maximum reset time for current detection is below 10 ms even if there is a superimposed DC-current in the secondary CT circuit and also regardless of the magnitude of the current. Different time delay settings for different type of faults is possible to set, for example single-phase start versus three-phase start of the breaker failure protection. But the time delay setting is the same for the phase and neutral current measuring elements. The timer output is arranged to operate the trip logic for adjacent circuit-breakers and may also initiate transferred tripping.

3.2 Pole-disagreement protection

3.2.1 Application

There is a risk that the circuit-breaker will malfunction during normal switching operations (open and close), when there is no primary fault in the power system. The circuit-breaker can get different states for the poles (one pole closed and two poles open or two poles closed and one pole open). In such cases the breaker failure protection function is not activated. The situation with unsymmetrical, due to this circuit-breaker malfunction, can not be accepted. To detect such events a pole-disagreement protection can be used. This protection initiate a trip of the circuit-breaker in case of pole-disagreement.

The principle has advantages compared to protection functions using auxiliary contacts in the circuit-breaker, as those contacts can give misleading information in case of a mechanical fault within the circuit-breaker.

3.2.2 Design

The pole-disagreement protection is always active. The three-phase currents through the circuit-breaker is supervised. The protection function has two sets of current level detectors. If all the three-phase currents are below the low current setting, or above the high current setting, there is no pole-disagreement. If any of the phase currents are below the low current setting at the same time as at least one of the other phase currents are above the high current setting, this is the criterion for pole-disagreement.

3.3 Overcurrent protection (option)

3.3.1 Application

In radially fed power networks the phase overcurrent function can be used as main or back-up short-circuit protection for lines, transformers and other equipment.

In combination with impedance relays or line differential protections, the phase overcurrent protection can serve as back-up short-circuit protection for the lines in meshed power systems. The time delay of such an overcurrent back-up protection must be chosen so that the selectivity of the main protections is not jeopardized.

For shunt capacitors, shunt reactors, motors and other similar equipment phase overcurrent protection can serve as main or back-up short-circuit protection.

A special application is to use the phase overcurrent protection as a detecting short-circuits between the line circuit-breaker and line CT in a line bay, in order to sent a trip signal to the remote line end. Such a fault is detected by the busbar protection but that protection does not normally trip the line circuit-breaker at the remote line end.

3.3.2 Design

The phase overcurrent protection function in RXHB 411 measures the three phase currents. The phase overcurrent protection has a low and a high set stage, both with definite time delayed function. The stages has also an option to use different trip delay for single- and multi-phase faults. The setting range for phase-faults is 0,1-4,0 times basic current. This basic current, which also is the base for the breaker failure protection function, is settable 1,0 - 10,0 times the rated current of the relay. This allows settings within a wide range

The phase overcurrent protection has also an option to use different trip delay for single- and multi-phase faults. This can be used for some different reasons, for example to assure transient stability in power systems where multi-phase faults (especially three-phase faults) should be tripped faster than single-phase fault or in a protection systems where phase to phase faults and phase to earth faults are separated. The time delay for trip of single-phase faults is often longer than for multi-phase faults. To coordinate with the other protections in the system different time delays are needed.

3.4 Earth-fault protection (option)

3.4.1 Application

The earth-fault protection is based on a measurement of the residual current. It can be used in high impedance grounded and isolated networks as well as in solidly grounded networks. The rated input current of the residual current (IN_r) is chosen according to the system grounding.

Earth-faults with high fault resistance can be detected by measuring the residual current. This type of protection provides maximum sensitivity to high resistive earth-faults in high impedance grounded systems as well as in solidly grounded systems.

In radially fed power networks the residual overcurrent function can be used as main or back-up earth-fault protection for lines, transformers and other equipment.

In combination with impedance relays or line differential protections, the residual overcurrent protection can serve as back-up earth-fault protection for the lines in meshed power systems. The time delay of such a residual overcurrent back-up protection must be chosen so that the selectivity of the main protections is not jeopardized.

For shunt capacitors, shunt reactors, motors and other similar equipment the residual overcurrent protection can serve as main or back-up earth-fault protection.

A special application is to use the residual overcurrent protection as a detecting earth-faults between the line circuit-breaker and line CT in a line bay, in order to sent a trip signal to the remote line end. Such a fault is detected by the busbar protection but that protection does not normally trip the line circuit-breaker at the remote line end.

3.4.2 Design

The residual overcurrent protection has a low and a high set stage both with definite time delayed function. The setting range for phase-faults is 0,1-4,0 times basic current. This basic current, which also is the base for the breaker failure protection function, is settable 1,0 - 10,0 times the rated current of the relay. This allows settings within a wide range.

A very low influence of harmonics superimposed on fault currents permits use also in otherwise demanding applications.

Chapter 3 Application

About this chapter

This chapter describes the application possibilities for various protection functions. The description is made in a general way, which means that all applications are not possible to be realized by means of the RXHB 411 relay. By reading this chapter the user will gain knowledge in how different protection functions can be used for different applications.

1 Protection system requirements

Protection systems have to fulfil different utility requirements. Often they also have to fulfil requirements specified in national safety regulations. In general the requirements can be summarized as follows:

- The protection system shall have a high degree of dependability. This means that the risk of missing fault clearance shall be low. Back-up protection is necessary to achieve this.
- The protection system shall have a high degree of security. This means that the risk of unwanted relay function shall be low.
- The fault clearing time shall be minimized in order to limit the damages to equipment, to assure angle stability and to minimize the risk for people from getting injuries.
- The protection system shall have sufficient sensitivity so that high resistive faults can be detected and cleared.
- The fault clearing shall be selective to minimize the outage and make it possible to continue the operation of the healthy parts of the power system.

2 Breaker failure protection

Normally it is requested that all faults in the power system shall be cleared even if one component in the fault clearance system fails. The back-up protection can be realised by means of remote back-up or local back-up protection. In a remote back-up protection system the back-up tripping of faults are done in remote substations. This is a simple principle but there are some drawbacks:

In many cases remote back-up protection is not possible to realize. This is because the remote line protections can not cover the required back-up zone.

To assure selectivity the back-up tripping must have sufficient delay. This delay can give stability problems in transmission systems. The long fault clearance time can also give unacceptable thermal stress on equipment.

Local back-up protection involves parallel subsystems with separated parallel protections, auxiliary DC systems, instrument transformer cores/windings, separated parallel communication, etc. It is however not realistic to have redundant circuit-breakers to a protected object. In local back-up system special breaker failure protections are therefor used.

The breaker failure protection function issues a back-up trip to adjacent circuit-breakers in case of a tripping failure of the object circuit-breaker (CB), and clears the fault as requested by the object protection.

The breaker failure protection is either started from external protection via one or more binary inputs or by an internal trip signal from the optional phase overcurrent protection and/or the optional residual overcurrent protection. We have some different cases:

Line protection with single pole tripping. In case of a single phase fault the line protection will detect this as a single phase fault, select the faulted phase and trip the circuit-breaker pole associated to the faulted phase. The line protection will send a phase selective start signal to the breaker failure protection. If there is no breaker failure the open pole will reclose after a set dead time. For a permanent fault this will be followed by a three phase definite trip. This trip will give a general three phase start signal to the breaker failure protection.

Protection, for lines or other equipment, with three pole tripping. For all faults the protection will send a general (three phase) start signal to the breaker failure protection.

Some protections detects faults where the fault current can be very small. In such cases the protection give a start signal to the breaker failure protection, treated as an unconditional start signal.

2.1 Re-trip function

There is a possibility of having a re-trip function in the breaker failure protection. The re-trip function is mainly a protection against personnel errors during relay testing. If a protection is tested by means of secondary voltage and current injection, the trip circuits from this protection are normally opened. If the protection starts the breaker failure protection there is a risk to forget to open also the start signal to the breaker failure protection. If the tested protection trips and there is a load current flow through the circuit-breaker, there is a risk to trip all back-up breakers. This might cause a severe disturbance. With the re-trip function the trip can be limited to the trip of one circuit-breaker only.

When the protection has received a start signal a second attempt to trip the main circuit-breaker can be made. If the start signal was a single pole start, the retrip will also be a single pole trip to the main circuit-breaker. If the start signal was a general three phase start, the retrip will also be a three pole trip to the main circuit-breaker. The re-trip function can have a selected delay, although as short time as possible is normally required. There is a possibility to have re-trip with current check or unconditional re-trip. If re-trip with current check is chosen, re-trip is only performed if there is a current flow through the circuit-breaker.

2.2 Back-up trip function

When the start signal is received by the breaker failure protection function a timer is started. If the protection detects failure to trip the fault, after the set back-up delay time, a trip signal is sent to the chosen back-up breakers. These circuit-breakers are normally the breakers connected to the same busbar section as the main circuit-breaker. For a breaker failure protection on a transmission line, the back-up trip is often sent also to the line circuit-breaker at the remote line end. The back-up trip is always a three pole trip signal to the back-up breakers.

The most common application is to have back-up trip with current check. This means that the criterion for breaker failure is that there is current flow through the circuit-breaker after the set back-up delay time. All three phase currents are checked as well as the residual current. For the function there can be chosen different current criteria logics:

One out of four currents: If at least one of the four currents (the three phase currents and the residual current) remain after the time delay, the back-up trip is activated. This logic is necessary for earth-fault protections in high impedance grounded systems.

Two out of four currents: If at least two of the four currents (the three phase currents and the residual current) remain after the time delay, the back-up trip is activated. With this logic the security (probability of not having unwanted trip) can be improved.

The back-up trip can also be an unconditional trip. This means that no current check is made. The only criterion for back-up trip is that the start signal is present also after the back-up trip time delay. The unconditional back-up trip function is used for protections detecting faults with low fault current level. As example of such protection can be given generator reverse power protection.

The timer setting of the back-up protection function should be selected with a certain margin to allow variation in the normal fault clearing time. The properties of the breaker failure protection allows the user to use smaller margins. Figure 2 shows the fault clearance time for the breaker failure situations.

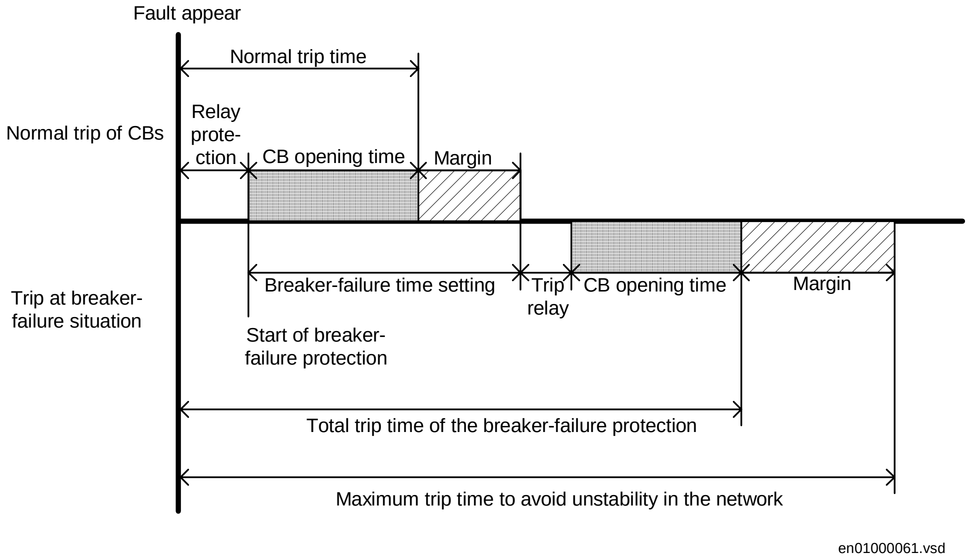


Figure 2: Operating diagram for the breaker failure situations.

The application functions of the breaker failure protection are:

- Individual phase and earth-fault function
- Fast re-trip at external start
- Time delay for the back-up trip of the adjacent circuit-breakers
- Accuracy of the timer and short reset time for the current elements, allowing the use of short back-up trip time

3 Pole-disagreement protection

During switching operations, not initiated by protection actions, a circuit-breaker can fail. We can get unsymmetrical conditions where one or two poles are closed while the others are opened. Such an event will cause a series fault where unsymmetrical currents (zero sequence and negative sequence) flow in the network. Such current can give unacceptable conditions such as disturbance of telecommunication systems and stress on rotating machines. It is therefor of great importance to detect and clear this fault, at least if the unsymmetrical currents are large.

The pole-disagreement protection compares the current levels of the three phases. If one or two of the phases carry a current larger than the high set value, while the other poles carry a current smaller than the low set value, this is the criterion of pole-disagreement. From the pole-disagreement protection a start signal is sent and after the time delay a trip signal is sent. This principle for pole-disagreement protection has some advantages compared to the normally used type, based on breaker auxiliary contacts. For example can one reason for pole-disagreement be that there is a mechanical fault within the breaker. In such a case the auxiliary contact for closed or open breaker, can have the wrong position.

The current setting of the function is made as sensitive as possible. Consideration must however be taken to unsymmetrical currents flowing during normal operation. Such current can occur if transmission lines are not properly transposed or if the load currents are not symmetrical. The difference between the high and low current setting must be larger than natural current differences.

In switch yards with one and a haft or double circuit-breaker configuration the load currents can have different distribution between the phases in the parallel current paths. In rare cases the principle used for the pole-disagreement protection can give unwanted operation. This is however often an indication of increased contact resistance in one of the parallel current paths. Current measurement between the phases can give an indication of the risk of unwanted operation of the pole-disagreement protection.

4 Phase overcurrent protection

Two- or three-phase time-overcurrent relays can be used as phase to phase short-circuit protection in radial high impedance grounded networks for over-head lines, cable lines and transformers. Three-phase time-overcurrent relays can also be used as phase to phase and phase to ground short-circuit protection in solidly grounded networks for over-head lines, cable lines and transformers. In RXHB 411 the phase overcurrent protection function is mainly used as back-up protection for phase to phase short-circuits.

4.1 Setting of phase overcurrent short-circuit protection in radial networks

4.1.1 Current Setting

The lowest current step must be given a current setting so that the highest possible load current does not cause relay operation. Here consideration also has to be taken to the relay reset current, so that a short peak of overcurrent does not cause operation of the relay even when the overcurrent has ceased. This phenomenon is described in figure 3.

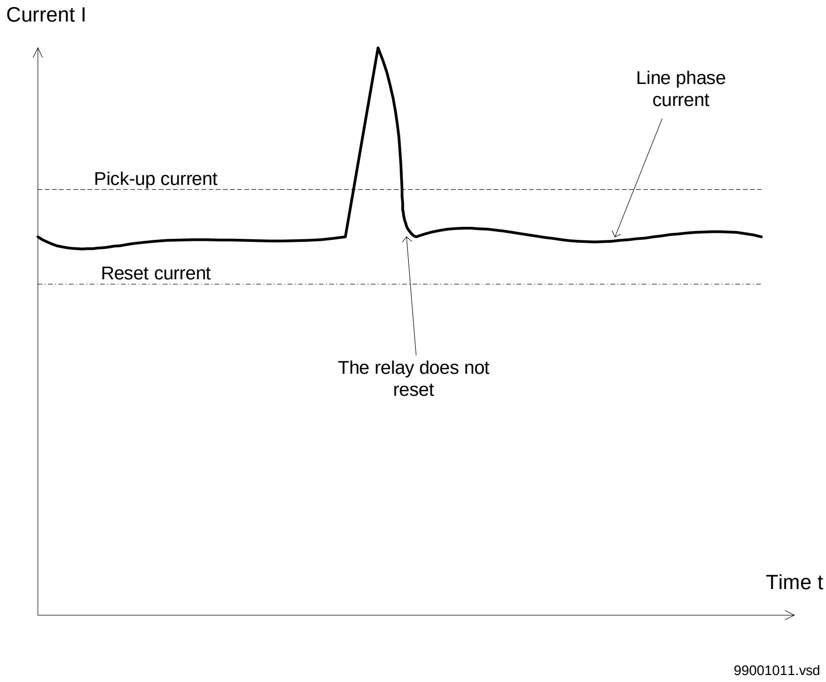


Figure 3: Clarification of reset current of overcurrent protection

The lowest setting value can be written:

$$I_{pu} \geq 1.2 \cdot \frac{I_{max}}{k}$$

Where:

1.2 = safety factor

k = resetting ratio of the relay

I_{max} = maximum load current

The maximum load current on the line has to be estimated. From operation statistics the load current up to the present situation can be found. The current setting must be valid also for some years ahead. It is, in most cases, realistic that the setting values are updated not more often than once every five years. In many cases this time interval is still longer. There can be given two possibilities to determine the maximum load current to be considered in the setting of the relay:

- Contact the planning department of the utility and ask them to estimate the future maximum load current on the line. It can be valuable to have estimated values approximately five and ten years ahead.
- Investigate the maximum load current that different equipment on the line can withstand. Study components such as: line conductors, current transformers, circuit-breakers, and disconnectors. The manufacturer of the equipment normally gives the maximum thermal load current of the equipment.

