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1 Introduction

The protection and control terminals employ a multiprocessor design to ensure the best possible operational security and dependability. The included main protection and control functions are to a great extent independent of one another and each terminal can be ordered with individual options to satisfy the user's needs in different applications in the best possible way. To achieve this, different binary inputs of a terminal can be configured to different functions. Various functional output signals are programmable to one or several binary outputs, as well as to the different inputs of other protection and control functions.

Each terminal has a few main functions as standard. These functions determine the basic application for a terminal, for example the distance protection function or the phase segregated line differential protection function. Additional functions, such as directional or non-directional earth-fault overcurrent protection, auto-reclosing function etc. are available as options.

The possible functional structure of each type of terminal within the REx 5xx family is described in the Buyer's Guides and also presented for each delivered unit separately in the corresponding documentation.

Each of the terminal related functions is described in detail in the documentation for the actual unit. The description of each function follows the same structure (where applicable):

- The application part states the most important reasons for the implementation of a particular protection function.
- The measuring principle gives a brief presentation of the measuring algorithm used for a particular function.
- The design part presents the general concept of a function, together with a list of the setting parameters and different signals.
- The setting instructions refer mostly to different application areas and give directions for setting of the particular parameters.
- The testing instructions describes primarily the necessary testing procedures and the requirements for the testing equipment. The expected results of some functions are also presented.

2 Design

The description of the design is chiefly based on simplified logic diagrams, which use IEC symbols, for the presentation of different functions, conditions etc. The functions are presented as a closed block with the most important internal logic circuits and configurable functional inputs and outputs.

Completely configurable binary inputs/outputs and functional inputs/outputs enable the user to prepare the REx 5xx with his own configuration of different functions, according to application needs and standard practice.

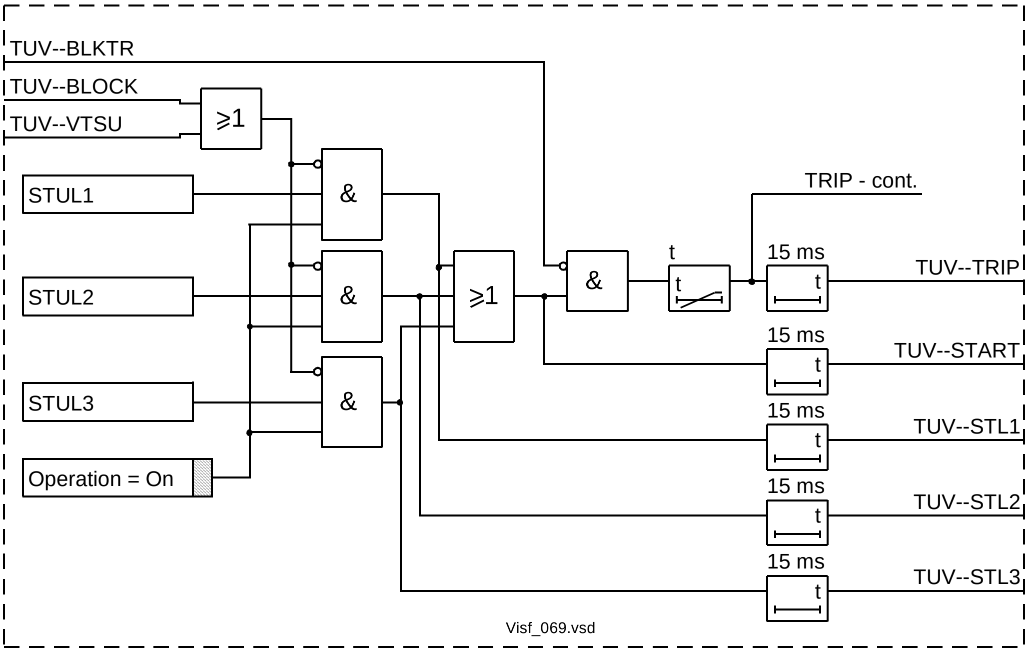


Figure 1: Example of a simplified logic diagram for a function block.

The names of the configurable logic signals consist of two parts divided by dashes. The first part consists of up to four letters and presents the abbreviated name for the corresponding function. The second part presents the functionality of the particular signal. According to this explanation, the meaning of the signal TUV--BLKTR in Figure 1: is as follows:

- The first part of the signal, TUV- represents the adherence to the **T**ime delayed **U**nder-**V**oltage function.
- The second part of the signal name, BLKTR informs the user that the signal will **BL**oc**K** the **TR**ip from the under-voltage function, when its value is a logical one (1).

Different binary signals have special symbols with the following significance:

- Signals drawn to the box frame to the left present functional input signals. It is possible to configure them to functional output signals of other functions as well as to binary input terminals of the REx 5xx terminal. Examples in Figure 1: are TUV--BLKTR, TUV--BLOCK and TUV--VTSU.

- Signals in frames with a shaded area on their right side present the logical setting signals. Their values are high (1) only when the corresponding setting parameter is set to the symbolic value specified within the frame. Example in Figure 1: is the signal Operation = On. These signals are not configurable. Their logical values correspond automatically to the selected setting value.
- The internal signals are usually dedicated to a certain function. They are normally not available for configuration purposes. Examples in Figure 1: are signals STUL1, STUL2 and STUL3.
- The functional output signals, drawn to the box frame to the right, present the logical outputs of functions and are available for configuration purposes. The user can configure them to binary outputs from the terminal or to inputs of different functions. Typical examples in Figure 1: are signals TUV--TRIP, TUV--START etc.
- Other internal signals configurated to other function blocks are written on a line with an identity and a cont. reference. An example is the signal TRIP - cont. The signal can be found in the corresponding function with the same identity.

1 Application

Circuit breaker pole position discordance can occour at the operation of a breaker with independent operating gears for the three poles. The reason may be an interruption in the trip coil circuits, or a mechanical failure resulting in a stuck breaker pole. A disagreement caused by one ore two poles failing to close or to open can be tolerated for just a limited time, for instance where the circuit breaker is driven by the single phase auto-reclosing.

The pole discordance function (PD) detects a breaker pole position discrepancy not generated by a single pole reclosing and generates a three phase command trip to the circuit breaker itself.

2 Theory of operation

The operation of the pole discordance function is based on checking the position of the circuit breaker through six of its auxiliary contacts: three parallel connected normally open contacts are connected in series with three parallel connected normally closed contacts. This hard-wired logic is very often integrated in the circuit breaker control cabinets and gives a closed signal in case of pole discordance in the circuit breaker. This signal is connected to the PD---POLDISC input of the pole discordance function. If the function is enabled, after a short delay, the activation of this input causes a trip command (PD---TRIP).

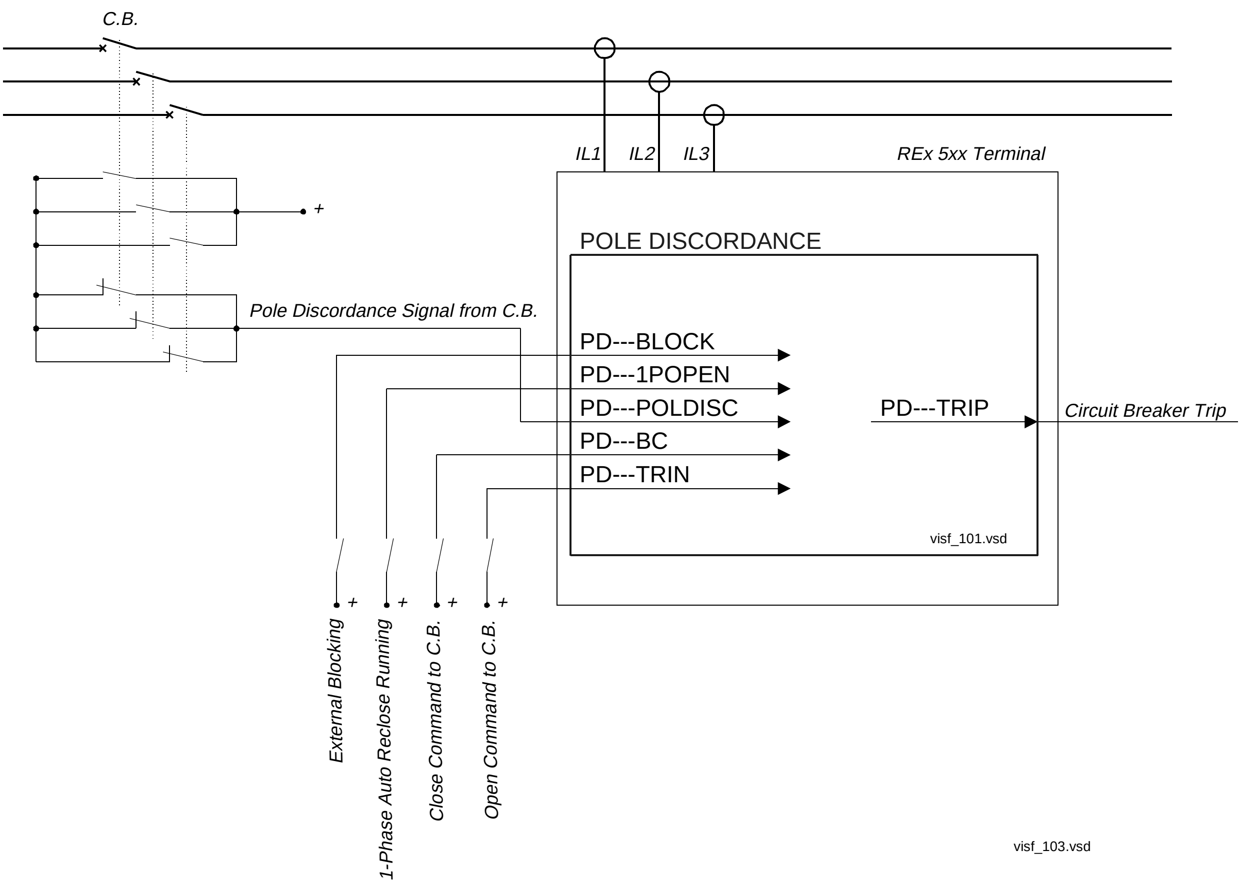


Figure 1: Typical connection diagram for pole discordance function

In addition the PD function performs a parallel detection of pole discordance based on current comparison in the breaker poles. This current based detection is enabled only for a few time after the breaker has received a closing or opening command in order to avoid unwanted operation in case of unsymmetrical load in service. If the circuit breaker has received a command (open or close), the PD function is enabled, and the current conditions are fulfilled, then a trip command is generated from the pole discordance function (PD---TRIP) after a short delay.

Figure 1 shows the typical application connection for the pole discordance function.

3 Design

The simplified block diagram of the pole discordance function is shown in figure 2.

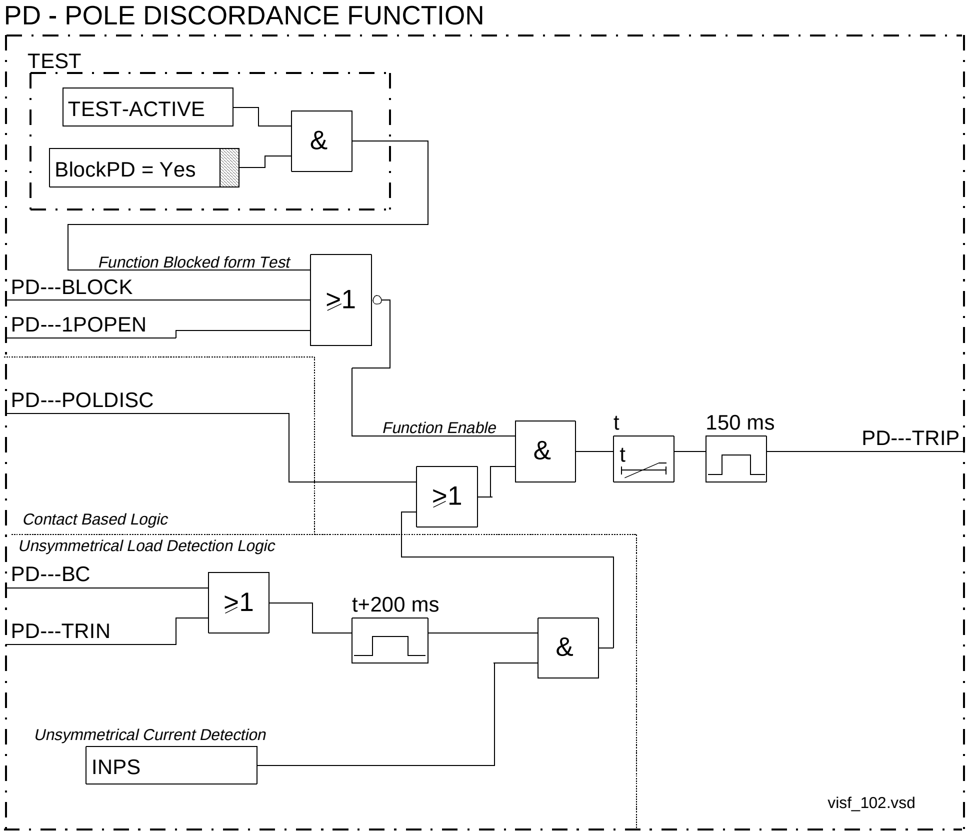


Figure 2: Simplified block diagram of pole discordance function

The pole discordance function is disabled if:

- The terminal is in TEST status (TEST-ACTIVE is high) and the function has been blocked from the HMI (BlockPD=Yes)
- The input signal PD---BLOCK is high
- The input signal PD---1POPEN is high

The PD---BLOCK signal is a general purpose blocking signal of the pole discordance function. It can be connected to a binary input of the terminal in order to receive a block command from external devices or can be software connected to other internal functions of the terminal itself in order to receive a block command from internal functions. Through OR gate it can be connected to both binary inputs and internal function outputs.

The PD---1POPEN signal blocks the pole discordance operation when a single phase auto-reclosing cycle is in progress. It can be connected to the output signal AR01-1PT1 if the autoreclosing function is integrated in the terminal; if the auto-reclosing function is an external device, then PD---1POPEN has to be connected to a binary input of the terminal and this binary input is connected to a signallisation “1phase auto-reclosing in progress” from the external auto-reclosing device.

If the pole discordance function is enabled, than two different criteria will generate a trip signal (PD---TRIP):

- Pole discordance signalling from the circuit breaker.
- Unsymmetrical load detection.

3.1 Pole discordance signalling from circuit breaker

If one or two poles of the circuit breaker have failed to open or to close (pole discordance status), then the function input PD---POLDISC is activated from the pole discordance signal derived from the circuit breaker auxiliary contacts (one NO contact for each phase connected in parallel, and in series with one NC contact for each phase connected in parallel) and, after a settable time interval t (0-60 s), a 150 ms trip pulse command (PD---TRIP) is generated by the pole discordance function.

3.2 Unsymmetrical load detection

The unsymmetrical load detection is based on the checking that:

- any phase current is lower than 80% of the highest current in the remaining two phases
- the highest phase current is grater than 10% of the rated current

If these conditions are both true, than an unsymmetrical condition is detected and the internal signal INPS is turned high. This detection is enabled to generate a trip after a set time delay t (0-60 s) if the detection occours in the next 200 ms after the circuit breaker has received a command to operate and if the unbalance lasts for the whole time t. This permits to avoid unwanted operation at unsymmetrical load in service.

The pole discordance function is informed that a trip or close command has been given to the circuit breaker through the inputs PD---BC (for closing command information) and PD---TRIN (for opening command information). These inputs can be connected to terminal binary inputs if the information are generated from the field (i.e. from auxiliary contacts of the close and open push buttons) or may be software connected to the outputs of other integrated functions (i.e. close command from a control function or a general trip from integrated protections).

OR gates will allow to connect the input signals PD---BC and PD---TRIN to both terminal internal and external signals.

4 Setting

The setting parameters are accessible through the HMI. The parameters for the pole discordance function are found in the HMI-tree under:

Settings
  Functions
    Group 1,2,3 and 4
      PoleDiscord

The parameters and their setting ranges are shown in the appendix.

Comments regarding settings:

Operation: Pole discordance protection On/Off. Activation or disactivation of the function.

Time delay , t: Delay timer. The time delay is not critical because the pole discordance function operates mainly with load conditions. If only the contact based function is used, the time delay should be chosen between 0.5 and 1 s.If also the current detection function is used, it is recommended to set the time delay at 3-4 s, depending on the application, in order for the unbalance to stabilize. The setting range of the time delay is 0 - 60 s.

5 Testing

5.1 General

The pole discordance function can be disabled during the test mode during these conditions:

- If the function should be blocked under the testing conditions, select the PD function under the menu:

  Test
    TestMode
      BlockFunctions

- The terminal is set to test mode by setting the Operation=On, which occurs under the menu:

  Test
    TestMode
      Operation

The terminal is automatically set to test mode by applying a logical 1 to the TEST-INPUT functional input.

Note: the function is blocked if the corresponding setting under the BlockFunctions menu remains on and the TEST-INPUT signal remains active.

The pole discordance function must not be blocked in order to be tested.

ABB Network Partner recommends, although it is not an absolute requirement, the use of testing equipment of type RTS 21 (FREJA) for secondary injection tests.

The used test equipment should be capable of providing an independent three-phase supply of currents to the tested terminal. Furthermore it must be possible to change the values of currents and phase angles between the measuring quantities, independent of each other, for each phase separately. The test currents should have a common source, with a very small content of higher harmonics.

5.2 Testing method

The settings shown in the following tests can be used as a reference during testing. After the tests the equipment should be restored to the normal or desiderd settings.

The following steps are necessary for testing the pole discordance protection function:

1.1 Check if the input and output logical signals of the function are configured to the corresponding binary inputs and outputs of the tested terminal. If not, configure them for testing purposes. .

1.2 Set the operation of the PD protection to On mode from the HMI according to below:

PoleDiscordance Operation=On
t = 1.0 s

1.3 This test checks the non operation for unsymmetrical load not related to a command to the circuit breaker.

Apply a symmetrical three phase current of 200 mA to the current inputs of the terminal. Turn off the current injection in phase L1 (IL1=0, IL2=200mA, IL3=200 mA). Wait for a few seconds and verify that the trip signal PD---TRIP does not appear on the corresponding binary output or on the local HMI unit.

Repeat the same procedure for phases L2 and L3.

1.4 This test checks the trip for unsymmetrical load related to an open or close command to the circuit breaker.

Apply a symmetrical three phase current of 200 mA to the current inputs of the terminal. Turn off the current injection in phase L1 (IL1=0, IL2=200mA, IL3=200 mA).

Activate the binary input PD---BC (or the binary input PD---TRIN) and verify that after 1s the trip signal PD---TRIP appears on the corresponding binary output or on the local HMI unit.

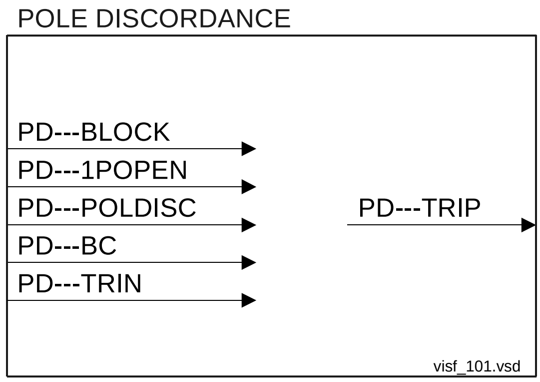
Repeat the same procedure for phases L2 and L3.

1.5 This test checks the trip by activation of the pole discordance signalling from the circuit breaker auxiliary contacts.

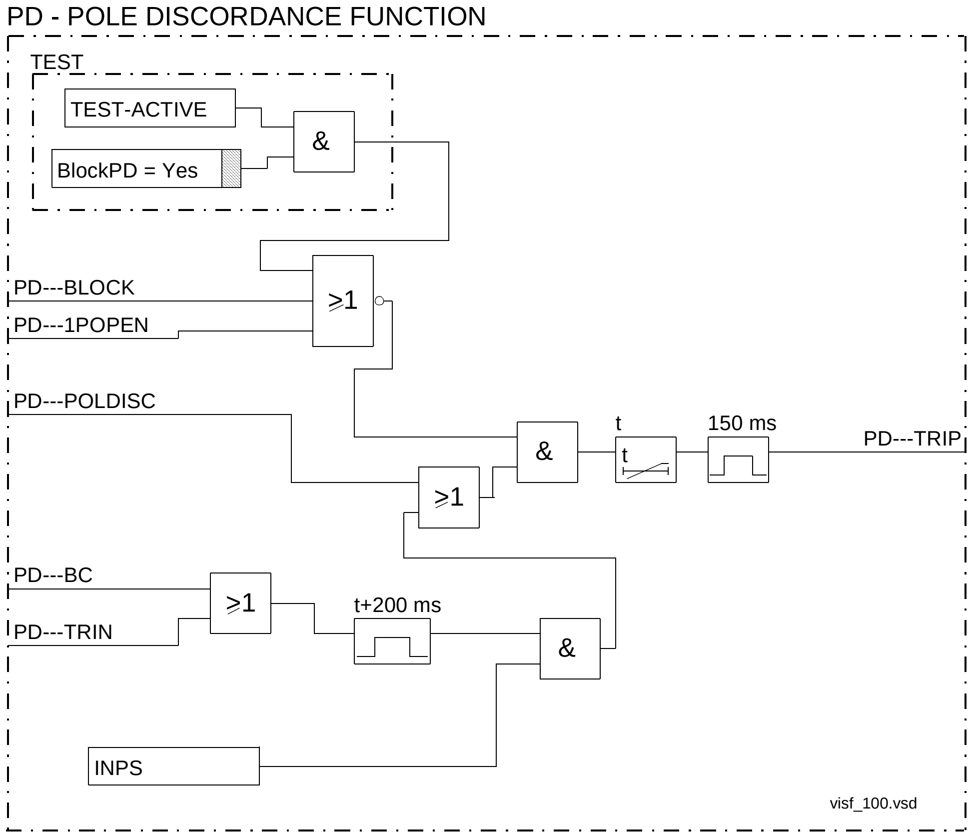
Do not apply any current to the terminal current inputs.Activate the binary input PD---POLDISC and verify that after 1s the trip signal PD---TRIP appears on the corresponding binary output or on the local HMI unit.

6 Appendix

6.1 Function block



6.2 Function block diagram



6.3 Signal list

Block	Signal	Type	Description
PD---	BLOCK	IN	Block of pole discordance function
PD---	1POPEN	IN	One phase open
PD---	POLDISC	IN	Pole discordance
PD---	BC	IN	Breaker closing
PD---	TRIN	IN	Activate from external trip
PD---	TRIP	OUT	Trip by pole discordance function

6.4 Setting table

Parameter	Range	Unit	Default	Parameter description
Operation	Off, On		Off	Pole discordance protection On/Off
t	0.000-60.000	s	0.500	Delay timer

1 Application

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

The breaker-failure function is started by a protection trip command, from the line and busbar protection through the breaker-related trip relays. The start can be single-phase or three-phase. Correct fault current clearing or failure is detected by a current check in each phase. The current level can be set at 0,05 to 2 times the rated current.

Retrip of the faulty CB can be done with or without current check. A delay, 0-60 s, can be set for the retrip.

The use of retrip, limits the impact on the power system if the breaker-failure protection function (BFP) is started by mistake during testing or other maintenance work.

A second time step is used for the back-up trip command. It should be connected to trip the adjacent breakers, to clear the busbar section and intertrip the remote end, if so required. The time setting range is 0-60 s.

By using separate timers for each phase, correct operation at evolving faults is ensured.

The timer setting should be selected with a certain margin to allow variation in the normal fault clearing time. The properties of the BFP function allow the use of a small margin.

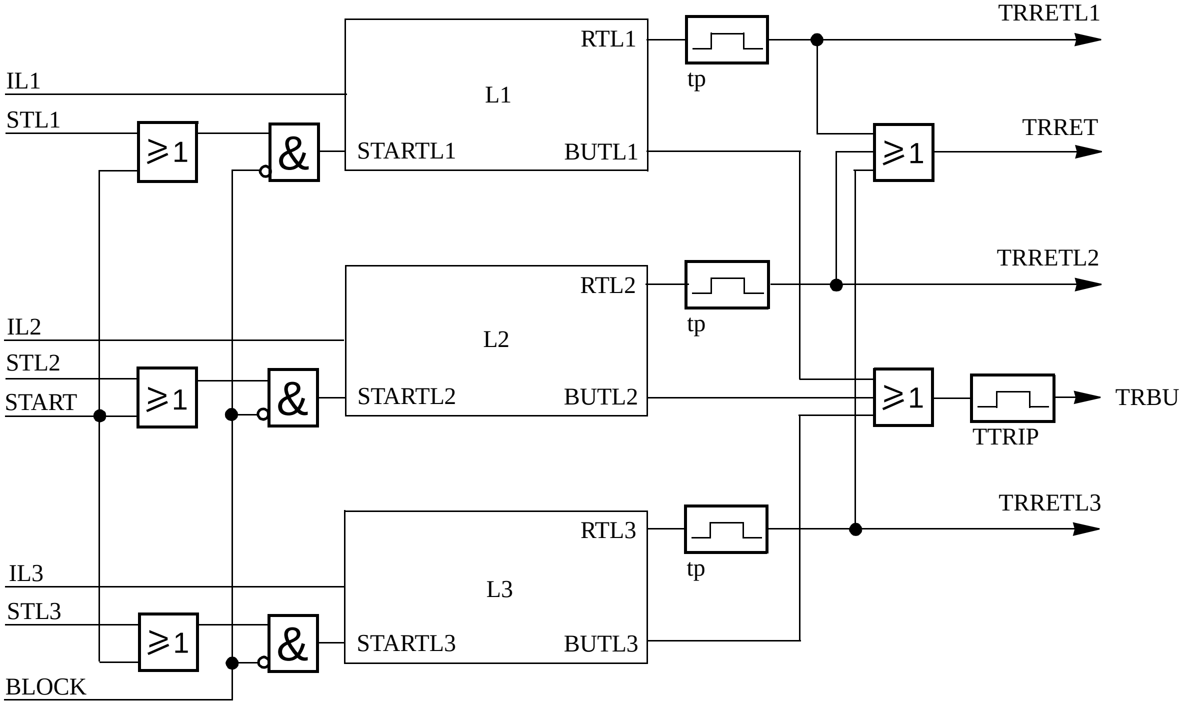


Figure 1: Start and trip functions

The application functions of the protection are:

- Individual phase-current detection
- Two time steps, one for retrip of the related circuit breaker and one for the back-up trip of the adjacent circuit breakers
- Selection of current controlled or unconditional retrip
- Phase separated timers gives correct operation at an evolving fault
- Accurate timers and current elements reset in 10 ms, allowing the use of short back-up trip time

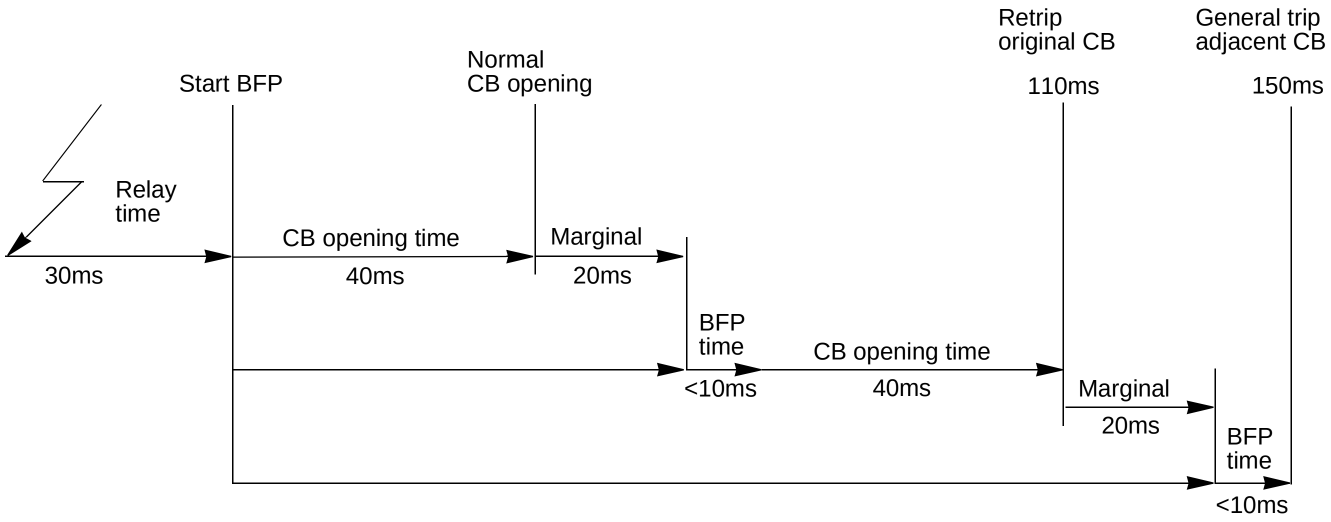


Figure 2: Time sequence

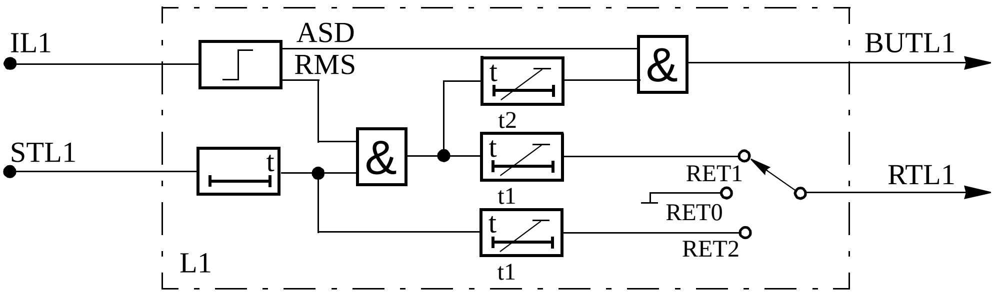
2 Theory of operation

The breaker-failure protection starts on a single-phase or three-phase condition, either from an external protection, or internally from a protection trip signal in the terminal.

The breaker receiving the original protection trip command can be retripped from the BFP. The retrip can be controlled by a current check, or carried out as a direct retrip without any current check. The direct retrip can be used, because the breaker-to-trip has already received a tripping command, and the direct retrip does not cause any unselective tripping

The use of retrip, limits the extent of unwanted power disconnection in case of an accidental start of the BFP at work in the initiating circuits, with the primary circuit in service and the load above the set current level.

The back-up trip is sent to the adjacent circuit breakers in order to clear the fault and disconnect the failing circuit breaker.



RET0: No retrip
RET1: Retrip with current check
RET2: Unconditional retrip

Figure 3: Logic diagram of breaker-failure protection, phase L1

2.1 Input and output signals

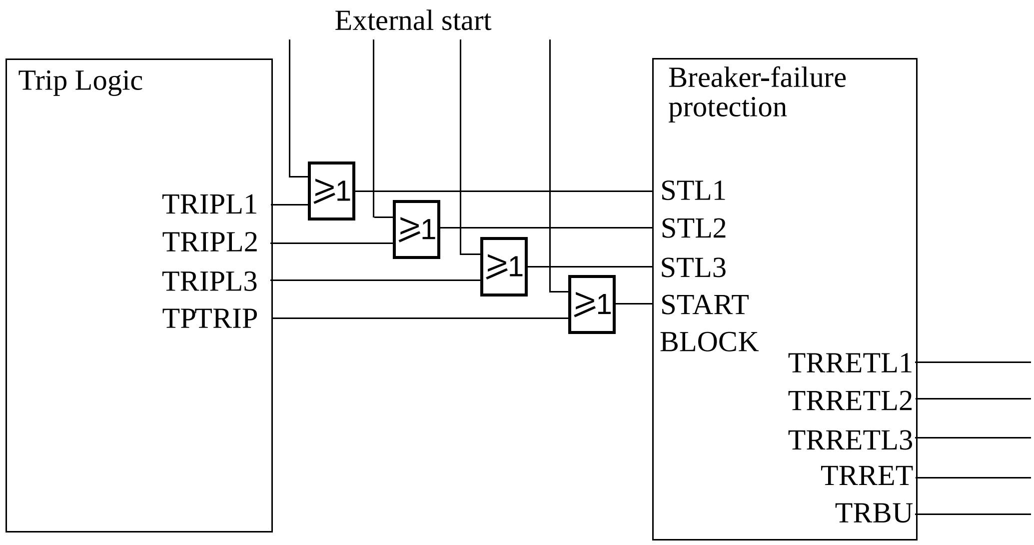


Figure 4: Input and output signals

The *connectable* inputs are connectable by configuration to the binary inputs of the terminal or to other internal functions' outputs. The outputs are connectable by configuration to the binary output relays. "Connectables" and "outputs" can be connected to the free-logic functions of the unit, OR gates, and in that way add connection links

Table 1:

Input signals:	**Start of breaker-failure protection:**
BFP--STL1	Phase L1
BFP--STL2	Phase L2
BFP--STL3	Phase L3
BFP--START	Three-phase start
BFP--BLOCK	Block of BFP
Output signals:	**Trip:**
BFP--TRBU	Back-up trip
BFP--TRRETL1	Trip breaker-failure phase L1
BFP--TRRETL2	Trip breaker-failure phase L2
BFP--TRRETL3	Trip breaker-failure phase L3
BFP--TRRET	Three-phase trip

2.2 Start functions

The breaker-failure protection can be started either internally or externally. The start pulse is sealed-in as long as the current exceeds the preset current level, to prevent a restart of the BFP timers in case of a chattering starting contact. The preset current level may be set to (0,05 - 2,0) · Ir where Ir is 1 or 5 A.

2.3 Measuring principles

The current is filtered through a specially designed high-pass filter to obtain the required suppression of the dc components.

High-pass filtering is performed basically for two reasons i.e to remove the:

- dc component caused by saturated current transformers with a decaying current due to de-energizing of the secondary circuit. This is done to achieve a more correct representation of the real current in the line.
- dc component that is a part of the fault current. This is done to achieve a correct base for both ASD and RMS calculations.