There is also a demand that all faults, within the zone that the protection shall cover, must be detected by the phase overcurrent relay. The minimum fault current I_{scmin}, to be detected by the relay, must be calculated. Taking this value as a base, the highest pick up current setting can be written:

$$I_{pu} \leq 0.7 \cdot I_{scmin}$$

Where:

0.7 = safety factor

I_{scmin} = smallest fault current to be detected by the overcurrent protection

As a summary the pick up current shall be select within the interval:

$$1.2 \cdot \frac{I_{max}}{k} \le I_{pu} \le 0.7 \cdot I_{scmin}$$

The high current function of the overcurrent relay, which only has a short or no delay of the operation, must be given a current setting so that the relay is selective to other relays in the power system. It is desirable to have a rapid tripping of faults within as large portion as possible of the part of the power system to be protected by the relay (primary protected zone). A fault current calculation gives the largest fault current, $I_{sc\text{-}max}$, at the most remote part of the primary protected zone. Considerations have to be made to the risk of transient overreach, due to a possible DC component of the short-circuit current. The lowest current setting of the most rapid stage, of the phase overcurrent relay, can be written:

$$I_{high} \ge 1.2 \cdot k_f \cdot I_{scmax}$$

Where:

1.2	= safety factor
k_f	= a factor considering the transient overreach due to the DC component of the fault current
I_{scmax}	= the largest fault current at a fault at the most remote point of the primary protection zone

4.1.2 Time setting

The operate times of the phase-overcurrent relay have to be selected so that the fault time is so short so that equipment will not be destroyed due to thermal overload, at the same time as selectivity is assured. The time setting is selected to get the shortest fault time with maintained selectivity. Selectivity is assured if the time difference between the protection in series is larger than a critical time difference.

To assure selectivity between different protections in a radial network, there has to be a minimum time difference Δt between the time delays of two following protections. The minimum time difference can be determined for different cases. To determine the shortest possible time difference we must know the operation time of relays, breaker opening times, relays inaccuracy measuring times and relays resetting times. These time delays can vary significantly between different devices of equipment. The following time delays can be estimated:

- Relay operation time: 15 - 60 ms
- Relay resetting time: 15 - 60 ms
- Breaker opening time: 20 - 120 ms
- Relay inaccuracy of measuring time: 50 - 100 ms

Assume two substations A and B directly connected to each other via one line, as shown in figure 4. We study a fault located at another line from the station B. The fault current to the overcurrent relay of terminal B1 has a magnitude so that the protection will have instantaneous function. The overcurrent protection of terminal A1 must have a delayed function. The sequence of events during the fault can be described using a time axis.

$t = 0$	The fault occurs
$t = t_1$	The trip signal from the distance relay at terminal B1 is sent. Operation time of zone 1 operation of the distance relay is t_1.
$t = t_2$	The circuit-breaker at terminal B1 opens. The circuit-breaker opening time is $t_2 - t_1$.
$t = t_3$	The distance relay at terminal A1 resets. The relay resetting time is $t_3 - t_2$.

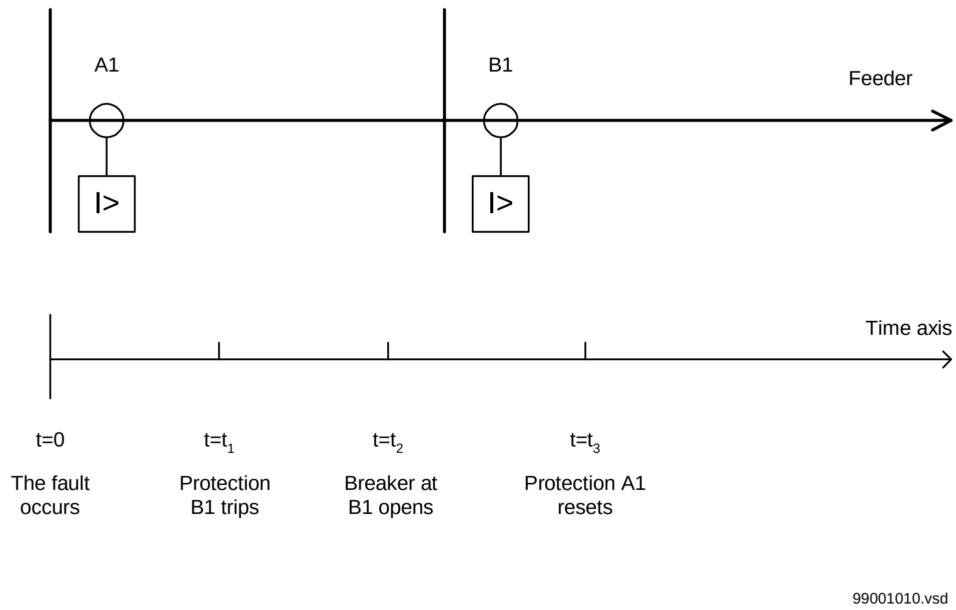


Figure 4: Example for estimation of selectivity time

To ensure that the overcurrent protection at terminal A1, is selective to the overcurrent protection at terminal B1, the minimum time difference must be larger that the time t_3. There are uncertainties in the values of breaker opening time and relay resetting time. Therefor a safety margin has to be included. With normal values the needed time difference can be calculated:

$$\Delta t \geq 40ms + 100ms + 40ms + 100\ ms + 40ms\ =\ 320ms$$

Where the following is considered:

- Operation time of overcurrent protection B1: 40 ms
- Breaker open time: 100 ms
- Reset time of protection A1: 40 ms
- Inaccuracy of measuring time: 100 ms
- Additional margin: 40 ms

Due to the microprocessor timing accuracy, these new relays can generally be used with a tighter co-ordination margin than required for earlier static and electromechanical relays.

4.1.3 Back-up protection

In meshed systems overcurrent relays can be used as back-up protection for phase to phase short-circuits and phase to ground short-circuits on transmission lines. A very simple way to realize this kind of back-up protection scheme is to use a two stage overcurrent relay. The high current stage, with short time delay for operation, is given a current setting to assure selectivity. In practice this means that this stage will normally only cover a small portion of the line. The low current stage, with a longer time delay for operation, is given a current setting so that the whole transmission line is covered. The difficulty with this kind of back-up protection is that the settings must be valid for different operation states of the system, with different fault current levels.

In radial distribution systems normally the overcurrent protection for the supply transformer shall serve as back-up protection for the feeders. In many stations the combination of high rated power of the transformer and long feeders makes it impossible to achieve acceptable back-up function to a large extent of the feeders. The problem will be even worse if two transformers operate in parallel.

To fulfil the basic requirement of back-up protection, the feeders that are lacking back-up function, should be equipped with a supplementary overcurrent protection, and breaker failure protection.

5 Earth-fault protection

The demands imposed on the earth-fault protection are dependent on system grounding and usually also on national requirements and previous practice. All electrical power systems have a coupling to ground. The method of how the neutral points of the system are connected to the ground defines the system grounding.

The system grounding can be either ungrounded, high-impedance grounded, low-impedance grounded or solidly grounded. The grounding methods will influence the earth-fault current and therefore also the selection of the earth-fault protection. The magnitude of earth-fault current will vary widely from less than one ampere to several kilo-amperes depending on the grounding methods. This implies that the demands imposed on the earth-fault protection vary considerably.

5.1 Earth-fault protection in ungrounded or high-impedance grounded system

An ungrounded system does not have any neutral-point equipment that influences the earth-fault current. Voltage transformers and surge arresters may connect phase conductors and transformer neutral points to ground. The system is coupled to ground via the distributed capacitance to ground of the overhead lines and cables in the system. In these systems the earth-fault currents are an order of magnitude smaller than the short-circuit currents and the shunt impedances determine the earth-fault currents. An earth-fault with zero fault resistance will give a capacitive earth-fault current and the magnitude is determined of the size of the capacitance. Networks with small extension can give earth-fault currents that are less than one ampere.

For ungrounded or high-impedance grounded systems the residual voltage will be three times the phase voltage all over the system, in case of a phase-to-earth-fault with zero fault resistance. Often there are demands on the protections to be able to clear faults even if there is a considerable fault resistance. In Sweden, for example, the earth-fault protections sometimes shall be able to clear faults even if the fault resistance is 5000 ohm. The fault resistance will reduce the residual voltage considerable.

The complex residual voltage (zero sequence) and earth-fault current, can be calculated as follows:

$$V_0 = \frac{V_{Phase}}{1 + \frac{3R_f}{Z_0}}$$

Here V_{Phase} is equal to the phase to ground voltage before the fault, R_f is equal to the fault resistance and Z_0 is the MV system zero sequence impedance to ground. Z_0 can be expressed as:

Ungrounded system:

$$Z_0 = -jX_c$$

Where:

X_c = the system capacitive reactance to ground

Resistance grounded system:

$$Z_0 = \frac{-jX_c \cdot 3R_n}{-jX_c + 3R_n}$$

Where:

R_n = the resistance of the neutral point resistor

Reactance-resistance grounded system:

$$Z_0 = \frac{j(3X_n - X_c) \cdot 3R_n}{j(3X_n - X_c) + 3R_n}$$

Where:

X_n = the reactance of the neutral point reactor (Petersen coil)

A alternative way to express the neutral point voltage is to express the development of the earth-fault:

$$\frac{V_0}{V_{Phase}} = \frac{1}{1 + \frac{3R_f}{Z_0}}$$

The total complex earth-fault current, in the fault point, can be expressed as:

$$I_j = 3I_0 = \frac{3V_{Phase}}{Z_0 + 3R_f}$$

The earth-fault current through the terminal of the faulted feeder is equal to the total earth-fault current, as shown above, minus the capacitive earth-fault current emanating from the faulted feeder itself.

In many cases the feeders have directional earth-fault current protection, sensitive to the active earth-fault current, emanating from the neutral point resistor. This active earth-fault current can be expressed:

$$I_{j,\,active} = \frac{V_0}{V_{Phase}} \cdot I_{Rn}$$

Where:

I_{Rn} = the rated current of the neutral point resistor

In networks with extensive overhead lines and underground cable systems, the capacitive earth-fault current can be larger than 100 A and cause hazardous potential rise and develop considerable heat at the fault location. It is therefore not acceptable to operate ungrounded networks with very large capacitive earth-fault currents. It may be necessary to ground the system via special equipment, that is compensator reactors, connected to a transformer neutral, in order to reduce the earth-fault current. Special equipment, for example neutral point resistors, may be used to enable earth-faults to be cleared selectively and rapidly. In a high-impedance grounded system the neutral-point can be connected to ground via a resistor or both a resistor and a reactor. The shunt impedances of lines and cables to ground and the neutral point impedance determine the earth-fault currents.

It may be necessary to introduce a resistor if the contribution from the short distribution line is too small to operate directional earth-fault relays.

5.1.1 Non-directional earth-fault current protection

In some cases and radial systems, non-directional residual current protections can be used as earth-fault protections. The earth-fault protection has an independent time delay and selectivity is obtained by time-grading the different relays. The current setting normally corresponds to 10-40% of the maximum fault current and is the same for all relays in the system.

In the case of overhead lines, the capacitive current generated by the protected feeder itself, should not exceed 66% of the operate value set on the line protection. For cables, this value should not exceed 30% of the set value. Directional relays should be used for higher values of the capacitive current of the protected feeder.

Depending on the configuration of the system, the different capacitive currents of the objects and the required sensitivity, directional earth-fault protections are often required.

Another application of the non-directional earth-fault protection is to detect cross-country faults. In this case the setting of the relay is higher than the capacitive earth-fault currents of the feeder. This means that this residual current protection does not operate for single-phase earth-faults. During normal operation the residual current is close to zero which means that the setting may be lower than the setting of the overcurrent protection. The current setting can also be set to a very low value but the delay of the function shall be set to a high value to assure selectivity for single phase-to-earth-faults.

5.2 Earth-fault protection in low-impedance grounded system

In a low-impedance grounded system, a separate resistor is connected to a transformer neutral point. In case of earth-faults the current from the neutral point resistor is significantly larger than the capacitive earth-fault current from overhead lines and cables in the system. The fault current can therefor be said to be generated from one point only. Selectivity is then achieved by time-grading the different earth-fault relays.

Normally, a sensitivity of 10-30% of the maximum fault current is required and this applies to all relays. An earth-fault relay can be included in the neutral point to serve as a supplement and back-up protection.

The current setting of the relay is often chosen to correspond with that which the neutral-point transformer can withstand continuously. It is also given a relatively long time delay.

5.3 Earth-fault protection in solidly grounded system

In solidly grounded systems there is a direct connection between transformer neutral points and the ground. The earth-fault currents can be of the same order of magnitude as the short-circuit currents and the series impedances determine the earth-fault currents. A fault-resistance can reduce the earth-fault currents considerably. Often the residual voltage is very small.

Except for measuring the residual current instead of the phase current the same principles and design of the earth-fault protection can be used in solidly grounded radial systems as for short-circuit overcurrent protection.

In meshed transmission systems distance protections are often used to clear earth-faults. In many cases, however the fault resistance is much higher than the resistance that can be covered by an impedance measuring distance relay.

Earth-faults with high fault resistance can be detected by measuring the residual current. This type of protection provides maximum sensitivity to earth-faults with additional resistance.

The non-directional earth-fault current protection can, in some cases, be used as a simplified earth-fault protection, particularly as back-up protection. The time delay must be chosen so that the selectivity of the main earth-fault protection system is not jeopardized.

It is often required to clear earth-faults with residual currents of magnitudes which are as low as 50-100 A. Small residual currents normally occur when there are high resistance faults or series faults.

A serial fault can be caused by interruption of one or two phase-conductors with no contact to ground, or pole discrepancy in a circuit-breaker or a disconnector. The most common type of serial fault is pole discrepancy at breaker maneuvering.

To detect high resistive earth-faults, a low operating current is required. On the other hand, a low setting will increase the risk for unwanted operation due to unbalance in the network and the current transformer circuits. The minimum operating current of the earth-fault overcurrent protection must be set higher than the maximum false earth-fault current.

The unbalance in the network that causes false earth-fault current is caused mainly by untransposed or not fully transposed transmission lines. In case of parallel lines with strong zero-sequence mutual coupling the false earth-fault current can be still larger. The false earth-fault current is directly proportional to the load current.

In a well transposed system, the false earth-fault current is normally lower than 5% of the line current, except for extremely short parallel lines (less than 5 km), where a higher false earth-fault current may be found.

In case of extremely short or not fully transposed parallel lines, the false earth-fault current must be measured or calculated when maximum sensitivity is desired. Generally, 80 A is recommended as a minimum primary operating value for the earth-fault overcurrent protection.

5.4 Connection of earth-fault relay

The current to the earth-fault relay can be connected in two different ways, by residual current connected line transformers or by using a separate open core current transformer.

In the case where the current transformers are residual current connected an unbalanced current can appear due to differences in the current transformers. In the event of a short-circuit, the unbalanced current can be of such a magnitude as to cause the operation of the earth-fault relay. This can be prevented if the operate time of the earth-fault relay is extended in relation to that of the short-circuit protection or if an open core current transformer is allowed to feed the earth-fault relay.

To reduce the unbalanced current in cases when the current transformers are residual current connected, the current summation must take place as near as possible to the current transformers. No other relays or instruments should be connected. If this cannot be avoided, the load should be symmetric and the burden low.

5.5 Blocking and enabling functions

The phase overcurrent protection and the earth-fault current protection can be used in combination with blocking and/or enabling functions. This can be a way to achieve short fault times for busbar faults or for faults on short lines. In figure 5 an example is shown where a blocking signal is used to enable short busbar fault time.

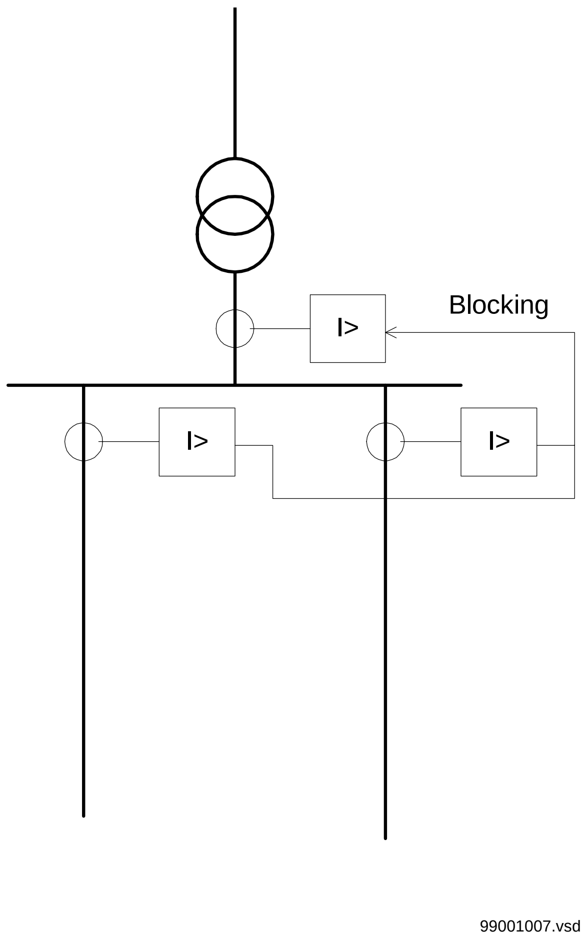


Figure 5: Example of application with blocking function

The overcurrent protection of the transformer has a high current stage with a short functional delay. This stage is blocked if a blocking signal is received from the feeder protections. In case of a fault on a feeder the blocking will assure selectivity. In case of a busbar fault the fault time will be relatively short.