The frequency limit of the filter is very close to the service frequency, to obtain a maximum suppression of the above dc components.

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 preset values. This is obtained by creating a new stabilizing signal to compare the current with.

The ASD works continuously, regardless of if the BFP was started. Its result is however considered only when the BFP has started and the preset time has elapsed.

As the current exceeds the previously stabilized sample, it adapts the value of the current and when it does not, it decays. This adaptive behaviour makes it possible to rapidly and securely detect a breaker failure situation after the pre-set time has elapsed.

Continuously and in parallel, the RMS value of the post-filtered signal is calculated and compared with a preset current level. As the RMS value decreases below the preset current level, the breaker-failure function is momentarily reset.

At normal operation of the circuit breaker, the stabilizing signal exceeds the post-filtered signal for a consecutive period of maximum 10 ms before it is reset. Resetting occurs before the back-up trip timer t2 has timed out.

At a breaker failure situation, the post-filtered current exceeds the stabilizing signal, resulting in a trip of the breaker-failure function within 10 ms after the trip timer t2 has elapsed.

The breaker-failure protection works with all three phases totally separated. But a possibility exists to start all three phases simultaneously.
The back-up trip is always three-phase

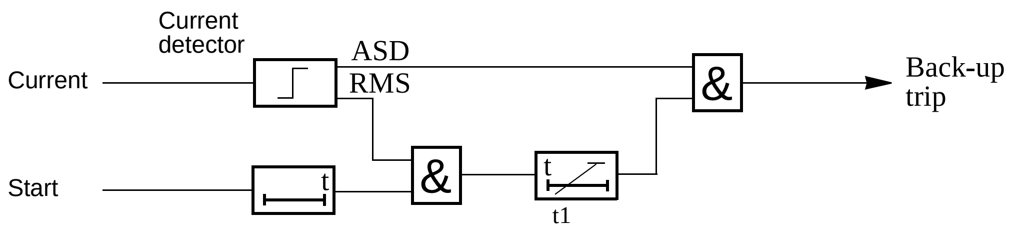


Figure 5: Breaker-failure protection

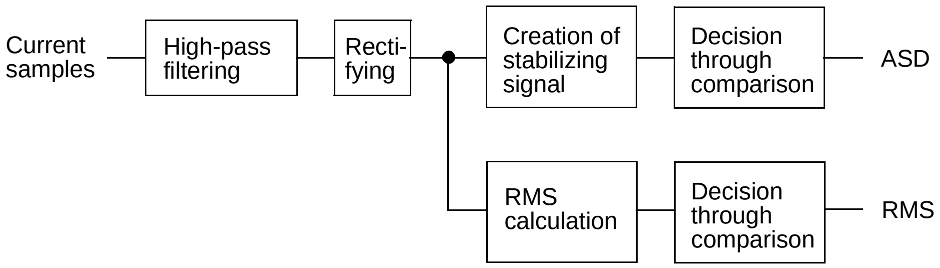


Figure 6: Current detector, ASD and RMS measurement

2.4 Retrip functions

The retrip function of the original circuit breaker is set at one of three options:

Setting:	**The retrip...**
Off	function is not executed.
I> check	occurs with a current check.
No I> check	occurs without a current check.

The retrip timer t1 can be set from 0 to 60 s.

A trip pulse, tp, is generated with a length of 150 ms.

2.5 Back-up trip

The back-up trip delay timer t2 can be set between 0 and 60 s.

A trip pulse, tp, is generated with a length of 150 ms.

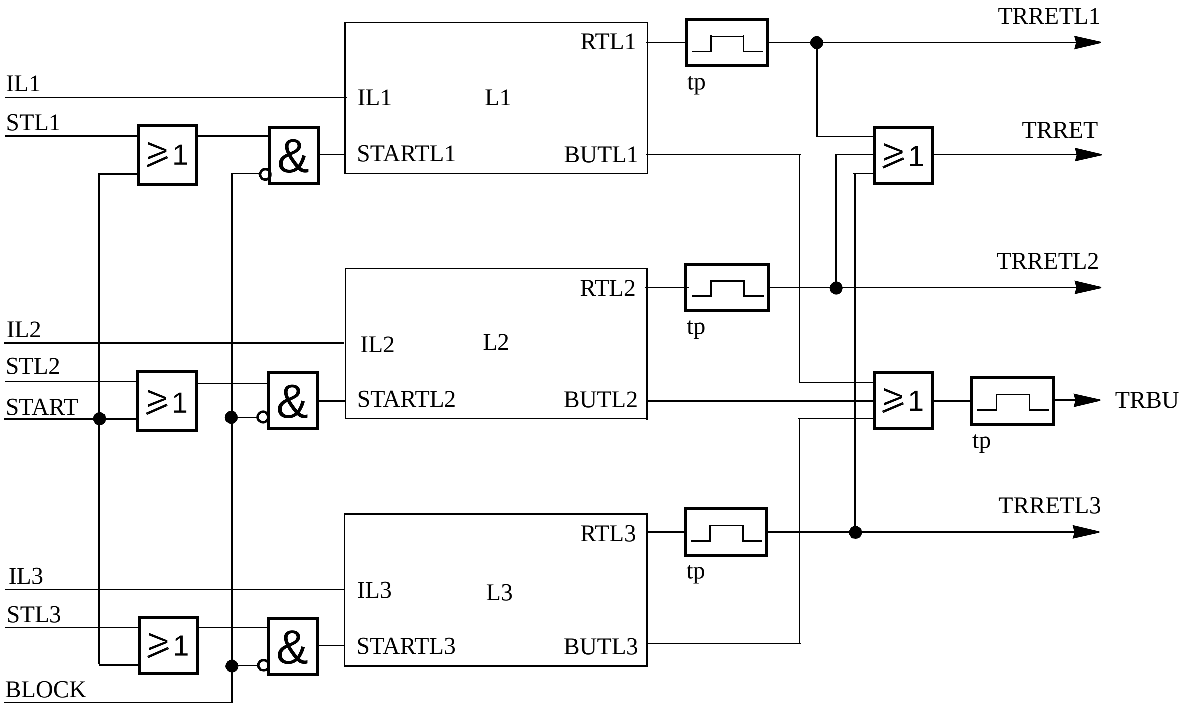


Figure 7: Breaker-failure protection

3 Setting

3.1 Human-machine interface (HMI)

The configuration of alternatives or settings to the functions is made on the built-in HMI:

Settings
- **Functions**
  - **Group n**
    - **Breaker Failure**

The breaker-failure protection can be controlled from the human-machine interface (HMI) by an “Operation” parameter, to be set between alternatives Off/On.

When “Operation” is set to Off, the function becomes inoperative.

The configuration of input and output signals to the function is made on the built-in HMI:

Configuration
- **Function Inputs**
  - **Breaker Failure**

The inputs and the outputs to and from the breaker-failure protection are presented in the signal list.

Fixed values

Trip pulse, tp	150 ms, fixed

4 Testing

The function can be disabled during the testing mode under these conditions:

- When the function is selected to be blocked under the testing conditions, select the functions, which should be blocked under the submenu:

  Test
  TestMode
  BlockFunctions

- Set the Operation parameter to On (Operation = On) to set the terminal in to testing mode. Select the operating mode under this submenu:

  Test
  TestMode
  Operation

- The terminal is switched to testing mode when the logical 1 is specified for the TEST-INPUT functional input.

Note: The function is blocked if the corresponding setting under the **BlockFunctions** submenu remains On and the TEST-INPUT signal remains active.

5 Test of the breaker-failure protection

The breaker-failure protection can be tested, for example at commissioning or after a changed configuration, in co-operation with some other functions, and in particular with the protection and trip functions.

The trip circuits to the breakers are opened at a test switch or at connection terminals with links. A secondary injection relay test is used to operate the protection function.

Suggested testing procedure:

5.1 Preparations

1.1 Check the settings and the alternatives of the breaker-failure protection (BFP).

The operation can be set to Stand-by (Off)

HMI submenu:

Settings
Functions
Group n
Breaker Failure

If the settings are changed to speed up times during the tests, they must later be reset and verified.

5.2 Check that the protection does not trip when set passive

2.1 Set operation = Off.
2.2 Apply a stationary current over the set value.
2.3 Apply a start pulse to BFP--STL1.
2.4 Verify that neither retrip nor back-up trip is achieved.

5.3 Check that the protection can be started from all start inputs

3.1 Set RetripType = No I>check, I> = 100% I_r and t1 = 50 ms.
3.2 Apply a stationary three-phase current over the set value.
3.3 Apply a start pulse to BFP--STL1.
3.4 Verify that retrip in phase L1 is achieved.
3.5 Apply a stationary current over the set value.
3.6 Apply a start pulse to BFP--START
3.7 Verify that all three retrips are achieved.

5.4 Check that the retrip function works

4.1 No retrip function

4.1.1 Set RetripType = Retrip Off and I> = 100% I_r.
4.1.2 Apply a stationary three-phase current over the set value.
4.1.3 Apply a start pulse to BFP--STL1.
4.1.4 Verify that retrip in phase L1 is not achieved.

4.2 Retrip function with current check

4.2.1 Set RetripType = I> check, t1 = 100 ms and I> = 100% I_r.
4.2.2 Apply a stationary three-phase current over the set value.
4.2.3 Apply a start pulse to BFP--STL1.
4.2.4 Verify that retrip is achieved.

4.3 Retrip function without current check

4.3.1 Set RetripType = No I> check, t1 = 100 ms and I> = 100% I_r.
4.3.2 Apply a stationary three-phase current over the set value.
4.3.3 Apply a start pulse to BFP--STL1.
4.3.4 Verify that retrip is achieved.

5.5 Check that the back-up trip function works

5.1 Set RetripType = Retrip Off, t2 = 200 ms and I> = 100% I_r.

5.2 Apply a stationary three-phase current over the set value.

5.3 Apply a start pulse to BFP--STL1.

5.4 Verify that back-up trip is achieved.

5.6 Terminate the test and restore the equipment to normal state

After the tests, restore the equipment to the normal or desired alternatives and settings!

Check especially that the:

- Setting parameters reset as required and that a verification test is made.
- Test switches or disconnected links of the connection terminals.
- Normal indications. (If preferred, the disturbance report can be cleared.)

6 Appendix

6.1 Function block

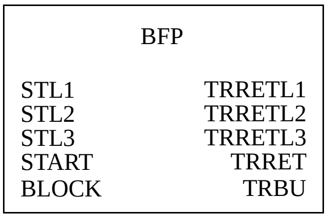


Figure 8: Simplified terminal diagram of the function

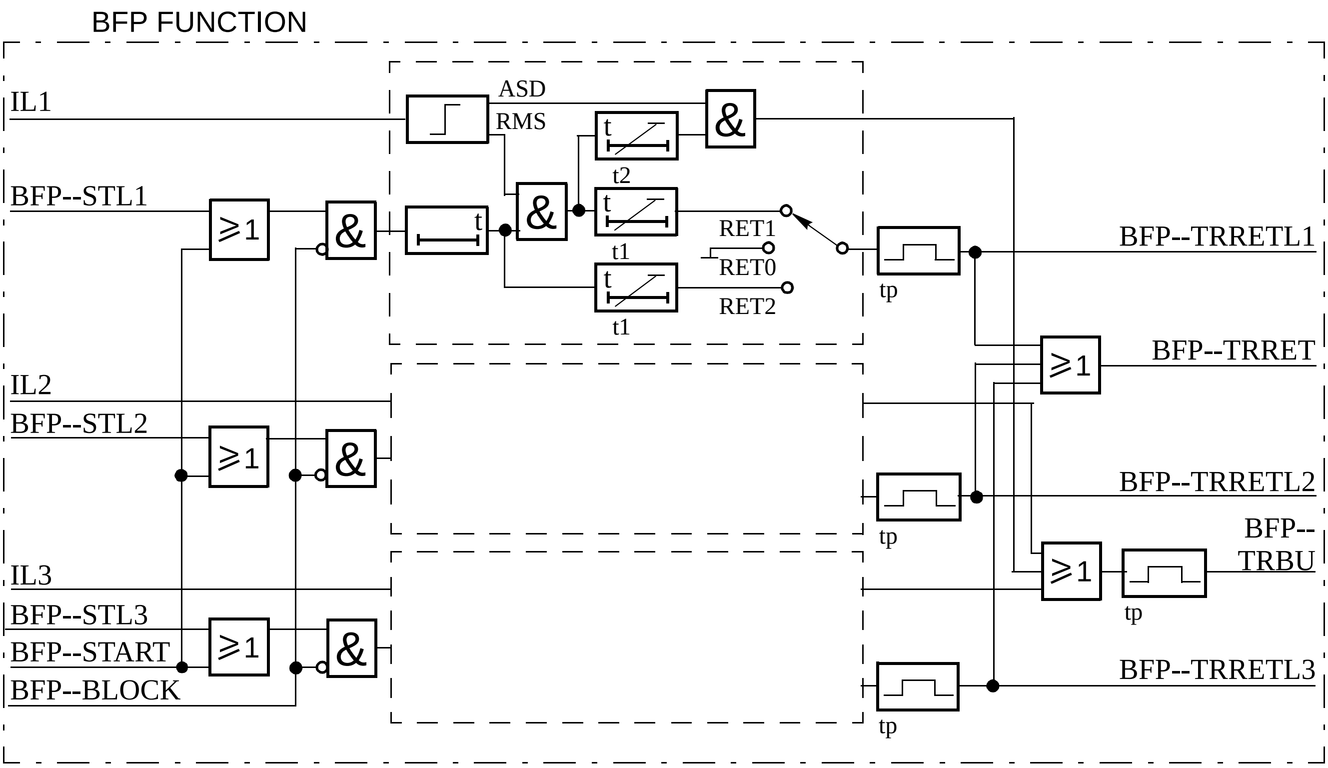


Figure 9: Terminal diagrams for the function

6.2 Signal list

Block	Signal	Type	Description
BFP--	BLOCK	IN	Block of breaker-failure function
BFP--	START	IN	Start of breaker-failure function
BFP--	STL1	IN	Start of breaker-failure function phase L1
BFP--	STL2	IN	Start of breaker-failure function phase L2
BFP--	STL3	IN	Start of breaker-failure function phase L3
BFP--	TRBU	OUT	Backup trip by breaker-failure function
BFP--	TRRET	OUT	Retrip by breaker-failure function
BFP--	TRRETL1	OUT	Retrip by breaker-failure function phase L1
BFP--	TRRETL2	OUT	Retrip by breaker-failure function phase L2
BFP--	TRRETL3	OUT	Retrip by breaker-failure function phase L3

6.3 Setting table

Parameter	Range	Unit	Default	Parameter description
Operation	Off, On		Off	Breaker failure function On/Off
IPgr	5-200	%	100	Operating phase current, as a percentage of I1b
t2	0.000-60.000	s	0.200	Delay timer for backup trip
RetripType	Retrip Off, I> Check, No I> Check		Retrip Off	Select type of retrip logic
t1	0.000-60.000	s	0.050	Delay timer for retrip

1 Application

The trip of the circuit breaker at a prolonged loss of voltage at all the three phases is normally used in automatic restoration systems to facilitate the system restoration after a major blackout. The loss of voltage check function gives a trip signal only if the voltage in all the three phases is low for more then 7 seconds. If the trip to the circuit breaker is not required, than the function can be used for signallization through an output contact or through the event recording function.

2 Theory of operation

The voltage-measuring elements continuously measure the three-phase-to-phase voltages and three-phase-to-earth voltages, and compare them with the set values. Fourier’s recursive filter filters the voltage signals, and a separate trip counter prevents overreaching of the measuring elements.

The logical values of the following signals become equal to 1, if the related phase measured voltage decrease under the pre-set value:

- STUL1N for U_{L1N} voltage
- STUL2N for U_{L2N} voltage
- STUL3N for U_{L3N} voltage

The 150 ms output trip pulse is emitted if all the three phase voltages are below the setting value for more than 7 s. The function can be blocked from the fuse failure supervision function intervention and when the main circuit breaker is opened.

3 Design

The simplified logic diagram of the stub protection function is shown in figure 1.

The function is disabled (blocked) if:

- The terminal is in TEST status (TEST-ACTIVE is high) and the function has been blocked from the HMI (BlockLOV=Yes)
- The input signal LOV--BLOCK is high

The LOV--BLOCK signal is a general purpose blocking signal of the loss of voltage check function. It can be connected to a binary input of the terminal in order to receive a block command from external devices or can be software connected to other internal functions of the terminal itself in order to receive a block command from internal functions. Through OR gate it can be connected to both binary inputs and internal function outputs.

The function has a particular internal latched enable logic that:

- enables the function (signal latched enable in figure 1 is set to 1) when the line is restored; i.e. at least one of the three voltages is high for more then 3 seconds (signal set enable in figure 1).

- disables the function (signal latched enable in figure 1 is set to 0) if the signal reset enable in figure 1 is set to 1 (reset of latced enable signal).

The latched enable signal is reset (i.e. the function is blocked) if:

- the main circuit breaker is opened. This is achieved by connecting a N.C. contact of the main circuit breaker to a terminal binary input connected to the function input LOV--BC
- the fuse failure supervision function has tripped. This is achieved by connecting the output signal of the fuse failure supervision, FUSE-VTSU, to the function input LOV--VTSU
- not all the three phase voltages are low for more then 10 s (only one or two phase voltages are low).

The output trip signal of the voltage check function is LOV--TRIP.

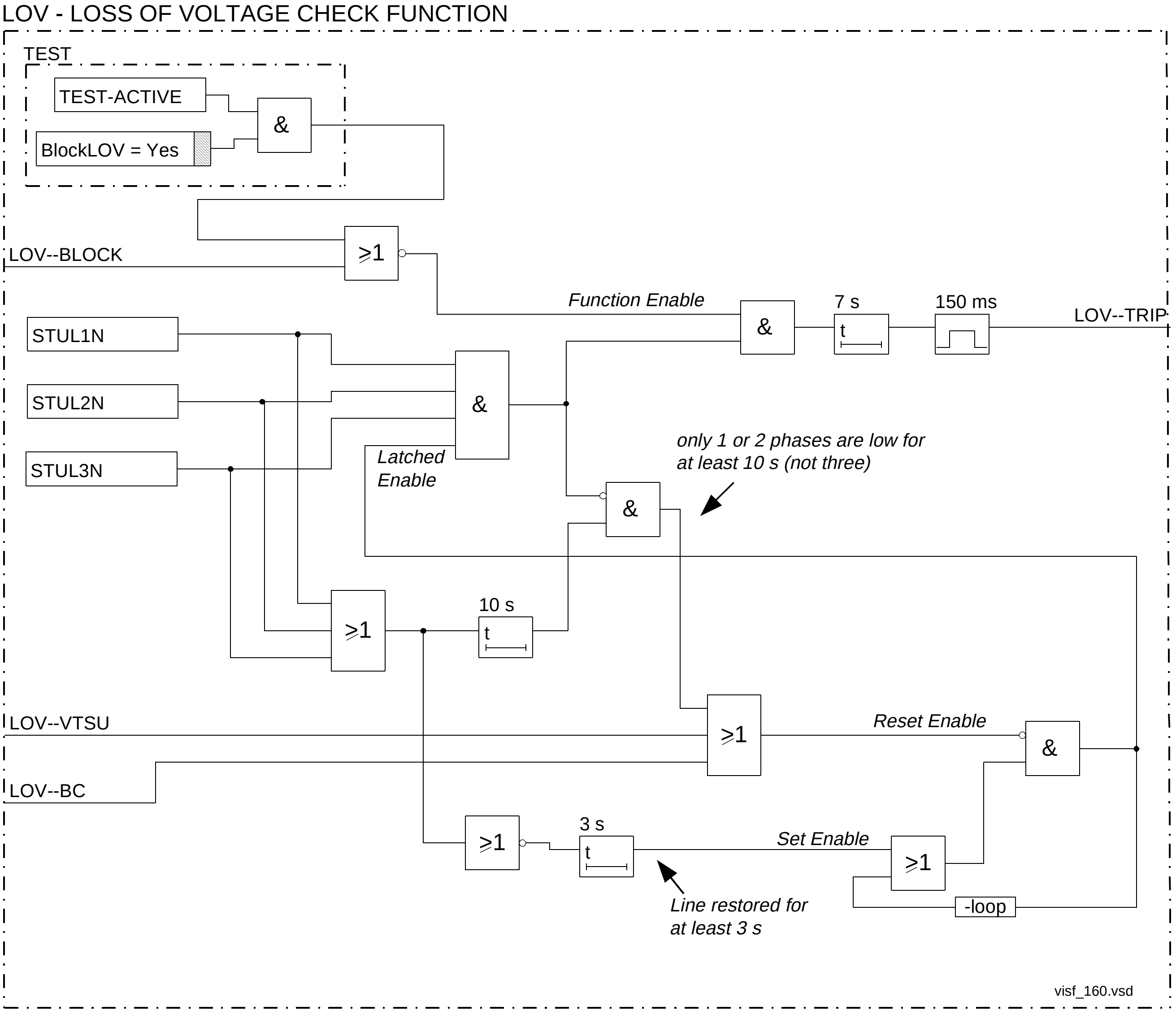


Figure 1: Simplified logic diagram of loss of voltage check protection function

4 Setting instructions

The setting parameters are accessible through the HMI. The parameters for the loss of voltage function are found in the HMI-tree under:

Settings
Functions
Group 1,2,3 and 4
LossOfVoltage

The parameter list and their setting ranges are shown in the appendix.

The low voltage primary setting should be lower than the minimum system operating voltage, U_{min}. Consider an additional 10% for safety margin.

The primary set value Us_{PRIM} will be:

$$Us_{PRIM} = 0.9 \cdot U_{min} \qquad \text{(Equation 1)}$$

The secondary setting value Us_{SEC} is:

$$Us_{SEC} = \frac{U_{SEC}}{U_{PRIM}} \cdot Us_{PRIM} \qquad \text{(Equation 2)}$$

where U_{SEC} is the secondary rated voltage of the main VT and U_{PRIM} is the primary rated voltage of the main VT.

The relay setting value UPE< is given in percentage of the secondary base voltage value, U_{1b}, associated to the voltage transformer input U1. The value for UPE< is given from this formula:

$$UPE< = \frac{Us_{SEC}}{U_{1b}} \cdot 100 \qquad \text{(Equation 3)}$$

and this is the value that has to be set in the relay.

5 Testing

The function can be disabled during the test mode during these conditions:

- When the function should be blocked under the testing conditions, select the functions that should be blocked under the menu:

  Test
  TestMode
  BlockFunctions

- The terminal is set to test mode by setting the Operation=On, which occurs under the menu:

  Test
  TestMode
  Operation

- The terminal is automatically set to test mode by applying the logical

1 to the TEST-INPUT functional input.

Important note: The function is blocked if the corresponding setting under the BlockFunctions menu remains on and the TEST-INPUT signal remains active.

The loss of voltage check protection function must not be blocked in order to be tested.

Check the operating values of the voltage measuring elements and corresponding functions during the commissioning and during regular maintenance tests. ABB Network Partner recommends, although it is not an absolute requirement, the use of the RTS 21 (FREJA) testing equipment for secondary injection-testing purposes.

Before testing, connect the testing equipment according to the valid terminal diagram of the specific REx 5xx terminal. Pay special attention to the correct connection of the input and output voltage terminals.

Follow these steps:

1.1 Check if the input and output logical signals in figure 1 are configured to the corresponding binary inputs and outputs of the tested terminal. If not, configure them for testing purposes. Set the operation of the LOV protection to On mode.

1.2 Set the input logical signals LOV--BLOCK, LOV--BC, LOV--VTSU to the logical zero. Supply a three phase rated voltage in all three phases and note on the local HMI that the LOV--TRIP logical signal is equal to the logical 0. Values of the logical signals belonging to the loss of voltage protection are available under menu tree:

Service Report
Functions
LossOfVoltage
FuncOutputs

1.3 Suddenly disconnect the voltage in all three phases and observe the LOV--TRIP pulse signal: after 7 seconds it should appear to the HMI. Its duration should be about 150 ms.

1.4 Increase the measured voltages to their rated values and decrease them again to zero within an interval shorter than 3 seconds. No LOV--TRIP signal should appear.

1.5 Increase the measured voltages to their rated values for at least 10 seconds. Instantaneously disconnect one phase and after an interval longer than 10 seconds, also disconnect the remaining two phases. No LOV--TRIP signal should appear.

1.6 Increase the measured voltages to their rated values for at least ten seconds. Apply the rated dc voltage to the binary input connected to the function input LOV--BC. Simultaneously disconnect all the three phase voltages from the terminal. No LOV--TRIP signal should appear. Disconnect the dc voltage from the LOV--BC input.

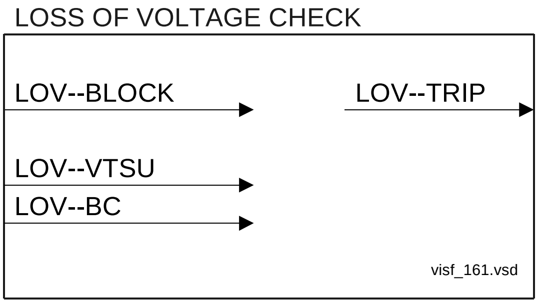
1.8 Increase the measured voltages to their rated values for at least ten seconds. Apply the rated dc voltage to the binary input connected to the function input LOV--VTSU. Simultaneously disconnect all the three phase voltages from the terminal. No LOV--TRIP signal should appear. Disconnect the dc voltage from the LOV--VTSU input.

1.9 Increase the measured voltages to their rated values for at least ten seconds. Apply the rated dc voltage to the binary input connected to the function input LOV--BLOCK. Simultaneously disconnect all the three phase voltages from the terminal. No LOV--TRIP signal should appear. Disconnect the dc voltage from the LOV--BLOCK input

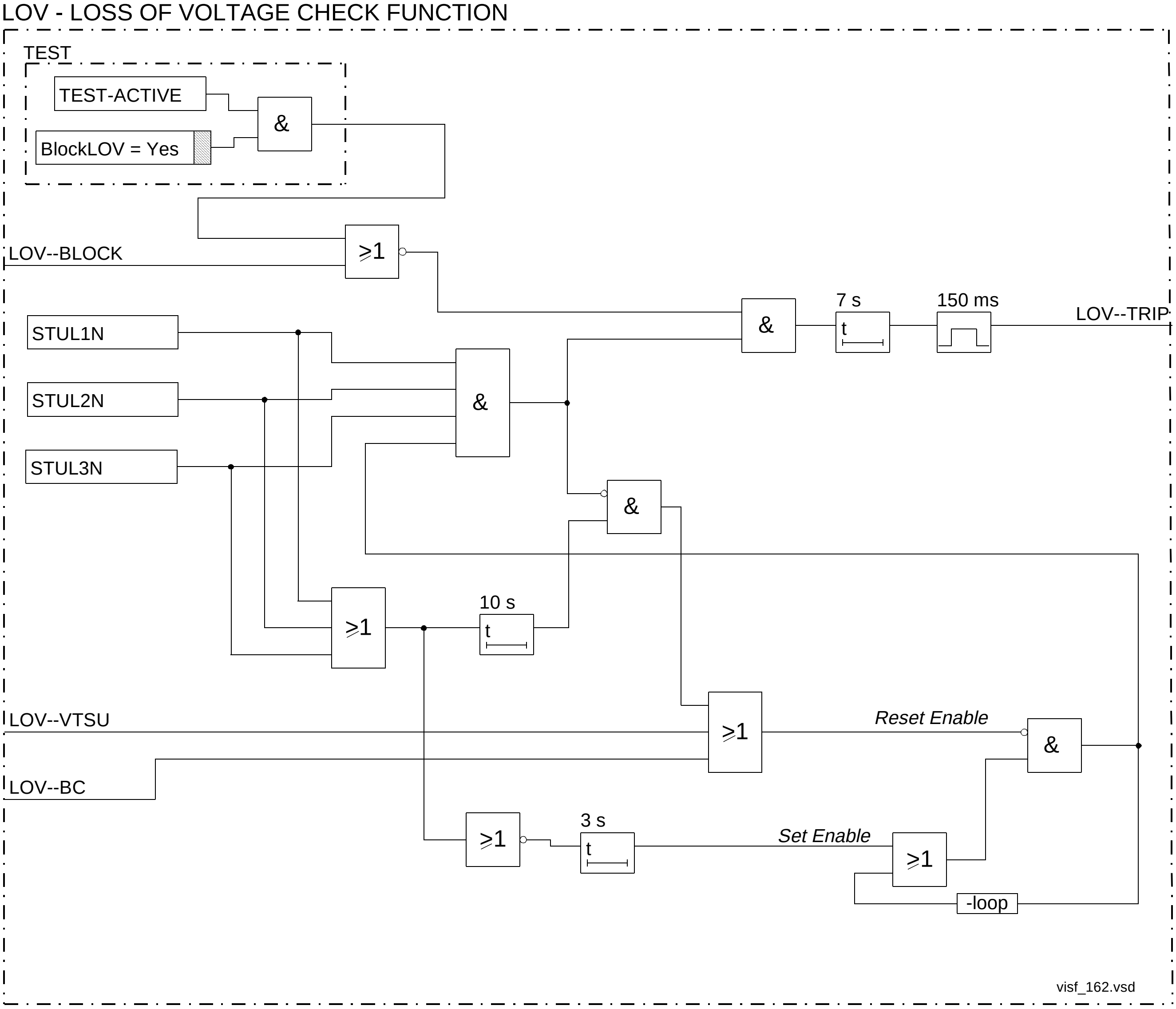
2.0 Configure (if necessary) the terminal to its normal operating configuration.

6 Appendix

6.1 Function block



6.2 Function block diagram



6.3 Signal list

Block	Signal	Type	Description
LOV--	BLOCK	IN	Block of loss of voltage function
LOV--	VTSU	IN	Block from voltage circuit supervision
LOV--	BC	IN	Breaker closing command
LOV--	TRIP	OUT	Trip by loss of voltage function

6.4 Setting table

Parameter	Range	Unit	Default	Parameter description
Operation	Off, On		Off	Loss of voltage function On/Off
UPE<	10-100	%	70	Operating phase voltage, as a percentage of U1b

1 Application

The overload supervision function sends an alarm signal when the current exceeds the set level for longer than a pre-set time. The operating level of the current measuring element can be set to the maximum, accepted, continuous current. So operators are alerted if the primary system operates in a dangerous overload mode. A typical application is the signalling of the overload of the current transformers connected to the terminal, as they usually can withstand a small current beyond their rated current.

2 Theory of operation

The current-measuring elements continuously measure the three-phase currents, and compare them with the set values. Fourier's recursive filter filters the current signals, and a separate trip counter prevents overreaching of the measuring elements.

The logical values of the following signals become equal to 1, if the measured current in any phase exceeds the pre-set value:

- STIL1
- STIL2
- STIL3

If any of the three phase currents exceeds the set value IP> for a period longer than the set time t, than the three phase trip signal OVLD-TRIP is emitted.

3 Design

The simplified logic diagram of the time delayed phase overcurrent function is shown in figure 1.

The function is disabled (blocked) if:

- The terminal is in TEST status (TEST-ACTIVE is high) and the function has been blocked from the HMI (BlockOVLD=Yes)
- The input signal OVLD-BLOCK is high

The OVLD-BLOCK signal is a blocking signal of the overload supervision function. It can be connected to a binary input of the terminal in order to receive a block command from external devices or can be software connected to other internal functions of the terminal itself in order to receive a block command from internal functions. Through OR gate it can be connected to both binary inputs and internal function outputs.

The output trip signal OVLD-TRIP is a three phase trip. It can be used to command a trip to the circuit breaker or for a signallization.

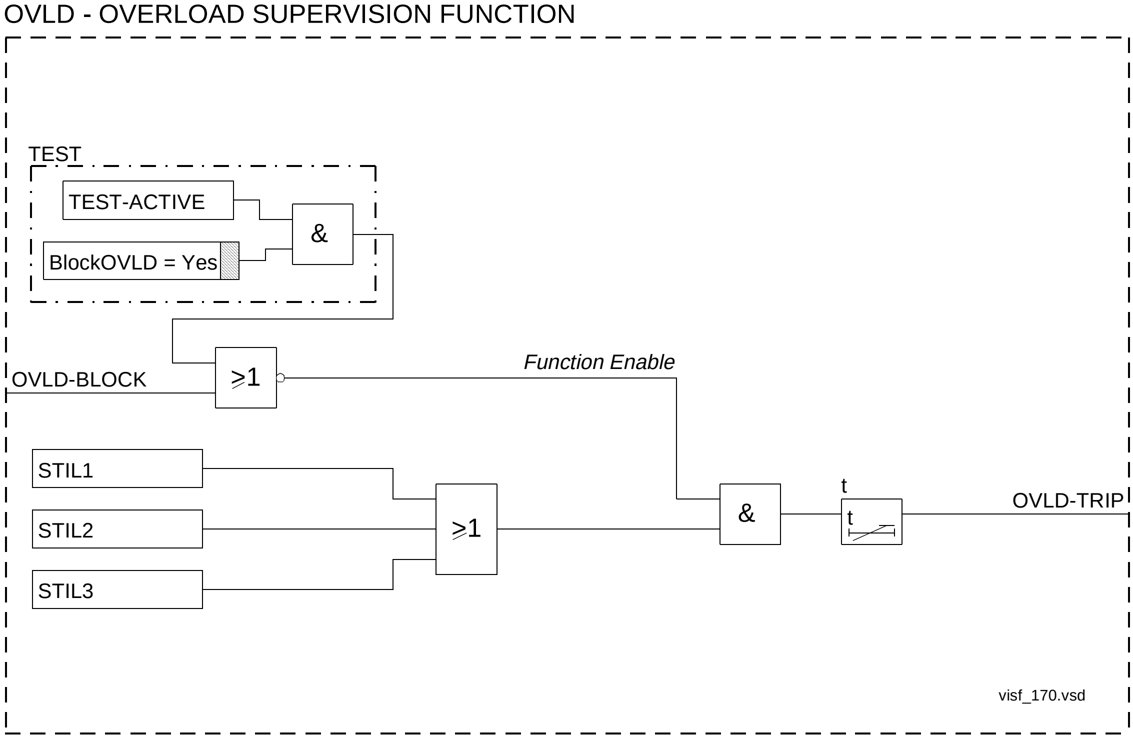


Figure 1: Simplified logic diagram of overload supervision function

4 Setting instructions

The setting of the operating values for the overload supervision functionoccurs under the menu:

Settings

Functions

Group n (n = 1...4)

OverLoad

The current level set should be above the maximum permissible load current. Consider the accuracy class of the used instrument current transformers and the specified accuracy of the current measuring elements in the REx 5xx terminals.