Another example is when we have a small generating unit remote in the MV network. With reference to figure 6, assume a short-circuit on the feeder connecting to the generating plant. This will give rise to a comparatively small fault current from the plant.

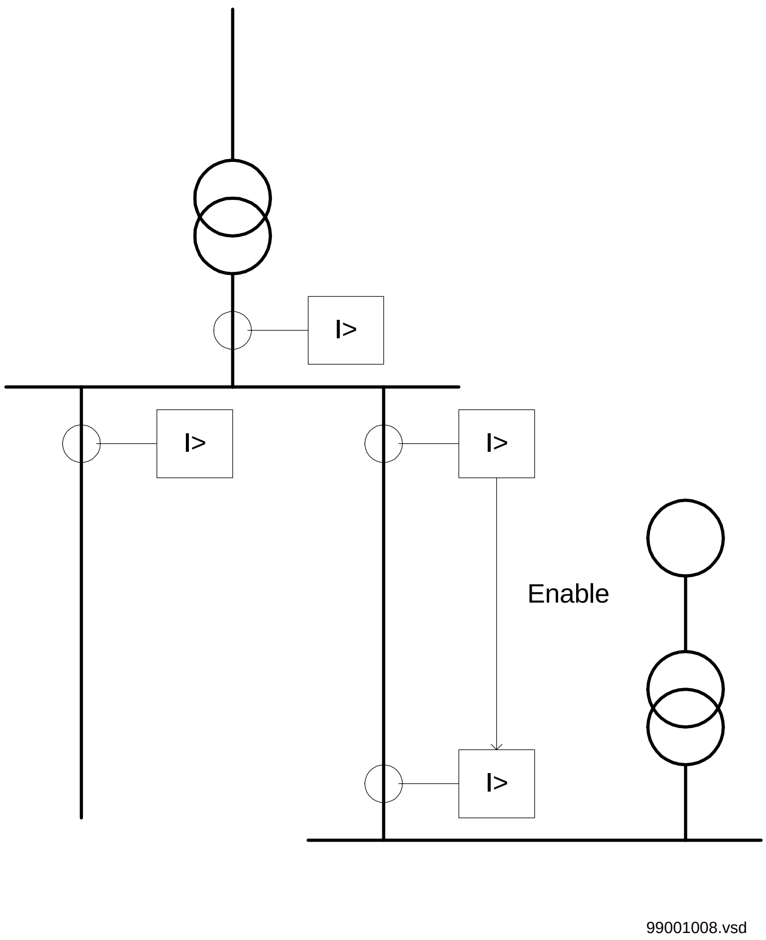


Figure 6: Example of application with enabling function

An enable signal is now sent from the feeder protection in the feeding station to the feeder protection in the generating plant station. The enable signal will activate an over-current protection stage with a low current setting. This will enable fault clearance from the relatively weak infeed from the power plant. An alternative to the remotely sent enabling signal can be a local under-voltage criterion.

6 Protection of line bay between current transformer and line circuit-breaker

A fault in a line bay, between the current transformer and the line circuit-breaker, will initiate operation of the busbar protection. The fault current from the busbar will be tripped. The fault current fed from the remote line end will however normally not be tripped directly. If nothing else is done the line protection at the remote line end will give a delayed trip (normally within 0.5 s). Such long time delay is often not acceptable for faults within a line bay. The fault is shown in the figure 7.

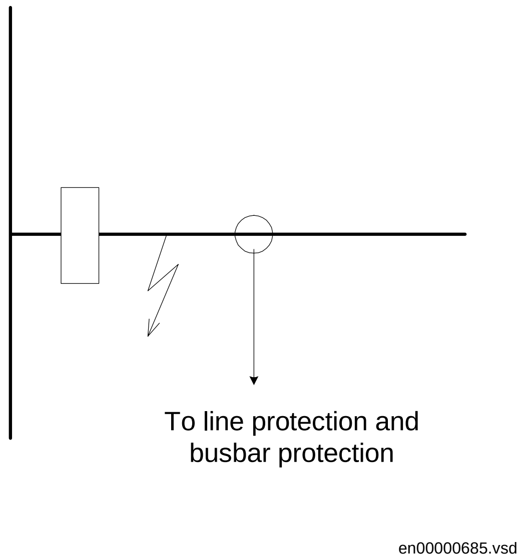


Figure 7: Example of a line bay with a fault between the CT and the line breaker.

The phase overcurrent protection and/or the residual overcurrent protection in RXHB 411 can be used for remote trip of the remote line circuit-breaker. The function might be released by trip of the line circuit-breaker in the bay.

7 Binary inputs

As the conditions in the power system change there can be of value to adopt the parameters of the protection functions. To perform such changes the protection must receive information about the changes. This can be done by means of binary input signals to the protection. The information can be given from switching devices, SCADA-systems, other protection, etc. Application examples, when binary inputs are used for the protection, are given below.

- Start of the breaker failure protection from external protections.
- Blocking of the high set phase overcurrent protection. This can be done to enable a short fault time at busbar faults.
- Enabling of low set phase overcurrent protection in cases with small fault current infeed. The binary enabling signal can be collected from other protections in the system.

Chapter 4 Requirements

About this chapter

This chapter describes the requirements that must be fulfilled to ensure reliable operation of the protection. The requirements on the instrument transformers feeding the protection are given.

1 Demands on the current transformer

The breaker failure protection is normally set to a low current value. Therefor the requirements on the rated limiting secondary e.m.f., E_{al} are negligible. To ensure reliable operation of the overcurrent protection, the following requirements must be fulfilled.

1.1 Overcurrent protection

1.1.1 Definitive time delay

To avoid failure to operate it must be assured that the current from the saturated current transformer is large enough for operation of the relay. The rated equivalent limiting secondary e.m.f., E_{al} should satisfy the following requirement:

$$E_{al} \geq 2 \cdot I_{set} \cdot [R_{CT} + R_l + Z_r]$$

Where:

I_{set} = the current set value of the relay

R_{CT} = the secondary resistance of the secondary winding of the current transformer

R_l = the resistance of a single secondary wire from the current transformer to the relay

Z_r = the actual burden of the current transformer

It must be observed that we consider only the single length of the secondary wire from the current transformer to the relay. This is valid when we study three-phase overcurrent protection in high impedance grounded systems.

1.1.2 Instantaneous function

To avoid failure to operate, of the instantaneous function, it must be assured that the current from the saturated current transformer is large enough for operation of the relay. The function should be assured for fault currents at least 1.5-2.0 times the value set on the relay. The margin depends on the time constant of the network. As a rule, the majority of fault points in distribution networks have low time constants and therefore a margin of 1.5 times the set value should be sufficient. The rated equivalent limiting secondary e.m.f., E_{al} should, in this case, satisfy the following requirement:

$$E_{al} \geq 1.5 \cdot I_{set} \cdot [R_{CT} + R_l + Z_r]$$

Where:

I_{set} = the current set value of the instantaneous function

R_{CT} = the secondary resistance of the secondary winding of the current transformer

R_l = the resistance of a single secondary wire from the current transformer to the relay

Z_r = the actual burden of the current transformer

1.2 Accuracy limit factor (ALF) - Calculation example

Table 1: Current transformer data

Ratio	50-100/5/5 A		
Core 1	5 VA	$F_s = 10$	$R_{CT} = 0.05$
Core 2	30 VA	$K_{SSC} = 10.0$ (ALF)	$R_{CT} = 0.07$
Connected	100/5/5 A		
Relay I_r = 5 A	Burden 0.3 VA		

1.2.1 Data for secondary conductors from current transformers to relay

Cross section = 2.5 mm^2. Length of copper = 25 m (single length).

Burden, relay = 0.3 / 5^2 = 0.012 ohm.

Burden, secondary conductor =

$$\rho \cdot \frac{L}{a} = 0.0175 \cdot \frac{25}{2.5} = 0.175\ \Omega$$

It should be noted that the resistance of the secondary conductors is the main burden of the current transformer circuit.

The rated equivalent limiting secondary e.m.f., E_{al} can be calculated as:

$$E_{al} = K_{ssc} \cdot I_n \cdot \left[R_{CT} + \frac{S_n}{I_n^2}\right]$$

$$E_{al} = 10 \cdot 5 \cdot \left[0.07 + \frac{30}{5^2}\right] = 63.5V$$

Where:

K_{ssc} = the rated symmetrical short-circuit current factor

I_n = the rated secondary current of the current transformer

R_{CT} = the secondary resistance of the secondary winding of the current transformer

S_n = the rated burden of the current transformer

If the relay has an instantaneous current setting of 2000 A (primary) corresponding to 100 A (secondary), the demand for E_{al} will be:

$$E_{al} \geq 1.5 \cdot 100 \cdot [0.07 + 0.175 + 0.012] = 38.5\text{ V}$$

As we can see the requirement on the current transformer is fulfilled.

In solidly grounded systems which are subject to fault currents of high magnitude, the total resistance of the current transformer secondary circuit must be taken into consideration; thus, according to the example, L = 2 · 25 m, if it is required to have a phase relay operate even in the event of ground faults. The secondary e.m.f. E_{al} must then be adapted to the maximum earth-fault current, the total resistance (2 · 25 m) and the maximum short-circuit current and a single length (1 · 25 m).

If an earth-fault relay, residual current connected to the CT's, is incorporated in the measuring circuit, as shown in figure 8, the earth-fault relay must also be taken into consideration.

1.3 Earth-fault protection

For the earth-fault protection (residual overcurrent protection) the demands on the current transformer are analyzed in the same way as for the phase overcurrent function.

The demand on the current transformers of the sensitive earth-fault relay is, that the composite error should be so small, that the sensitivity of the protections is not significantly reduced. This is secured by checking the efficiency factor.

1.3.1 Efficiency factor

In isolated and high-impedance grounded systems, the earth-fault currents fed to the earth-fault relays are normally small and relays with low operating currents are used. In this case, the efficiency factor of the relay should be checked.

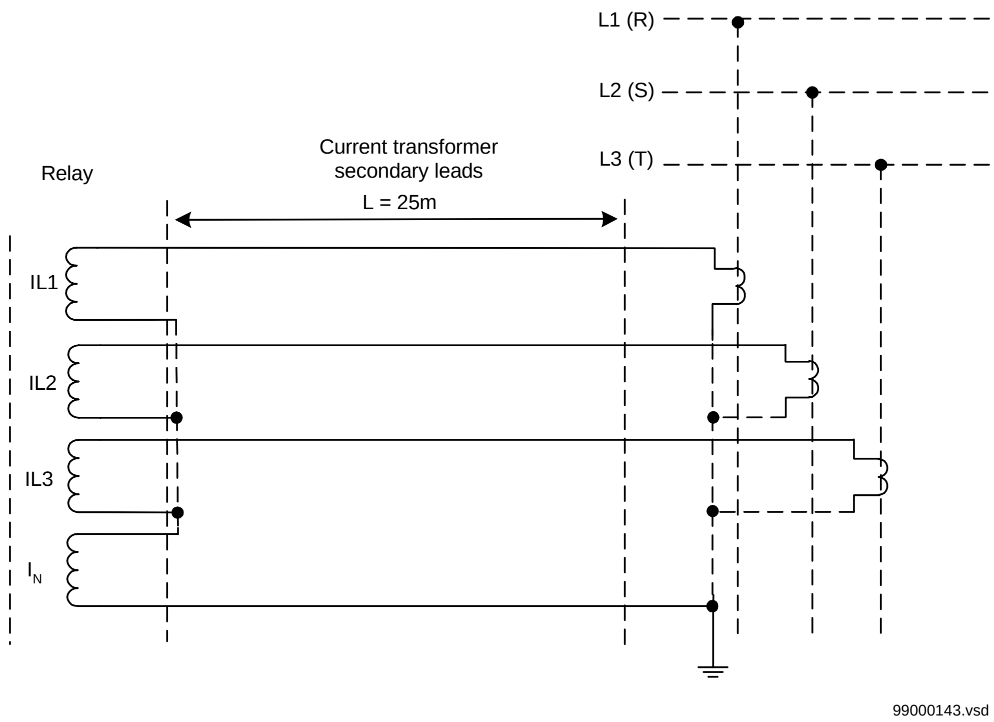


Figure 8: Equivalent circuit for current transformer to earth-fault relay.

The efficiency factor is defined as:

$$\eta = \frac{I_r}{I_N} \cdot N_{CT} \cdot 100\ \%$$

Where:

I_r = current supplied to the relay

I_N = primary earth-fault current

N_{CT} = current transformer ratio

The efficiency factor can be calculated from the formula:

$$\eta = 100 \cdot \frac{Z_m}{Z_m + Z_2 + C \cdot (Z_L + Z_r)} \%$$

Where:

Z_m = magnetizing impedance of the current transformer(s)

Z_2 = resistance of the current transformer secondary winding plus resistance of wires up to the interconnection (per phase)

Z_L = resistance of wires up to the earth-fault relay (loop resistance)

Z_r = impedance (resistance) of the measuring circuit of the relay

C = 1 for core balanced CTs

C = 3 for residual connected current transformers

It should be observed that the magnetizing impedance varies with the voltage. The impedance Z_m at the secondary voltage which gives relay operation is inserted in the formula. If the angle of the impedance Z_m is not known, the value 45 degrees (lagging) can be assumed.

The requirement on η is:

η >80% for earth-fault relays

Chapter 5 Functional description

About this chapter

This chapter describes how the relay and each protection function is working. The theories behind the measurement principles and how the function operates is given. By reading this chapter the reader will gain knowledge about how the relay works.

1 Compact breaker failure relay RXHB 411

1.1 Theory of operation

The compact breaker failure relay RXHB 411 constitutes the measuring unit of the protection assembly RAHB 411.

A simplified logic diagram for the compact breaker failure relay is shown in figure 9.

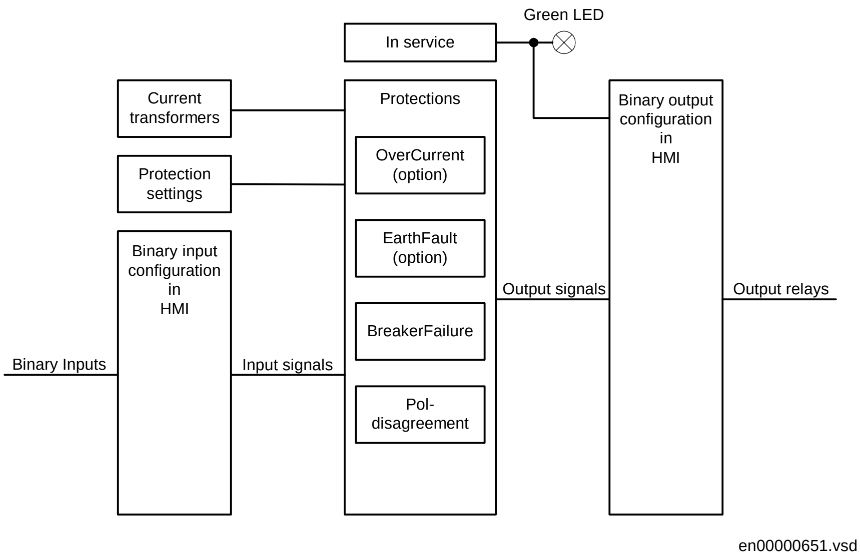


Figure 9: Simplified logic diagram for the compact breaker failure relay RXHB 411.

1.1.1 Measuring principle

The compact breaker failure relay RXHB 411 has four current measuring inputs which are galvanically separated with transformers. The voltage from each transformers shunt resistor is applied to zero crossing detectors for frequency estimation and to the measuring circuitry trough bandpass filters with a centre frequency equal to 55 Hz.

The relay samples the input signals with a sample rate of 18 samples per duty cycle. The relay is tracking the input signals to increase the accuracy of the measured values. The tracking function is enabled within the following ranges: 40-60 Hz when rated frequency is set to 50 Hz or 50-70 Hz when rated frequency is set to 60 Hz. Figure 10 shows which values the relay calculates from the input signals.

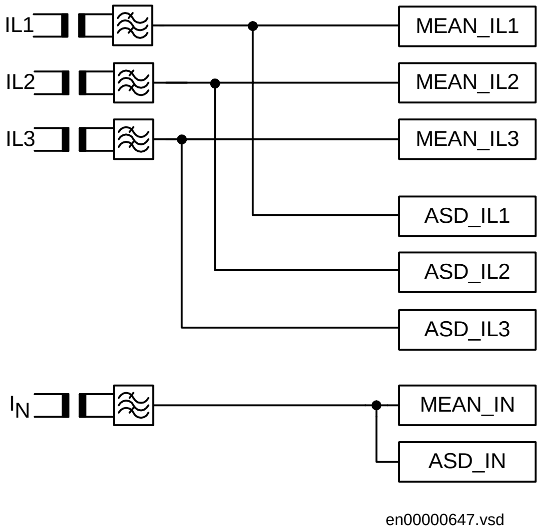


Figure 10: Calculated values from the input signals.

Calculated values	**Used by protection**
MEAN value of each phase current, IL1, IL2 and IL3	• Breaker failure protection • Pole-disagreement protection • Overcurrent protection (option)
MEAN value of neutral current	• Breaker failure protection • Earth-fault protection (option)
ASD signal of each phase current, IL1, IL2 and IL3	• Breaker failure protection
ASD signal of neutral current	• Breaker failure protection

The intention of the Adaptive Signal Detection (ASD) concept is to achieve independence from the absolute filtering requirement, when dealing with extremely high fault currents in combination with low pre-set values. This is obtained by creating a new stabilizing signal to compare the current with.

When the current exceeds the previously stabilized sample, it adapts the value of the current and when it does not, it decays. This adaptive behavior makes it possible to rapidly and securely detect a breaker failure situation.

1.2 Basic protection setting parameters

Table 2: Setting parameters, basic current

Parameter	Range	Unit	Default	Let you...
I_b	1.00-10.0 x I_r	A	1.00 x I_r	Set the basic phase current level for all protection functions.
I_{Nb}	1.00-10.0 x IN_r	A	1.00 x IN_r	Set the basic neutral current level for all protection functions.

Table 3: Setting parameter, rated system frequency

Parameter	Range	Unit	Default	Let you...
Freq	50/60	Hz	50 Hz	Select the rated frequency.

2 Breaker failure protection

2.1 Theory of operation

2.1.1 Single- and three-phase breaker failure protection

The breaker failure protection includes, single-phase, three-phase, three-phase unconditional re-trip and a three-phase back-up trip function.The breaker failure functions use the same levels for current detection and also the minimum trip pulse length.

The breaker failure function can be blocked via binary inputs.

A simplified logic diagrams for the breaker failure protection is shown in figure 11.

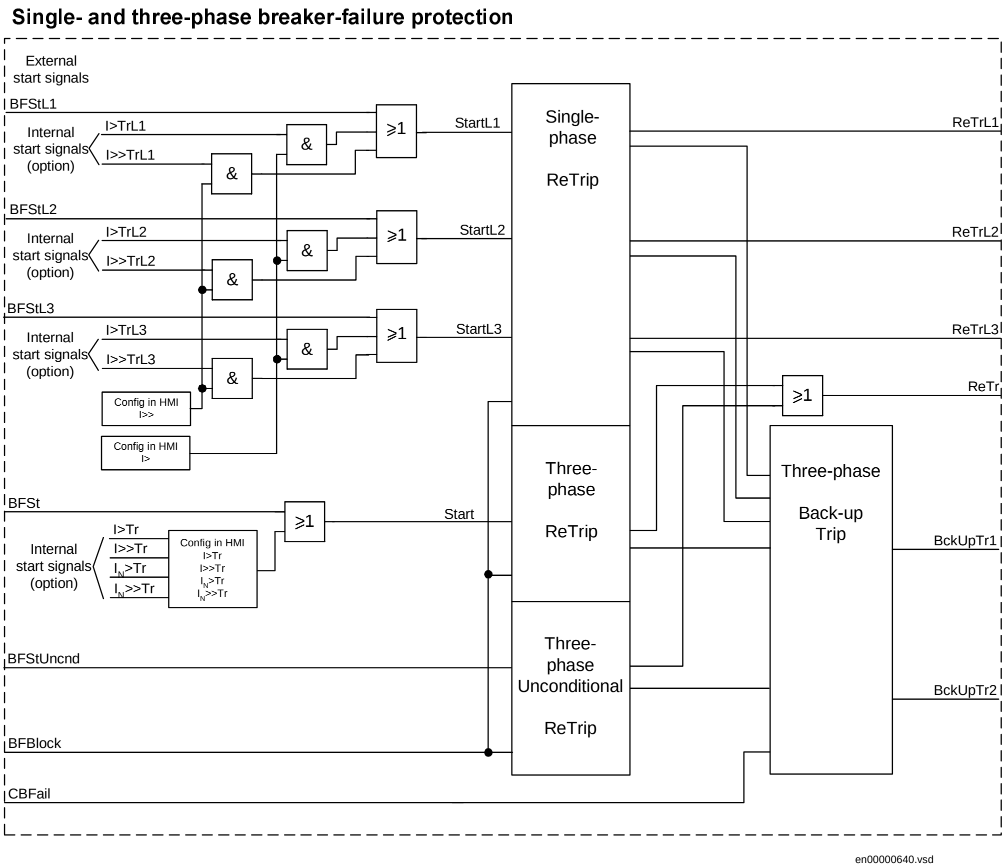


Figure 11: Simplified logic diagram for the breaker failure protection.

2.1.2 Single-phase re-trip module

The single-phase re-trip function is started externally via binary input signals or internally via the overcurrent protection. The re-trip function includes three identical logic blocks one for each phase.

The single-current comparison criteria is always performed, the current in selected phase shall be above the pre-set current level before the current criteria is fulfilled. If the criteria is fulfilled a single-phase start signal from the function is transferred to the three-phase back-up trip module.

The single-phase re-trip function has two different settable criterias, it can also be switched off. Re-trip function with or without current criteria. Re-trip function with current criteria will always generate a re-trip signal after the set time delay has expired if the current has not disappear. Re-trip function without current criteria will always generate a re-trip signal after the set time delay has expired.

The breaker failure function can be blocked via binary inputs.

A simplified logic diagram for the single-phase re-trip module is shown in figure 12.

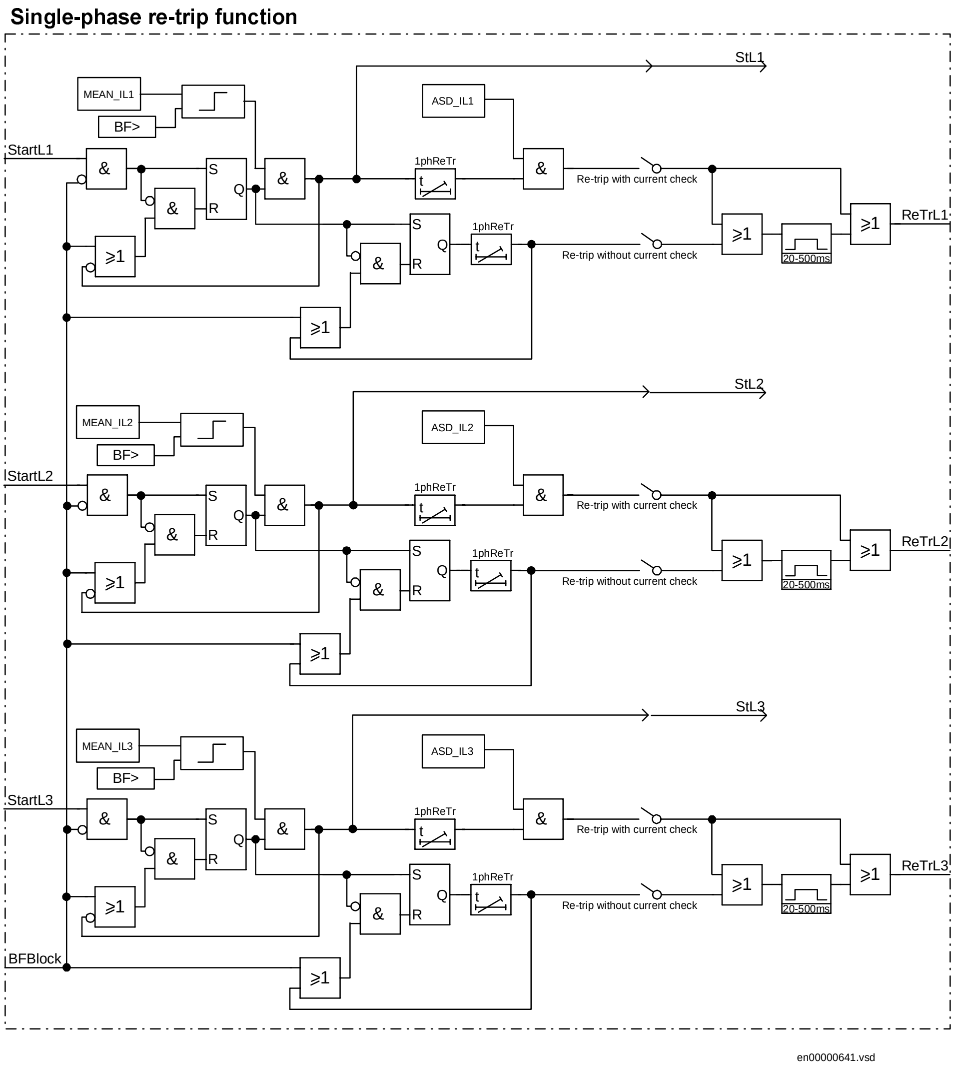


Figure 12: Simplified logic diagram for the single-*phase re-trip module.*

2.1.3 Current detection logic for three-phase re-trip and back-up trip function

The three-phase re-trip and back-up function has a current detection criteria where either one out of four or two out of four currents shall be above the pre-set current levels before the current criteria is fulfilled.

A simplified logic diagram for the current detection criteria is shown in figure 13.

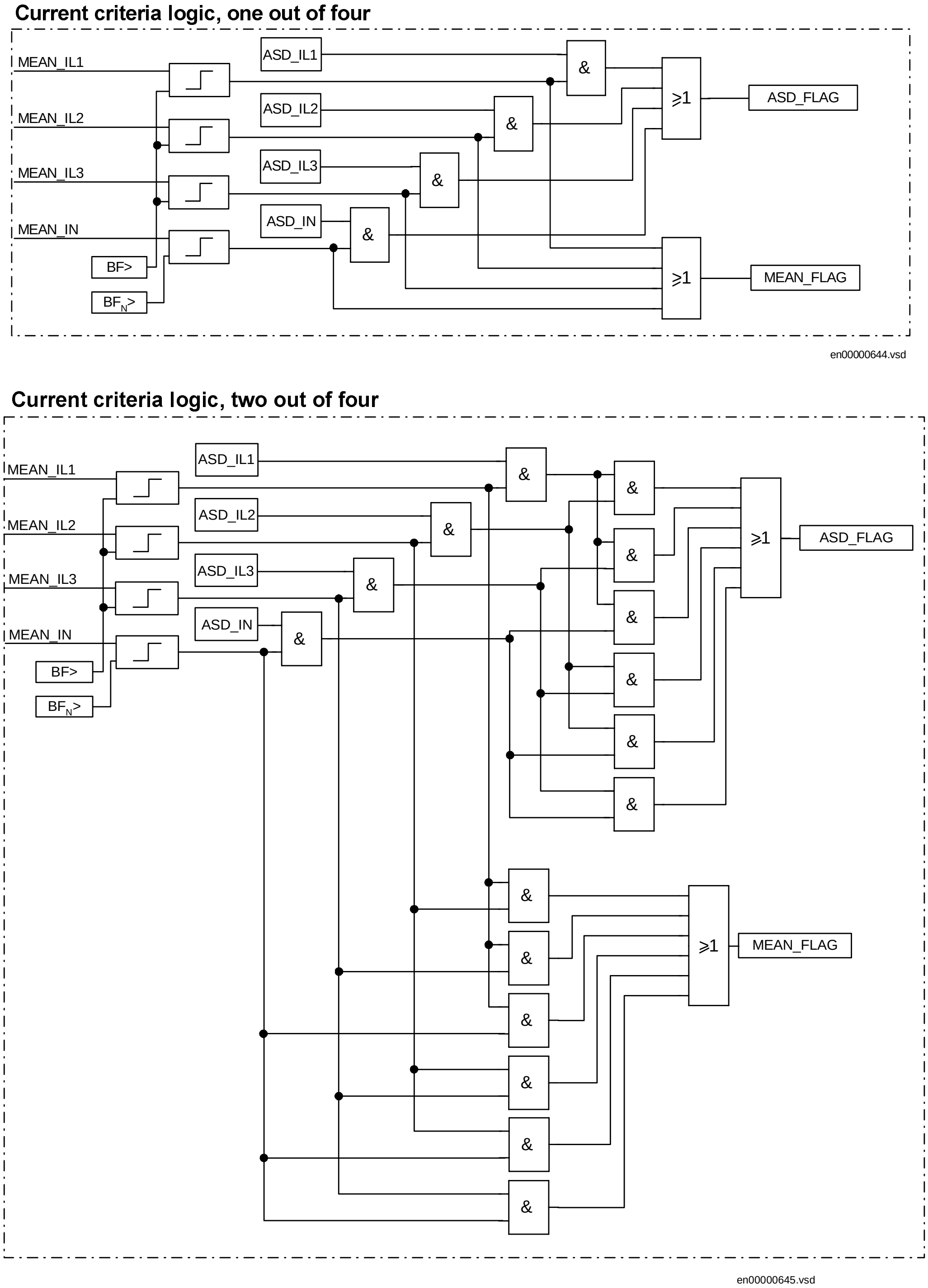


Figure 13: Simplified logic diagram for the current detection criterion.

2.1.4 Three-phase re-trip module

The three-phase re-trip function is started externally via a binary input signal or internally via the overcurrent or the earth-fault protections.

The three-phase current comparison criteria is always performed, where either one of four or two of four currents shall be above the pre-set current levels before the current criteria is fulfilled. If the criteria is fulfilled a three-phase start signal from the function is transferred to the three-phase back-up trip module.

The three-phase re-trip function has two different settable criterias, it can also be switched off. Re-trip function with or without current criteria. Re-trip function with current criteria will always generate a re-trip signal after the set time delay has expired if the current has not disappear. Re-trip function without current criteria will always generate a re-trip signal after the set time delay has expired.

The breaker failure function can be blocked via binary inputs.

A simplified logic diagram for the three-phase re-trip module is shown in figure 14.

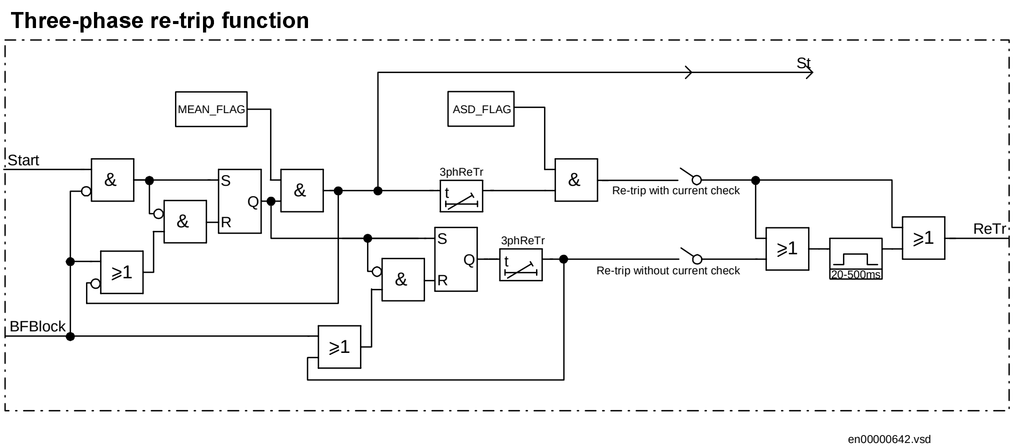


Figure 14: Simplified logic diagram for the three-phase re-trip module.

2.1.5 Three-phase unconditional re-trip module

The three-phase unconditional re-trip function is used where system faults result in very low fault currents. The unconditional re-trip function only use the time delay criteria for it is function.

The unconditional re-trip function is started via an external binary input signal and after set time delay the function generates a three-phase re-trip signal if not the start signal has reset. At the same when the unconditional re-trip function is started a three-phase unconditional start signal from the function is transferred to the three-phase back-up trip module.

The breaker failure function can be blocked via binary inputs.

A simplified logic diagram for the unconditional re-trip module is shown in figure 15.

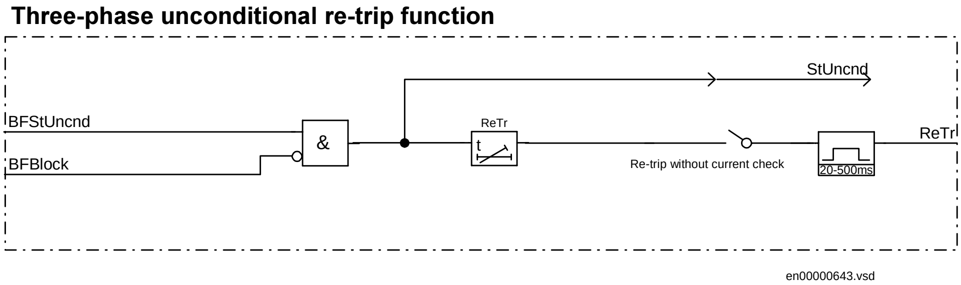


Figure 15: Simplified logic diagram for the unconditional re-trip module.