The corresponding time delay must comply with the selectivity planning of the protection in the whole network, and with the permissible overloading of the conductors, if the function is used for tripping the circuit breaker. The above settings might change to a lower current value and higher time delay if the function serves only for alarming and not for tripping purposes.

4.1 Setting of operating current IP>

The relay setting value IP> is given in percentage of the secondary base current value, I_{1b} , associated to the current transformer input I1.

If Is_{SEC} is the secondary current setting operating value of the function, then the relay setting value IP> is given from this formula:

$$IP> = \frac{Is_{SEC}}{I_{1b}} \cdot 100 \qquad \text{(Equation 1)}$$

and this is the value that has to be set in the relay.

Set this value under the setting menu:

Settings
Functions
Group n
OverLoad

on the value IP>.

4.2 Setting of time delay t

Set the time delay of the function, t, under the setting menu:

Settings
Functions
Group n
OverLoad

on the value t.

5 Testing

The function can be disabled during the test mode during these conditions:

- When the function should be blocked under the testing conditions, select the functions that should be blocked under the menu:

  Test
  TestMode
  BlockFunctions

- The terminal is set to test mode by setting the Operation=On, which appears under the menu:

  Test
  TestMode
  Operation

- The terminal is automatically set to test mode by applying the logical 1 to the TEST-INPUT functional input.

Important note: The function is blocked if the corresponding setting under the BlockFunctions menu remains on and the TEST-INPUT signal remains active.

The overload supervision function must not be blocked in order to be tested.

Check the operating values of the current measuring elements and corresponding functions during the commissioning and during regular maintenance tests. ABB Network Partner recommends, although it is not an absolute requirement, the use of the RTS 21 (FREJA) testing equipment for secondary injection-testing purposes.

Before testing, connect the testing equipment according to the valid terminal diagram of the specific REx 5xx terminal. Pay special attention to the correct connection of the input and output current terminals.

Follow these steps:

1.1 Check if the input and output logical signals in figure 1 are configured to the corresponding binary inputs and outputs of the tested terminal. If not, configure them for testing purposes. Set the operation of the OVLD protection to On mode.

1.2 Set the input logical signals to the logical zero and note on the local HMI that the OVLD-TRIP logical signal is equal to the logical 0. Values of the logical signals belonging to the time delayed overcurrent protection are available under menu tree:

Service Report
Functions
OverLoad
FuncOutputs

1.3 Set the time delay t to 0.0 ms.

1.4 Slowly increase the injected current (measured current) in all three phases simultaneously until the OVLD-TRIP signal appears on the corresponding binary output or on the local HMI. Record the operating value. Compare the measured operating current with the set value. The result should be within the 5% accuracy limits with the addition of the accuracy class of the testing equipment.

1.5 Set the time delay t to 500 ms.

1.6 Quickly set the measured current (fault current) in all three phases to about 1.5 times the measured operating current, and disconnect the current with the switch.

1.7 Switch on the fault current and measure the operating time of the OVLD protection. Use the OVLD-TRIP signal from the configured binary output to stop the timer. Compare the measured time with the set value t.

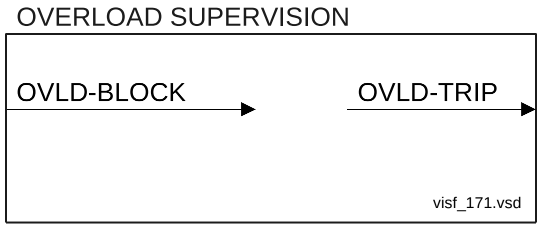
1.8 Connect the rated dc voltage to the OVLD-BLOCK configured binary input, and switch on the fault current. No OVLD-TRIP signal should appear. Switch off the fault current. Disconnect the dc voltage from the OVLD-BLOCK binary input.

1.9 Set the operation of the protection at Off mode and switch on the fault current. Note that no corresponding binary signals should appear on the terminal. Switch off the fault current.

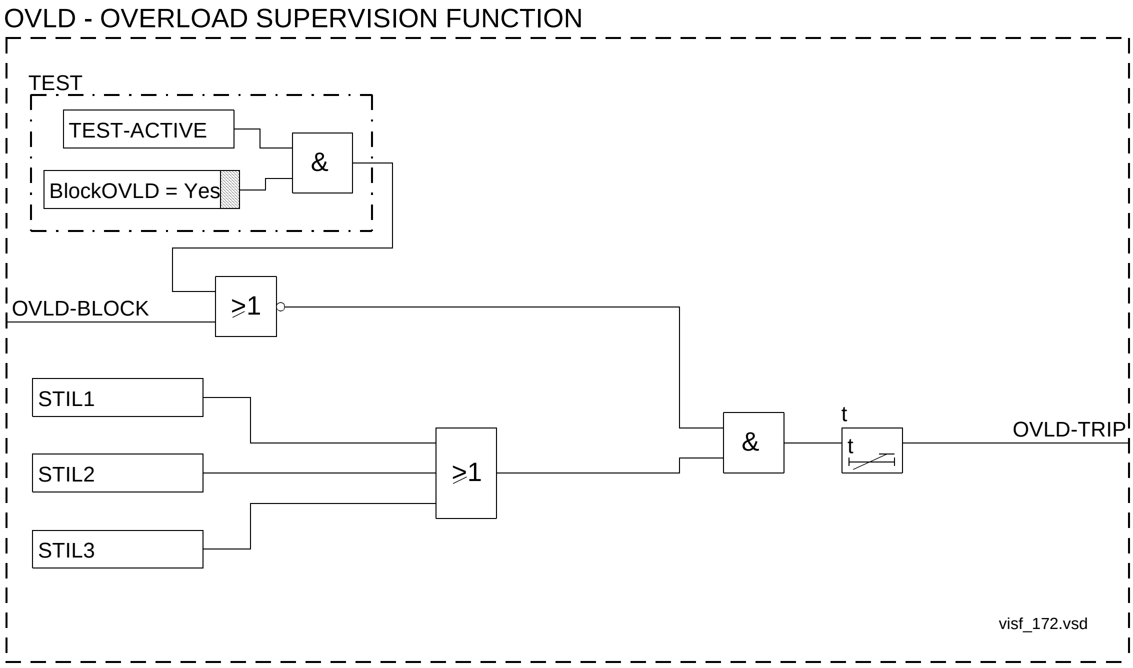
2.0 Configure (if necessary) the terminal to its normal operating configuration.

6 Appendix

6.1 Function block



6.2 Function block diagram



6.3 Signal list

Block	Signal	Type	Description
OVLD-	BLOCK	IN	Block of overload function
OVLD-	TRIP	OUT	Trip by overload function

6.4 Setting table

Parameter	Range	Unit	Default	Parameter description
Operation	Off, On		Off	Overload function On/Off
IP>	20-300	%	100	Operating phase current, as a percentage of I1b
t	0.000-9000.000	s	20.000	Time delay

1 Application

The correct operation of a protection depends on correct information about the primary value of currents and voltages. When currents from two independent 3-phase sets of CT's, or CT cores, measuring the same primary currents are available, a reliable current circuit supervision can be arranged by comparing the currents from the two sets. If an error in the CT circuits is detected, the protection functions concerned are to be blocked and an alarm given.

In case of large currents, unequal transient saturation of CT cores with different remanence or different saturation factor may result in differences in the secondary currents from the two CT sets. Unwanted blocking of protection functions during the transient period must be avoided.

The supervision function must be sensitive and have short operate time to prevent unwanted tripping from fast-acting, sensitive numerical protections in case of errors in the current circuits.

Note that the same current input transformer (I5) in REx 5xx is used for the reference current I_{ref} of the CT supervision, the residual current from the parallel line for the fault locator and, dependent on setting I4 or I5, maybe for the earth-fault protection function. Hence, when the CT supervision function is used, the settings Xm0 = 0 and Rm0 = 0 must be used for the fault locator.

2 Theory of operation

The supervision function compares the numerical value of the sum of the three phase currents $|\Sigma I_{phase}|$ (current inputs I1, I2 and I3) and the numerical value of the residual current $|\Sigma I_{ref}|$ (current input I5) from another current transformer set, see figure 1.

The CTSU-FAIL output will be set to a logical one when following criterias are fulfilled:

- the numerical value of the difference $|\Sigma I_{phase}| - |\Sigma I_{ref}|$ is higher then 80% of the numerical value of the sum $|\Sigma I_{phase}| + |\Sigma I_{ref}|$
- the numerical value of the current $|\Sigma I_{phase}| - |\Sigma I_{ref}|$ is equal to or higher than the set operate value I_{MinOp} (5 - 100% of I1b)
- no phase current has exceeded 1.5 times rated relay current I1b during the last 10 ms
- the current circuit supervision is released by setting Operation = On.

The CTSU-FAIL output remains activated 100 ms after the And-gate resets when being activated for more than 20 ms. If the CTSU-FAIL lasts for more than 150 ms an CTSU-ALARM will be issued. In this case the CTSU-FAIL and CTSU-ALARM will remain activated 1 s after the and-gate resets. This prevents unwanted resetting of the blocking function when phase current supervision element(s) operate, e.g. during a fault.

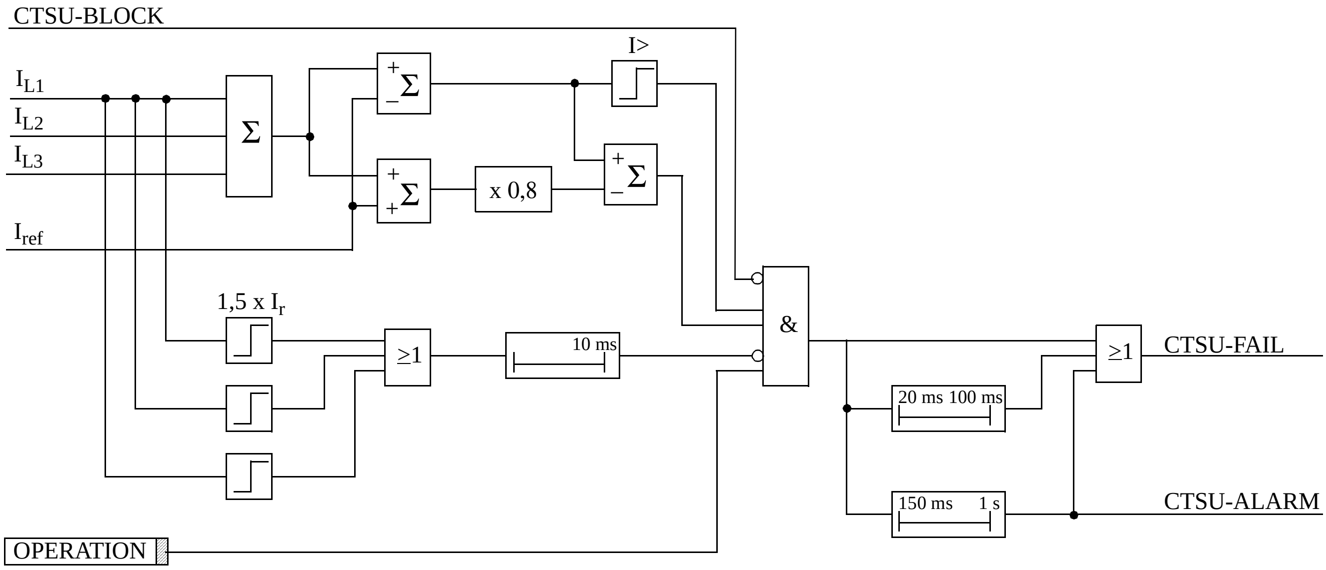


Figure 1: Simplified logic diagram for the current circuit supervision

The operate characteristic is percentage restrained, see figure 2.

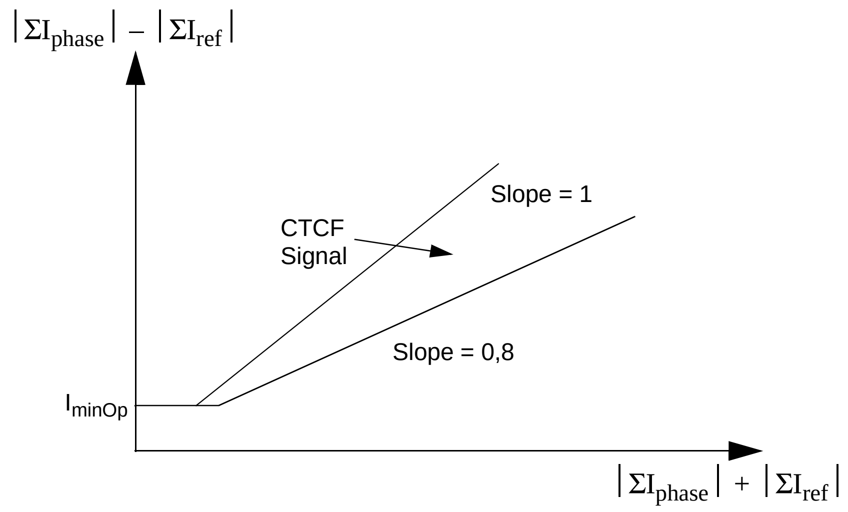


Figure 2: Operate characteristics

Note that due to the formulas for the axis compared, $|\Sigma I_{phase}|$ - $|\Sigma I_{ref}|$ and $|\Sigma I_{phase}| + |\Sigma I_{ref}|$ respectively, the slope can not be above 1.

3 Setting

The function is activated by setting Operation = On.

The minimum operate current (I_{MinOp}) should as a minimum be set twice the residual current in the supervised CT circuits under normal service conditions and rated primary current. The setting range is 5 – 100% of I1b

The CTSU-FAIL and CTSU-ALARM outputs are connected to the blocking input of the actual protection function and output alarm relay respectively via the internal logic programming of the REx 5xx relay.

4 Testing

The current circuit supervision function is conveniently tested with the same 3-phase test set as used when testing the measuring functions in the REx 5xx.

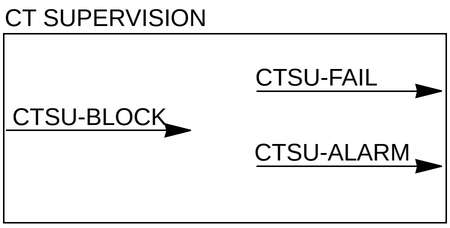
1.Check the input circuits and the operate value of the I_{MinOp} current level detector by injecting current, one phase at a time.

2.Check the phase current blocking for all three phases by injecting current, one phase at a time. The output blocking signal shall reset with a delay of 1 s when the current exceeds 1.5 x I1b.

3.Inject a current 0.90 x I1b to phase L1 and a current 0.15 x I1b to the reference current input. Decrease slowly the current to the reference current input and check that blocking is obtained when the current is about 0.10 x I1b.

5 Appendix

5.1 Function block



5.2 Signal list

Block	Signal	Type	Description
CTSU-	ALARM	OUT	Alarm for current circuit failure
CTSU-	BLOCK	IN	Block of current circuit supervision function
CTSU-	FAIL	OUT	Detection of current circuit failure

5.3 Setting table

Parameter	Range	Unit	Default	Parameter description
Operation	Off, On		Off	Activation of CT-Supervision
IMinOp	5-100	%	20	Minimum operate phase current, as a percentage of I1b

1 Application

Different protection functions within the REx 5xx protection, control and monitoring terminals operate on the basis of the measured voltage in the relay point. Examples are: distance protection function, undervoltage measuring function, and voltage check for the weak infeed logic.

These functions can operate unnecessarily if a fault occurs in the secondary circuits between the voltage instrument transformers and the terminal.

It is possible to use different measures to prevent such unwanted operations. Miniature circuit breakers in the voltage measuring circuits, located as close as possible to the voltage instrument transformers, are one of them. Separate fuse-failure measuring relays or elements within the protection and monitoring devices are another possibility. These solutions are combined to get the best possible effect in the fuse failure supervision function (FUSE) of REx 5xx terminals.

The fuse-failure supervision function as built into the REx 5xx terminals has these possibilities; it can operate:

- On the basis of external binary signals from the miniature circuit breaker or from the line disconnector. The first case influences the operation of all voltage-dependent functions while the second one does not affect the impedance measuring functions.
- On the basis of the negative-sequence measuring quantities: a high value of voltage $3 \cdot U_2$ without the presence of the negative-sequence current $3 \cdot I_2$.

Because of the negative sequence detection algorithm, this function is recommended for terminals used in isolated or high-impedance earthed networks.

2 Theory of operation

The current and voltage measuring elements within one of the built-in digital signal processors continuously measure the currents and voltages in all three phases and calculate:

- The negative-sequence current $3 \cdot I_2$
- The negative-sequence voltage $3 \cdot U_2$

comparing them with their respective set values 3I2< and 3U2> .

Fourier's recursive filter filters the current and voltage signals, and a separate trip counter prevents high overreaching of the measuring elements. The signal STNEG is set to 1, if the negative sequence measured voltage exceeds its set value 3U2> and if the negative sequence measured current does not exceed its pre-set value 3I2<.

Signals STUL1N, STUL2N and STUL3N are related to phase to earth voltages and become 1 when the respective phase voltage is lower then the set value. The set value (U<) is chosen in the dead line detection function, that is always present in the terminal when the fuse failure supervision is present.

3 Design

The simplified logic diagram of the fuse failure supervision function is shown in figure 1.

The function is disabled (blocked) if:

- The terminal is in TEST status (TEST-ACTIVE is high) and the function has been blocked from the HMI (BlockFUSE=Yes)
- The input signal FUSE-BLOCK is high

FUSE-BLOCK signal is a general purpose blocking signal of the fuse failure supervision function. It can be connected to a binary input of the terminal in order to receive a block command from external devices or can be software connected to other internal functions of the terminal itself in order to receive a block command from internal functions. Through OR gate it can be connected to both binary inputs and internal function outputs.

Function input signal FUSE-MCB is supposed to be connected via a terminal binary input to the N.C. auxiliary contact of the miniature circuit-breaker protecting the VT secondary circuit.

Function input signal FUSE-DISC is supposed to be connected via a terminal binary input to the N.C. auxiliary contact of the line disconnector.

The function output FUSE-VTSU can be used for blocking the voltage related measuring functions (undervoltage protection, synchrocheck etc.) except for the impedance protection.

Function output FUSE-VTSZ can be used for blocking the impedance protection function.

The FUSE-MCB signal sets the output signals FUSE-VTSU and FUSE-VTSZ in order to block all the voltage related functions when the MCB is open. The additional drop-off timer of 150 ms prolongs the presence of FUSE-MCB signal to prevent the unwanted operation of voltage dependent function due to non simultaneous closing of the main contacts of the miniature circuit breaker.

The FUSE-DISC signal sets the output signal FUSE-VTSU in order to block the voltage related functions when the line disconnector is open. The impedance protection function is not affected by the position of the line disconnector.

The function input signal FUSE-DLCND is related to the dead line condition detection. It has to be connected to the output signal of the dead line condition function DLD-STPH (dead phase condition detected). This signal is activated from the dead line condition function when the voltage and the current in at least one phase are below their respective setting values. It prevents the blocking of the impedance protection by a fuse failure detection during dead line condition (that occurs also during single pole auto-reclosing). The 200 ms drop-off timer prolongs the dead line condition after the line-energization in order to prevent the blocking of the impedance protection for unequal pole closing.

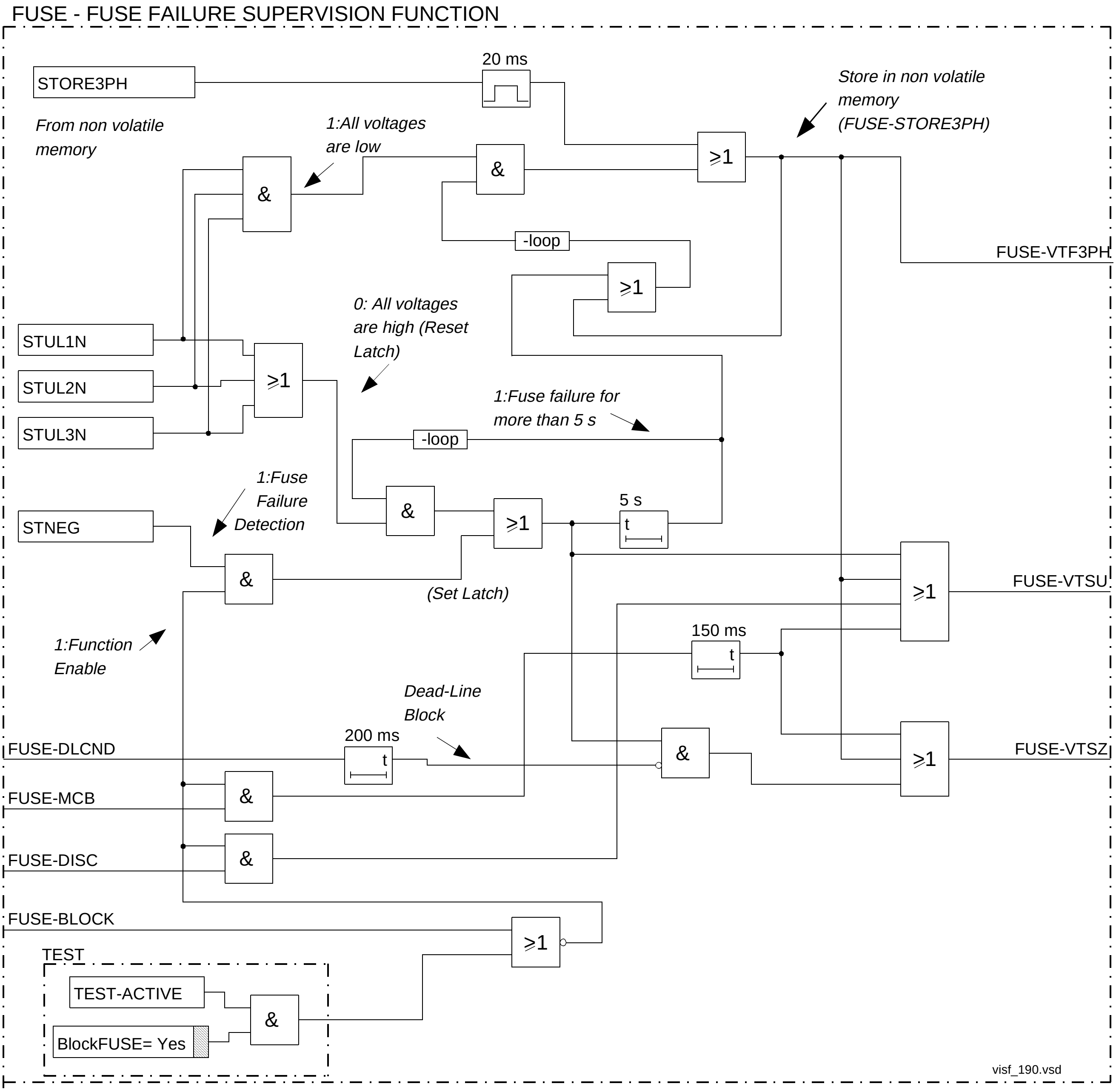


Figure 1: Simplified logic diagram for fuse failure supervision function

If a fuse failure condition is detected for more then five seconds and at least one of the phases has a low phase to earth voltage, then the fuse failure condition is latched: signal FUSE-VTSU is turned high, if there is no dead line condition also FUSE-VTSZ is high; if all the three phases have no voltage (STUL1N = STUL2N = STUL3N = 1) then the output signal FUSE-VTF3PH is turned high.

The output signal FUSE-VTF3PH is high if the fuse failure condition is detected for 5 seconds and all the three measured voltages are low.

Fuse failure condition is unlatched when the normal voltage conditions are restored (STUL1N = STUL2N = STUL3N = 0).

Fuse failure condition is stored in the non volatile memory of the terminal. In the new start-up procedure the terminal checks the VTF3PH (STORE3PH) value in its non volatile memory and establishes the corresponding starting conditions.

4 Setting instructions

The operating value for the voltage check function (signals STUL1N, STUL2N, STUL3N) is the same as the operating value of the dead line detection function. The setting of the voltage minimum operating value U< occurs under the submenu:

Settings
Functions
Group n
DeadLineDet

Some values of the negative-sequence voltages and currents always exist due to different non-symmetries in the primary system and differences in the current and voltage instrument transformers. The minimum value for the operation of the current and voltage measuring elements must always be set with a safety margin of 10 to 15%, depending on the system operating conditions.

Pay special attention to the dissymmetry of the measuring quantities when the function is used on longer untransposed lines, on multicircuit lines, and so on.

The parameter list and their setting ranges are shown in the appendix.

4.1 Setting of negative sequence voltage 3U2>

The relay setting value 3U2> is given in percentage of the secondary base voltage value, U_{1b}, associated to the voltage transformer input U1. If Us_{SEC} is the secondary setting value of the relay, then the value for 3U2> is given from this formula:

$$3U2> = \frac{Us_{SEC}}{U_{1b}} \cdot 100 \qquad \text{(Equation 1)}$$

and this is the value that has to be set in the relay.

Set this value under the setting menu:

Settings
Functions
Group n
FuseFailure

on the value 3U2>.

4.2 Setting of negative sequence current 3I2<

The relay setting value 3I2< is given in percentage of the secondary base current value, I_{1b}, associated to the current transformer input I1. If Is_{SEC} is the secondary setting value of the relay, then the value for 3I2< is given from this formula:

$$3I2< = \frac{Is_{SEC}}{I_{1b}} \cdot 100 \qquad \text{(Equation 2)}$$

and this is the value that has to be set in the relay.

Set this value under the setting menu:

Settings
  Functions
    Group n
      FuseFailure

on the value 3I2<.

5 Testing

It is possible to disable the function during the test mode under the following conditions:

- When the function should be blocked under the testing conditions. The selection of functions, which should be blocked is possible under the menu:

  Test
    TestMode
      BlockFunctions

- The terminal has been set into the test mode by setting the Operation=On. This selection takes place under the menu:

  Test
    TestMode
      Operation

- The terminal has been set automatically into test mode by applying the logical 1 to the TEST-INPUT functional input

Important note: The function will be blocked if the corresponding setting under the BlockFunctions menu remains on and the TEST-INPUT signal remains active.

The fuse failure supervision function must not be blocked in order to be tested.

Check the operation of the FUSE function during the commissioning and during regular maintenance tests. ABB Network Partner recommends, although it is not an absolute requirement, the use of the RTS 21 (FREJA) testing equipment for secondary injection testing purposes.

The test equipment used should be able to provide an independent three-phase supply of voltages and currents to the tested terminal. It must be possible to separately change the values of voltages, currents, and phase angles among them independent of each other, for each phase. The test voltages and currents should have a common source, with very small content of higher harmonics. If the test equipment cannot indicate the phase angles between the measured quantities, a separate phase angle meter is needed.

The corresponding binary signals that inform the operator about the operation of the FUSE function are available on the local human-machine interface (HMI) unit under the menu:

Service Report
Functions
FuseFailure
FuncOutputs

The appendix reports the corresponding signals that display information on the operation of the FUSE function.

These steps are necessary for testing the FUSE function:

1.1 Check if the input and output logical signals as shown in figure 1 on page 63 are configured to the corresponding binary inputs and outputs of the tested terminal. If not, configure them for testing purposes. Set the operation of FUSE protection to On mode under the submenu:

Settings
Functions
Group n
FuseFailure
NegativeSeq

1.2 Connect the three-phase testing equipment to the tested terminal, and simulate normal operating conditions with the three-phase currents in phase with their corresponding phase voltages and with all of them equal to their rated values.

1.3 Connect the nominal dc voltage to the FUSE-DISC binary input, and check that the signal FUSE-VTSU appears with almost no time delay. No signals FUSE-VTSZ and FUSE-VTF3PH should appear on the terminal. Only the distance protection function operates. No other voltage-dependent functions must operate. Disconnect the dc voltage from the FUSE-DISC binary input terminal.

1.4 Connect the nominal dc voltage to the FUSE-MCB binary input and check that the FUSE-VTSU and FUSE-VTSZ signals appear without any time delay. No voltage-dependent functions must operate. Disconnect the dc voltage from the FUSE-MCB binary input terminal.

1.5 Disconnect one of the phase voltages and observe the logical output signals on the terminal binary outputs. FUSE-VTSU and FUSE-VTSZ signals should simultaneously appear.

1.6 After more than 5 seconds disconnect the remaining two phase voltages and all three currents. There should be no change in the high statuses of the output signals FUSE-VTSU and FUSE-VTSZ. The signal FUSE-VTF3PH will instead appear.

1.7 Simultaneously establish normal voltage and current operating conditions and observe the corresponding output signals. They should change to the logical 0 as follows:

- •Signal FUSE-VTF3PH after about 25 ms
- •Signal FUSE-VTSU after about 50 ms
- •Signal FUSE-VTSZ after about 200 ms

1.8 Slowly decrease the measured voltage in one phase until the FUSE-VTSU signal appears. Record the measured voltage and calculate the corresponding negative-sequence voltage according to the equation (observe that the voltages in the equation are phasors):

$$3 \cdot \overline{U_2} = \overline{U_{L1}} + a^2 \cdot \overline{U_{L2}} + a \cdot \overline{U_{L3}} \qquad \text{(Equation 3)}$$

where:

$\overline{U_{L1}}$, $\overline{U_{L2}}$ and $\overline{U_{L3}}$ are the measured phase voltages

and

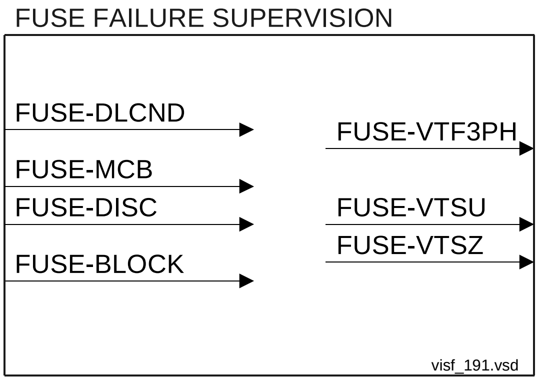
$$a = 1 \cdot e^{j\frac{2 \cdot \pi}{3}} = -0,5 + j\frac{\sqrt{3}}{2} \qquad \text{(Equation 4)}$$

Compare the result with the set value (consider that the set value 3U2> is in percentage of the base voltage U1b) of the negative-sequence operating voltage. The result should be within the $\pm$5% limits of accuracy with the addition of declared accuracy for testing equipment.

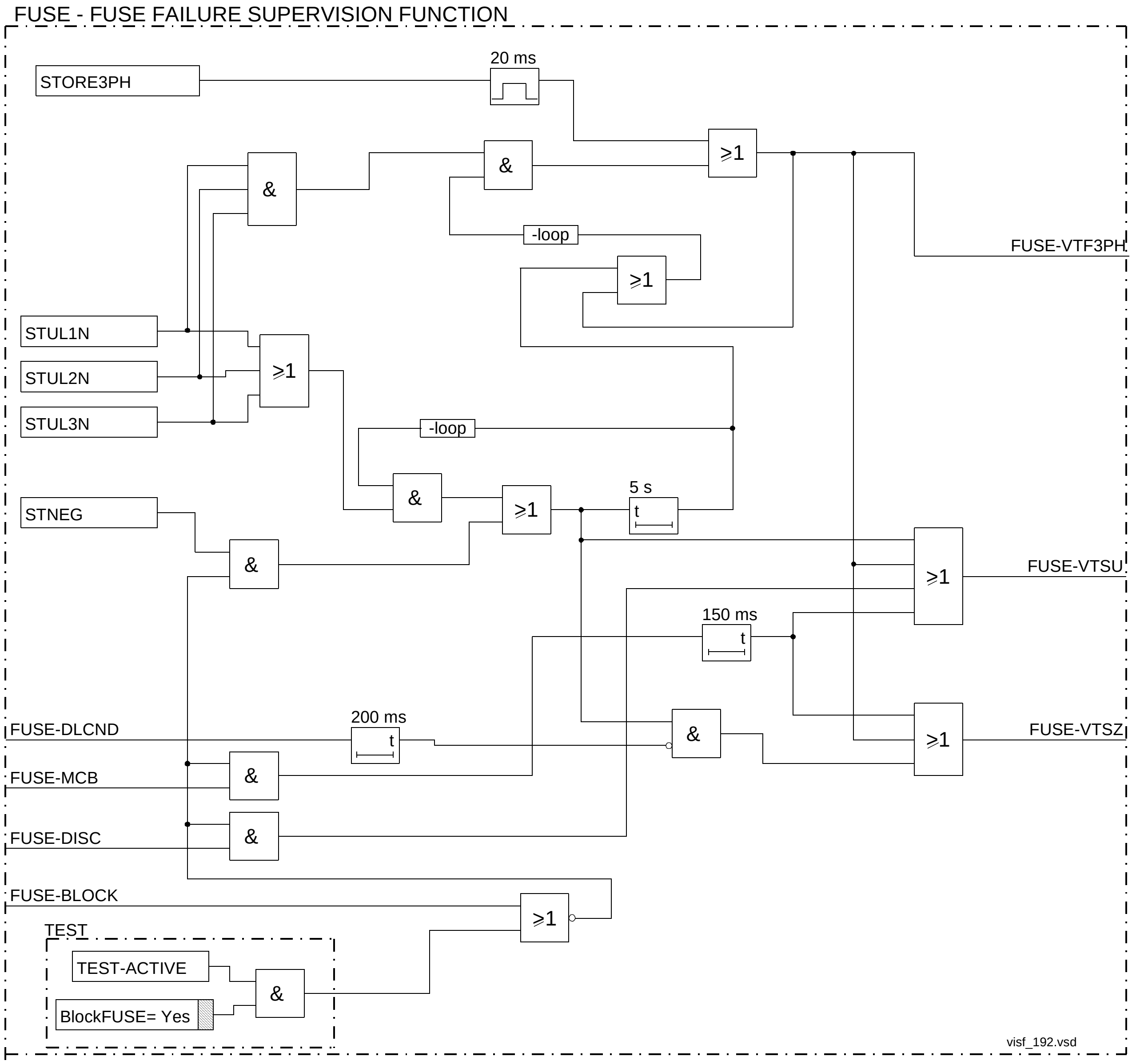
1.9 Disconnect the testing equipment. Don’t forget to configure the terminal, if necessary, to its normal operating configuration.