2.1.6 Three-phase back-up trip module

The logic module for the back-up trip function activates by the re-trip functions.

The back-up trip logic use different time delays for different type of faults; single-phase, three-phase or unconditional three-phase start of the breaker failure protection.

After set time delay the back-up trip function compares the three-phase current criteria where either one of four or two of four currents shall be above the pre-set current levels before the back-up trip function generates a trip signal. For the three-phase unconditional start the current criteria for the back-up trip function is disabled and the function operates if the input signal still is activated when the back-up trip time delay has expired.

If the CBFail signal is or gets high when the back-up trip logic is activated an instantaneous operation of the back-up trip function is generated.

The second back-up trip stage has an additional time delay which is used to reduce the electrical stress of the DC-system if many circuit-breakers are involved.

A simplified logic diagram for the back-up trip module is shown in figure 16.

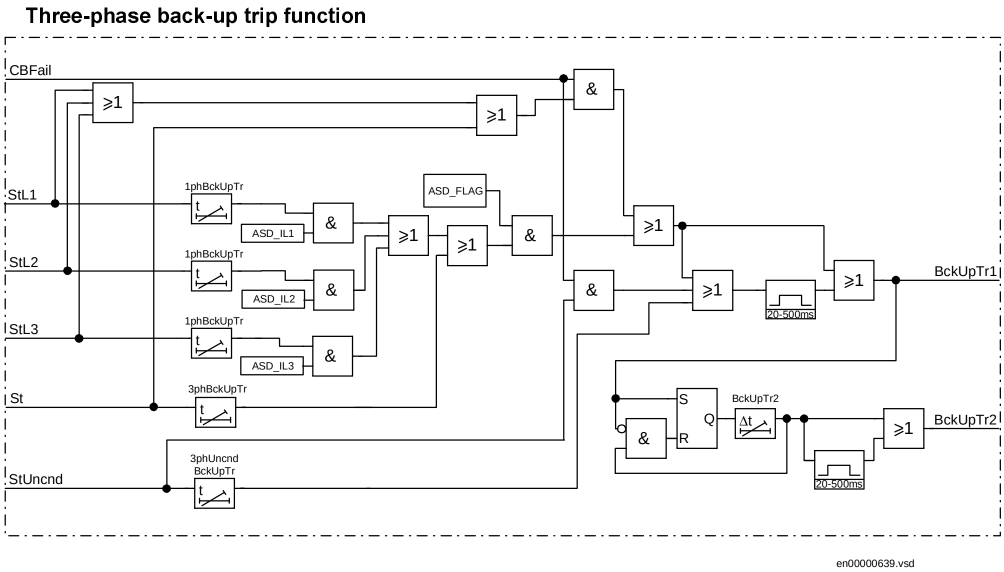


Figure 16: Simplified logic diagram for the back-up trip module.

2.1.7 During normal operation of the line circuit-breaker

During normal operation of the line circuit-breaker, the stabilizing signal exceeds the input current signal which results in a reset of the breaker failure protection before the back-up trip timer has expired.

2.1.8 During a breaker failure situation

During a breaker failure situation, the input current exceeds the stabilizing signal which results in a trip of the breaker failure protection after the back-up trip timer has expired.

2.2 Input and output signals

Table 4: Input signals, breaker failure protection

Signal	Default	Description
BFStL1	-	Active signal starts the single-phase breaker failure function in phase IL1.
BFStL2	-	Active signal starts the single-phase breaker failure function in phase IL2.
BFStL3	-	Active signal starts the single-phase breaker failure function in phase IL3.

Signal	Default	Description
BFSt	Input 1	Active signal starts the three-phase breaker failure function.
BFStUncnd	-	Active signal starts the three-phase unconditional breaker failure function.
CBFail	-	Active signal generates an instantaneous back-up trip 1 function in a case of a breaker failure start.
BFBlock	-	Active signal blocks the breaker failure protection.

Table 5: Output signals, breaker failure protection

Signal	Default	Description
ReTrL1	-	Re-trip signal, single-phase IL1.
ReTrL2	-	Re-trip signal, single-phase IL2.
ReTrL3	-	Re-trip signal, single-phase IL3.
ReTr	Relay 2	Re-trip signal, three-phase.
BckUpTr1	Relay 3	Back-up trip 1 signal to adjacent circuit-breakers.
BckUpTr2	-	Back-up trip 2 signal to adjacent circuit-breakers.

2.3 Setting parameters

Table 6: Setting parameters, general for breaker failure protection

Parameter	Range	Unit	Default	Let you...
BF>	0.10 - 1.00 x I_b	A	0.10 x I_b	Set the detection level for the phase current on the breaker failure protection.
BF_N>	0.10 - 1.00 x I_{Nb}	A	0.10 x I_{Nb}	Set the detection level for the neutral current on the breaker failure protection.
CurCrit	1:4 - 2:4	-	1:4	Select the three-phase current criteria to be 1 out of 4 or 2 out of 4 above the current detection levels.
BkUpTr2	On - Off	-	Off	Select back-up trip 2 to be active or not.
ΔTime	0.00 - 0.50	-	0.00 s	Set the additional time delay between back-up trip 1 and 2.
TrPulse	0.02 - 0.50	s	0.25 s	Set the minimum length of the trip pulse.

Table 7: Setting parameters, single-phase breaker failure function

Parameter	Range	Unit	Default	Let you...
1-PhBF	On - Off	-	Off	Select the single-phase breaker failure function to be active or not.
ReTrip	Off, I>Check, UncndBF	-	I>Check	Select the re-trip criteria: off, current check or unconditional.
Time	0.00 - 1.00	s	0.00 s	Set the time delay for re-trip function.
BkUpTr1	0.05 - 1.00	s	0.05 s	Set the time delay for back-up trip 1.
I>	On - Off	-	Off	Select activation or not for trip signal of the low overcurrent set stage I> (option).
I>>	On - Off	-	Off	Select activation or not for trip signal of the high overcurrent set stage I>> (option).

Table 8: Setting parameters, three-phase breaker failure function

Parameter	Range	Unit	Default	Let you...
3-PhBF	On - Off	-	On	Select the three-phase breaker failure function to be active or not.
ReTrip	Off, I>Check, UncndBF	-	I>Check	Select the re-trip criteria: off, current check or unconditional.
Time	0.00 - 1.00	s	0.00 s	Set the time delay for re-trip function.
BkUpTr1	0.05 - 1.00	s	0.05 s	Set the time delay for back-up trip 1.
I>	On - Off	-	On	Select activation or not for trip signal of the low overcurrent set stage I> (option).
I>>	On - Off	-	On	Select activation or not for trip signal of the high overcurrent set stage I>> (option).
I_N>	On - Off	-	On	Select activation or not for trip signal of the low earth-fault set stage I_N> (option).
I_N>>	On - Off	-	On	Select activation or not for trip signal of the high earth-fault set stage I_N>> (option).

Table 9: Setting parameters, three-phase unconditional breaker failure function

Parameter	Range	Unit	Default	Let you...
UncndBF	On - Off	-	Off	Select the three-phase unconditional breaker failure function to be active or not.
ReTrip	Off, UncndBF	-	UncndBF	Select the re-trip criteria: off or unconditional.
Time	0.00 - 1.00	s	0.00 s	Set the time delay for re-trip function.
BkUpTr1	0.05 - 1.00	s	0.05 s	Set the time delay for back-up trip 1.

3 Pole-disagreement protection

3.1 Theory of operation

The pole-disagreement protection compares the measured and calculated phase current values with the pre-set current values. If one or two of the phase current values have a magnitude lower than the pre-set under current level, at the same time as the other(s) phases have a magnitude with is higher than the pre-set over current level, this is the criteria for pole-disagreement. When the criteria is fulfilled a start signal is generated and after set time delay the function generates a trip signal. This function can be blocked during a single-phase reclosing internally via the single-phase start of the breaker failure protection, a reset time delay has to be set in co-ordination with the dead-time for the automatic reclosing function. This function can also be blocked via binary inputs.

A simplified logic diagram for the pole-disagreement protection is shown in figure 17.

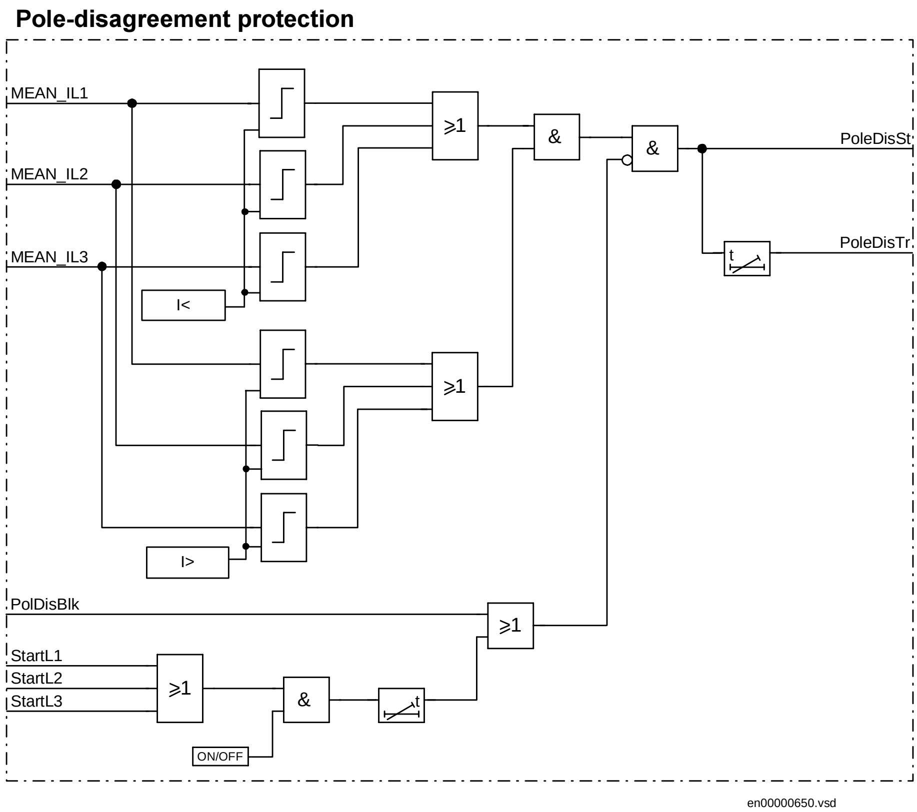


Figure 17: Simplified logic diagram for the pole-disagreement protection.

3.2 Input and output signals

Table 10: Input signals, pole-disagreement protection

Signal	Default	Description
PoleDisBlk	-	Active signal blocks the pole-disagreement protection.

Table 11: Output signal, pole-disagreement protection

Signal	Default	Description
PoleDisSt	-	Pole-disagreement, start signal.
PoleDisTr	-	Pole-disagreement, trip signal.

3.3 Setting parameters

Table 12: Setting parameters, pole-disagreement protection

Parameter	Range	Unit	Default	Let you...
PoleDis	On - Off	-	Off	Select pole-disagreement protection to be active or not.
I<	0.10 - 0.15 x I_b	A	0.10 x I_b	Set undercurrent level.
I>	0.20 - 0.50 x I_b	A	0.20 x I_b	Set overcurrent level.
Time	0.00 - 20.0	s	0.00 s	Set definite time delay.
1PhBlk	On - Off	-	Off	Select block of pole-disagreement protection at a single-phase start of breaker failure protection (internal logic) or not.
ResetT	0.00 - 10.0	s	0.00 s	Set reset time delay after an internal single-phase blocking. The reset time shall be coordinated to the dead-time for a single-phase reclosing.

4 Overcurrent protection (Option)

4.1 Theory of operation

The overcurrent protection has two stages, a low set stage and a high set stage both with definite time delay. The two stages uses single-phase measurement and operates independently of each other. Each stage compares the measured and calculated phase current value with the pre-set current values. When the measured and calculated current exceeds or is equal to a pre-set value of a stage, the start function in actual phase generates a start signal. At the same time the single-phase trip delay starts to count-up and after set time delay the single-phase trip function generates a trip signal. The overcurrent protection is also provided with a separate time delay for multi-phase faults, following configuration can be done:

- Single-phase trip is configured and the multi-phase function can be configured to a faster trip time delay for two or three-phase faults.
- Three-phase trip is configured via the multi-phase function, the function operates for single-, two- and three-phase faults.

A simplified logic diagram for the overcurrent protection is shown in figure 18 and 19.

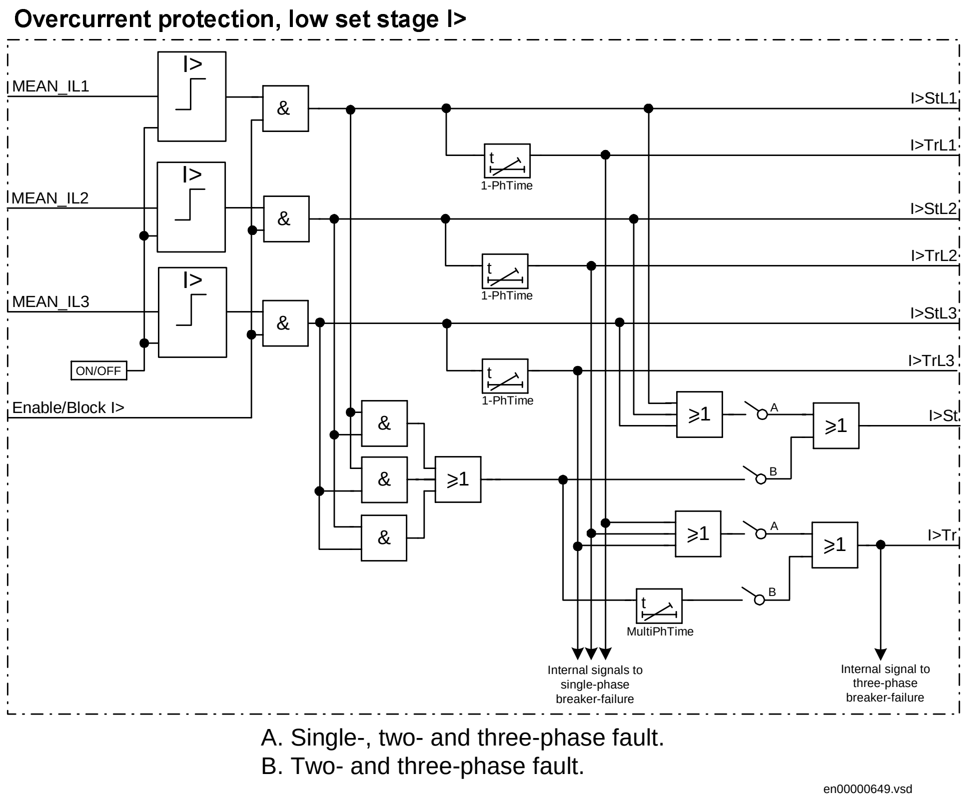


Figure 18: Simplified logic diagram for the overcurrent protection, low set stage.

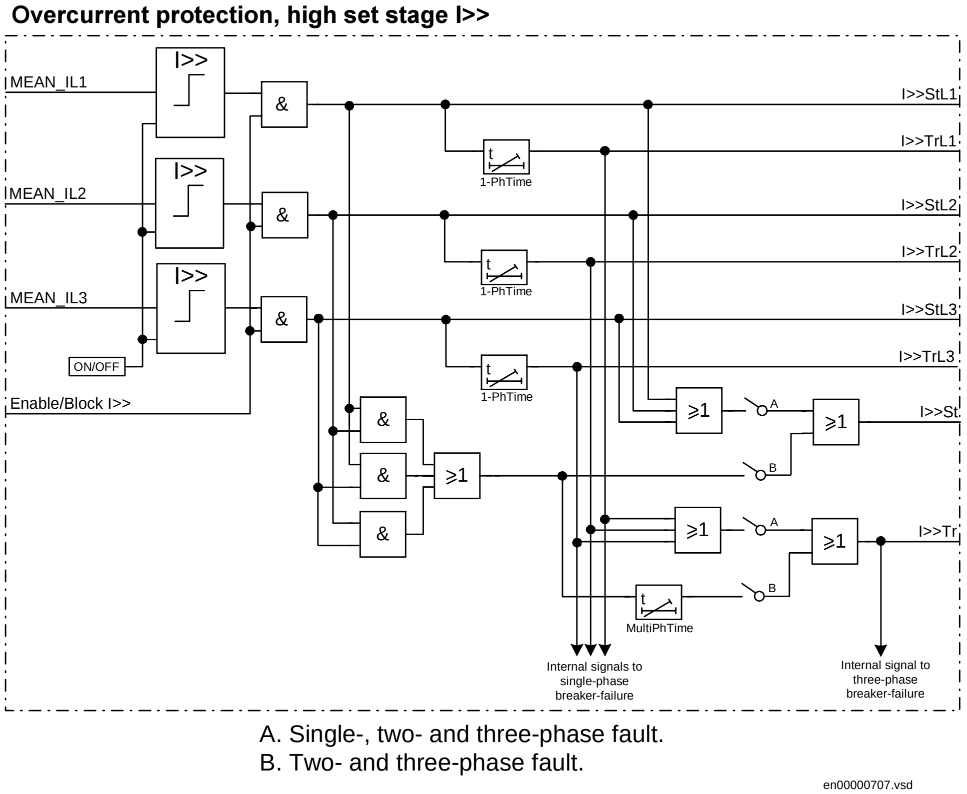


Figure 19: Simplified logic diagram for the overcurrent protection, high set stage.