6 Appendix

6.1 Function block



6.2 Function block diagram



6.3 Signal lists

Block	**Signal**	**Type**	**Description**
FUSE-	DLCND	IN	Dead line condition
FUSE-	MCB	IN	Operation of MCB
FUSE-	DISC	IN	Line disconnector position
FUSE-	BLOCK	IN	Block of fuse failure function
FUSE-	VTF3PH	OUT	Detection of 3-phase fuse failure
FUSE-	VTSU	OUT	Block for voltage measuring functions
FUSE-	VTSZ	OUT	Block for impedance measuring functions

6.4 Setting table

Parameter	**Range**	**Unit**	**Default**	**Parameter description**
Nega-tiveSeq	Off, On		Off	Fuse failure negative sequence function On/Off
3U2>	10-50	%	10	Operating negative sequence voltage, as a percentage of U1b
3I2<	10-50	%	10	Operating negative sequence current, as a percentage of I1b

1 Application

Different protection functions within the REx 5xx protection, control and monitoring terminals operate on the basis of the measured voltage in the relay point. Examples are: distance protection function, undervoltage measuring function, and voltage check for the weak infeed logic.

These functions can operate unnecessarily if a fault occurs in the secondary circuits between the voltage instrument transformers and the terminal.

It is possible to use different measures to prevent such unwanted operations. Miniature circuit breakers in the voltage measuring circuits, located as close as possible to the voltage instrument transformers, are one of them. Separate fuse-failure measuring relays or elements within the protection and monitoring devices are another possibility. These solutions are combined to get the best possible effect in the fuse failure supervision function (FUSE) of REx 5xx terminals.

The fuse-failure supervision function as built into the REx 5xx terminals has these possibilities; it can operate:

- On the basis of external binary signals from the miniature circuit breaker or from the line disconnector. The first case influences the operation of all voltage-dependent functions while the second one does not affect the impedance measuring functions.
- On the basis of the zero-sequence measuring quantities: a high value of voltage $3 \cdot U_0$ without the presence of the residual current $3 \cdot I_0$.

2 Theory of operation

The current and voltage measuring elements within one of the built-in digital signal processors continuously measure the currents and voltages in all three phases and calculate:

- The zero-sequence current $3 \cdot I_0$
- The zero-sequence voltage $3 \cdot U_0$

comparing them with their respective set values 3I0< and 3U0> .

Fourier’s recursive filter filters the current and voltage signals, and a separate trip counter prevents high overreaching of the measuring elements. The signal STZERO is set to 1, if the zero sequence measured voltage exceeds its set value 3U0> and if the zero sequence measured current does not exceed its pre-set value 3I0<.

Signals STUL1N, STUL2N and STUL3N are related to phase to earth voltages and become 1 when the respective phase voltage is lower then the set value. The set value (U<) is chosen in the dead line detection function, that is always present in the terminal when the fuse failure supervision is present.

3 Design

The simplified logic diagram of the fuse failure supervision function is shown in figure 1.

The function is disabled (blocked) if:

- The terminal is in TEST status (TEST-ACTIVE is high) and the function has been blocked from the HMI (BlockFUSE=Yes)
- The input signal FUSE-BLOCK is high

The FUSE-BLOCK signal is a general purpose blocking signal of the fuse failure supervision function. It can be connected to a binary input of the terminal in order to receive a block command from external devices or can be software connected to other internal functions of the terminal itself in order to receive a block command from internal functions. Through OR gate it can be connected to both binary inputs and internal function outputs.

The function input signal FUSE-MCB is supposed to be connected via a terminal binary input to the N.C. auxiliary contact of the miniature circuit-breaker protecting the VT secondary circuit.

The function input signal FUSE-DISC is supposed to be connected via a terminal binary input to the N.C. auxiliary contact of the line disconnector.

The function output FUSE-VTSU can be used for blocking the voltage related measuring functions (undervoltage protection, synchrocheck etc.) except for the impedance protection.

The function output FUSE-VTSZ can be used for blocking the impedance protection function.

The FUSE-MCB signal sets the output signals FUSE-VTSU and FUSE-VTSZ in order to block all the voltage related functions when the MCB is open. The additional drop-off timer of 150 ms prolongs the presence of FUSE-MCB signal to prevent the unwanted operation of voltage dependent function due to non simultaneous closing of the main contacts of the miniature circuit breaker.

The FUSE-DISC signal sets the output signal FUSE-VTSU in order to block the voltage related functions when the line disconnector is open. The impedance protection function is not affected by the position of the line disconnector.

The function input signal FUSE-DLCND is related to the dead line condition detection. It has to be connected to the output signal of the dead line condition function DLD-STPH (dead phase condition detected). This signal is activated from the dead line condition function when the voltage and the current in at least one phase are below their respective setting values. It prevents the blocking of the impedance protection by a fuse failure detection during dead line condition (that occurs also during single pole auto-reclosing). The 200 ms drop-off timer prolongs the dead line condition after the line-energization in order to prevent the blocking of the impedance protection for unequal pole closing.

If the fuse failure condition is detected for more then five seconds and at least one of the phases has a low phase to earth voltage, then the fuse failure condition is latched: signal FUSE-VTSU is turned high, if there is no dead line condition also FUSE-VTSZ is high; if all the three phases have no voltage (STUL1N = STUL2N = STUL3N = 1) then the output signal FUSE-VTF3PH is turned high.

The output signal FUSE-VTF3PH is high if the fuse failure condition is detected for 5 seconds and all the three measured voltages are low.

The fuse failure condition is unlatched when the normal voltage conditions are restored (STUL1N = STUL2N = STUL3N = 0).

The fuse failure condition is stored in the non volatile memory of the terminal. In the new start-up procedure the terminal checks the VTF3PH (STORE3PH) value in its non volatile memory and establishes the corresponding starting conditions.

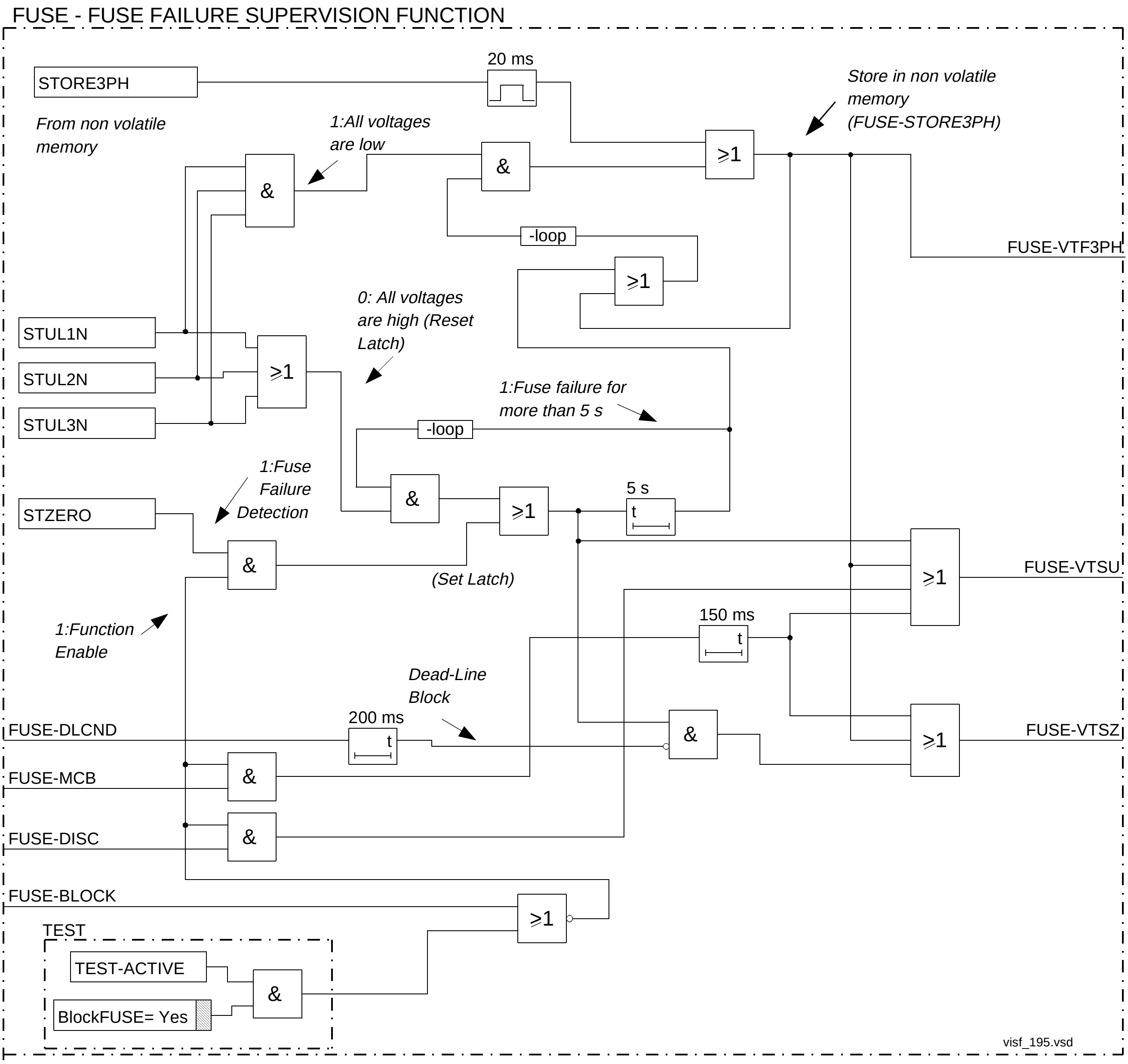


Figure 1: Simplified logic diagram for fuse failure supervision function

4 Setting instructions

The operating value for the voltage check function (signals STUL1N, STUL2N, STUL3N) is the same as the operating value of the dead line detection function. The setting of the voltage minimum operating value U< occurs under the submenu:

Settings

Functions

Group n

DeadLineDet

Some values of the zero-sequence voltages and currents always exist due to different non-symmetries in the primary system and differences in the current and voltage instrument transformers. The minimum value for the operation of the current and voltage measuring elements must always be set with a safety margin of 10 to 15%, depending on the system operating conditions.

Pay special attention to the dissymmetry of the measuring quantities when the function is used on longer untransposed lines, on multicircuit lines, and so on.

The parameter list and their setting ranges are shown in the appendix.

4.1 Setting of zero sequence voltage 3U0>

The relay setting value 3U0> is given in percentage of the secondary base voltage value, U_{1b}, associated to the voltage transformer input U1. If Us_{SEC} is the secondary setting value of the relay, then the value for 3U0> is given from this formula:

$$3U0> = \frac{Us_{SEC}}{U_{1b}} \cdot 100 \qquad \text{(Equation 1)}$$

and this is the value that has to be set in the relay.

Set this value under the setting menu:

Settings
  Functions
    Group n
      FuseFailure

on the value 3U0>.

4.2 Setting of zero sequence current 3I0<

The relay setting value 3I0< is given in percentage of the secondary base current value, I_{1b}, associated to the current transformer input I1. If Is_{SEC} is the secondary setting value of the relay, then the value for 3I0< is given from this formula:

$$3I0< = \frac{Is_{SEC}}{I_{1b}} \cdot 100 \qquad \text{(Equation 2)}$$

and this is the value that has to be set in the relay.

Set this value under the setting menu:

Settings
  Functions
    Group n
      FuseFailure

on the value 3I0<.

5 Testing

It is possible to disable the function during the test mode under the following conditions:

- When the function should be blocked under the testing conditions. The selection of functions, which should be blocked is possible under the menu:

  Test
  TestMode
  BlockFunctions

- The terminal has been set into the test mode by setting the Operation=On. This selection takes place under the menu:

  Test
  TestMode
  Operation

- The terminal has been set automatically into test mode by applying the logical 1 to the TEST-INPUT functional input

Important note: The function will be blocked if the corresponding setting under the BlockFunctions menu remains on and the TEST-INPUT signal remains active.

The fuse failure supervision function must not be blocked in order to be tested.

Check the operation of the FUSE function during the commissioning and during regular maintenance tests. ABB Network Partner recommends, although it is not an absolute requirement, the use of the RTS 21 (FREJA) testing equipment for secondary injection testing purposes.

The test equipment used should be able to provide an independent three-phase supply of voltages and currents to the tested terminal. It must be possible to separately change the values of voltages, currents, and phase angles among them independent of each other, for each phase. The test voltages and currents should have a common source, with very small content of higher harmonics. If the test equipment cannot indicate the phase angles between the measured quantities, a separate phase angle meter is needed.

The corresponding binary signals that inform the operator about the operation of the FUSE function are available on the local human-machine interface (HMI) unit under the menu:

Service Report
Functions
FuseFailure
FuncOutputs

The appendix reports the corresponding signals that display information on the operation of the FUSE function.

These steps are necessary for testing the FUSE function:

1.1 Check if the input and output logical signals as shown in figure 1 on page 74 are configured to the corresponding binary inputs and outputs of the tested terminal. If not, configure them for testing purposes. Set the operation of FUSE protection to On mode under the submenu:

Settings
Functions
Group n
FuseFailure
ZeroSeq

1.2 Connect the three-phase testing equipment to the tested terminal, and simulate normal operating conditions with the three-phase currents in phase with their corresponding phase voltages and with all of them equal to their rated values.

1.3 Connect the nominal dc voltage to the FUSE-DISC binary input, and check that the signal FUSE-VTSU appears with almost no time delay. No signals FUSE-VTSZ and FUSE-VTF3PH should appear on the terminal. Only the distance protection function operates. No other voltage-dependent functions must operate. Disconnect the dc voltage from the FUSE-DISC binary input terminal.

1.4 Connect the nominal dc voltage to the FUSE-MCB binary input and check that the FUSE-VTSU and FUSE-VTSZ signals appear without any time delay. No voltage-dependent functions must operate. Disconnect the dc voltage from the FUSE-MCB binary input terminal.

1.5 Disconnect one of the phase voltages and observe the logical output signals on the terminal binary outputs. FUSE-VTSU and FUSE-VTSZ signals should simultaneously appear.

1.6 After more than 5 seconds disconnect the remaining two phase voltages and all three currents. There should be no change in the high statuses of the output signals FUSE-VTSU and FUSE-VTSZ. The signal FUSE-VTF3PH will instead appear.

1.7 Simultaneously establish normal voltage and current operating conditions and observe the corresponding output signals. They should change to the logical 0 as follows:

- Signal FUSE-VTF3PH after about 25 ms
- Signal FUSE-VTSU after about 50 ms
- Signal FUSE-VTSZ after about 200 ms

1.8 Slowly decrease the measured voltage in one phase until the FUSE-VTSU signal appears. Record the measured voltage and calculate the corresponding zero-sequence voltage according to the equation (observe that the voltages in the equation are phasors):

$$3 \cdot \overline{U_0} = \overline{U_{L1}} + \overline{U_{L2}} + \overline{U_{L3}} \quad \text{(Equation 3)}$$

where:

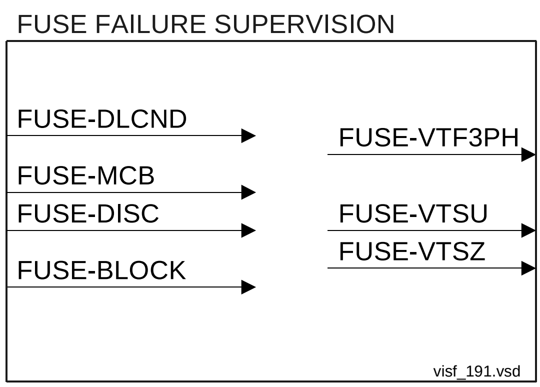
$\overline{U_{L1}}$, $\overline{U_{L2}}$ and $\overline{U_{L3}}$ are the measured phase voltages

Compare the result with the set value (consider that the set value 3U0> is in percentage of the base voltage U1b) of the zero-sequence operating voltage. The result should be within the ±5% limits of accuracy with the addition of declared accuracy for testing equipment.

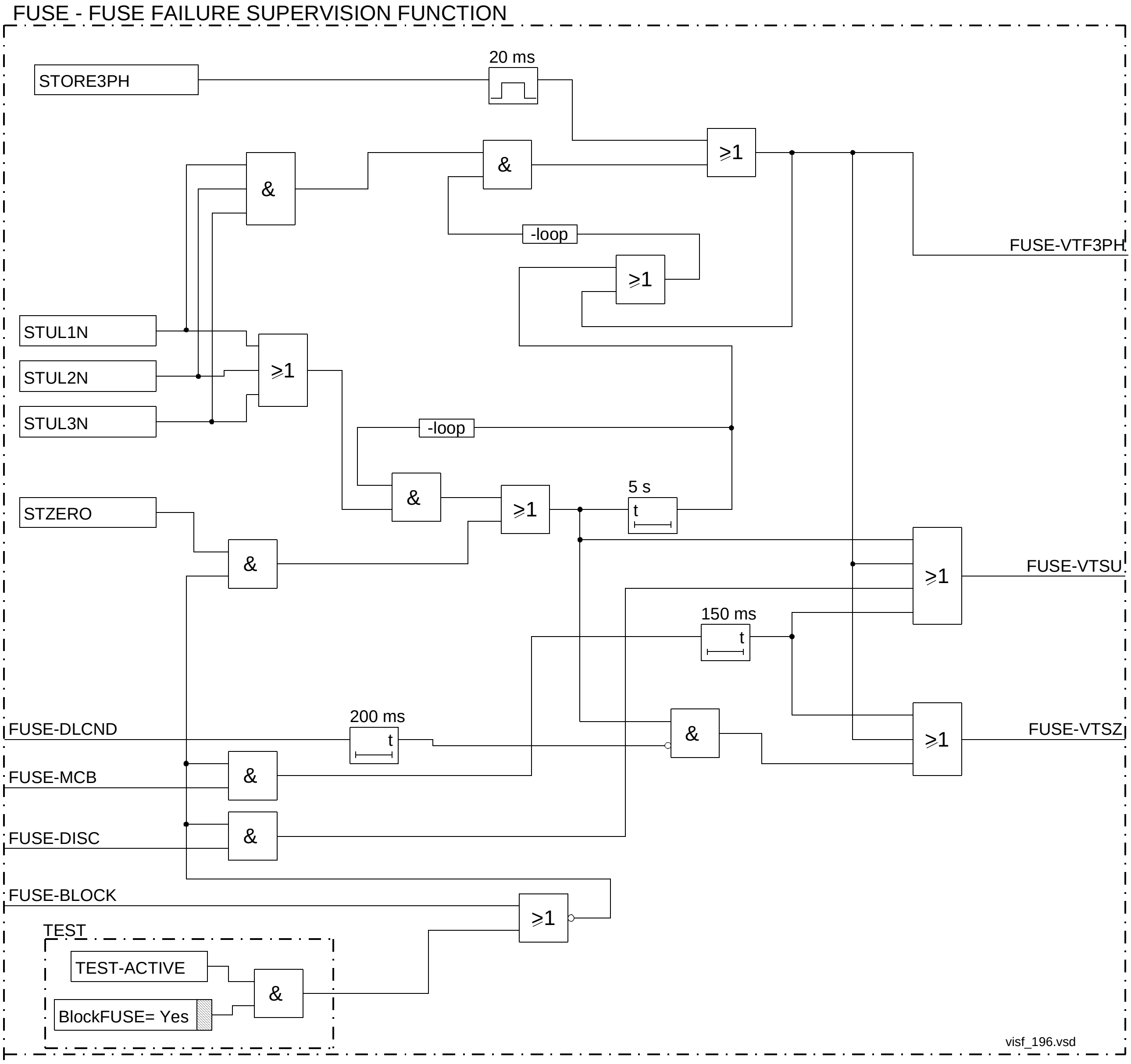
1.9 Disconnect the testing equipment. Don’t forget to configure the terminal, if necessary, to its normal operating configuration.

6 Appendix

6.1 Function block



6.2 Function block diagram



6.3 Signal list

Block	Signal	Type	Description
FUSE-	DLCND	IN	Dead line condition
FUSE-	MCB	IN	Operation of MCB
FUSE-	DISC	IN	Line disconnector position
FUSE-	BLOCK	IN	Block of fuse failure function
FUSE-	VTF3PH	OUT	Detection of 3-phase fuse failure
FUSE-	VTSU	OUT	Block for voltage measuring functions
FUSE-	VTSZ	OUT	Block for impedance measuring functions

6.4 Setting table

Parameter	Range	Unit	Default	Parameter description
ZeroSeq	Off, On		Off	Fuse failure zero sequence function On/Off
3U0>	10-50	%	10	Operating zero sequence voltage, as a percentage of U1b
3I0<	10-50	%	10	Operating zero sequence current, as a percentage of I1b

1 Application

The REx 5xx terminals may be provided with output functions that can be controlled either from a Substation Control System or from the local HMI. The output functions can be used, for example, to control high-voltage apparatuses in switchyards. For local control functions, the local HMI can be used. Together with the configuration logic circuits, the user can govern pulses or steady output signals for control purposes within the terminal or via binary outputs.

2 Design

The command control function consists of one single command function block, CD01 for 16 binary output signals.

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

0=Off sets all outputs to 0, independent of the values sent from the station level, that is, the operator station or remote-control gateway.

1=Steady sets the outputs to a steady signal 0 or 1, depending on the values sent from the station level.

2=Pulse gives a pulse with one execution cycle duration, if a value sent from the station level is changed from 0 to 1. That means that the configured logic connected to the command function block may not have a cycle time longer than the execution cycle time for the command function block.

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

The output signals, here CD01-OUT1 to CD01-OUT16, are then available for configuration to built-in functions or via the configuration logic circuits to the binary outputs of the terminal.

The command function can be connected according to the application examples in Fig. 1 to Fig. 3. Note that the execution cyclicity of the configured logic connected to the command function block cannot have a cycle time longer than the command function block.

Fig. 1 shows an example of how the user can, in an easy way, connect the command function via the configuration logic circuit to control a high-voltage apparatus. This type of command control is normally performed by a pulse via the binary outputs of the terminal. Fig. 1 shows a close operation, but an open operation is performed in a corresponding way without the synchro-check condition.

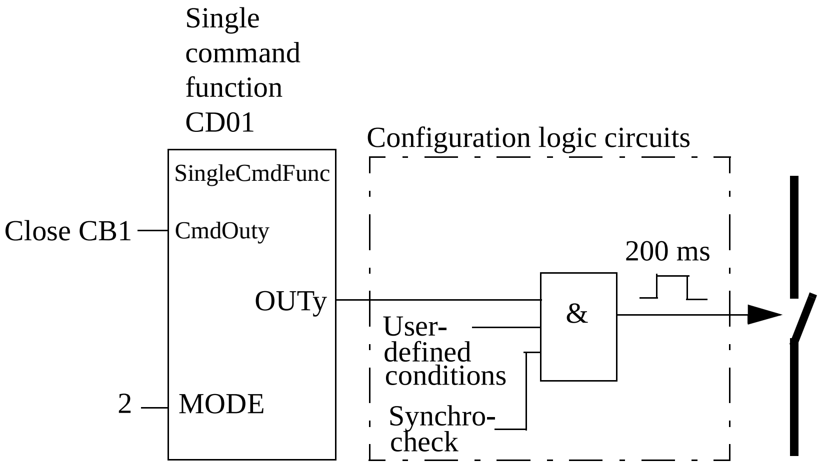


Figure 1: Application example showing a logic diagram for control of a circuit breaker via configuration logic circuits

Fig. 2 and Fig. 3 show other ways to control functions, which require steady signals On and Off. The output can be used to control built-in functions or external equipment.

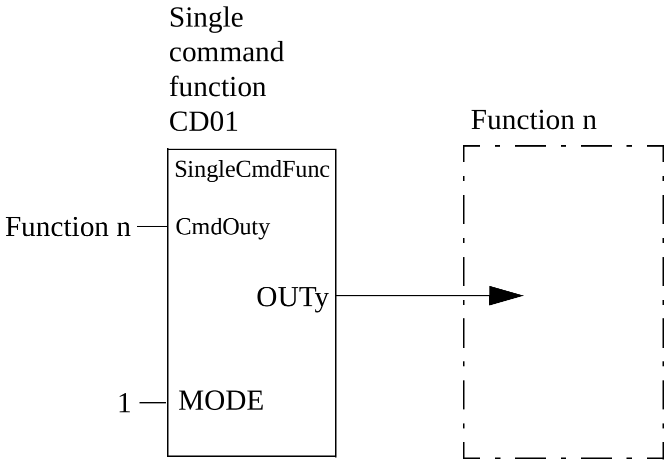


Figure 2: Application example showing a logic diagram for control of built-in functions

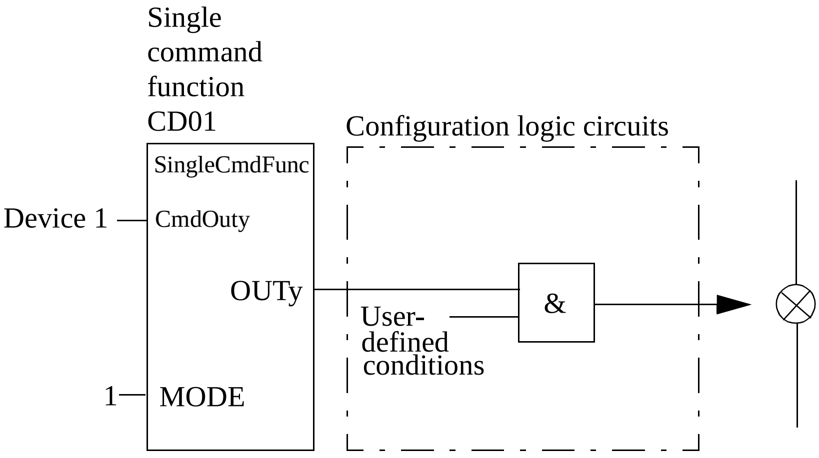


Figure 3: Application example showing a logic diagram for control of external equipment via configuration logic circuits

3 Configuration

The configuration of the signal outputs from the single command function in is made by the CAP 531 configuration tool.

4 Commands

The outputs of the single command function block can be activated from the local HMI. This can be performed under the menu:

Command
CD01

Fig. 4 shows the dialogue box for the local HMI after the selection of the command menu above. The display shows the name of the output to control (CmdOut1) and the present status (Old) and proposes a new value (New).

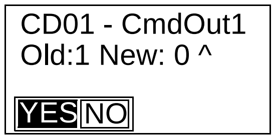


Figure 4: Command dialogue to control an output from the single command function block

The dialogue to operate an output from the single command function block is performed from different states as follows:

1. Selection active; select the:

- C button, and then the No box activates.
- Up arrow, and then New: 0 changes to New: 1. The up arrow changes to the down arrow.
- E button, and then the Yes box activates.

2. Yes box active; select the:

- C button to cancel the action and return to the CMD/CD01 menu window.
- E button to confirm the action and return to the CMD/CD01 menu window.
- Right arrow to activate the No box.

3. No box active; select the:

- C button to cancel the action and return to the CMD/CD01 menu window.
- E button to confirm the action and return to the CMD/CD01 menu window.
- Left arrow to activate the Yes box.

5 Setting

The setting parameters for the single command function are set from the CAP 531 configuration tool.

Parameters to be set are MODE, common for the whole block, and CmdOuty - including the name for each output signal. The MODE input sets the outputs to be one of the types Off, Steady, or Pulse.

The appendix shows the parameters and their setting ranges.

6 Testing

For the single command function block, it is necessary to configure the output signal to corresponding binary output of the terminal. The operation of the function is then checked from the local HMI by applying the commands with the MODE Off, Steady, or Pulse and by observing the logic statuses of the corresponding binary output.

Command control functions included in the operation of different built-in functions must be tested at the same time as their corresponding functions.

7 Appendix

7.1 Function block

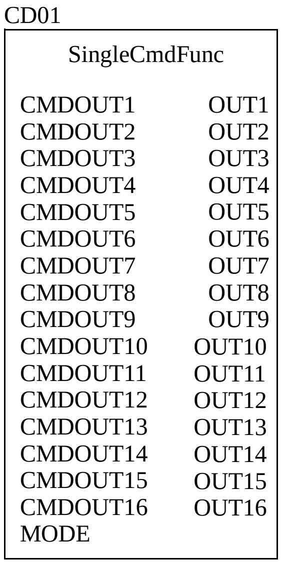


Figure 5: Function block for the single command function

7.2 Signal list

In the signal list, xx=01

Block	**Signal**	**Type**	**Description**
CDxx-	OUTy	OUT	Command output y (y=1-16)
CDxx-	CMDOUTy		See settings table
CDxx-	MODE		See settings table

7.3 Setting table

In the setting table, xx=01

Parameter	**Range**	**Unit**	**Default**	**Parameter description**
CMDOUTy	User def. string	String	CDxx-CMD-OUTy	User defined name for output y (y=1-16) of function block CDxx. String length up to 13 characters,all characters available on the HMI can be used
MODE	0, 1, 2		0	Operation mode, 0: Off, 1: Not pulsed (steady). 2: Pulsed. Can only be set from the CAP 531 configuration tool

1 Application

1.1 Synchrocheck

The synchrocheck function is used for controlled closing of a circuit in an interconnected network. When used, the function gives an enable signal at satisfied voltage conditions across the breaker to be closed. When there is a parallel circuit established, the frequency is normally the same at the two sides of the open breaker. At power swings, e.g. after a line fault, an oscillating difference can appear. Across the open breaker, there can be a phase angle and a voltage amplitude difference due to voltage drop across the parallel circuit or circuits. The synchro-check function measures the difference between the U-line and the U-bus, regarding voltage (UDiff), phase angle (PhaseDiff), and frequency (FreqDiff). It operates and permits closing of the circuit breaker when these conditions are simultaneously fulfilled.

- The voltages U-line and U-bus are higher than the set value for UHigh of the base voltage U1b.
- The differences in the voltage and phase angles are smaller than the set values of UDiff and PhaseDiff.
- The difference in frequency is less than the set value of FreqDiff. The bus frequency must also be within a range of ±5 Hz from the rated frequency.

The function can be used as a condition to be fulfilled before the breaker is closed at manual closing and/or together with the auto-recloser function.

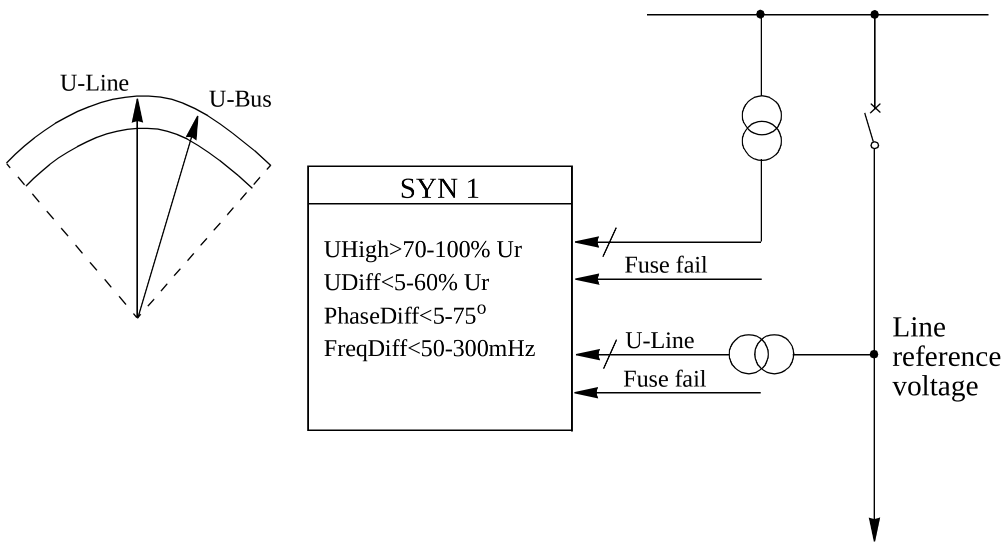


Figure 1: Synchrocheck

The voltage circuits are arranged differently depending on the number of synchrocheck functions that are included in the terminal.

In terminals intended for one bay the U-line voltage reference phase is selected on the human-machine interface (HMI). The reference voltage can be single-phase L1, L2, L3 or phase-phase L1-L2, L2-L3, L3-L1. The U-bus voltage must then be connected to the same phase or phases as are chosen on the HMI. Figure 2: shows the voltage connection.

In terminals intended for several bays, all voltage inputs are single phase circuits. The voltage can be selected for single phase or phase-to-phase measurement on the HMI. All voltage inputs must be connected to the same phase or phases.

The circuit breaker can be closed when the conditions for FreqDiff, PhaseDiff, and UDiff are fulfilled with the UHigh condition.

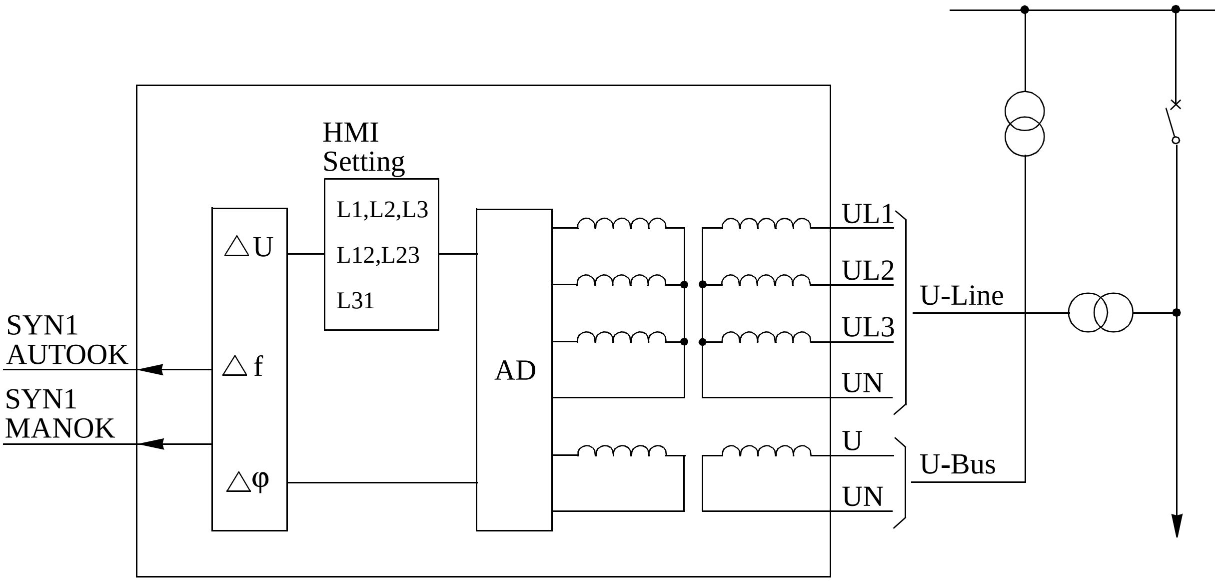


Figure 2: Connection of the synchrocheck function for one bay.

1.2 Energising check

The energising check is made when a disconnected line is to be connected to an energised section of a network, see Figure 3:. The check can also be set to allow energisation of the busbar or in both directions.

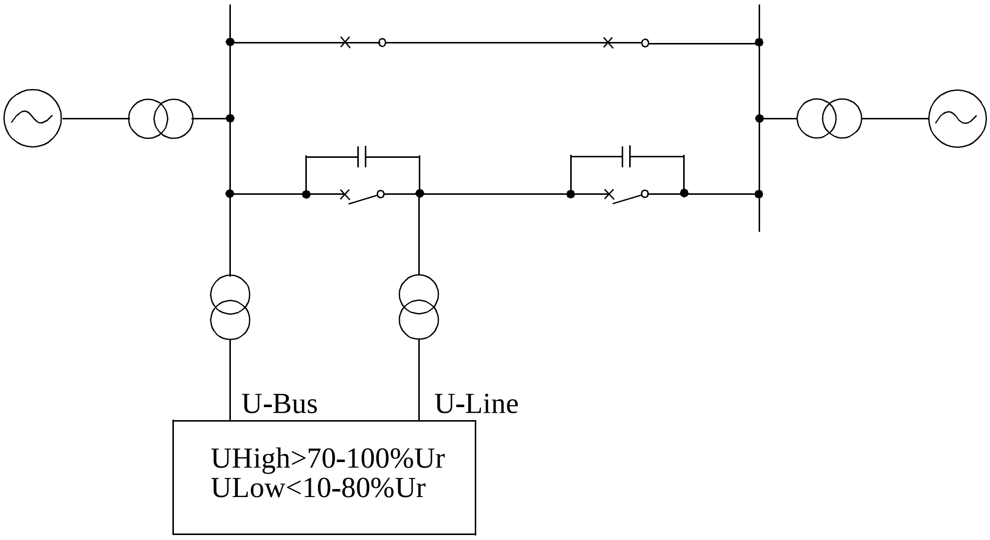


Figure 3: Principle for energising check.

The voltage level considered to be a non-energised bus or line is set on the HMI. An energising can occur — depending on the set direction of the energising function. There are separate settable limits for energised (live) condition, UHigh, and non-energised (dead) ULow conditions. The equipment is considered energised if the voltage is above the set value UHigh (e.g. 80% of base voltage), and non-energised if it is below the set value, ULow (e.g. 30% of the base voltage). The user can set the UHigh condition between 70-100% U1b and the ULow condition between 10-80% U1b.

A disconnected line can have a considerable potential due to, for instance, induction from a line running in parallel, or by being fed via the extinguishing capacitors in the circuit breakers. This voltage can be as high as 30% or more of the rated voltage of the line.

The energising operation can be set to operate in either direction over the circuit breaker, or it can be permitted to operate in both directions. Use the AutoEnerg and ManEnerg HMI setting to select the energising operation in:

- Both directions (Both)
- Dead line live bus (DLLB)
- Dead bus live line (DBLL)

The voltage check can also be set Off. A closing impulse is issued to the circuit breaker if one of the U-line or U-bus voltages is High and the other is Low, that is, when only one side is energised. The user can set AutoEnerg and ManEnerg to enable different conditions during automatic and manual closing of the circuit breaker.

In the manual mode it is also possible to allow closing when both sides of the breaker are dead. This is done by setting the parameter ManDBDL = “On” **and** ManEnerg to “DLLB”, “DBLL” or “Both”.

1.3 Voltage selection

The voltage selection function is used for the synchronisation and synchronism (SYNx) and energising check functions. When the terminal is used in a double bus, the voltage that should be selected depends on the positions of the breakers and/or disconnectors. By checking the position of the disconnectors and/or breakers auxiliary contacts, the terminal can select the right voltage for the synchronism and energising function. Select the type of voltage selection from the synchrocheck, Uselection, SingleBus or DbleBus on the HMI. When using voltage selection, an extra I/O-module is required.

The configuration of internal signal inputs and outputs may be different for different busbar systems, and the actual configuration for the substation must be done during engineering of the terminal.

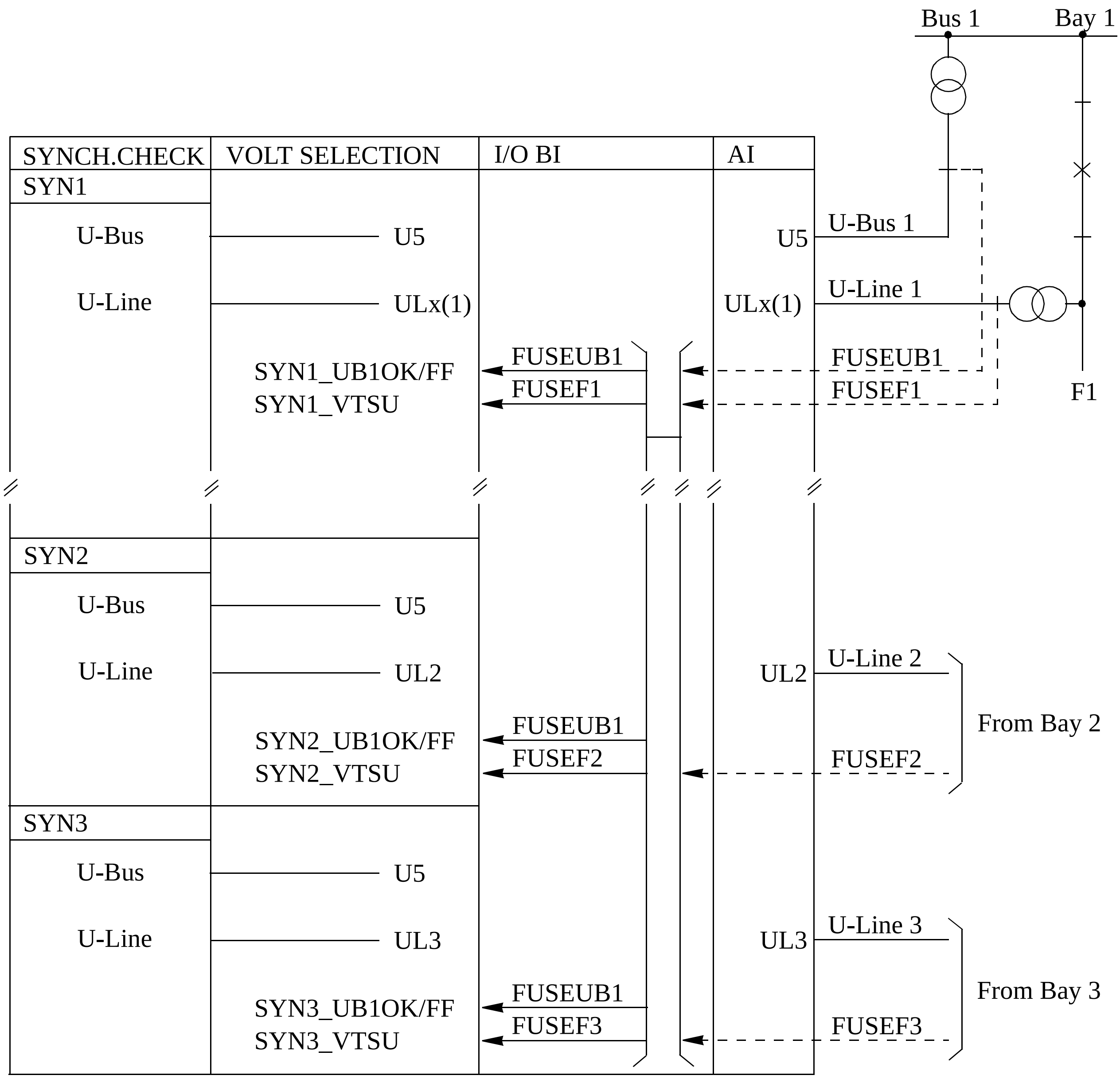


Figure 4: Voltage connection in a single busbar arrangement. Alternatively, it can be extended up to three bays in one terminal.

1.3.1 Voltage selection for a single busbar

Single bus is selected on the HMI. Figure 4: shows the principle for the connection arrangement. One terminal unit is used for each bay, or it can alternatively be common for three bays. For the synchrocheck (SYNx) and energising check function, there is one voltage transformer at each side of the circuit breaker. The voltage transformer circuit connections are straight forward, no special voltage selection is needed.

For the synchrocheck and energising check, the voltage from Bus 1 (SYNx-U-Bus) is connected to the single phase analogue input (U5) on the terminal unit.

For the terminal intended for one bay, the line voltage (SYN1-U-line 1) is connected as a three-phase voltage to the analogue inputs UL1, UL2, UL3 (ULx). For the version intended for three bays, the line voltages are connected as three single-phase inputs, UL1 for Bay 1, UL2 for Bay 2, and UL3 for Bay 3.

1.3.1.1 Fuse failure and Voltage OK signals

The external fuse-failure signals or signals from a tripped fuse switch/ MCB are connected to binary inputs configured to inputs of the synchro-check functions in the terminal. There are two alternative connection possibilities. Inputs named OK must be supplied if the voltage circuit is healthy. Inputs named FF must be supplied if the voltage circuit is faulty.

The SYNx-UB1OK and SYNx-UB1FF inputs are related to the busbar voltage. Configure them to the binary inputs that indicate the status of the external fuse failure of the busbar voltage. The SYNx-VTSU input is related to the line voltage from each line.

For the terminal that is intended for one bay, the user can use the FUSE-VTSU signal from the built-in optional selectable fuse-failure function as an alternative to the external fuse-failure signals.

In case of a fuse failure, the energising check (dead line-check) is blocked via the inputs (SYN1-UB1OK/FF or SYN1-VTSU).

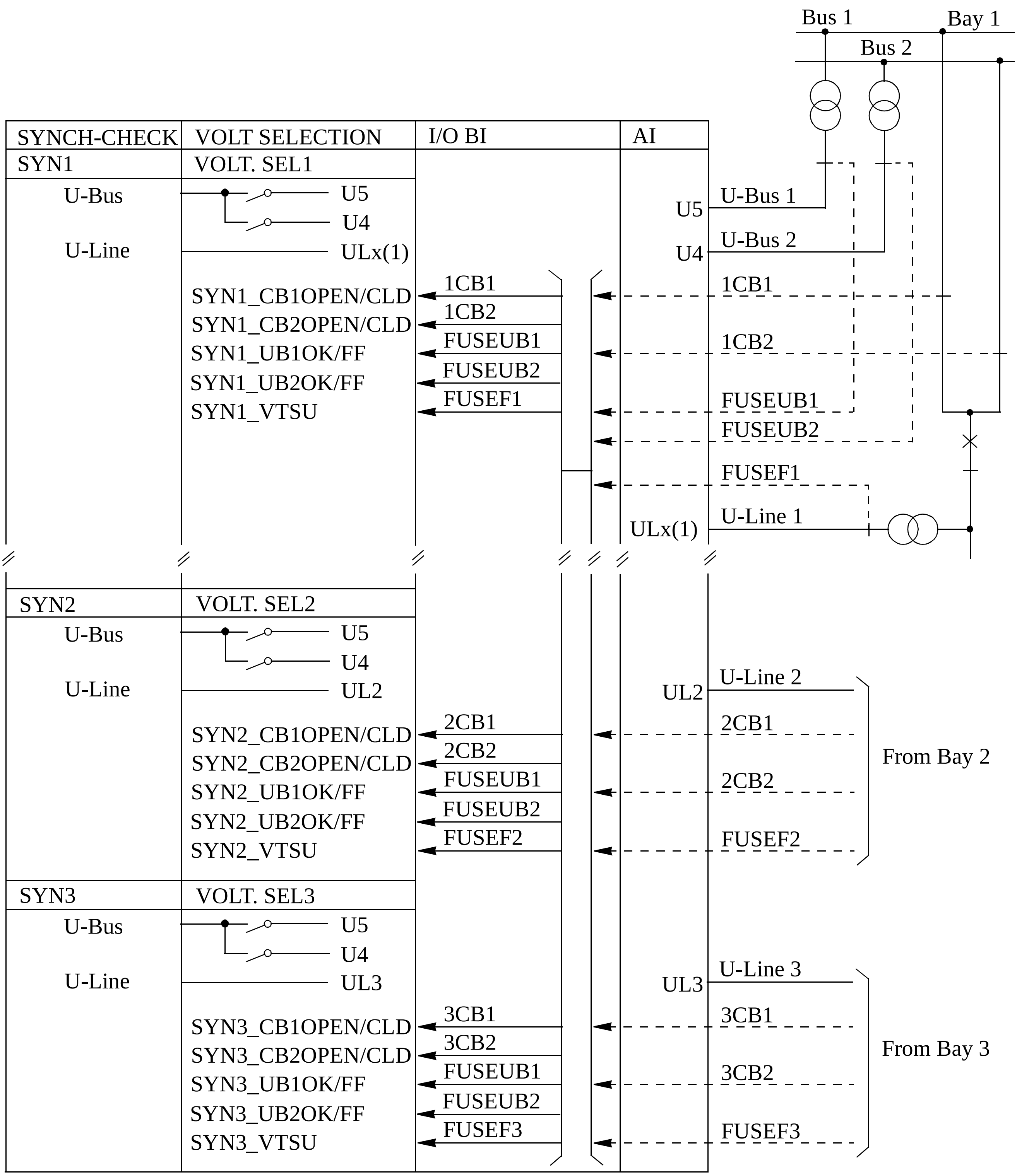


Figure 5: Voltage selection in a double bus arrangement. Alternatively it can be extended up to three bays in one terminal

1.3.2 Voltage selection for a double bus

Select DbleBus on the HMI. Figure 5: shows the principle for the connection arrangement. One terminal unit is used for each bay or it can alternatively be common for three bays. For the synchrocheck (SYNx) and energising check function, the voltages on the two busbars are selected by voltage selection (VOLT.SELx) in the terminal unit. The bus voltage from Bus 1 is fed to the U5 analogue single-phase input, and the bus voltage from Bus 2 is fed to the U4 analogue single-phase input. The line voltage transformers are connected as a three-phase voltage UL1, UL2, UL3 (ULx) to the input U-line. For the version intended for three bays, the line voltages are connected as three, single-phase inputs, UL1 for Bay1, UL2 for Bay2 and UL3 for Bay3.

The selection of the bus voltage is made by checking the position of the disconnectors' auxiliary contacts connected via binary inputs of the voltage selection logic inputs, SYNx-CB1OPEN (Disconnector section 1 open), SYNx-CB1CLD (Disconnector section 1 closed) and SYNx-CB2OPEN (Disconnector section 2 open), SYNx-CB2CLD (Disconnector section 2 closed).

1.3.2.1 Fuse failure and Voltage OK signals

The external fuse-failure signals or signals from a tripped fuse switch/MCB are connected to binary inputs configured to inputs of the synchrocheck functions in the terminal. There are two alternative connection possibilities. Inputs named OK must be supplied if the voltage circuit is healthy. Inputs named FF must be supplied if the voltage circuit is faulty.

The SYNx-UB1(2)OK and SYNx-UB1(2)FF inputs are related to each busbar voltage. The SYNx-VTSU input is related to each line voltage. Configure them to the binary inputs that indicate the status of the external fuse failure of the busbar respectively the line voltage. Only the fuse failure of a selected voltage causes a blocking of the relevant energising check unit.

For the terminal that is intended for one bay, you can use the FUSE-VTSU signal from the built-in optional selectable fuse-failure function as an alternative to the external fuse-failure signals.

In case of a fuse failure, the energising check (dead line-check) is blocked via the inputs (SYNx-UB1OK/FF, SYNx-UB2OK/FF or SYNx-VTSU).

2 Theory of operation

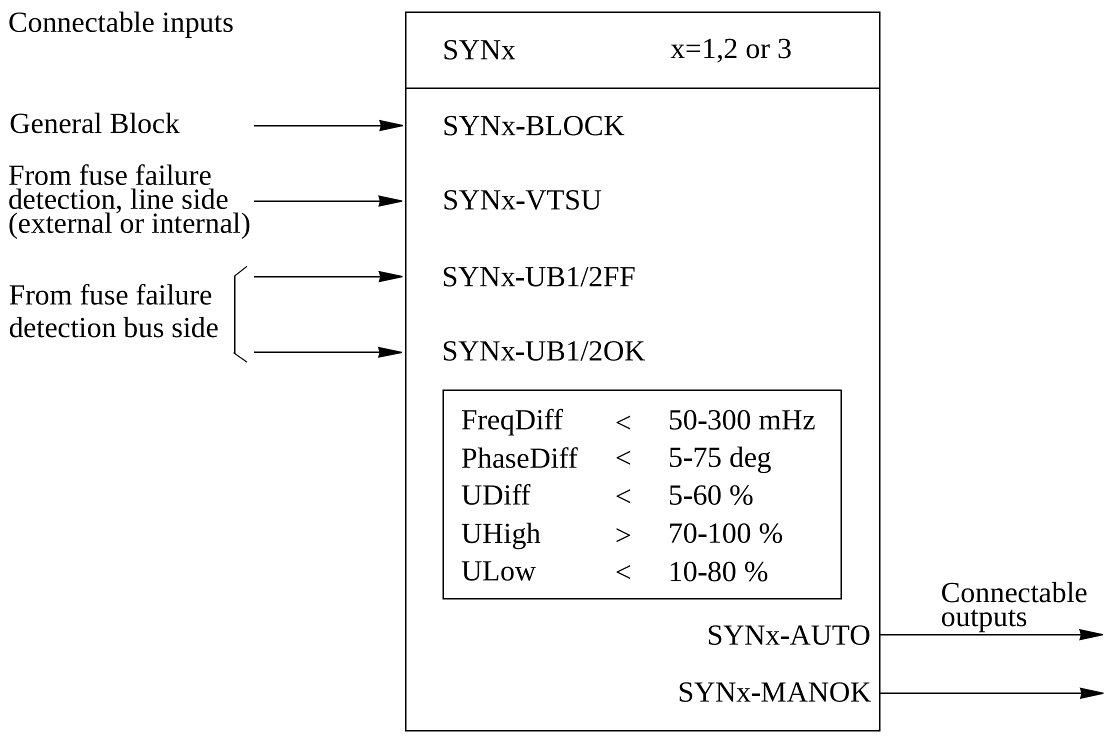


Figure 6: Input and output signals.

2.1 Synchrocheck

Description of input and output signals for the synchro-check function.

Input signals	**Description**
SYNx-BLOCK	General block input from any external condition, that should block the synchrocheck**.**
SYNx-VTSU	The SYNC function cooperates with the FUSE-VTSU connected signal, which is the built-in optional fuse failure detection. It can also be connected to external condition for fuse failure. This is a blocking condition for the energising function.
SYNx-UB1FF	External fuse failure input from busbar voltage Bus 1 (U5). This signal can come from a tripped fuse switch (MCB) on the secondary side of the voltage transformer. In case of a fuse failure the energising check is blocked.
SYNx-UB1OK	No external voltage fuse failure (U5). Inverted signal.

SYNx-UB2FF	External fuse failure input from busbar voltage Bus 2 (U4). This signal can come from a tripped fuse switch (MCB) on the secondary side of the voltage transformer. In case of a fuse failure the energising check is blocked.
SYNx-UB2OK	No external voltage fuse failure (U4). Inverted signal.

Output signals	**Description**
SYNx-AUTOOK	Synchrocheck/energising OK. The output signal is high when the synchrocheck conditions set on the HMI are fulfilled. It can also include the energising condition, if selected. The signal can be used to release the auto-recloser before closing attempt of the circuit breaker. It can also be used as a free signal.
SYNx-MANOK	Same as above but with alternative settings of the direction for energising to be used during manual closing of the circuit breaker.

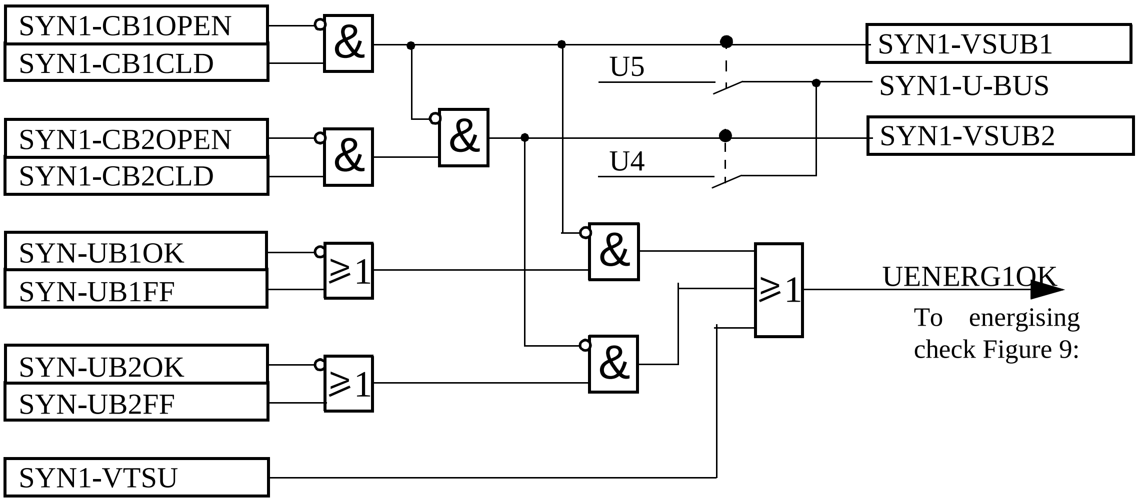


Figure 7: Voltage selection logic in a double bus, single breaker arrangement. In case of three bay arrangement the 1 in SYN1 and UENERG1OK are replaced by 2 and 3 in the logic.

2.2 Voltage selection

Description of the input and output signals shown in the above simplified logic diagrams for voltage selection:

Input signal	Description
SYNx-CB1OPEN	Disconnector section of Bay x open. Connected to the auxiliary contacts of a disconnector section in a double-bus, single- breaker arrangement, to inform the voltage selection about the positions.
SYNx-CB1CLD	Disconnector section of Bay x closed. Connected to the auxiliary contacts of a disconnector section in a double-bus, single-breaker arrangement to inform the voltage selection about the positions.
SYNx-CB2OPEN	Same as above but for disconnector section 2.
SYNx-CB2CLD	Same as above but for disconnector section 2.
SYNx-UB1FF	External fuse failure input from busbar voltage Bus 1 (U5). This signal can come from a tripped fuse switch (MCB) on the secondary side of the voltage transformer. In case of a fuse failure, the energising check is blocked.
SYNx-UB1OK	No external voltage fuse failure (U5). Inverted signal.
SYNx-UB2FF	External fuse failure input from busbar voltage Bus 2 (U4). This signal can come from a tripped fuse switch (MCB) on the secondary side of the voltage transformer. In case of fuse failure, the energising check is blocked.

SYNx-UB2OK	No external voltage fuse failure (U4). Inverted signal.
SYNx-VTSU	Internal fuse failure detection or configured to a binary input indicating external fuse failure of the UL1, UL2, UL3 line-side voltage. Blocks the energising function.

Output signals	**Description**
SYNx-VSUB1	Signal for indication of voltage selection from Bus 1 voltage.
SYNx-VSUB2	Signal for indication of voltage selection from Bus 1 voltage.

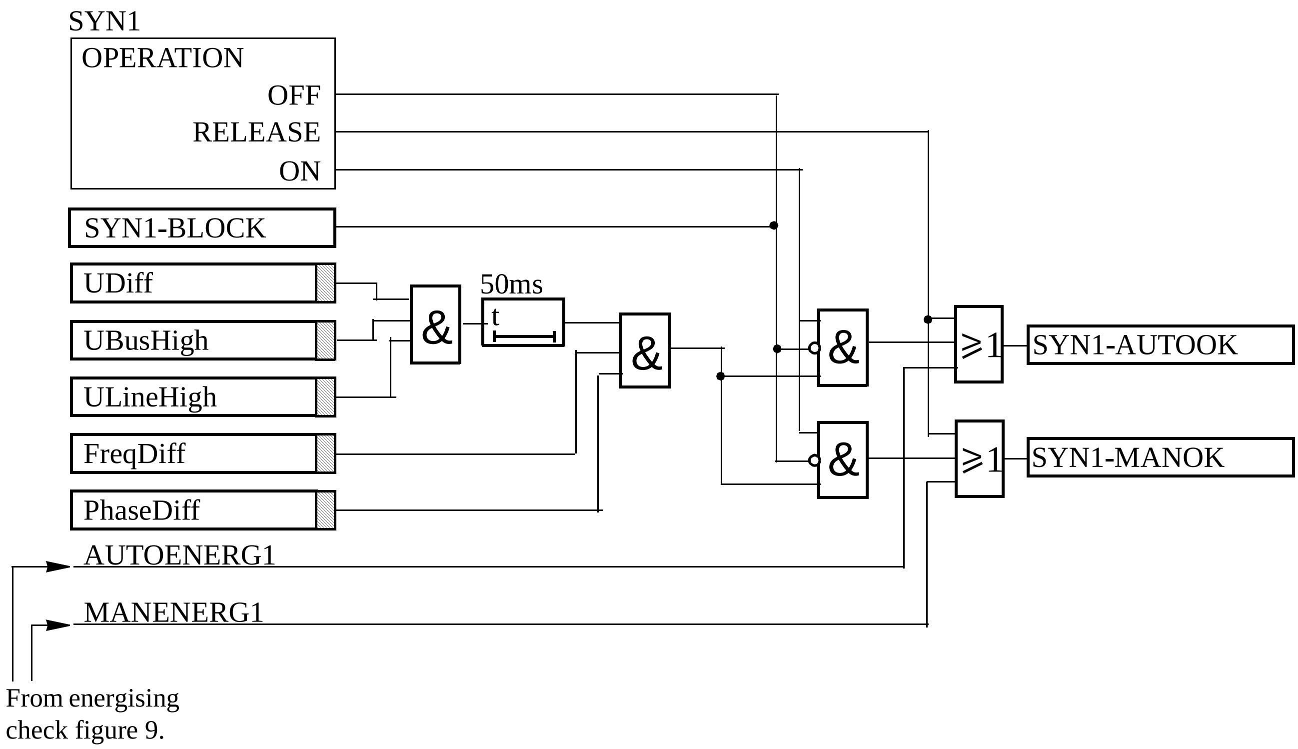


Figure 8: Simplified logic diagram - Synchrocheck.

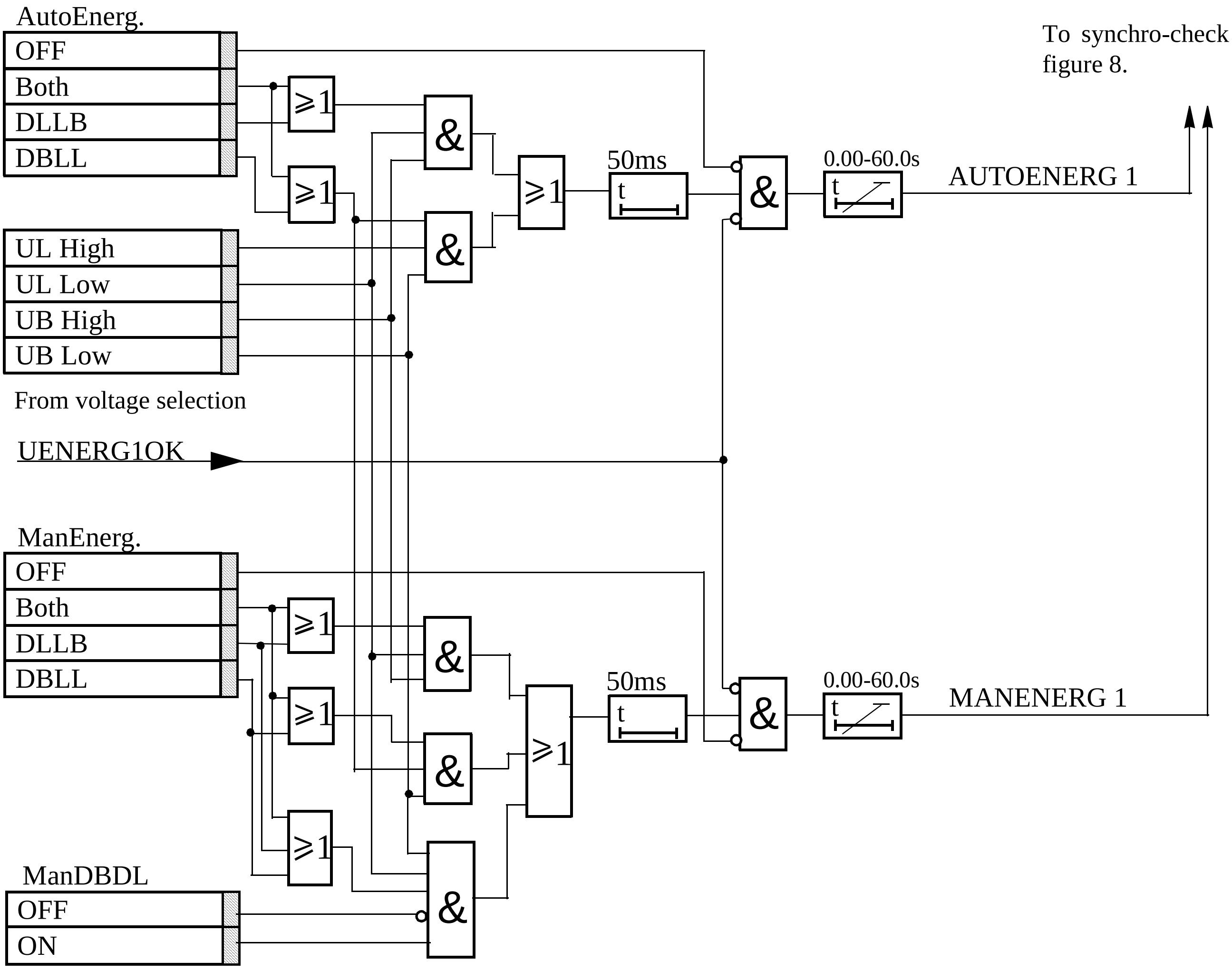


Figure 9: Simplified logic diagram - energising check.

3 Setting

The setting parameters are accessible through the HMI. The parameters for the synchrocheck function are found in the HMI tree under:

Settings
Functions
Group n
SynchroCheck
SynchroCheck n (n=1-3)

(The number of SynchroCheck functions is dependent of the version)

Comments regarding settings.

3.1 Operation

Off/Release/On

Off	The synchrocheck function is off and the output is low.
Release	There are fixed, high output signals SYN1-AUTOOK = 1 and SYN1-MANOK = 1.
On	The function is in service and the output signal depends on the input conditions.

3.2 Input phase

The measuring phase of the UL1, UL2, UL3 line voltage, which can be of a single-phase (phase-neutral) or two-phases (phase-phase). (Only available in terminals intended for one bay).

3.3 UMeasure

Selection of single-phase (phase-neutral) or two-phase (phase-phase) measurement.(Only available in terminals intended for several bays).

3.4 PhaseShift

This setting is used to compensate for a phase shift caused by a line transformer between the two measurement points for UBus and ULine. The set value is added to the measured phase difference. The bus voltage is reference voltage.

3.5 URatio

The URatio is defined as URatio=UBus/ULine. A typical use of the setting is to compensate for the voltage difference caused if one wishes to connect the UBus phase-phase and ULine phase-neutral. The “Input phase”-setting should then be set to phase-phase and the “URatio”-setting to sqr3=1.732. This setting scales up the line voltage to equal level with the bus voltage.

3.6 USelection

Selection of single or double bus voltage-selection logic.

3.7 AutoEnerg and ManEnerg

Two different settings can be used for automatic and manual closing of the circuit breaker.

Off	The energising function is Off
DLLB	The line voltage U-line is low, below (10-80% U1b) and the bus voltage U-bus is high, above (70-100% U1b).
DBLL	The bus voltage U-bus is low, below (10-80% U1b) and the line voltage U-line is high, above (70-100% U1b).
Both	Energising can be done in both directions, DLLB or DBLL.
tAutoEnerg	The required consecutive time of fulfillment of the energising condition to achieve SYN1-AUTOOK.
tManEnerg	The required consecutive time of fulfillment of the energising condition to achieve SYN1-MANOK.