4.2 Input and output signals

Table 13: Input signals, overcurrent protection (option)

Signal	Default	Description
I> Block/Enable	-	Active signal blocks or enables the low set overcurrent stage I>.
I>> Block/Enable	-	Active signal blocks or enables the high set overcurrent stage I>>.

Table 14: Output signals, overcurrent protection (option)

Signal	Default	Description
I>StL1	-	Low set stage I>, start signal on phase IL1.
I>TrL1	-	Low set stage I>, trip signal on phase IL1.
I>StL2	-	Low set stage I>, start signal on phase IL2.
I>TrL2	-	Low set stage I>, trip signal on phase IL2.
I>StL3	-	Low set stage I>, start signal on phase IL3.
I>TrL3	-	Low set stage I>, trip signal on phase IL3.
I>St	Relay 1	Low set stage I>, start signal multi-phase faults.
I>Tr	Relay 2	Low set stage I>, trip signal multi-phase faults.
I>>StL1	-	High set stage I>>, start signal on phase IL1.
I>>TrL1	-	High set stage I>>, trip signal on phase IL1.
I>>StL2	-	High set stage I>>, start signal on phase IL2.
I>>TrL2	-	High set stage I>>, trip signal on phase IL2.
I>>StL3	-	High set stage I>>, start signal on phase IL3.
I>>TrL3	-	High set stage I>>, trip signal on phase IL3.
I>>St	Relay 1	High set stage I>>, start signal multi-phase faults.
I>>Tr	Relay 2	High set stage I>>, trip signal multi-phase faults.

Table 15: Internal output signals, overcurrent protection (option)

Signal	Description
I>TrL1	Trip signal to single-phase breaker failure function from low set stage I>, trip signal on phase IL1.
I>TrL2	Trip signal to single-phase breaker failure function from low set stage I>, trip signal on phase IL2.
I>TrL3	Trip signal to single-phase breaker failure function from low set stage I>, trip signal on phase IL3.
I>Tr	Trip signal to three-phase breaker failure function from low set stage I>, trip signal multi-phase faults.
I>>TrL1	Trip signal to single-phase breaker failure function from high set stage I>>, trip signal on phase IL1.

Signal	Description
I>>TrL2	Trip signal to single-phase breaker failure function from high set stage I>>, trip signal on phase IL2.
I>>TrL3	Trip signal to single-phase breaker failure function from high set stage I>>, trip signal on phase IL3.
I>>Tr	Trip signal to three-phase breaker failure function from high set stage I>>, trip signal multi-phase faults.

4.3 Setting parameters

Table 16: Setting parameters, overcurrent protection (option)

Parameter	Range	Unit	Default	Let you...
I>	On - Off	-	On	Select low set overcurrent stage I> to be active or not.
I>	0.10 - 4.00 x I_b	A	0.10 x I_b	Set operate level.
Time	0.00 - 20.0	s	0.00 s	Set definite time delay for single-phase fault or for single-, two and three-phase fault, when multi-phase logic below is set to 1/2/3.
MultiPh	1/2/3 - 2/3	-	1/2/3	Select multi-phase logic for single-, two- and three-phase fault or for two- and three-phase fault.
Time2/3	0.00 - 20.0, Not used	s	Not used	Set definite time delay for two and three-phase fault, when multi-phase logic above is set to 2/3.
I>>	On - Off	-	On	Select high set overcurrent stage I> to be active or not.
I>>	0.10 - 4.00 x I_b	A	0.10 x I_b	Set operate level.

Parameter	**Range**	**Unit**	**Default**	**Let you...**
Time	0.00 - 20.0	s	0.00 s	Set definite time delay for single-phase fault or for single-, two and three-phase fault, when multi-phase logic below is set to 1/2/3.
MultiPh	1/2/3 - 2/3	-	1/2/3	Select multi-phase logic for single-, two- and three-phase fault or for two- and three-phase fault.
Time2/3	0.00 - 20.0, Not used	s	Not used	Set definite time delay for two and three-phase fault, when multi-phase logic above is set to 2/3.

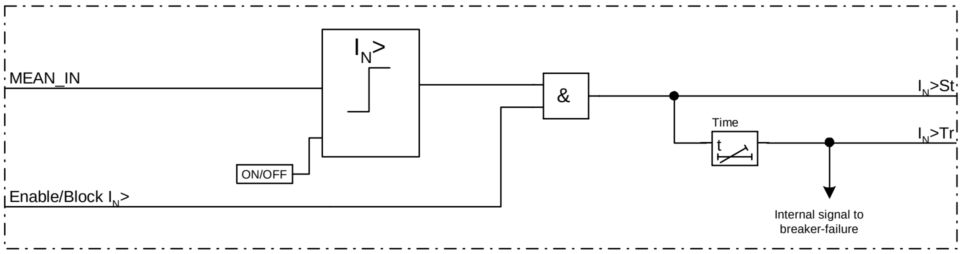
5 Earth-fault protection (Option)

5.1 Theory of operation

The earth-fault protection has two stages, a low set stage and a high set stage both with definite time delay. Each stage compares the measured and calculated neutral current value with the pre-set current values. When the measured and calculated current exceeds or is equal to a pre-set value of a stage, the start function generates a start signal. At the same time the trip delay starts to count-up and after set time delay the function generates a trip signal.

A simplified logic diagram for the earth-fault protection is shown in figure 20.

Earth-fault protection, low set stage I_N>



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Earth-fault protection, high set stage I_N>>

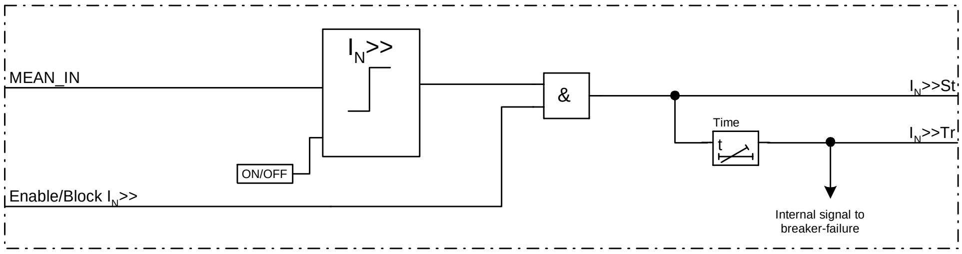

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Figure 20: Simplified logic diagram for the earth-fault protection.

5.2 Input and output signals

Table 17: Input signals, earth-fault protection (option)

Signal	Default	Description
I_N> Block/Enable	-	Active signal blocks or enables the low set earth-fault stage I_N>.
I_N>> Block/Enable	-	Active signal blocks or enables the high set earth-fault stage I_N>>.

Table 18: Output signals, earth-fault protection (option)

Signal	Default	Description
I_N>St	Relay 1	Low set stage I_N>, start signal.
I_N>Tr	Relay 2	Low set stage I_N>, trip signal.
I_N>>St	Relay 1	High set stage I_N>>, start signal.
I_N>>Tr	Relay 2	High set stage I_N>>, trip signal.

Table 19: Internal output signals, earth-fault protection (option)

Signal	Description
I_N>Tr	Trip signal to three-phase breaker failure function from low set stage I_N>.
I_N>>Tr	Trip signal to three-phase breaker failure function from high set stage I_N>.

5.3 Setting parameters

Table 20: Setting parameters, earth-fault protection (option)

Parameter	Range	Unit	Default	Let you...
I_N>	On - Off	-	On	Select low set earth-fault stage I_N> to be active or not.
I_N>	0.10 - 4.00 x I_{Nb}	A	0.10 x I_{Nb}	Set operate level.
Time	0.00 - 20.0	s	0.00 s	Set definite time delay.

Parameter	**Range**	**Unit**	**Default**	**Let you...**
I_N>>	On - Off	-	On	Select high set earth-fault stage I_N>> to be active or not.
I_N>>	0.10 - 4.00 x I_{Nb}	A	0.10 x I_{Nb}	Set operate level.
Time	0.00 - 20.0	s	0.00 s	Set definite time delay.

6 Service values

6.1 Theory of operation

The service values are presented in both primary and secondary values. In normal service when the plastic cover covers the relay only the primary service values are presented. The following service values are presented:

- Phase current, IL1, IL2 and IL3
- Neutral current, I_N
- Frequency

If a secondary current value is over four times the set basic current level out-of-range (OOR) is presented. A frequency deviation more than 10 Hz from rated frequency will be presented as ---- Hz.

6.2 Setting parameters

Table 21: Setting parameters, main phase CT ratio

Parameter	Range	Unit	Default	Let you...
Primary	1.00 - 999	A	1.00 A	Set the primary rated value of the phase CT’s.
	1.00 - 100	kA	-	
Secondary	0.40 - 10.0	A	1.00 A	Set the secondary rated value of the phase CT’s.

Table 22: Setting parameters, main earth CT ratio

Parameter	Range	Unit	Default	Let you...
Primary	1.00 - 999	A	1.00 A	Set the primary rated value of the neutral CT.
	1.00 - 100	kA	-	
Secondary	0.40 - 10.0	A	1.00 A	Set the secondary rated value of the neural CT.

7 Indications

7.1 Theory of operation

The relay store all disturbance information in the indications menu, for example start signals, trip signals and trip values. Via a binary input also the actual service values can be stored, the recorded service values are also presented via the indications menu. All recorded signals and values are stored in non-volatile memory.

7.2 Indications menu

The following indications are presented when the indications menu is entered. Through this menu also primary recorded trip values and externally recorded service values are presented. The recorded primary trip values are always from the last disturbance.

Indications	Start	Trip	Option	Function description, status for
I>L1	□	□	Yes	Low set overcurrent stage, single-phase IL1.
I>L2	□	□	Yes	Low set overcurrent stage, single-phase IL2.
I>L3	□	□	Yes	Low set overcurrent stage, single-phase IL3.
I>	□	□	Yes	Low set overcurrent stage, multi-phase faults.
I>>L1	□	□	Yes	High set overcurrent stage, single-phase IL1.
I>>L2	□	□	Yes	High set overcurrent stage, single-phase IL2.
I>>L3	□	□	Yes	High set overcurrent stage, single-phase IL3.
I>>	□	□	Yes	High set overcurrent stage, multi-phase faults.
I_N>	□	□	Yes	Low set earth-fault stage.
I_N>>	□	□	Yes	High set earth-fault stage.
1-PhBF	□			Single-phase start of breaker failure.
	L123			Phase indication which caused single-phase start.
3-PhBF	□			Three-phase start of breaker failure.
UncndBF	□			Three-phase unconditional start of breaker failure.
ReTrL1		□		Re-trip function, single-phase IL1.
ReTrL2		□		Re-trip function, single-phase IL2.
ReTrL3		□		Re-trip function, single-phase IL3.

Indications	Start	Trip	Option	Function description, status for
ReTrip		☐		Re-trip function, three-phase.
BkUpTr1		☐		Back-up trip 1 function, three-phase.
BkUpTr2		☐		Back-up trip 2 function, three-phase.
PoleDis	☐	☐		Pole-disagreement function.

All start functions are connected to the yellow LED and all trip functions are connected to the red LED. The appearance of the boxes in the local HMI describes the status of the function.

Appearance of indication boxes	Provides information about
Filled (black)	Latest recorded event.
Grayed	Previous recorded event.
Blank	No recorded event (since last clearing).
Criteria for a new event: All started functions has to be reset before the relay can treat a new disturbance as a new event.	

Recorded trip values (option)	Provides information about
IL1	The recorded phase-1 current.
IL2	The recorded phase-2 current.
IL3	The recorded phase-3 current.
I_N	The recorded neutral current.

Externally recorded service values	Provides information about
ExtIL1	The recorded phase-1 current.
ExtIL2	The recorded phase-2 current.
ExtIL3	The recorded phase-3 current.
ExtI_N	The recorded neutral current.

Out-of-range (OOR) is presented if a recorded current in secondary value is over four times the set basic current level.

7.3 Input and output signals

Table 23: Input signal, indications

Signal	Default	Description
StoreSerVal	-	Active signal records actual service values.
ResetLED	-	Active signal resets LED’s, clears recorded disturbances and trip values.

8 Self-supervision

8.1 Theory of operation

All micro-processors in the measuring relay executes a self test sequence during start-up. The green “In service” LED will light-up when the relay is ready for operation. In a case of an internal fault, the LED’s will start flashing or an error message will be presented in the local HMI-display. The tables below are provided with more fault information. The program in the micro-processors is executed in a fixed loop.

The loop is supervised by an internal watch dog which initiates a program restart if the program malfunctions.

Both hardware and software supervision is included and it is also possible to indicate eventual faults through a binary output error signal.

Table 24: Self-supervision indications in RXHB 411

Indication	Test sequence	Description
Green, yellow and red LED’s are flashing.	Internal watchdog	Internal watchdog has timed out.
Green and yellow LED’s are flashing.	ROM	Checksum error.
Green and red LED’s are flashing.	RAM	Error in memory cells.
“E ain” is presented in the HMI-display	Internal communication error	Analog printed circuit card is not responding.
“E bin” is presented in the HMI-display	Internal communication error	Binary I/O (option) printed circuit card is not responding.

8.2 Input and output signals

Table 25: Output signal, self-supervision function

Signal	Default	Description
InService	Relay 5	Active signal when relay is in normal service

Chapter 6 Design description

About this chapter

This chapter describes how the protection assembly and the measuring relay is designed. The different parts and the different variants that make up the protection assemblies are described.

1 Protection assembly

1.1 Compact breaker failure protection assembly RAHB 411

The protection assemblies are of protective class I equipment in which protection against electric shock does not rely on basic insulation only, but which includes additional safety precautions in such a way that accessible conductive parts are connected to protective earth. The protections are based on the compact breaker failure relay RXHB 411. Test device RTXP 8, RTXP 18 and DC/DC-converter RXTUG 22H can also be included for specific application requirements. Test device, RTXP 8 and RTXP 18 are tools for relay testing. DC/DC-converter RXTUG 22H can be used either separately for a single protection or to feed other protections of the same relay family. With RXTUG 22H all requirements concerning emission and immunity disturbances with this protection assembly will be met.

The basic version of the measuring relay has 2 binary inputs and 5 binary outputs. The binary I/O option includes 4 additional inputs and 4 additional outputs. Protections are normally available with output logic with heavy duty contacts, relay RXME 18 with indicating flag, and can upon request be completed with an output logic of free choice. Output relays are connected to separate auxiliary voltage. The interface voltage for enable or block impulses can be connected to either 48-60 V DC or 110-220 V DC by connecting the voltage circuit to separate terminals. At delivery all relays are connected for 110-220 V DC.

All the protections in the COMBIFLEX® modular system are mounted on apparatus bars. The connections to the protections are done by COMBIFLEX® socket equipped leads. All internal connections are made and the protection assembly is tested before delivery from factory. The type of modules and their physical position and the modular size of the protection are shown in the diagrams of the respective protection. Figure 21 shows an example of a protection assembly.

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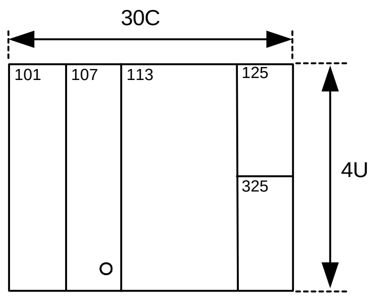


101 RTXP 18
107 RXTUG 22H
113 RXHB 411
125 RXME 18
325 RXME 18

xx00000661.vsd

Figure 21: Protection assembly example

The height and width of the protection assembly are given in the circuit diagram with height (U) and width (C) modules, where U = 44.45 mm and C = 7 mm. The depth of the protection assembly, including space for the connection wires, is approximately 200 mm.

1.2 Test switch RTXP 18

The test switch RTXP 18 is a part of the COMBITEST testing system described in the Technical overview brochure No. 1MRK 512 001-BEN. A complete secondary testing of the protection can be performed by using a test-plug handle RTXH 18, connected to a test set. When the test-plug handle is inserted into the test switch, preparations for testing are automatically carried out in a proper sequence, that is blocking of tripping circuits, short-circuiting of current circuits, opening of voltage circuits. This makes the protection available for secondary testing. Test switch RTXP 18 has the modular dimensions 4U 6C.

All input currents can be measured by a test plug RTXM connected to an ammeter. The tripping circuits can be blocked by a trip-block plug RTXB and the protection can be totally blocked by a block-plug handle RTXF 18.

1.3 DC/DC-converter RXTUG 22H

The DC/DC-converter RXTUG 22H converts the station battery voltage to an alternating voltage which is then transformed, rectified, smoothed and in this application regulated to +/-24 V DC. The auxiliary voltage is in that way adapted to the measuring unit. The input and output voltages are galvanically separated, which contributes to damping of possible transients in the auxiliary voltage supply to the measuring relay. The converter has a built-in signal relay and a green LED for supervision of the output voltage.

RXTUG 22H has the modular dimensions 4U 6C. It is described in the technical overview brochure No. 1MRK 513 001-BEN.

1.4 Measuring relay

1.4.1 Compact breaker failure relay RXHB 411

The compact breaker failure relay RXHB 411 constitutes the measuring relay of RAHB 411 and is available in four different versions.

The compact breaker failure relay RXHB 411 is a protective class II equipment in which protection against electric shock does not rely on basic insulation only, but in which additional safety precaution such as double insulation or reinforced insulation are provided.

RXHB 411 is a three-phase numerical, microprocessor-based relay with four input current transformers for galvanic insulation. The input signals are connected to D/A-converters and then filtered. The signals are sampled in the A/D-converter and read into the microprocessor. The unfiltered input signals are also connected to zero crossing detectors and read into the microprocessor. All settings of the relay will be done in the local HMI.

The relay is provided with three LED's; one for start, one for trip and one for "in service". The relay is provided with two or six binary inputs and five or nine binary outputs, the binary inputs are galvanically separated from the electronics with optocouplers. The binary outputs consist of electromechanical relays, each with one change over contact.

RXHB 411 requires a DC/DC-converter for the auxiliary voltage supply +/-24 V; RXTUG 22H is recommended. The relay is delivered with 4-short-circuiting connectors RTXK for mounting on the rear of the terminal base. The connectors will automatically short-circuit the input currents when the relay is removed from the terminal base.

RXHB 411	Basic version, terminal diagram figure 22
RXHB 411	Basic version together with overcurrent and earth-fault protection, terminal diagram figure 22
RXHB 411	Basic version together with binary I/O option, terminal diagram figure 23
RXHB 411	Basic version together with overcurrent and earth-fault protection and binary I/O option, terminal diagram figure 23

Terminal diagrams

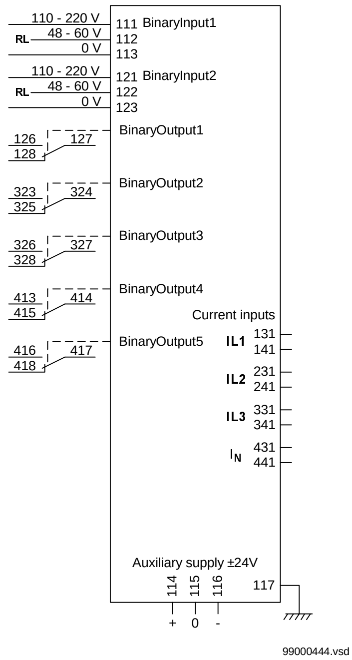


Figure 22: RXHB 411 basic version

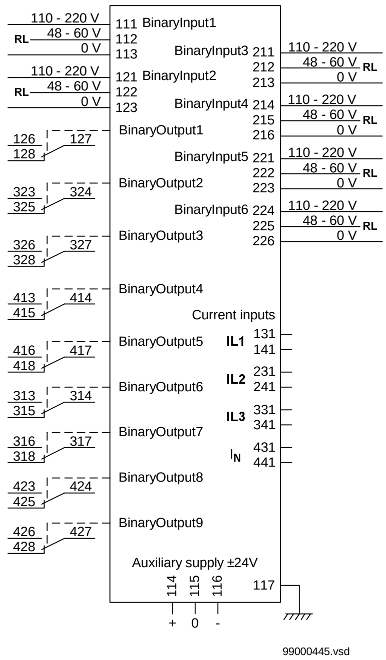


Figure 23: RXHB 411 with binary I/O option

Frequency characteristic

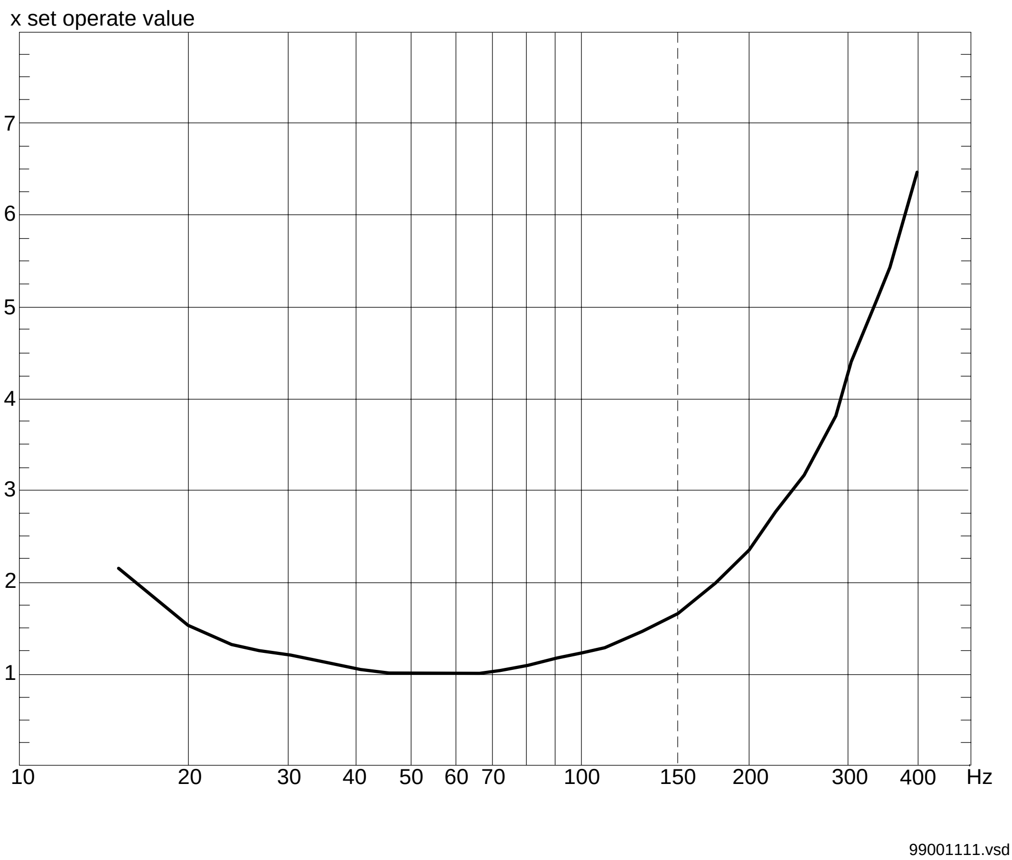


Figure 24: Frequency characteristic

1.4.2 Binary inputs and outputs

Binary inputs

The relay is provided with two or six binary inputs which are galvanically separated from the electronics with opto-couplers. The binary inputs can flexible be configured in the local HMI. A binary input signal or signals can be configured to one or more than one function. Binary input signals are defined as OR functions.

Binary outputs

The relay is provided with five or nine binary outputs with change-over contacts. The binary outputs can flexible be configured in the local HMI. A function output signal or signals can be configured to one or more than one binary output. Binary output signals are defined as OR functions.

RXHB 411	Binary inputs	Binary outputs
Basic version	2	5
Basic version with binary I/O option	6	9

Binary I/O-test

The relay is provided with a test function for the binary I/O signals into and out from the relay. Energized binary inputs can be overview via the local HMI. Activation of binary outputs can be done via the local HMI.

1.5 Tripping relay RXME 18

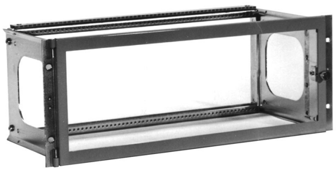
The auxiliary relay RXME 18 is used as a tripping relay. It has two heavy duty make contacts and a red flag. The flag will be visible when the armature picks up and is manually reset by a knob in the front of the relay. Typical operate time is 35 ms.

RXME 18 has the modular dimensions 2U 6C. The relay is described in the technical overview brochure No. 1MRK 508 015-BEN.

2 Equipment frames and relay cases

The equipment frames and cases are described more detailed in the technical overview brochure No. 1MRK 513 003-BEN. All protection assemblies are mounted on apparatus bars. The apparatus bars are used for the mounting of the COMBIFLEX© terminal bases and are screwed directly on the supporting frame by using 3.5 mm tapping screws.

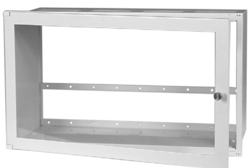
2.1 19” equipment frame



These types of equipment frames are used for cubicle mounting or panel mounting of plug-in units in the COMBIFLEX© range. The frames are available in 3 sizes for mounting of 20, 40 and 60 module seats respectively:

- 4U (17” x 19”)
- 8U (14” x 19”)
- 12U (21” x 19”)

2.2 RHGS cases for 19” cubicle mounting or surface mounting



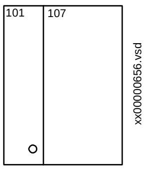
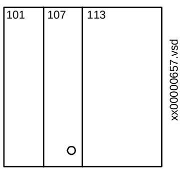
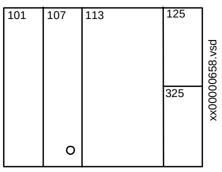
This type of case can be used for all common ways of mounting. The RHGS cases are available in three different sizes, which can be combined with mounting accessories to get maximum flexibility. The cases can also be combined together with the protections in the 500 range. The figure shows a RHGS 30 case.

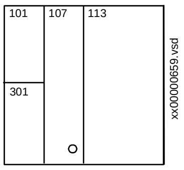
2.3 RHGX cases for flush- or semi-flush panel mounting

The RHGX cases are available in five sizes. The case, a metal box open at the back, has a flange (with a rubber sealing strip) at the front which acts as a stop when the case is inserted into a front panel opening. At the front of the case there is a door with a window and a rubber seal. The figure shows a RHGX 8 case.

3 Protection assemblies

The table below shows the different versions of the compact breaker failure relay RXHB 411 in protection assemblies type RAHB 411.

RAHB 411 protection assembly variants	Ordering No.	RXHB 411 options	Circuit diagram	Terminal diagram	Available diagrams
 101 RXTUG 22H 107 RXHB 411	1MRK 002 028-AA	Basic version	1MRK 002 029-AA	1MRK 002 029-AAA	On request
		With binary I/O option	1MRK 002 029-AB	1MRK 002 029-ABA	On request
 101 RTXP 18 107 RXTUG 22H 113 RXHB 411	1MRK 002 028-BA	Basic version	1MRK 002 029-BA	1MRK 002 029-BAA	On request
		With binary I/O option	1MRK 002 029-BB	1MRK 002 029-BBA	On request
 101 RTXP 18 107 RXTUG 22H 113 RXHB 411 125 RXME 18 325 RXME 18	1MRK 002 028-CA	Basic version	1MRK 002 029-CA	1MRK002 029-CAA [a)]	[b)]
		With binary I/O option	1MRK 002 029-CB	1MRK 002 029-CBA [a)]	[b)]

RAHB 411 protection assembly variants	Ordering No.	RXHB 411 options	Circuit diagram	Terminal diagram	Available diagrams
 101 RTXP 8 107 RXTUG 22H 113 RXHB 411 301 RXME 18	1MRK 002 028-DA	Basic version	1MRK 002 029-DA	1MRK 002 029-DAA	On request
	1MRK 002 028-EA[c)]		1MRK 002 029-EA[c)]	1MRK 002 029-EAA[c)]	[b)]
		With binary I/O option	1MRK 002 029-DB	1MRK 002 029-DBA	On request
			1MRK 002 029-EB[c)]	1MRK 002 029-EBA[c)]	[b)]

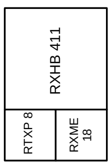
a) Terminal diagrams available in technical overview brochure for RXHB 411 and RAHB 411

b) Terminal and circuit diagrams available in installation and commissioning manual for RXHB 411 and RAHB 411

c) Selection of phase and neutral rated currents must be the same, $I_r = IN_r = 1$ A or $I_r = IN_r = 5$ A

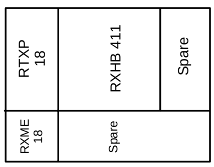
3.1 Mounting alternatives

The RAHB 411 protection assemblies described in the table above can be supplied in RHGX or RHGS cases. The layouts below show alternative packaging into three different sizes of RHGS cases. The RHGS cases are 6U tall which is the same as for the 500 series.



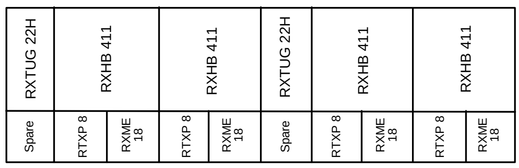
xx00000653.vsd

Mounting of RXHB 411 in RHGS 6.



xx00000654.vsd

Mounting of RXHB 411 in RHGS 12.



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Mounting of RXHB 411 in RHGS 30 with dual power supplies RXTUG 22H, individual test switches and optional tripping relays.

RHGP cases offer compact and low cost panel mounting alternatives. RHGP sizes 4, 4B are suitable for housing RXHB 411 only. The RHGP 8 can be used when for example test switch and power supply is needed in addition to the compact breaker failure relay RXHB 411 for example with protection assemblies with ordering number 1MRK 002 028-BA, -DA or -EA. The RHGP cases are specified for separate purchase in document 1MRK 513 013-BEN.

xx00000630

Example of a panel mounting alternative.

Chapter 7 Technical data

About this chapter

This chapter presents the technical data for the measuring relay and each protection function.

1 Compact breaker failure relay RXHB 411

Table 26: Current inputs

Rated phase current I_r		1 A or 5 A
Rated neutral current IN_r	For I_r = 1 A	30 mA, 0.1 A or 1 A
	For I_r = 5 A	30 mA, 0.1 A, 1 A or 5 A
Setting range basic current	Phase I_b	1.0-10 x I_r
	Neutral I_{Nb}	1.0-10 x IN_r
Setting range breaker failure protection	Phase current, BF>	0.1-1.0 x I_b
	Neutral current, BF_N>	0.1-1.0 x I_{Nb}
Setting range pole-disagreement protection	Undercurrent, I<	0.1-0.15 x I_b
	Overcurrent, I>	0.2-0.5 x I_b
Setting range overcurrent protection (option)	Stage I>	0.1-4.0 x I_b
	Stage I>>	0.1-4.0 x I_b
Setting range earth-fault protection (option)	Stage I_N>	0.1-4.0 x I_{Nb}
	Stage I_N>>	0.1-4.0 x I_{Nb}
Effective phase current range		0.1-40 x I_r
Effective neutral current range		0.1-40 x IN_r
Rated frequency f_r		50 and 60 Hz
Frequency range		40-60 Hz/50-70 Hz
Power consumption, per phase at rated current	I_r = 1 A	< 30 mVA
	I_r = 5 A	< 150 mVA
Power consumption, at rated neutral current	IN_r = 30 mA	< 10 mVA
	IN_r = 0.1 A	< 15 mVA
	IN_r = 1 A	< 30 mVA
	IN_r = 5 A	< 150 mVA
Overload capacity for phase current input	I_r = 1 A continuously	4 A
	I_r = 5 A continuously	20 A
	I_r = 1 A during 1 s	100 A
	I_r = 5 A during 1 s	350 A

Overload capacity for neutral current input	IN_r = 30 mA continuously	0.4 A
	IN_r = 0.1 A continuously	0.4 A
	IN_r = 1 A continuously	4 A
	IN_r = 5 A continuously	20 A
	IN_r = 30 mA during 1 s	10 A
	IN_r = 0.1 A during 1 s	10 A
	IN_r = 1 A during 1 s	100 A
	IN_r = 5 A during 1 s	350 A

Table 27: Binary inputs

Inputs			**Rated values**
Binary inputs	Basic version		2
	Basic version with binary I/O option		6
Binary input voltage RL	Low		48-60 V DC, -20% to +10%
	High		110-220 V DC, -20% to +10%
Power consumption	Low	48 V DC	< 0.15 W / input
		60 V DC	< 0.3 W / input
	High	110 V DC	< 0.3 W / input
		220 V DC	< 0.8 W / input

Table 28: Output relays

Outputs			**Rated values**
Contacts	Basic version		5 change-over
	Basic version with binary I/O option		9 change-over
Maximum system voltage			250 V AC/DC
Current carrying capacity		Continuous	5 A
		During 1 s	15 A
Making capacity at inductive load with L/R >10 ms		During 200 ms	30 A
		During 1 s	10 A