3.8 ManDBDL

If the parameter is set to “On”, closing is enabled when Both U-Line and U-bus are below ULow and ManEnerg is set to “DLLB”, “DBLL” or “Both”.

4 Testing

At periodical checks, the functions should preferably be tested with the used settings. To test a specific function, it might be necessary to change some setting parameters, for example:

- AutoEnerg = On/Off/DLLB/DBLL/Both
- ManEnerg = Off
- Operation = Off, On

The tests explained in section “Synchro-check tests” on page 102 describe the settings, which can be used as references during testing, are presented before the final settings are specified. After testing, restore the equipment to the normal or desired settings.

4.1 Test equipment

A secondary injection test set with the possibility to alter the phase angle by regulation of the resistive and reactive components is needed. Here, the phase angle meter is also needed. To perform an accurate test of the frequency difference, a frequency generator at one of the input voltages is needed. The tests can also be performed with the computer-aided test system FREJA which has a specially designed program for evaluating the synchro-check function.
Figure 10: shows the general test connection principle, which can be used during testing.

This description describes the test of the version intended for one bay.

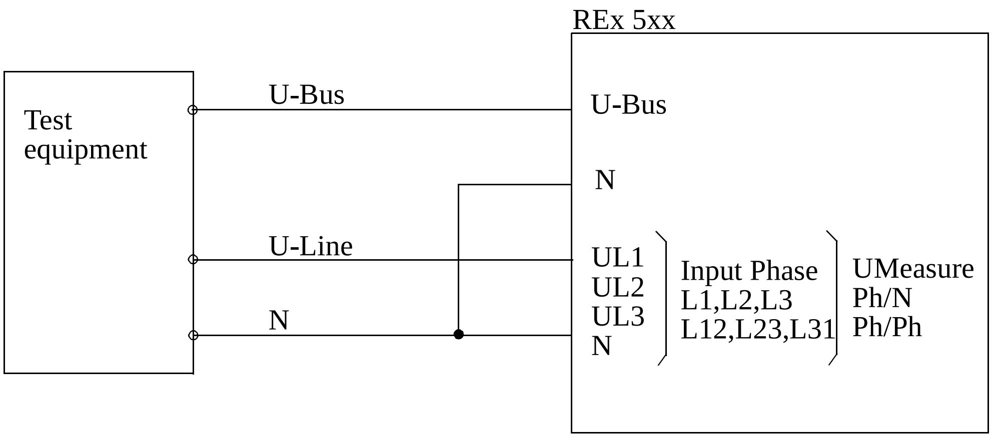


Figure 10: General test connection for synchro-check with three-phase voltage connected to the line side.

4.2 Synchro-check tests

4.2.1 Test of voltage difference

Set the voltage difference at 30% U1b on the HMI, and the test should verify that operation is achieved when the voltage difference UDiff is lower than 30% U1b.

These voltage inputs are used:

U-line UL1, UL2 or UL3 voltage input on the terminal.

U-bus U5 voltage input on the terminal

These HMI settings can be used during the test if the final setting is not determined:

1 Set these HMI settings, which are found under:

Settings
  Functions
    Group n
      SynchroCheck
        SynchroCheck1

Table 1:

Parameter:	Setting:
Operation	On
InputPhase	UL1
USelection	SingleBus
PhaseShift	0 deg
URatio	1.00
AutoEnerg	Off
ManEnerg	Off
ManDBDL	Off
UHigh	70% U1b
ULow	40% U1b
FreqDiff	0.05 Hz
PhaseDiff	45°
UDiff	30% U1b
tAutoEnerg	0.5 s
tManEnerg	0.5 s

2 **Test with UDiff = 0%**

- Apply voltages U-line (UL1) = 80% U1b and U-Bus (U5) = 80% U1b with no frequency or phase difference.
- Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.
- The test can be repeated with different voltage values to verify that the function operates within UDiff <30%.

3 **Test with UDiff = 40%**

- Increase the U-bus (U5) to 120% U1b, and the U-line (UL1) = 80% U1b.

- Check that the two outputs are **NOT** activated.

4 **Test with UDiff = 20%, Uline < UHigh**

- Decrease the U-line (UL1) to 60% U1b and the U-bus (U5) to be equal to 80% U1b.
- Check that the two outputs are **NOT** activated.

5 **Test with URatio=0.20**

- Run the test under section 2 to 4 but with U-bus voltages 5 times lower.

6 **Test with URatio=5.00**

- Run the test under section 2 to 4 but with U-line voltages 5 times lower.

4.2.2 Test of phase difference

The phase difference is set at 45° on the HMI, and the test should verify that operation is achieved when the PhaseDiff (phase difference) is lower than 45°.

1 Set these HMI settings:

Table 2: Test settings for phase difference

Parameter:	Setting:
Operation	On
InputPhase	UL1
USelection	SingleBus
PhaseShift	0 deg
URatio	1.00
AutoEnerg	Off
ManEnerg	Off
ManDBDL	Off
UHigh	70% U1b
ULow	40% U1b
FreqDiff	0.05 Hz
PhaseDiff	45°
UDiff	15% U1b
tAutoEnerg	0.5 s
tManEnerg	0.5 s

2 **Test with PhaseDiff = 0°**

Apply voltages U-line (UL1) = 100% U1b and U-bus (U5) = 100% U1b, with no frequency or phase difference.
Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.

By changing the phase angle on U1 connected to U-bus, between +/- 45° you can check that the two outputs are activated for a PhaseDiff lower than 45°. It should not operate for other values. See Figure 11:.

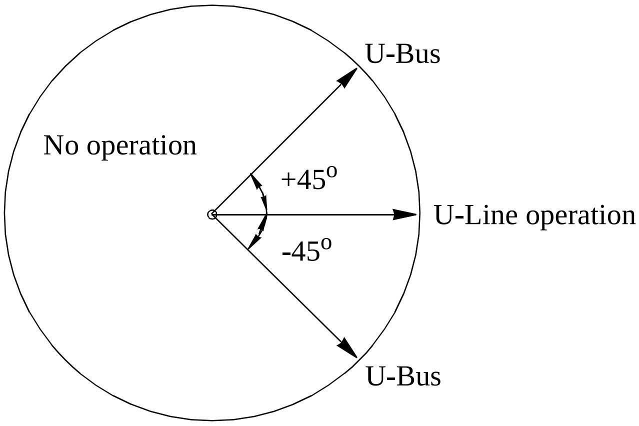


Figure 11: Test of phase difference.

4 Apply a PhaseShift setting of 10 deg. Change the phase angle between +55 and -35 and verify that the two outputs are activated for phase differences between these values but not for phase differences outside. See Figure 12:.

Change the PhaseShift setting to 350 deg. Change the phase angle between +35 and -55 and verify as above.

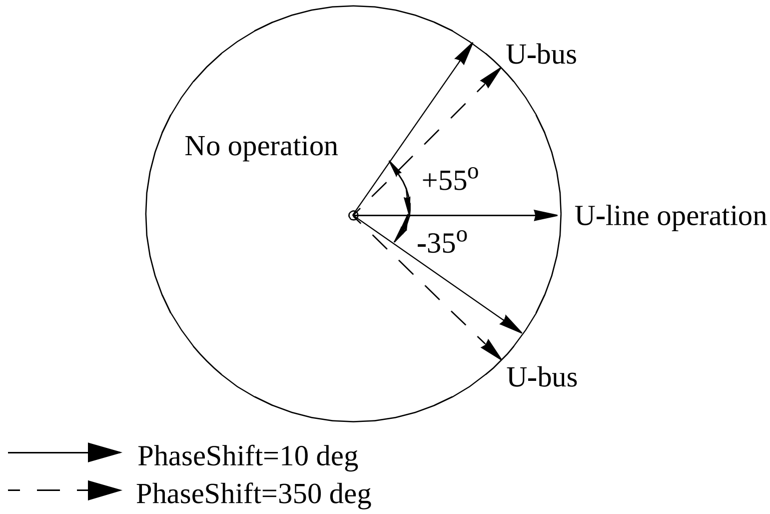


Figure 12: Test of phase difference.

4.2.3 Test of frequency difference

The frequency difference is set at 50 mHz on the HMI, and the test should verify that operation is achieved when the FreqDiff frequency difference is lower than 50 mHz.

1 Use the same HMI setting as in section “Test of phase difference” on page 104.

2 **Test with FreqDiff = 0 mHz**
Apply voltages U-Line (UL1) equal to 100% U1b and U-Bus (U5) equal to 100% U1b, with a frequency difference equal to 0 mHz and a phase difference lower than 45°. Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.

3 **Test with FreqDiff = 1Hz**
Apply voltage to the U-line (UL1) equal to 100% U1b with a frequency equal to 50 Hz and voltage U-bus (U5) equal to 100% U1b, with a frequency equal to 49 Hz.
Check that the two outputs are **NOT** activated.

4 The test can be repeated with different frequency values to verify that the function operates for values lower than the set ones. If the FREJA program, Test of synchronising relay, is used the frequency can be changed continuously.

Note that a frequency difference also implies a floating mutual-phase difference. So the SYN1-AUTOOK and SYN1-MANOK outputs might NOT be stable, even though the frequency difference is within set limits, because the phase difference is not stable!

4.2.4 Test of reference voltage

1 Use the same basic test connection as in Figure 10:. The UDiff between the voltage connected to U-bus and U-line should be 0%, so that the SYN1-AUTOOK and SYN1-MANOK outputs are activated first.
Change the U-Line voltage connection to UL2 without changing the setting on the HMI
Check that the two outputs are **NOT** activated.

2 The test can also be repeated by moving the U-line to the UL3 input.

4.3 Test of energising check

Use these voltage inputs:

U-line = UL1, UL2 or UL3 voltage input on the terminal.

U-bus = U5 voltage input on the terminal.

4.3.1 Test of dead line live bus (DLLB)

The test should verify that the energising function operates for a low voltage on the U-Line and for a high voltage on the U-bus. This corresponds to an energising of a dead line to a live bus.

Use these HMI settings during the test if the final setting is not determined.

1 Set these HMI settings:

Table 3: Test settings for DLLB

Parameter:	Setting:
Operation	On
InputPhase	UL1
USelection	SingleBus
PhaseShift	0 deg
URatio	1.00
AutoEnerg	DLLB
ManEnerg	DLLB
ManDBDL	Off
UHigh	80% U1b
ULow	40% U1b
FreqDiff	0.05 Hz
PhaseDiff	45°
UDiff	15% U1b
tAutoEnerg	0.5 s
tManEnerg	0.5 s

2 Apply a single-phase voltage 100% U1b to the U-bus (U5), and a single-phase voltage 30% U1b to the U-line (UL1).

3 Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.

4 Increase the U-Line (UL1) to 60% U1b and U-Bus(U5) to be equal to 100% U1b. The outputs should **NOT** be activated.

5 The test can be repeated with different values on the U-Bus and the U-Line.

4.3.2 Dead bus live line (DBLL)

The test should verify that the energising function operates for a low voltage on the U-bus and for a high one on the U-line. This corresponds to an energising of a dead bus from a live line.

1 Change the HMI settings AutoEnerg and ManEnerg to DBLL**.**

2 Apply a single-phase voltage of 30% U1b to the U-bus (U5) and a single-phase voltage of 100% U1b to the U-line (UL1).

3 Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.

4 Decrease the U-line to 60% U1b and keep the U-bus equal to 30% U1b.
The outputs shall **NOT** be activated.

5 The test can be repeated with different values on the U-bus and the U-line.

4.3.3 Energising in both directions (DLLB or DBLL)

1 Change the HMI settings AutoEnerg and ManEnerg to Both.

2 Apply a single-phase voltage of 30% U1b to the U-line (UL1) and a single-phase voltage of 100% U1b to the U-bus (U5).

3 Check that the “SYN1-AUTOOK” and “SYN1-MANOK” outputs are activated.

4 Change the connection so that the U-line (UL1) is equal to 100% U1b and the U-bus (U5) is equal to 30% U1b.

5 The outputs should still be activated.

6 The test can be repeated with different values on the U-bus and the U-line.

7 Restore the equipment to normal or desired settings.

4.3.4 Dead bus Dead line (DBDL)

The test should verify that the energising function operates for a low voltage on both the U-bus the U-line, i.e closing of the breaker in a non energised system.

1 Set AutoEnerg to Off and ManEnerg to DBLL.

Set ManDBDL to On.

2 Apply a single-phase voltage of 30% U1b to the U-bus (U5) and a single-phase voltage of 30% U1b to the U-line (UL1).

3 Check that the SYN1-MANOK output is activated.

4 Increase the U-bus to 80% U1b and keep the U-line equal to 30% U1b.

The outputs shall **NOT** be activated.

5 Repeat the test with ManEnerg set to DLLB and Both, and different values on the U-bus and the U-line.

4.4 Test of voltage selection

This test should verify that the correct voltage is selected for the measurement in the energising function used in a double-bus arrangement. Apply a single-phase voltage of 30% U1b to the U-line (UL1) and a single-phase voltage of 100% U1b to the U-bus (U5).

If the SYN1-UB1/2OK inputs for the fuse failure are used, normally they must be activated, thus activated and deactivated must be inverted in the description of tests below.

1 Set these HMI settings:

Table 4: Test settings for voltage selection

Parameter	**Setting**
Operation	On
InputPhase	UL1
USelection	DbleB
PhaseShift	0 deg
URatio	1.00
AutoEnerg	Both
ManEnerg	Both
ManDBDL	Off
UHigh	80% U1b
ULow	40% U1b
FreqDiff	0,05 Hz
PhaseDiff	45°
UDiff	15% U1b
tAutoEnerg	0.5 s
tManEnerg	0.5 s

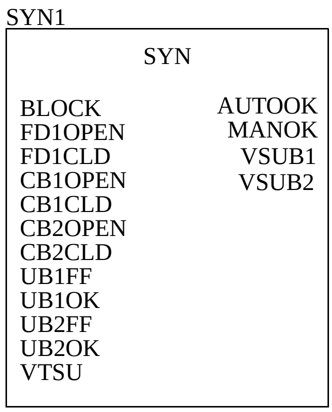
2 Connect the signals below to binary inputs and binary outputs. Apply signals according to the table and verify that correct output signals are generated.

Table 5: Signals

VOLTAGE FROM BUS1 U5	VOLTAGE FROM BUS2 U4	BINARY INPUTS	CB1OPEN	CB1CLD	CB2OPEN	CB2CLD	UB1FF	UB2FF	VTSU	BINARY OUTPUTS	AUTOOK	MANOK	VSUB1	VSUB2
1	0		1	0	1	0	0	0	0		1	1	1	0
1	0		0	1	1	0	0	0	0		1	1	1	0
1	0		0	1	1	0	1	0	0		0	0	1	0
1	0		0	1	1	0	0	1	0		1	1	1	0
1	0		0	1	1	0	0	0	1		0	0	1	0
1	0		0	1	0	1	0	0	0		1	1	1	0
1	0		1	0	0	1	0	0	0		0	0	0	1
0	1		0	1	1	0	0	0	0		0	0	1	0
0	1		0	1	0	1	0	0	0		0	0	1	0
0	1		1	0	0	1	0	0	0		1	1	0	1
0	1		1	0	0	1	1	0	0		1	1	0	1
0	1		1	0	0	1	0	1	0		0	0	0	1
0	1		1	0	0	1	0	0	1		0	0	0	1
0	1		0	1	0	1	0	0	0		0	0	1	0

5 Appendix

5.1 Function block



5.2 Signal list

Block	**Signal**	**Type**	**Description**
SYNx-	BLOCK	IN	Block of synchrocheck function x (x=1-3)
SYNx-	FD1OPEN	IN	Feeder disconnector 1 open
SYNx-	FD1CLD	IN	Feeder disconnector 1 closed
SYNx-	CB1OPEN	IN	Breaker section 1 open
SYNx-	CB1CLD	IN	Breaker section 1 closed
SYNx-	CB2OPEN	IN	Breaker section 2 open
SYNx-	CB2CLD	IN	Breaker section 2 closed
SYNx-	UB1FF	IN	External voltage fuse failure, bus 1
SYNx-	UB1OK	IN	External voltage fuse healthy, bus 1
SYNx-	UB2FF	IN	External voltage fuse failure, bus 2
SYNx-	UB2OK	IN	External voltage fuse healthy, bus 2
SYNx-	VTSU	IN	Block from internal fuse failure supervision or from external fuse failure of the line voltage.
SYNx-	AUTOOK	OUT	Automatic synchronism/energising check OK
SYNx-	MANOK	OUT	Manual synchronism/energising check OK
SYNx-	VSUB1	OUT	Voltage selection from bus 1
SYNx-	VSUB2	OUT	Voltage selection from bus 2

5.3 Setting table

Parameter	Range	Unit	Default	Parameter description
Operation	Off, Release, On		Off	Synchrocheck function Off/Release/On
InputPhase	L1, L2, L3, L1-L2, L2-L3, L3-L1		L1	Select input voltage
UMeasure	Ph/N, Ph/Ph		Ph/N	Select input voltage Ph/N or Ph/Ph
PhaseShift	0-360	degrees	0	Phase shift between U-bus and U-line
URatio	0.20-5.00		1.00	Voltage ratio between U-bus and U-line
USelection	SingleBus, DbleBus		Single-Bus	Bus arrangement for voltage selection
AutoEnerg	Off, DLLB, DBLL, Both		Off	Auto energising/synchronising method
ManEnerg	Off, DLLB, DBLL, Both		Off	Manual energising/synchronising method
ManDBDL	Off, On		Off	Manual dead bus and dead line energising
UHigh	50-120	%	80	High voltage limit, as a percentage of Ub
ULow	10-100	%	40	Low voltage limit, as a percentage of Ub
FreqDiff	0.05-0.30	Hz	0.20	Frequency difference limit
PhaseDiff	5-75	degrees	20	Phase difference limit
UDiff	5-50	%	20	Voltage difference limit, as a percentage of Ub
tAutoEnerg	0.000-60.000	s	0.100	Auto energising time delay period
tManEnerg	0.000-60.000	s	0.100	Manual energising time delay period

1 Application

1.1 Synchrocheck

The synchrocheck function is used for controlled closing of a circuit in an interconnected network. When used, the function gives an enable signal at satisfied voltage conditions across the breaker to be closed. When there is a parallel circuit established, the frequency is normally the same at the two sides of the open breaker. At power swings, e.g. after a line fault, an oscillating difference can appear. Across the open breaker, there can be a phase angle and a voltage amplitude difference due to voltage drop across the parallel circuit or circuits. The synchrocheck function measures the difference between the U-line and the U-bus, regarding voltage (UDiff), phase angle (PhaseDiff), and frequency (FreqDiff). It operates and permits closing of the circuit breaker when these conditions are simultaneously fulfilled.

- The voltages U-line and U-bus are higher than the set value for UHigh of the base voltage U1b.
- The differences in the voltage and phase angles are smaller than the set values of UDiff and PhaseDiff.
- The difference in frequency is less than the set value of FreqDiff. The bus frequency must also be within a range of ±5 Hz from the rated frequency.

The function can be used as a condition to be fulfilled before the breaker is closed at manual closing and/or together with the auto-recloser function.

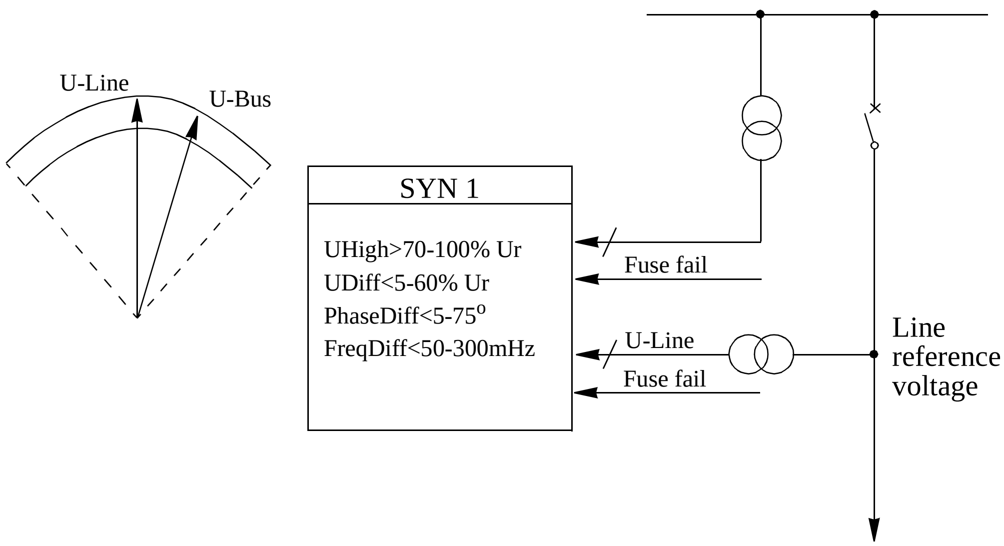


Figure 1: Synchrocheck

The voltage circuits are arranged differently depending on the number of synchrocheck functions that are included in the terminal.

In terminals intended for one bay the U-line voltage reference phase is selected on the human-machine interface (HMI). The reference voltage can be single-phase L1, L2, L3 or phase-phase L1-L2, L2-L3, L3-L1. The U-bus voltage must then be connected to the same phase or phases as are chosen on the HMI. Figure 2: shows the voltage connection.

In terminals intended for several bays, all voltage inputs are single phase circuits. The voltage can be selected for single phase or phase-to-phase measurement on the HMI. All voltage inputs must be connected to the same phase or phases.

The circuit breaker can be closed when the conditions for FreqDiff, PhaseDiff, and UDiff are fulfilled with the UHigh condition.

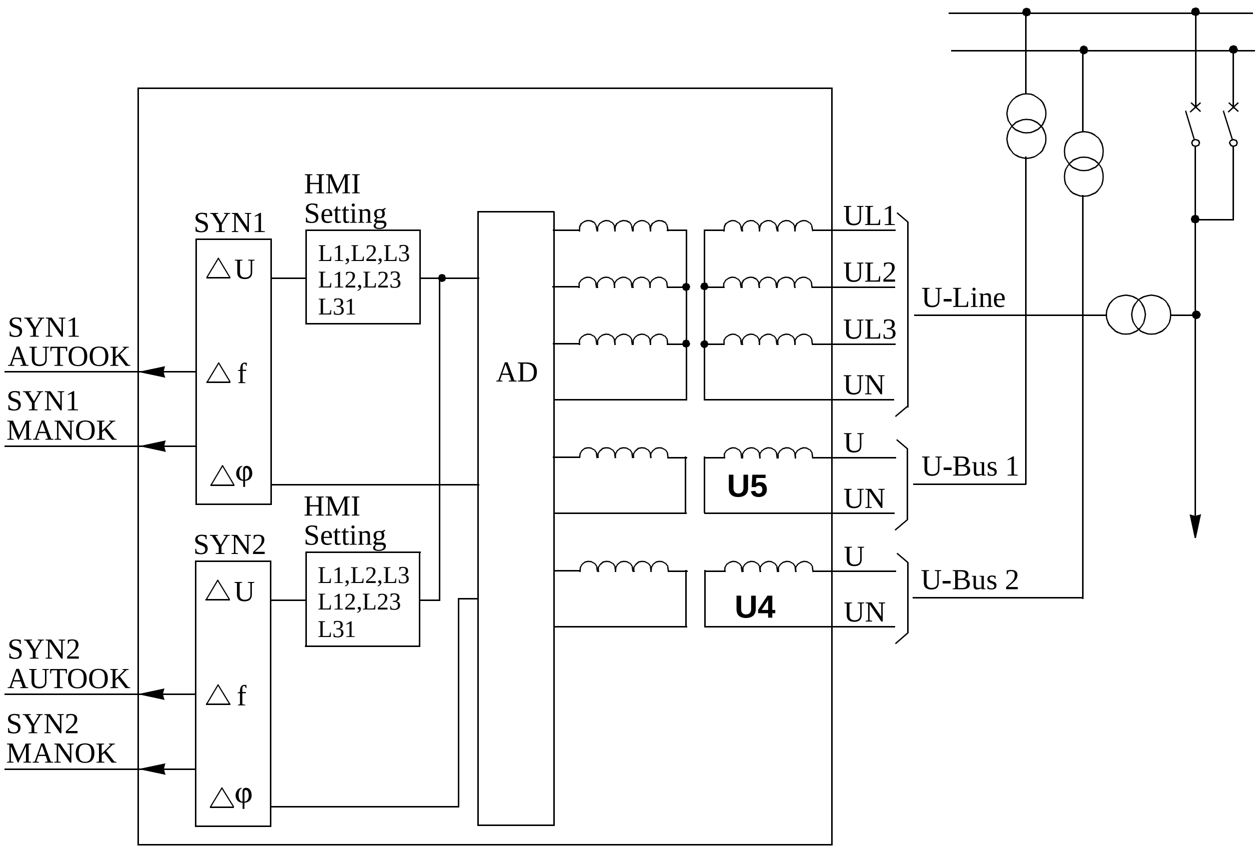


Figure 2: Connection of the synchrocheck function for one bay

1.2 Energising check

The energising check is made when a disconnected line is to be connected to an energised section of a network, see Figure 3:. The check can also be set to allow energisation of the busbar or in both directions.

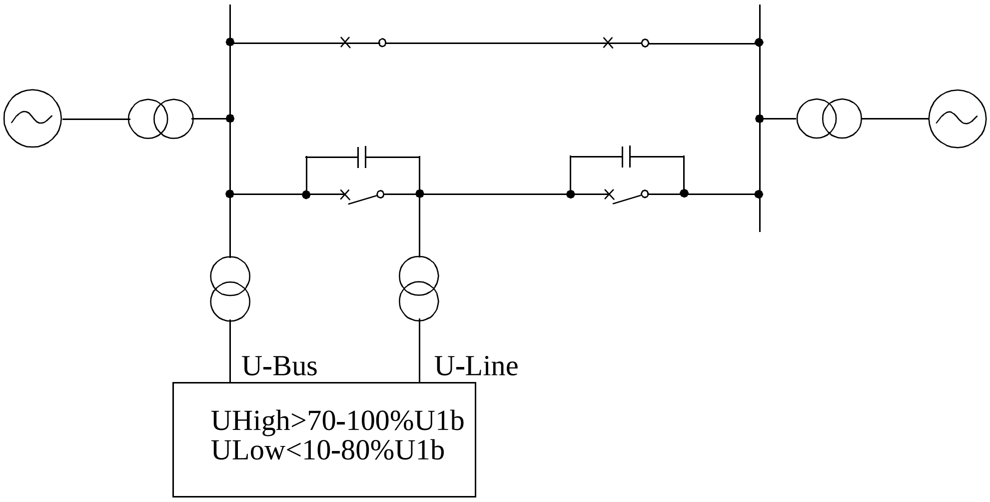


Figure 3: Principle for energising check.

The voltage level considered to be a non-energised bus or line is set on the HMI. An energising can occur — depending on the set direction of the energising function. There are separate settable limits for energised (live) condition, UHigh, and non-energised (dead) ULow conditions. The equipment is considered energised if the voltage is above the set value UHigh (e.g. 80% of the base voltage), and non-energised if it is below the set value, ULow (e.g. 30% of the base voltage) The user can set the UHigh condition between 70-100% U1b and the ULow condition between 10-80% U1b.

A disconnected line can have a considerable potential due to, for instance, induction from a line running in parallel, or by being fed via the extinguishing capacitors in the circuit breakers. This voltage can be as high as 30% or more of the rated voltage of the line.

The energising operation can be set to operate in either direction over the circuit breaker, or it can be permitted to operate in both directions. Use the AutoEnerg and ManEnerg HMI setting to select the energising operation in:

- Both directions (Both)
- Dead line live bus (DLLB)
- Dead bus live line (DBLL)

The voltage check can also be set Off. A closing impulse is issued to the circuit breaker if one of the U-line or U-bus voltages is High and the other is Low, that is, when only one side is energised. The user can set AutoEnerg and ManEnerg to enable different conditions during automatic and manual closing of the circuit breaker.

In the manual mode it is also possible to allow closing when both sides of the breaker are dead. This is done by setting the parameter ManDBDL = “On” **and** ManEnerg to “DLLB”, “DBLL” or “Both”.

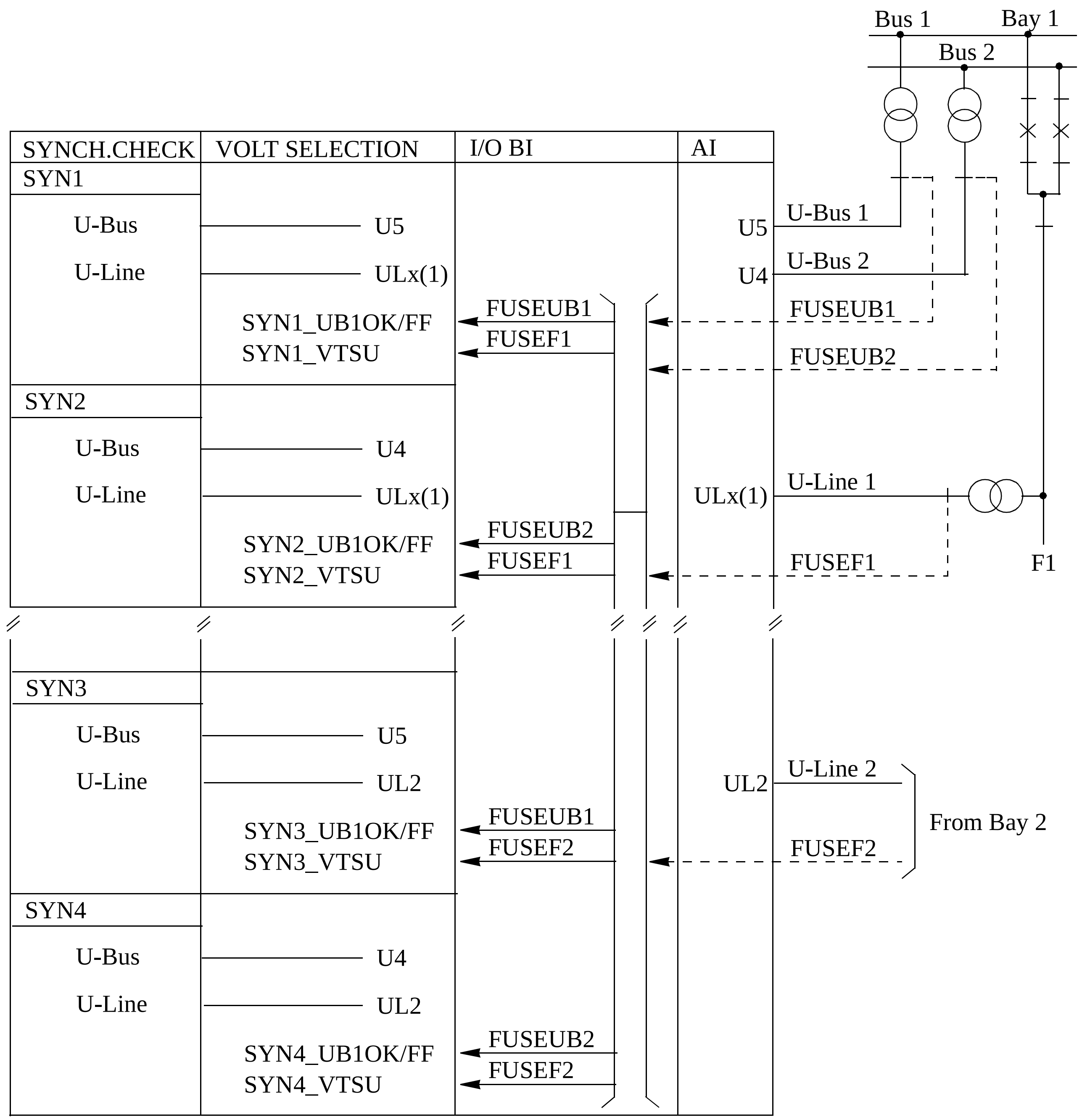


Figure 4: Voltage connection in a double busbar double breaker arrangement. Alternatively, it can be extended up to two bays in one terminal

1.3 Voltage connection

The principle for the connection arrangement is shown in Figure 4:. One terminal is used for the two circuit breakers in one or two bays dependent of selected option. There is one voltage transformer at each side of the circuit breaker, and the voltage transformer circuit connections are straightforward, without any special voltage selection.

For the synchrocheck and energising check, the voltage from Bus 1 (SYN1(3)-U-bus) is connected to the single-phase analogue input (U5) on the terminal and the voltage from Bus 2 (SYN2(4)-U-bus) is connected to the single-phase analogue input (U4).

For the terminal intended for one bay the line voltage transformers are connected as a three-phase voltage to the analogue inputs UL1, UL2, UL3 (ULx) (SYN1(2)-U-Line) voltage. For the version intended for two bays the line voltages are connected as two single phase inputs, UL1 for Bay 1 and UL2 for Bay 2

The synchronism condition is set on the HMI of the terminal, and the voltage is taken from Bus 1 and the Line or from Bus 2 and the Line (U-line). This means that the two synchrocheck units are operating without any special voltage selection, but with the same line (U-line) voltage.

The configuration of internal signals, inputs, and outputs may be different for different busbar systems, and the actual configuration for the substation must be done during engineering of the terminal.

1.3.1 Fuse failure and Voltage OK signals

The external fuse-failure signals or signals from a tripped fuse switch/ MCB are connected to binary inputs configured to inputs of the synchrocheck functions in the terminal. There are two alternative connection possibilities. Inputs named OK must be supplied if the voltage circuit is healthy. Inputs named FF must be supplied if the voltage circuit is faulty.

The SYNx-UB1OK and SYNx-UB1FF inputs are related to the busbar voltage. Configure them to the binary inputs that indicate the status of the external fuse failure of the busbar voltage. The SYNx-VTSU input is related to the line voltage from each line.

The user can use the FUSE-VTSU signal from the built-in optional selectable fuse-failure function as an alternative to the external fuse-failure signals.

In case of a fuse failure, the energising check (dead line check) is blocked via the inputs (SYN1-UB1OK/FF orSYN1-VTSU).