<table>
<tr><th colspan="3">Outputs</th><th>Rated values</th></tr>
<tr><td rowspan="5">Breaking capacity</td><td>AC, cos φ> 0.4</td><td>Max. 250 V</td><td>8 A</td></tr>
<tr><td rowspan="4">DC, L/R < 40 ms</td><td>48 V</td><td>1 A</td></tr>
<tr><td>110 V</td><td>0.4 A</td></tr>
<tr><td>220 V</td><td>0.2 A</td></tr>
<tr><td>250 V</td><td>0.15 A</td></tr>
</table>

Table 29: Auxiliary DC voltage supply

<table>
<tr><th colspan="3">Power consumption</th><th>Rated values</th></tr>
<tr><td colspan="3">Auxiliary voltage EL for RXTUG 22H</td><td>24-250 V DC, +/-20%</td></tr>
<tr><td colspan="3">Auxiliary voltage for the relay</td><td>+/-24 V (from RXTUG 22H)</td></tr>
<tr><td rowspan="4">Power consumption with back-light on basic version</td><td rowspan="2">With RXTUG 22H, input 24-250 V</td><td>Before operation</td><td>< 5.0 W</td></tr>
<tr><td>After operation</td><td>< 7.0 W</td></tr>
<tr><td rowspan="2">Without RXTUG 22H, +/-24 V</td><td>Before operation</td><td>< 2.7 W</td></tr>
<tr><td>After operation</td><td>< 4.3 W</td></tr>
<tr><td rowspan="4">Power consumption with back-light on basic version with binary I/O option</td><td rowspan="2">With RXTUG 22H, input 24-250 V</td><td>Before operation</td><td>< 5.5 W</td></tr>
<tr><td>After operation</td><td>< 8.5 W</td></tr>
<tr><td rowspan="2">Without RXTUG 22H, +/-24 V</td><td>Before operation</td><td>< 3.0 W</td></tr>
<tr><td>After operation</td><td>< 5.5 W</td></tr>
<tr><td colspan="3">Power consumption, back-light.</td><td>Approximately 0.5 W</td></tr>
</table>

Table 30: Electromagnetic compatibility (EMC), immunity tests

<table>
<tr><th colspan="3">All tests are performed together with the DC/DC-converter, RXTUG 22H</th></tr>
<tr><th>Test</th><th>Severity</th><th>Standard</th></tr>
<tr><td>Surge</td><td>1 and 2 kV</td><td>IEC 61000-4-5, class 3</td></tr>
<tr><td>AC injection</td><td>500 V AC</td><td>SS 436 15 03, PL 4</td></tr>
<tr><td>Power frequency magnetic field</td><td>1000 A/m</td><td>IEC 61000-4-8</td></tr>
<tr><td>1 MHz burst</td><td>2.5 kV</td><td>IEC 60255-22-1, class 3</td></tr>
<tr><td>Spark</td><td>4-8 kV</td><td>SS 436 15 03, PL 4</td></tr>
<tr><td>Fast transient</td><td>4 kV</td><td>IEC 60255-22-4, class 4</td></tr>
</table>

<table>
<tr><th colspan="4">All tests are performed together with the DC/DC-converter, RXTUG 22H</th></tr>
<tr><th colspan="2">Test</th><th>Severity</th><th>Standard</th></tr>
<tr><td colspan="2" rowspan="3">Electrostatic discharge at normal service with cover on</td><td>6 kV (contact)</td><td>IEC 60255-22-2, class 3</td></tr>
<tr><td>8 kV (air)</td><td>IEC 60255-22-2, class 3</td></tr>
<tr><td>6 kV, indirect application</td><td>IEC 61000-4-2, class 3</td></tr>
<tr><td colspan="2">Radiated electromagnetic field, sweep</td><td>10 V/m, 80-1000 MHz</td><td>IEC 60255-22-3</td></tr>
<tr><td colspan="2">Radiated electromagnetic field, pulse</td><td>10 V/m, 900 MHz</td><td>IEC 60255-22-3</td></tr>
<tr><td colspan="2">Radiated electromagnetic field, spot</td><td>10 V/m, 80, 160, 450 and 900 MHz</td><td>IEC 60255-22-3</td></tr>
<tr><td colspan="2">Conducted electromagnetic</td><td>10 V, 0.15-80 MHz</td><td>IEC 61000-4-6, Level 3</td></tr>
<tr><td colspan="2">Interruptions in auxiliary voltage</td><td>2-200 ms</td><td rowspan="4">IEC 60255-11</td></tr>
<tr><td rowspan="3">No reset for inter-ruptions</td><td>24 V DC</td><td>< 20 ms</td></tr>
<tr><td>110 V DC</td><td>< 70 ms</td></tr>
<tr><td>250 V DC</td><td>< 300 ms</td></tr>
</table>

Table 31: Electromagnetic compatibility (EMC), emission tests

All tests are performed together with the DC/DC-converter, RXTUG 22H		
Test	**Severity**	**Standard**
Conducted	0.15-30 MHz	IEC 60255-25
Radiated	30-1000 MHz	IEC 60255-25

Table 32: CE-demand

Test	Reference standard
Immunity	EN 50263
Emission	EN 50263
Low voltage directive	EN 50178

Table 33: Insulation tests

Test		**Severity**	**Standard**
Dielectric	Current circuit to circuit and current circuit to earth	2.5 kV AC, 1 min	IEC 60255-5
	Circuit to circuit and circuit to earth	2.0 kV AC, 1 min	
	Over open contact	1.0 kV AC, 1 min	
Impulse voltage		5 kV, 1.2/50 μs, 0.5 J	IEC 60255-5
Insulation resistance		> 100 MΩ at 500 V DC	IEC 60255-5

Table 34: Mechanical test

Test	**Severity**	**Standard**
Vibration	Response: 1 g, 1-150-10 Hz	IEC 60255-21-1, class 2
	Endurance: 1 g, 10-150-10 Hz, 20 sweeps	IEC 60255-21-1, class 1
Shock	Response: 5 g, 11 ms, 3 pulses	IEC 60255-21-2, class 1
	Withstand: 15 g, 11 ms, 3 pulses	
Bump	Withstand: 10 g, 16 ms, 1000 pulses	IEC 60255-21-2, class 1
Seismic	X-axis: 3 g, 1-50-1 Hz	IEC 60255-21-3, class 2, extended (Method A)
	Y-axis: 3 g, 1-50-1 Hz	
	Z-axis: 2 g, 1-50-1 Hz	

Table 35: Climatic conditions

Climatic condition	Partially weather protected locations, switch-gear environment, class 3K3
Storage	-40° C to +70° C
Permitted ambient temperature	-5° C to +55° C

Table 36: Weight and dimensions

Equipment	**Weight**	**Height**	**Width**
Relay without RXTUG 22H	Approximately 1.3 kg	4U	12C

2 Functions

Table 37: Service values

Service values			Range	Accuracy
Currents	Secondary	Phase	0.1-4.0 x I_b	< 3%
		Neutral	0.1-4.0 x I_{Nb}	< 3%
	Primary	Phase	0.1-250 000 x secondary value	< 3%
		Neutral	0.1-250 000 x secondary value	< 3%
Frequency	Frequency	f_r = 50 Hz	40-60 Hz	0.1 Hz
		f_r = 60 Hz	50-70 Hz	0.1 Hz

Table 38: Breaker failure protection, general

Breaker failure protection, general		Setting range
Setting range, basic current detection	Phase current, BF>	(0.10-1.0) x I_b
	Neutral current, BF_N>	(0.10-1.0) x I_{Nb}
Limiting errors of set operate value for current measuring 50/60 Hz	$I_r = IN_r$ = 1 A and 5 A	< 3%
	IN_r = 0.1 A	< 3% or 1 mA up to 30 mA
	IN_r = 30 mA	< 3% or 0.5 mA up to 10 mA
Consistency of set operate value 50/60 Hz		< 1%
Typical reset ratio		95%
Current criteria for detection		1 out of 4 or 2 out of 4
Delta time delay between back-up trip 1 and 2		0-0.5 s
Minimum trip pulse length		0.02-0.5 s
Operate time for current reset detection		Max. 10 ms
Overshoot time[a)]		< 40 ms
Accuracy, time delays	External start	± 10 ms
	Internal start (option)	-25 ms and ± 10 ms
Temperature dependence within range -5° C to +55° C		< 2%
[a)] Minimum time between circuit-breaker time and set time delay		

Table 39: Single-phase function

Single-phase function		Setting range
Start of single-phase function	External start	Via binary inputs
	Internal start (option)	Via overcurrent protection
Re-trip function		Off, current criteria or unconditional
Re-trip time delay		0.00-1.0 s
Back-up trip 1 time delay		0.05-1.0 s
Accuracy, time delays	External start	± 10 ms
	Internal start (option)	-25 ms and ± 10 ms

Table 40: Three-phase function

Three-phase function		Setting range
Start of three-phase function	External start	Via binary inputs
	Internal start (option)	Via overcurrent and earth-fault protection
Re-trip function		Off, current criteria or unconditional
Re-trip time delay		0.00-1.0 s
Back-up trip 1 time delay		0.05-1.0 s
Accuracy, time delays	External start	± 10 ms
	Internal start (option)	-25 ms and ± 10 ms

Table 41: Three-phase unconditional function

Three-phase unconditional function	Setting range
Start of three-phase unconditional function	External start via binary inputs
Re-trip function	Off or unconditional
Re-trip time delay	0.00-1.0 s
Back-up trip 1 time delay	0.05-1.0 s
Accuracy, time delays	± 10 ms

Table 42: Pole-disagreement protection

Pole-disagreement protection		Setting range
Setting range	Undercurrent, I<	(0.10-0.15) x I_b
	Overcurrent, I>	(0.20-0.50) x I_b
Limiting errors of set operate value for current measuring 50/60 Hz		< 3%
Consistency of set operate value 50/60 Hz		< 1%
Typical reset ratio	Undercurrent, I<	105%
	Overcurrent, I>	95%
Typical operate time I = 0 = 2 x set operate value		60 ms
Typical reset time I = 2 = 0 x set operate value		60 ms
Definite time delay		0-20 s
Reset time delay		0-10 s
Accuracy, time delays		± 30 ms
Temperature dependence within range -5° C to +55° C		< 2%

Table 43: Overcurrent protection (option)

Overcurrent protection	Stage I> and I>>
Setting range	(0.1-4.0) x I_b
Limiting errors of set operate value for current measuring 50/60 Hz	< 3%
Consistency of set operate value 50/60 Hz	< 1%
Typical reset ratio	95%
Typical operate time I = 0 => 3 x set operate value	40 ms
Typical reset time I = 3 => 0 x set operate value	45 ms
Transient over-reach L/R = 50 ms	< 5%
Typical overshoot time	30 ms
Recovery time at I = 3 x set operate value	< 55 ms

Overcurrent protection		**Stage I> and I>>**
Frequency dependency	F_r = 50 Hz (45-55 Hz)	< 5%
	F_r = 60 Hz (54-66 Hz)	< 5%
	150/180 Hz	Typical 1.5/2.0 x set operate value
	250/300 Hz	Typical 3.0/4.0 x set operate value
Influence of harmonics	100/120 Hz, 10%	< 2%
	150/180 Hz, 20%	< 6%
	250/300 Hz, 20%	< 3%
Temperature dependence within range -5° C to +55° C		< 2%

Table 44: Time functions for overcurrent protection (option)

Time function		**Stage I> and I>>**
Setting range, definite time delay	Single-phase fault	0-20 s
	Multi-phase fault	0-20 s
Accuracy, definite time		± 30 ms

Table 45: Earth-fault protection (option)

Earth-fault protection		**Stage I_N> and I_N>>**
Setting range		(0.1-4.0) x I_{Nb}
Limiting errors of set operate value for current measuring 50/60 Hz	IN_r = 1 A and 5 A	< 3%
	IN_r = 0.1 A	< 3% or 1 mA up to 30 mA
	IN_r = 30 mA	< 3% or 0.5 mA up to 10 mA
Consistency of set operate value 50/60 Hz		< 1%
Typical reset ratio		95%
Typical operate time I = 0 => 3 x set operate value		40 ms
Typical reset time I = 3 => 0 x set operate value		45 ms
Transient over-reach L/R = 50 ms		< 5%
Typical overshoot time		30 ms
Recovery time at I = 3 x set operate value		< 55 ms

Earth-fault protection		**Stage I_N> and I_N>>**
Frequency dependency	F_r = 50 Hz (45-55 Hz)	< 5%
	F_r = 60 Hz (54-66 Hz)	< 5%
	150/180 Hz	Typical 1.5/2.0 x set operate value
	250/300 Hz	Typical 3.0/4.0 x set operate value
Influence of harmonics	100/120 Hz, 10%	< 2%
	150/180 Hz, 20%	< 6%
	250/300 Hz, 20%	< 3%
Temperature dependence within range -5° C to +55° C		< 2%

Table 46: Time functions for earth-fault protection (option)

Time function	**Stage I_N> and I_N>>**
Setting range, definite time delay	0-20 s
Accuracy, definite time	± 30 ms

Chapter 8 Ordering

About this chapter

This chapter contains ordering tables which should be used when ordering.

1 RAHB 411 protections

1.1 Basic data to specify

RAHB 411 protection	Quantity:	☐	1MRK 002 028- ____

Desired wording on the lower half of the test switch max. 13 lines with 14 characters per line.

Rated AC inputs

Phase I_r = 1 A, neutral IN_r = 30 mA	☐	1MRK 000 322-HC
Phase I_r = 1 A, neutral IN_r = 0,1 A	☐	1MRK 000 322-HD
Phase I_r = 1 A, neutral IN_r = 1 A	☐	1MRK 000 322-HE
Phase I_r = 5 A, neutral IN_r = 30 mA	☐	1MRK 000 322-HF
Phase I_r = 5 A, neutral IN_r = 0,1 A	☐	1MRK 000 322-HG
Phase I_r = 5 A, neutral IN_r = 1 A	☐	1MRK 000 322-HH
Phase I_r = 5 A, neutral IN_r = 5 A	☐	1MRK 000 322-HK

1.2 Options

Functions

Overcurrent and earth-fault protection	☐	1MRK 002 027-AA
Additional binary I/O (inputs 4/outputs 4)	☐	1MRK 000 322-ET

Auxiliary voltage for included auxiliary relay

RXME 18, 24 V DC	☐	RK 221 825-AD
RXME 18, 48-55 V DC	☐	RK 221 825-AH
RXME 18, 110-125 V DC	☐	RK 221 825-AN
RXME 18, 220-250 V DC	☐	RK 221 825-AS

Mounting alternatives	**Size**		
Apparatus bars (always included)			
Equipment frame without door	4U 19”	☐	1MRK 000 137-GA
Equipment frame with door	4U 19”	☐	1MRK 000 137-KA
RHGX 8	4U 24C	☐	RK 927 002-AB
RHGX 12	4U 36C	☐	RK 927 003-AB
RHGX 20	4U 60C	☐	RK 927 004-AB
RHGS 30	6U x 1/1 19” rack	☐	1MRK 000 315-A
RHGS 12	6U x 1/2 19” rack	☐	1MRK 000 315-B

1.3 Accessories

User documentation RXHB 411 and RAHB 411			
Operator’s manual	Quantity:	☐	1MRK 509 071-UEN
Technical reference manual	Quantity:	☐	1MRK 509 072-UEN
Installation and commissioning manual	Quantity:	☐	1MRK 509 073-UEN

2 RXHB 411 relays

2.1 Included functions in basic version

Single- and three-phase breaker failure protection

Pole-disagreement protection

Local Human Machine Interface (HMI)

Service value reading (primary or secondary values)

2.2 Basic data to specify

RXHB 411, includes basic functions	Quantity:	▭	1MRK 001 982-AA

Rated AC inputs

Phase I_r = 1 A, neutral IN_r = 30 mA	☐	1MRK 000 322-HC
Phase I_r = 1 A, neutral IN_r = 0,1 A	☐	1MRK 000 322-HD
Phase I_r = 1 A, neutral IN_r = 1 A	☐	1MRK 000 322-HE
Phase I_r = 5 A, neutral IN_r = 30 mA	☐	1MRK 000 322-HF
Phase I_r = 5 A, neutral IN_r = 0,1 A	☐	1MRK 000 322-HG
Phase I_r = 5 A, neutral IN_r = 1 A	☐	1MRK 000 322-HH
Phase I_r = 5 A, neutral IN_r = 5 A	☐	1MRK 000 322-HK

2.3 Options

Functions

Overcurrent and earth-fault protection	☐	1MRK 002 027-AA
Additional binary I/O (inputs 4/outputs 4)	☐	1MRK 000 322-ET

2.4 Accessories

User documentation RXHB 411 and RAHB 411

Operator's manual	Quantity:		1MRK 509 071-UEN
Technical reference manual	Quantity:		1MRK 509 072-UEN
Installation and commissioning manual	Quantity:		1MRK 509 073-UEN