2 Theory of operation

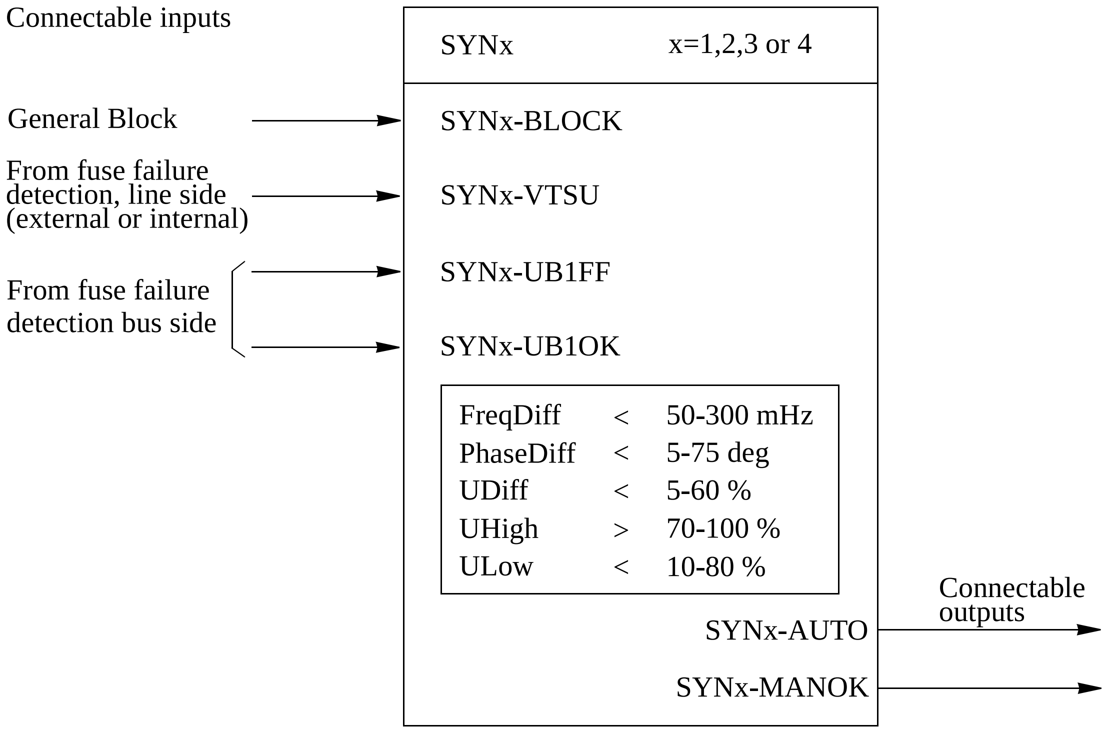


Figure 5: Input and output signals.

2.1 Synchro-check

Description of input and output signals for the synchrocheck function.

Input signals	Description
SYNx-BLOCK	General block input from any external condition, that should block the synchrocheck.
SYNx-VTSU	The SYNC function cooperates with the FUSE-VTSU connected signal, which is the built-in optional fuse failure detection. It can also be connected to external condition for fuse failure. This is a blocking condition for the energising function.
SYNx-UB1FF	External fuse failure input from busbar voltage Bus 1 (U5). This signal can come from a tripped fuse switch (MCB) on the secondary side of the voltage transformer. In case of a fuse failure the energising check is blocked.
SYNx-UB1OK	No external voltage fuse failure (U5). Inverted signal.

Output signals	Description
SYNx-AUTOOK	Synchrocheck/energising OK. The output signal is high when the synchrocheck conditions set on the HMI are fulfilled. It can also include the energising condition, if selected. The signal can be used to release the auto-recloser before closing attempt of the circuit breaker. It can also be used as a free signal.
SYNx-MANOK	Same as above but with alternative settings of the direction for energising to be used during manual closing of the circuit breaker.

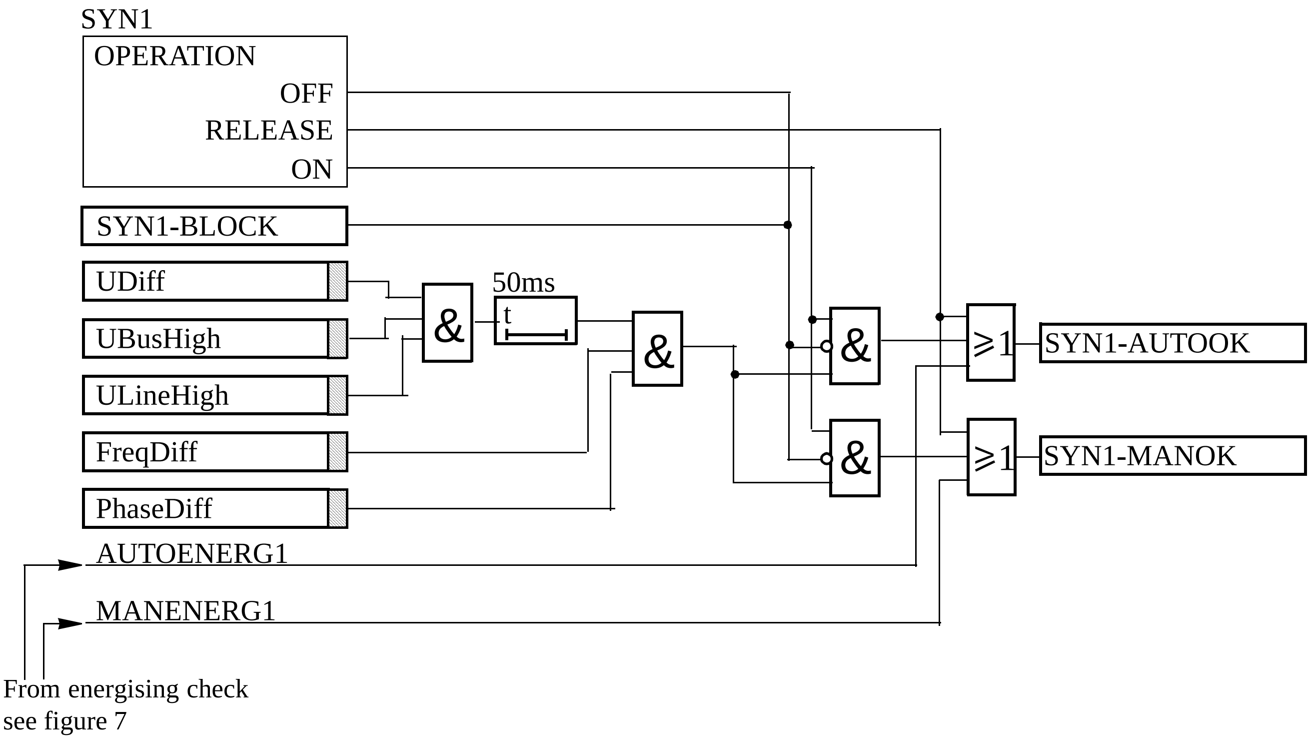


Figure 6: Simplified logic diagram - Synchrocheck.

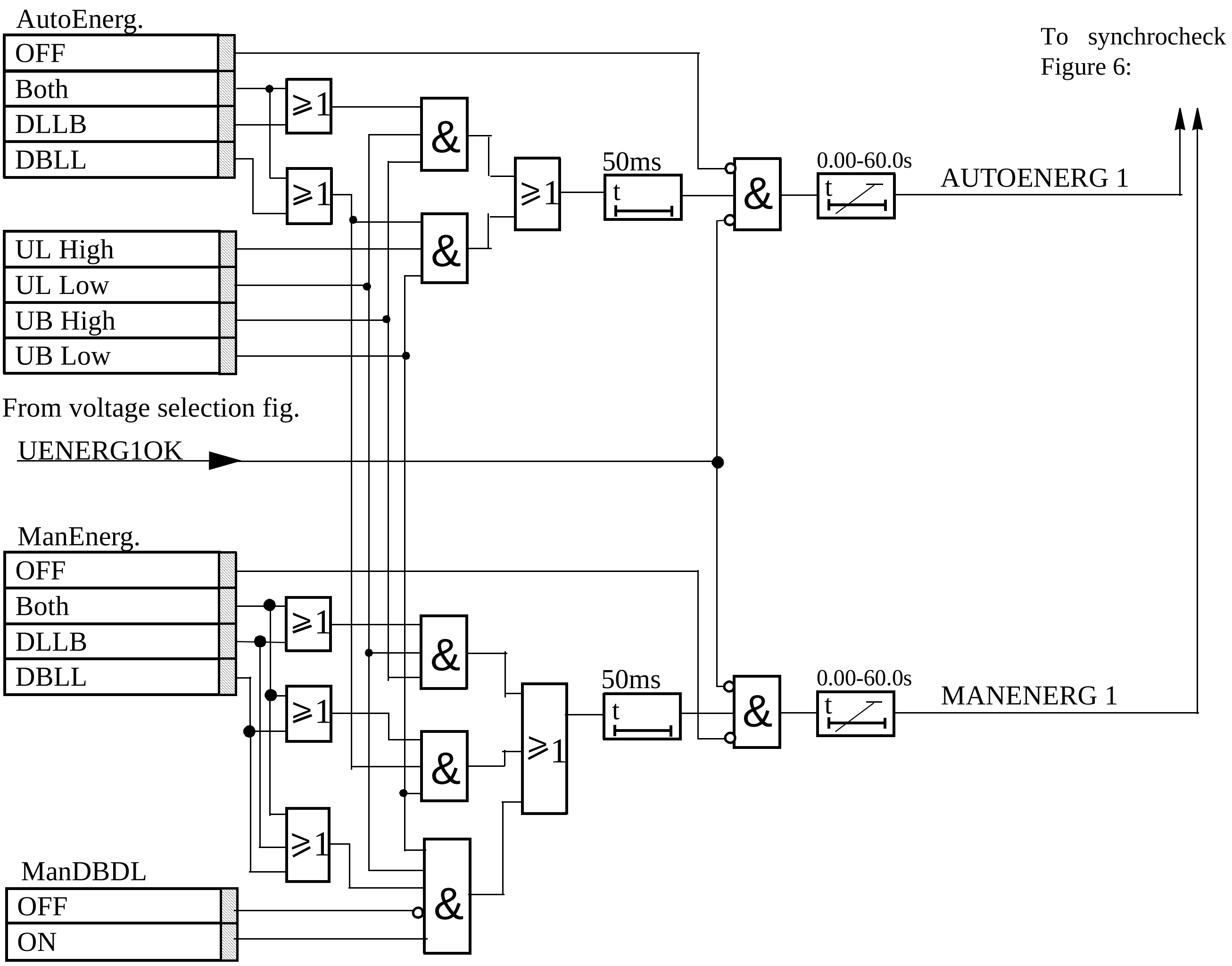


Figure 7: Simplified logic diagram - energising check.

3 Setting

The setting parameters are accessible through the HMI. The parameters for the synchrocheck function are found in the HMI tree under:

Settings
Functions
Group n
SynchroCheck
SynchroCheck n (n=1-4)

(The number of SynchroCheck settings is dependent of the version)

Comments regarding settings.

3.1 Operation

Off/Release/On

Off	The synchrocheck function is off and the output is low.
Release	There are fixed, high output signals SYN1-AUTOOK = 1 and SYN1-MANOK = 1.
On	The function is in service and the output signal depends on the input conditions.

3.2 Input phase

The measuring phase of the UL1, UL2, UL3 line voltage, which can be of a single-phase (phase-neutral) or two-phases (phase-phase). (Only available in terminals intended for one bay).

3.3 UMeasure

Selection of single-phase (phase-neutral) or two-phase (phase-phase) measurement. (Only available in terminals intended for several bays).

3.4 PhaseShift

This setting is used to compensate for a phase shift caused by a line transformer between the two measurement points for UBus and ULine. The set value is added to the measured phase difference. The bus voltage is reference voltage.

3.5 URatio

The URatio is defined as URatio=UBus/ULine. A typical use of the setting is to compensate for the voltage difference caused if one wishes to connect the UBus phase-phase and ULine phase-neutral. The “Input phase”-setting should then be set to phase-phase and the “URatio”-setting to sqr3=1.732. This setting scales up the line voltage to equal level with the bus voltage.

3.6 AutoEnerg and ManEnerg

Two different settings can be used for automatic and manual closing of the circuit breaker.

Off	The energising function is Off.
DLLB	The line voltage U-line is low, below (10-80% U1b) and the bus voltage U-bus is high, above (70-100% U1b).
DBLL	The bus voltage U-bus is low, below (10-80% U1b) and the line voltage U-line is high, above (70-100% U1b).
Both	Energising can be done in both directions, DLLB or DBLL.
tAutoEnerg	The required consecutive time of fulfillment of the energising condition to achieve SYN1-AUTOOK.
tManEnerg	The required consecutive time of fulfillment of the energising condition to achieve SYN1-MANOK.

3.7 ManDBDL

If the parameter is set to “On”, closing is enabled when Both U-Line and U-bus are below ULow and ManEnerg is set to “DLLB”, “DBLL” or “Both”.

4 Testing

At periodical checks, the functions should preferably be tested with the used settings. To test a specific function, it might be necessary to change some setting parameters, for example:

- AutoEnerg = On/Off/DLLB/DBLL/Both
- ManEnerg = Off
- Operation = Off, On

The tests explained in the section “Synchrocheck tests” on page 124 describe the settings, which can be used as references during testing, are presented before the final settings are specified. After testing, restore the equipment to the normal or desired settings.

4.1 Test equipment

A secondary injection test set with the possibility to alter the phase angle by regulation of the resistive and reactive components is needed. Here, the phase angle meter is also needed. To perform an accurate test of the frequency difference, a frequency generator at one of the input voltages is needed. The tests can also be performed with the computer-aided test system FREJA which has a specially designed program for evaluating the synchro-check function.
Figure 8: shows the general test connection principle, which can be used during testing.

This description describes the test of the version intended for one bay.

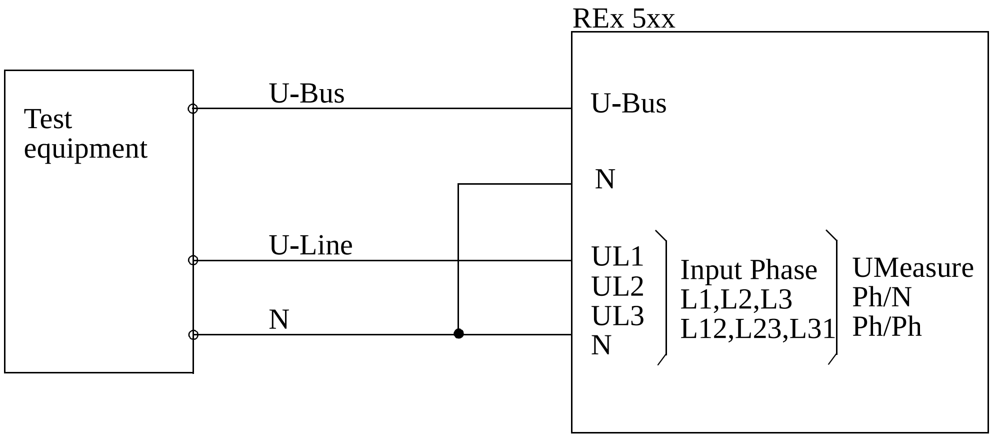


Figure 8: General test connection for synchrocheck with three-phase voltage connected to the line side.

4.2 Synchrocheck tests

4.2.1 Test of voltage difference

Set the voltage difference at 30% U1b on the HMI, and the test should check that operation is achieved when the voltage difference UDiff is lower than 30% U1b.

These voltage inputs are used:

U-line UL1, UL2 or UL3 voltage input on the terminal.

U-bus U5 voltage input on the terminal

These HMI settings can be used during the test if the final setting is not determined:

1 Set these HMI settings, which are found under:

Settings

Functions

Group n

SynchrCheck

SynchroCheck1

Table 1: Test settings for voltage difference

Parameter	Setting
Operation	On
InputPhase	UL1
USelection	SingleBus
PhaseShift	0 deg
URatio	1.00
AutoEnerg	Off
ManEnerg	Off
ManDBDL	Off
UHigh	70% U1b
ULow	40% U1b
FreqDiff	0.05 Hz
PhaseDiff	45°
UDiff	30%U1b
tAutoEnerg	0.5 s
tManEnerg	0.5 s

2 **Test with UDiff = 0%**

- Apply voltages U-line (UL1) = 80% U1b and U-Bus (U5) = 80% U1b with no frequency or phase difference.
- Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.
- The test can be repeated with different voltage values to verify that

the function operates within UDiff <30%.

3 **Test with UDiff = 40%**
- Increase the U-bus (U5) to 120% U1b, and the U-line (UL1) = 80% U1b with no frequency or phase difference.
- Check that the two outputs are **not** activated.

4 **Test with UDiff = 20%, Uline < UHigh**
- Decrease the U-line (UL1) to 60% U1b and the U-bus (U5) to be equal to 80% U1b.
- Check that the two outputs are **not** activated.

5 **Test with URatio=0.20**
- Run the test under section 2 to 4 but with U-bus voltages 5 times lower.

6 **Test with URatio=5.00**
- Run the test under section 2 to 4 but with U-line voltages 5 times lower.

4.2.2 Test of phase difference

The phase difference is set at 45° on the HMI, and the test should verify that operation is achieved when the PhaseDiff (phase difference) is lower than 45°.

1 Set these HMI settings:

Table 2: Test settings for phase difference

Parameter	Setting
Operation	On
InputPhase	UL1
USelection	SingleBus
PhaseShift	0 deg
URatio	1.00
AutoEnerg	Off
ManEnerg	Off
ManDBDL	Off
UHigh	70% U1b
ULow	40% U1b
FreqDiff	0,05 Hz
PhaseDiff	45°
UDiff	15% U1b
tAutoEnerg	0.5 s
tManEnerg	0.5 s

2 **Test with PhaseDiff = 0°**

Apply voltages U-line (UL1) = 100% U1b and U-bus (U5) = 100% U1b, with no frequency or phase difference.
Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.

By changing the phase angle on U1 connected to U-bus, between +/-45° you can check that the two outputs are activated for a PhaseDiff lower than 45°. It should not operate for other values. See Figure 9:.

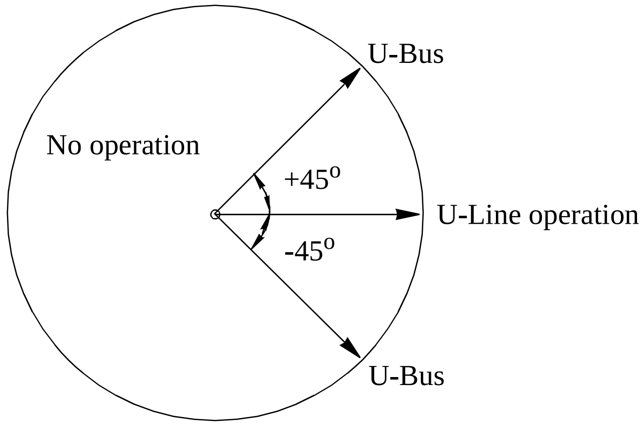


Figure 9: Test of phase difference.

4 Apply a PhaseShift setting of 10 deg. Change the phase angle between +55 and -35 and verify that the two outputs are activated for phase differences between these values but not for phase differences outside. See Figure 9:.

Change the PhaseShift setting to 350 deg. Change the phase angle between +35 and -55 and verify as above.

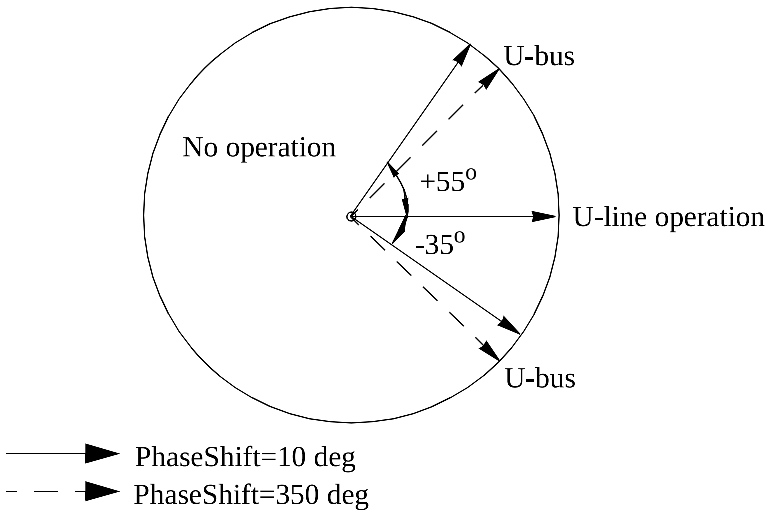


Figure 10: Test of phase difference

4.2.3 Test of frequency difference

The frequency difference is set at 50 mHz on the HMI, and the test should verify that operation is achieved when the FreqDiff frequency difference is lower than 50 mHz.

1 Use the same HMI setting as in section "Test of phase difference" on page 125.

2 **Test with FreqDiff = 0 mHz**
Apply voltages U-Line (UL1) equal to 100% U1b and U-Bus (U5) equal to 100% U1b, with a frequency difference equal to 0 mHz and a phase difference lower than 45°. Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.

3 **Test with FreqDiff = 1Hz**
Apply voltage to the U-line (UL1) equal to 100% U1b with a frequency equal to 50 Hz and voltage U-bus (U5) equal to 100% U1b, with a frequency equal to 49 Hz.
Check that the two outputs are **NOT** activated.

4 The test can be repeated with different frequency values to verify that the function operates for values lower than the set ones. If the FREJA program, Test of synchronising relay, is used the frequency can be changed continuously.

But note that a frequency difference also implies a floating mutual-phase difference. So the SYN1-AUTOOK and SYN1-MANOK outputs might not be stable, even though the frequency difference is within set limits, because the phase difference is not stable!

4.2.4 Test of reference voltage

1 Use the same basic test connection as in Figure 8:. The UDiff between the voltage connected to U-bus and U-line should be 0%, so that the SYN1-AUTOOK and SYN1-MANOK outputs are activated first.
Change the U-Line voltage connection to UL2 without changing the setting on the HMI
Check that the two outputs are **not** activated.

2 The test can also be repeated by moving the U-line to the UL3 input.

4.3 Test of energising check

Use these voltage inputs:

U-line = UL1, UL2 or UL3 voltage input on the terminal.

U-bus = U5 voltage input on the terminal.

4.3.1 Test of dead line live bus (DLLB)

The test should verify that the energising function operates for a low voltage on the U-Line and for a high voltage on the U-bus. This corresponds to an energising of a dead line to a live bus.

Use these HMI settings during the test if the final setting is not determined.

1 Set these HMI settings:

Table 3: Test settings for DLLB

Parameter	Setting
Operation	On
InputPhase	UL1
USelection	SingleBus
PhaseShift	0 deg
URatio	1.00
AutoEnerg	DLLB
ManEnerg	DLLB
ManDBDL	Off
UHigh	80% U1b
ULow	40% U1b
FreqDiff	0,05 Hz
PhaseDiff	45°
UDiff	15% U1b
tAutoEnerg	0.5 s
tManEnerg	0.5 s

2 Apply a single-phase voltage 100% U1b to the U-bus (U5), and a single-phase voltage 30% U1b to the U-line (UL1).

3 Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.

4 Increase the U-Line (UL1) to 60% U1b and U-Bus(U5) to be equal to 100% U1b. The outputs should **NOT** be activated.

5 The test can be repeated with different values on the U-Bus and the U-Line.

4.3.2 Dead bus live line (DBLL)

The test should verify that the energising function operates for a low voltage on the U-bus and for a high one on the U-line. This corresponds to an energising of a dead bus from a live line.

1 Change the HMI settings AutoEnerg and ManEnerg to DBLL**.**

2 Apply a single-phase voltage of 30% U1b to the U-bus (U5) and a single-phase voltage of 100% U1b to the U-line (UL1).

3 Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.

4 Decrease the U-line to 60% U1b and keep the U-bus equal to 30% U1b.
The outputs should **NOT** be activated.

5 The test can be repeated with different values on the U-bus and the U-line.

4.3.3 Energising in both directions (DLLB or DBLL)

1 Change the HMI settings AutoEnerg and ManEnerg to Both.

2 Apply a single-phase voltage of 30% U1b to the U-line (UL1) and a single-phase voltage of 100% U1b to the U-bus (U5).

3 Check that the “SYN1-AUTOOK” and “SYN1-MANOK” outputs are activated.

4 Change the connection so that the U-line (UL1) is equal to 100% U1b and the U-bus (U5) is equal to 30% U1b.

5 The outputs should still be activated.

6 The test can be repeated with different values on the U-bus and the U-line.

7 Restore the equipment to normal or desired settings.

4.3.4 Dead bus Dead line (DBDL)

The test should verify that the energising function operates for a low voltage on both the U-bus the U-line, i.e closing of the breaker in a non energised system.

1 Set AutoEnerg to Off and ManEnerg to DBLL.

Set ManDBDL to On

2 Apply a single-phase voltage of 30% U1b to the U-bus (U5) and a single-phase voltage of 30% U1b to the U-line (UL1).

3 Check that the SYN1-MANOK output is activated.

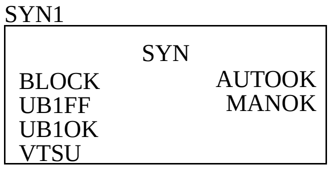
4 Increase the U-bus to 80% U1b and keep the U-line equal to 30% U1b.

The outputs should **NOT** be activated.

5 Repeat the test with ManEnerg set to DLLB and Both, and different values on the U-bus and the U-line.

5 Appendix

5.1 Function block



5.2 Signal list

Block	**Signal**	**Type**	**Description**
SYNx-	BLOCK	IN	Block of synchrocheck function x (x=1-4)
SYNx-	UB1FF	IN	External voltage fuse failure, bus 1
SYNx-	UB1OK	IN	External voltage fuse healthy, bus 1
SYNx-	VTSU	IN	Block from internal fuse failure supervision or from external fuse failure of the line voltage.
SYNx-	AUTOOK	OUT	Automatic synchro-/energising check OK
SYNx-	MANOK	OUT	Manual synchro-/energising check OK

5.3 Setting table

Parameter	**Range**	**Unit**	**Default**	**Parameter description**
Operation	Off, Release, On		Off	Synchrocheck function Off/Release/On
InputPhase	L1, L2, L3, L1-L2, L2-L3, L3-L1		L1	Select input voltage
UMeasure	Ph/N, Ph/Ph		Ph/N	Select input voltage Ph/N or Ph/Ph
PhaseShift	0-360	degrees	0	Phase shift between U-bus and U-line
URatio	0.20-5.00		1.00	Voltage ratio between U-bus and U-line
AutoEnerg	Off, DLLB, DBLL, Both		Off	Auto energising/synchronising method
ManEnerg	Off, DLLB, DBLL, Both		Off	Manual energising/synchronising method
ManDBDL	Off, On		Off	Manual deadbus and deadline energising
UHigh	50-120	%	80	High voltage limit, as a percentage of Ub
ULow	10-100	%	40	Low voltage limit, as a percentage of Ub
FreqDiff	0.05-0.30	Hz	0.20	Frequency difference limit
PhaseDiff	5-75	degrees	20	Phase difference limit
UDiff	5-50	%	20	Voltage difference limit, as a percentage of Ub
tAutoEnerg	0.000-60.000	s	0.100	Auto energising time delay period
tManEnerg	0.000-60.000	s	0.100	Manual energising time delay period

1 Application

1.1 Synchrocheck

The synchrocheck function is used for controlled closing of a circuit breaker in an interconnected network. When used, the function gives an enable signal at satisfied voltage conditions across the breaker to be closed. When there is a parallel circuit established, the frequency is normally the same at the two sides of the open breaker. At power swings, e.g. after a line fault, an oscillating difference can appear. Across the open breaker, there can be a phase angle and a voltage amplitude difference due to voltage drop across the parallel circuit or circuits.

The function can be used as a condition to be fulfilled before the breaker is closed at manual closing and/or together with the auto-recloser function.

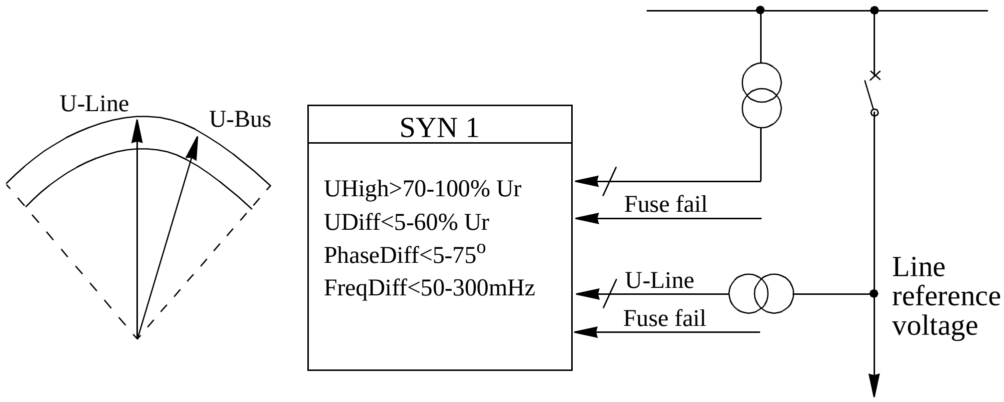


Figure 1: Synchrocheck.

1.2 Energising check

The energising check is made when a disconnected line is to be connected to an energised section of a network, see Figure 2:. The check can also be set to allow energising of the busbar or in both directions.

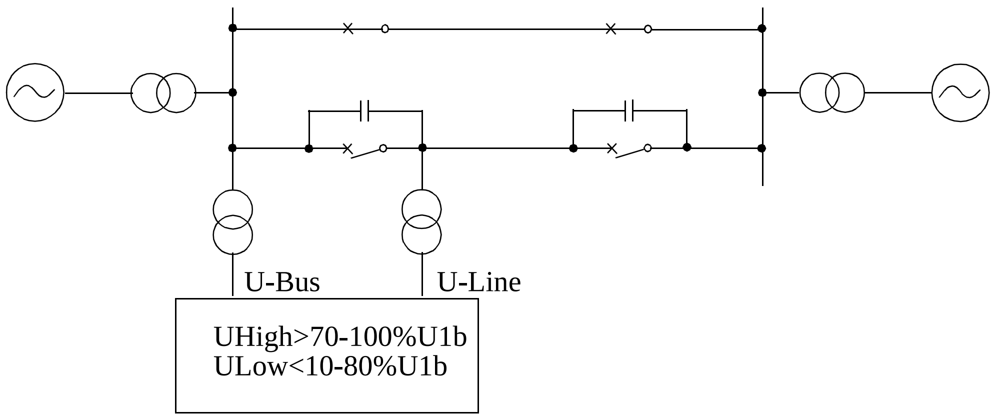


Figure 2: Principle for energising check.

A disconnected line can have a considerable potential due to, for instance, induction from a line running in parallel, or by being fed via the extinguishing capacitors in the circuit breakers. This voltage can be as high as 30% or more of the rated voltage of the line.

1.3 Voltage connection

The voltage circuits are arranged differently depending on the number of synchrocheck functions that are included in the terminal.

In terminals intended for one bay the U-line voltage reference phase is selected on the human-machine interface (HMI). The reference voltage can be single-phase L1, L2, L3 or phase-phase L1-L2, L2-L3, L3-L1. The U-bus voltage must then be connected to the same phase or phases as chosen on the HMI. Figure 3: shows the voltage connection.

In terminals intended for several bays, all voltage inputs are single-phase circuits. The voltage can be selected for single-phase or phase-to-phase measurement on the HMI. All voltage inputs must be connected to the same phase or phases.

The circuit breaker can be closed when the conditions for FreqDiff, PhaseDiff, and UDiff are fulfilled with the UHigh condition.

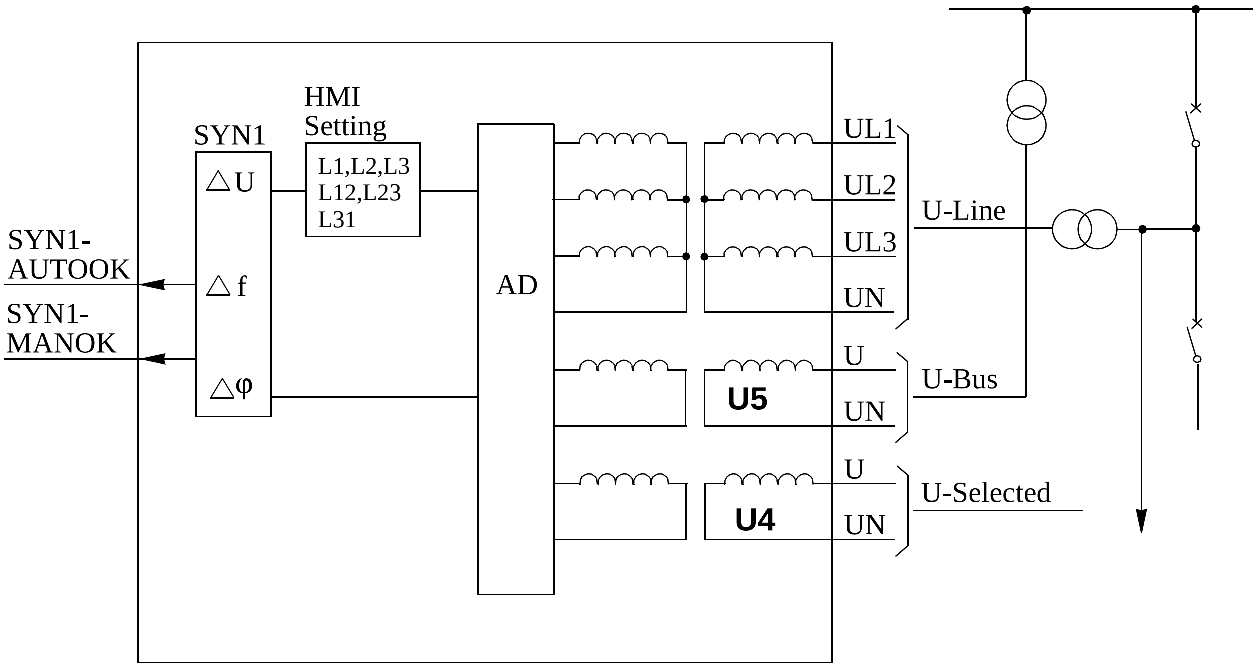
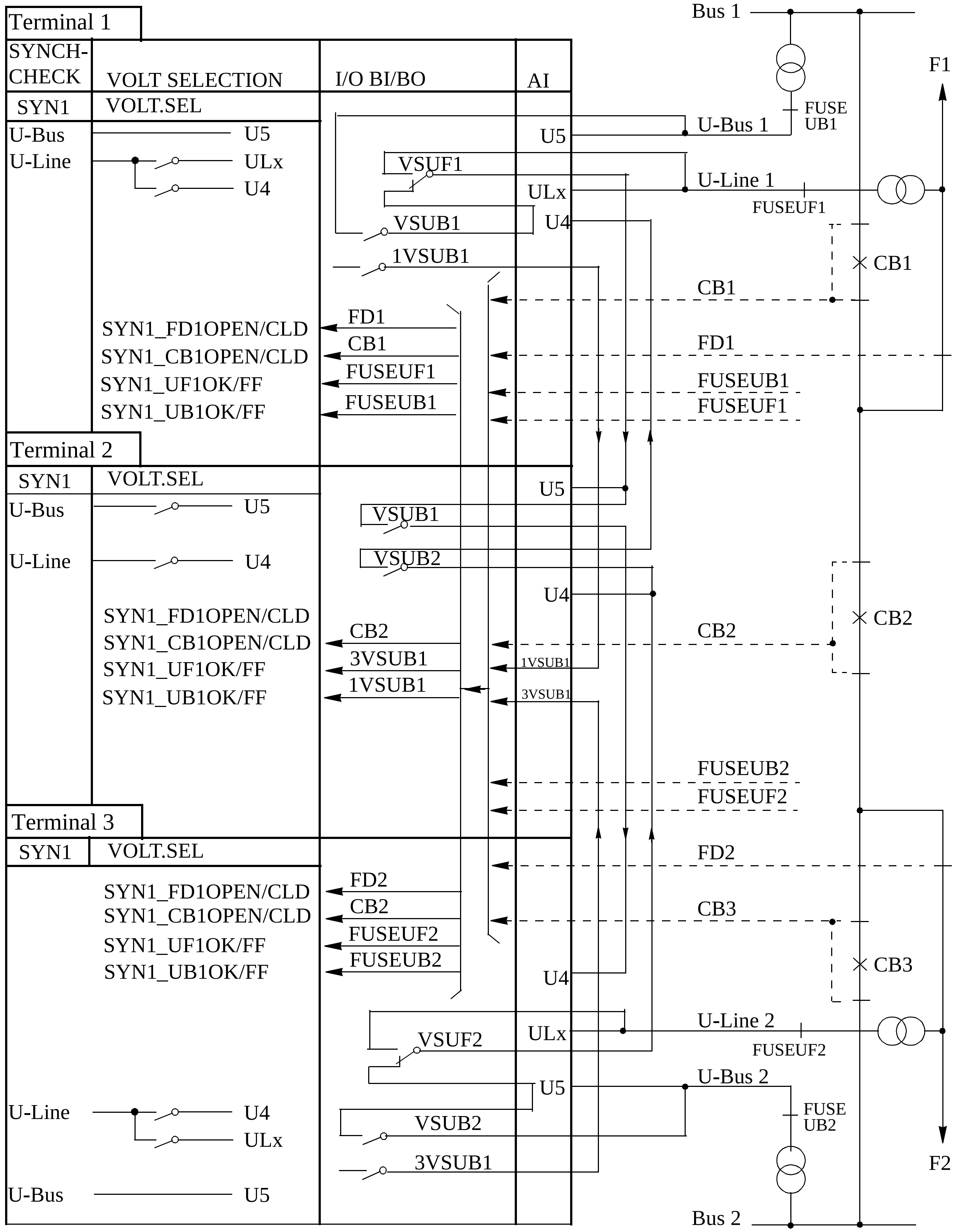


Figure 3: Connection of the synchrocheck function for one bay.

2 Theory of operation



*) Explanation of signal names, see Section 2.4

Figure 4: Connections in 1 $^1/_2$ circuit breaker arrangement.

2.1 Synchrocheck

The synchrocheck function measures the difference between the U-line and the U-bus, regarding voltage (*UDiff*), phase angle (*PhaseDiff*), and frequency (*FreqDiff*). It operates and permits closing of the circuit breaker when the following conditions are simultaneously fulfilled.

- The voltages U-line and U-bus are higher than the set value for *UHigh* of the base voltage U1b.
- The differences in the voltage and phase angles are smaller than the set values of *UDiff* and *PhaseDiff*.
- The difference in frequency is less than the set value of *FreqDiff*. The bus frequency must also be within a range of ±5 Hz from the rated frequency.

2.2 Energising check

The energising operation can be set to operate in either direction over the circuit breaker, or it can be permitted to operate in both directions. Use the setting of the parameters *AutoEnerg* and *ManEnerg* to select the energising operation in:

- Both directions (Both)
- Dead line live bus (DLLB)
- Dead bus live line (DBLL)

The voltage level considered to be a non-energised bus or line is set on the HMI. An energising can occur — depending on:

- the set direction of the energising function,
- the set limit for energised condition (live - *UHigh*) and
- the set limit for non-energised (dead - *ULow*) condition.

The equipment is considered energised if the voltage is above the set value *UHigh* (e.g. 80% of the base voltage), and non-energised if it is below the set value, *ULow* (e.g. 30% of the base voltage).

The voltage check can also be set Off. A closing impulse is issued to the circuit breaker if one of the U-line or U-bus voltages is High and the other is Low, that is, when only one side is energised. Set *AutoEnerg* and *ManEnerg* to enable different conditions during automatic and manual closing of the circuit breaker.

In the manual mode it is also possible to allow closing when both sides of the breaker are dead. This is done by setting the parameter *ManDBDL* = *On* **and** *ManEnerg* to *DLLB*, *DBLL* or *Both.*

2.3 Voltage connection

The principle for the connection arrangement is shown in Figure 4:. One terminal is used for the two circuit breakers in one or two bays dependent of selected option. There is one voltage transformer at each side of the circuit breaker, and the voltage transformer circuit connections are straight forward, without any special voltage selection.
For the synchrocheck and energising check, the voltage from Bus 1

(SYN1(T1) - U-bus 1) is connected to the single-phase analogue input (U5) on terminal 1 and the voltage from Bus 2 (SYN1(T3) - U-bus 2) is connected to the single-phase analogue input (U4) on terminal 1.

Vice verse, the voltage from Bus 1 (SYN1(T1) - U-bus 1) is connected to the single-phase analogue input (U4) on terminal 3 and the voltage from Bus 2 (SYN1(T3) - U-bus 2) is connected to the single-phase analogue input (U5) on terminal 3.

For a terminal intended for one bay the line voltage transformers are connected as a three-phase voltage to the analogue inputs UL1, UL2, UL3 (ULx) (SYN1(T2) - U-Line) voltage. For the version intended for two bays the line voltages are connected as two single-phase inputs, UL1 for Bay 1 and UL2 for Bay 2.

The synchronism condition is set on the local HMI of the terminal, and the voltage is taken from Bus 1 and the Line or from Bus 2 and the Line (U-line). This means that the two synchro-check units are operating without any special voltage selection, but with the same line (U-line) voltage.

The configuration of internal signals, inputs, and outputs may be different for different busbar systems, and the actual configuration for the substation must be done during engineering of the terminals.

2.3.1 Fuse failure and Voltage OK signals

The external fuse-failure signals or signals from a tripped fuse switch/ MCBs are connected to binary inputs configured to inputs of the synchro-check functions in the terminal. There are two alternative connection possibilities. Inputs named OK must be supplied if the voltage circuit is healthy. Inputs named FF must be supplied if the voltage circuit is faulty.

The SYN1-UB1OK and SYN1-UB1FF inputs are related to the busbar voltage. Configure them to the binary inputs that indicate the status of the external fuse failure of the busbar voltage. The SYN1-VTSU input is related to the line voltage from each line.

The FUSE-VTSU signal, from the built-in optional selectable fuse-failure function, can be used as an alternative to the external fuse-failure signals.

In case of a fuse failure, the energising check (dead line - check) is blocked via the inputs (SYN1-UB1OK/FF or SYN1-VTSU).

2.4 Function block and logics

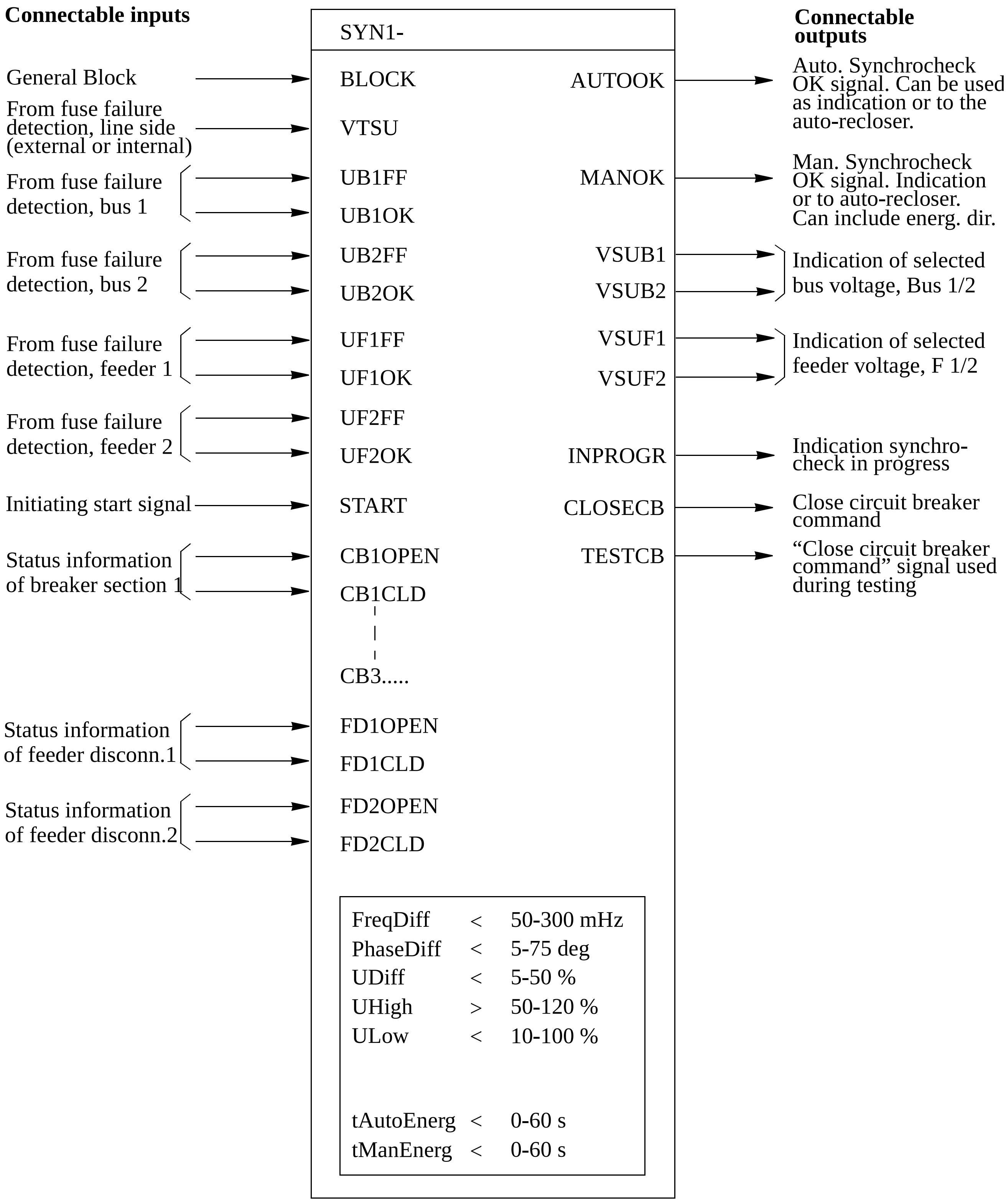


Figure 5: Input and output signals.

Figure 5: shows possible connections for the synchrocheck function and different parameters. A description of the input and output signals follows below.

Input signals	Description
SYN1-BLOCK	General block input from any external condition, that should block the synchrocheck.
SYN1-VTSU	The SYNC function cooperates with the FUSE-VTSU connected signal, which is the built-in optional fuse failure detection. It can also be connected to external condition for fuse failure. This is a blocking condition for the energising function.
SYN1-UBxFF	External fuse failure input from busbar voltage Bus 1 or 2 resp. (U5). This signal can come from a tripped fuse switch (MCB) on the secondary side of the voltage transformer. In case of a fuse failure the energising check is blocked.
SYN1-UBxOK	No external voltage fuse failure (U5). Inverted signal.
SYN1-UFxFF	External fuse failure input from feeder voltage Feeder 1 or 2 resp. (U4). This signal can come from a tripped fuse switch (MCB) on the secondary side of the voltage transformer. In case of a fuse failure the energising check is blocked.
SYN1-UFxOK	No external voltage fuse failure (U4). Inverted signal.
SYN1-START	Signal to initiate the synchrocheck function. Can be connected to a binary input, other function blocks or logics.
SYN1-CBnOPEN	Status signal of breaker section n (n=1..3), indicating *Open* breaker section.
SYN1-CBnCLD	Status signal of breaker section n, indicating *Closed* breaker section.
SYN1-FDmOPEN	Status signal of feeder disconnector m (m=1..2), indicating *Open* disconnector. Can be used for interlocking.
SYN1-FDmCLD	Status signal of feeder disconnector m, indicating *Closed* disconnector. Can be used as interlocking condition.

Output signals	Description
SYN1-AUTOOK	Synchro-/energising check OK. The output signal is high when the synchrocheck conditions set on the HMI are fulfilled. It can also include the energising condition, if selected. The signal can be used to release the autorecloser before closing attempt of the circuit breaker. It can also be used as a free signal.
SYN1-MANOK	Same as above but with alternative settings of the direction for energising to be used during manual closing of the circuit breaker.
SYN1-VSUBx	Voltage Bus 1 (and Bus 2 respectively) selected for the synchro-check function.
SYN1-VSUFx	Voltage Feeder 1 (and Feeder 2 respectively) selected for the synchro-check function.
SYN1-CLOSECB	Close breaker command from synchrocheck. Used to the circuit breaker or to be connected to the auto-reclosing function.
SYN1-TESTCB	Output when the function is in test mode. In test mode a complete synchrocheck sequence is performed except for closing of the circuit breaker. The output signal SYN1-TESTCB indicates when the SYN1-CLOSECB signal would have been submitted from the function block or when the conditions for energising are fulfilled.
SYN1-INPROGR	The signal is high when a synchrocheck is in progress, i.e from the moment a SYN1-START is received until the operation is terminated. The operation is teminated when SYN1-CLOSECB or SYN1-TESTCB has been submitted or if a SYN1-BLOCK is received.

Figure 6: is a simplified logic diagram of the internal voltage selection function. All input signals can be find above. The voltage selection function requires an extra I/O-module.

The internal resulting signal UENERG1OK is further used by the internal energising check function as a condition to release an xxxENERG 1 output. See Figure 7: for a simplified logic diagram of the energising check.

The output signals, AUTOENERG 1 and MANENERG 1, from the energising check is dependent of the actual parameter settings. These signals are further connected to the main synchro-check. See Figure 8:.

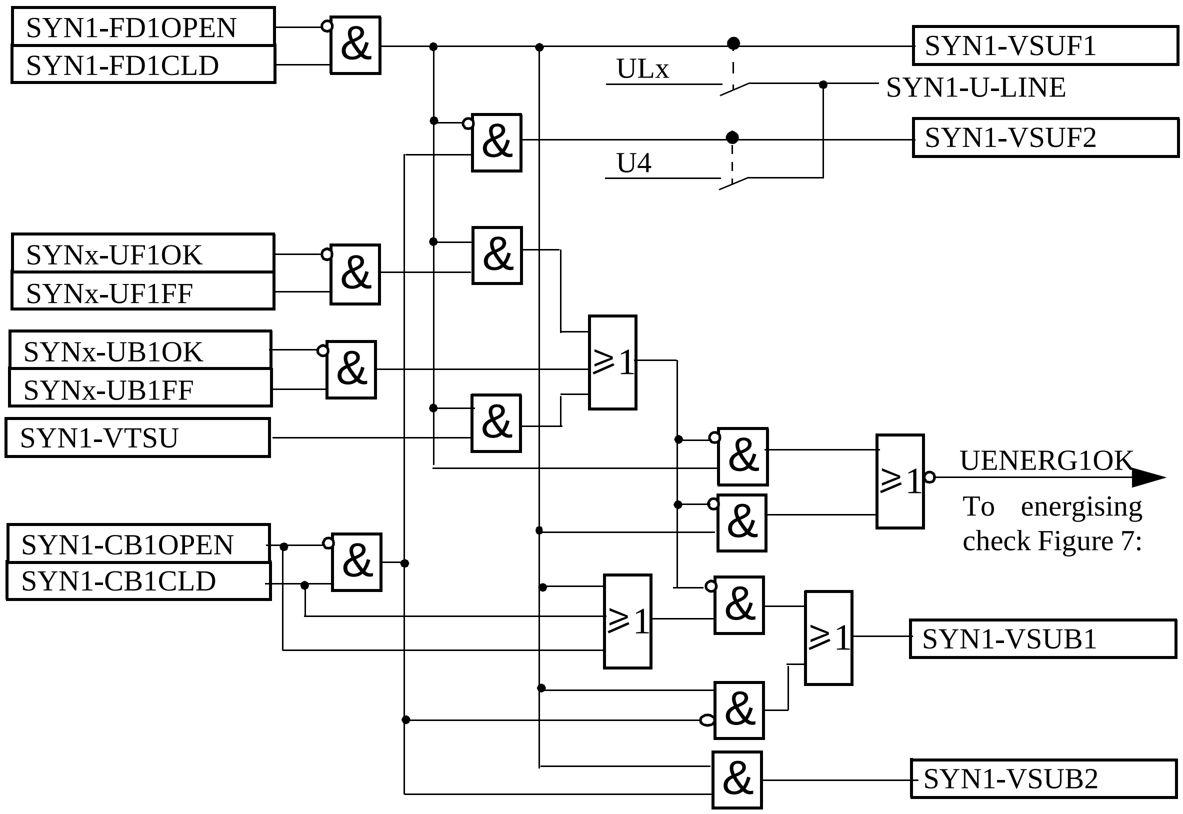


Figure 6: Simplified logic diagram - Voltage selection

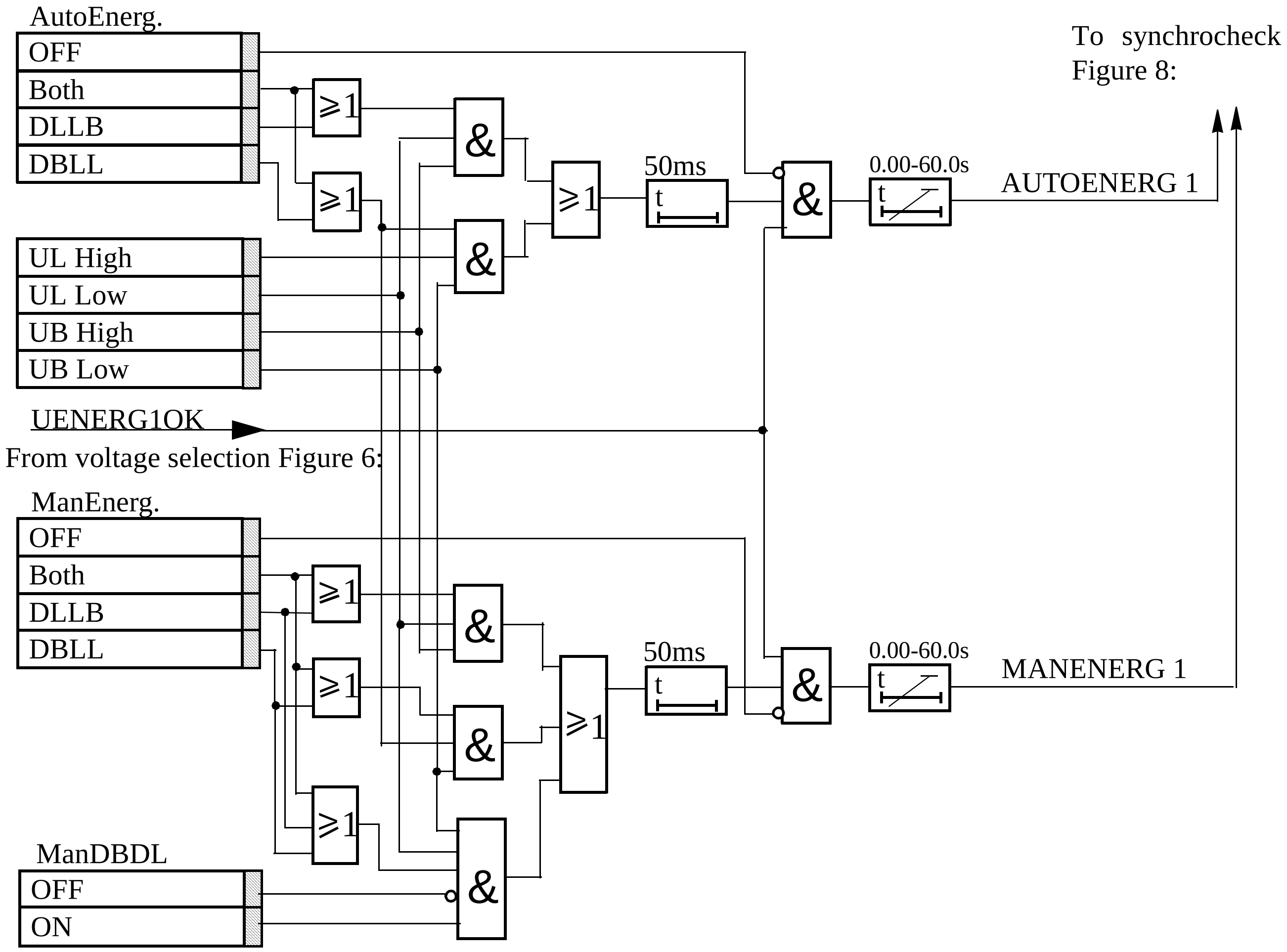


Figure 7: Simplified logic diagram - Energising check

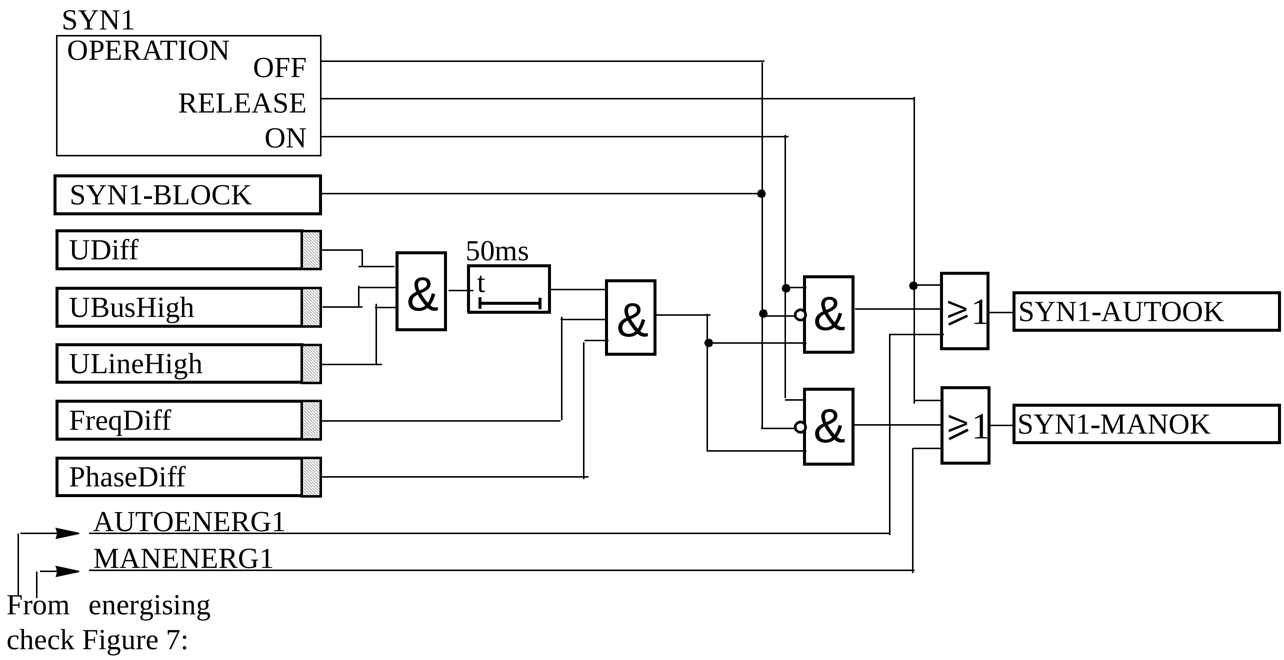


Figure 8: Simplified logic diagram - Synchrocheck

3 Setting

The setting parameters are accessible through the local HMI. The parameters for the synchrocheck function are found in the HMI tree under:

Settings
  Functions
    Group n (n = 1..4)
      SynchroCheck
        SynchroCheck1

Comments regarding settings:

3.1 Operation

Off/Release/On

Off	The synchrocheck function is off and the output is low.
Release	There are fixed, high output signals SYN1-AUTOOK = 1 and SYN1-MANOK = 1.
On	The function is in service and the output signal depends on the input conditions.

3.2 Input phase

The measuring phase of the UL1, UL2, UL3 line voltage, which can be single-phase (phase-neutral) or two-phase (phase-phase).

Note! Only available in terminals intended for one bay.

3.3 UMeasure

Selection of single-phase (phase-neutral) or two-phase (phase-phase) measurement.

Note! Only available in terminals intended for several bays.

3.4 PhaseShift

This setting is used to compensate for a phase shift caused by a line transformer between the two measurement points for UBus and ULine. The set value is added to the measured phase difference. The bus voltage is reference voltage.

3.5 URatio

The *URatio* is defined as URatio=UBus/ULine. A typical use of the setting, is to compensate for the voltage difference caused if desired to connect the UBus as phase-phase and the ULine as phase-neutral. The *Input phase* -setting should then be set to phase-phase and the *URatio*-setting to sqr(3) (=1.732). This setting scales up the line voltage to equal level with the bus voltage.

3.6 AutoEnerg and ManEnerg

Two different settings can be used for automatic and manual closing of the circuit breaker.

Off	The energising function is Off.
DLLB	The line voltage U-line is dead (low), below (10-80% U1b) and the bus voltage U-bus is live (high), above (70-100% U1b).
DBLL	The bus voltage U-bus is dead (low), below (10-80% U1b) and the line voltage U-line is live (high), above (70-100% U1b).
Both	Energising can be done in both directions, DLLB or DBLL.
tAutoEnerg	The required consecutive time of fulfillment of the energising condition to achieve SYN1-AUTOOK.
tManEnerg	The required consecutive time of fulfillment of the energising condition to achieve SYN1-MANOK.

3.7 ManDBDL

If the parameter is set to *On*, closing is enabled when Both U-Line and U-bus are below ULow and ManEnerg is set to *DLLB*, *DBLL* or *Both*.

4 Testing

At periodical checks, the functions should preferably be tested with the used settings. To test a specific function, it might be necessary to change some setting parameters, for example:

- AutoEnerg = On/Off/DLLB/DBLL/Both
- ManEnerg = Off
- Operation = Off, On

The tests explained under “Synchrocheck tests” on page 143 describe the settings, which can be used as references during testing. They are presented before the final settings are specified. After testing, restore the equipment to the normal or desired settings.

4.1 Test equipment

A secondary injection test set with the possibility to alter the phase angle by regulation of the resistive and reactive components is needed. Here, the phase angle meter is also needed. To perform an accurate test of the frequency difference, a frequency generator at one of the input voltages is needed. The tests can also be performed with the computer-aided test system FREJA, which has a specially designed program for evaluating the synchro-check function.
Figure 9: shows the general test connection principle, which can be used during testing.

This description describes the test of the version intended for one bay.

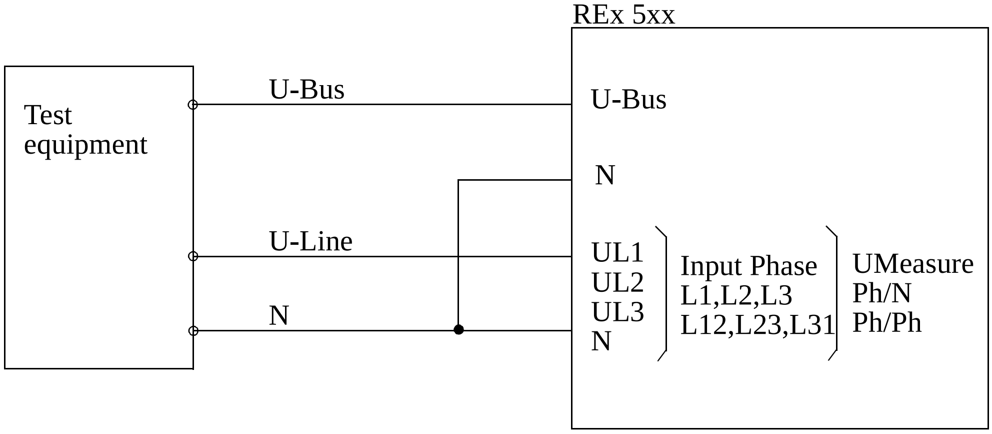


Figure 9: General test connection for synchrocheck with three-phase voltage connected to the line side.

4.2 Synchrocheck tests

4.2.1 Test of voltage difference

Set the voltage difference at 30% of U1b on the local HMI, and the test should check that operation is achieved when the voltage difference *UDiff* is lower than 30% of U1b.

These voltage inputs are used:

U-line UL1, UL2 or UL3 voltage input on the terminal.

U-bus U5 voltage input on the terminal

These settings can be used during the test if the final setting is not determined:

1 Set these parameters, which are found in the local HMI under:

Settings

Functions

Group n (n = 1..4)

SynchroCheck

SynchroCheck1

Table 1: Test settings for voltage difference

Parameter	Setting
Operation	On
InputPhase	UL1
USelection	SingleBus
PhaseShift	0 deg
URatio	1.00
AutoEnerg	Off
ManEnerg	Off
ManDBDL	Off
UHigh	70% U1b
ULow	40% U1b
FreqDiff	0.05 Hz
PhaseDiff	45 deg
UDiff	30% U1b
tAutoEnerg	0.5 s
tManEnerg	0.5 s

2 **Test with UDiff = 0%**

- Apply voltages U-line (UL1) = 80% of U1b and U-Bus (U5) = 80% of U1b with no frequency or phase difference.
- Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.
- The test can be repeated with different voltage values to verify that the function operates within *UDiff* <30%.

3 **Test with UDiff = 40%**

- Increase the U-bus (U5) to 120% of U1b, and the U-line (UL1) = 80% of U1b with no frequency nor phase difference.
- Check that the two outputs are **NOT** activated.

4 **Test with UDiff = 20%, Uline < UHigh**

- Decrease the U-line (UL1) to 60% of U1b and the U-bus (U5) to be equal to 80% of U1b.
- Check that the two outputs are **NOT** activated.

5 **Test with URatio=0.20**

- Run the test under section 2 to 4 but with the U-bus voltages one fifth of before.

6 **Test with URatio=5.00**

- Run the test under section 2 to 4 but with the U-line voltages one fifth of before.

4.2.2 Test of phase difference

The phase difference is set at 45° on the local HMI, and the test should verify that operation is achieved when the *PhaseDiff* (phase difference) is lower than 45°.

1 Set these parameters accordingly:

Table 2: Test settings for phase difference

Parameter	Setting
Operation	On
InputPhase	UL1
USelection	SingleBus
PhaseShift	0 deg
URatio	1.00
AutoEnerg	Off
ManEnerg	Off
ManDBDL	Off
UHigh	70% U1b
ULow	40% U1b
FreqDiff	0.05 Hz
PhaseDiff	45 deg
UDiff	15% U1b
tAutoEnerg	0.5 s
tManEnerg	0.5 s

2 **Test with PhaseDiff = 0°**

Apply voltages U-line (UL1) = 100% of U1b and U-bus (U5) = 100% of U1b, with no frequency or phase difference.
Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.

By changing the phase angle on U1 connected to U-bus, between +/-45° enables to check that the two outputs are activated for a *PhaseDiff* lower than 45°. It should not operate for other values. See Figure 10:.

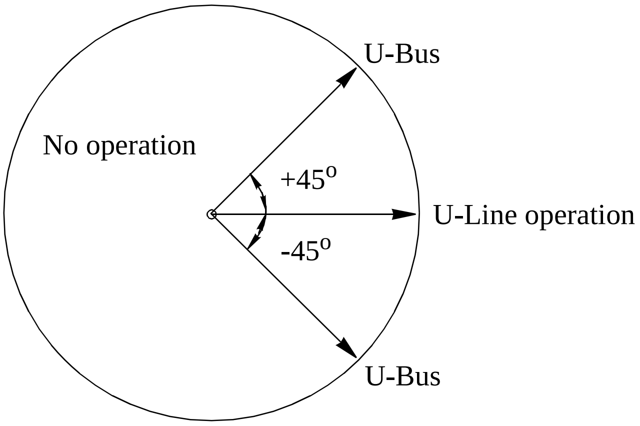


Figure 10: Test of phase difference.

4 Apply a *PhaseShift* setting of 10 deg. Change the phase angle between +55° and -35° and verify that the two outputs are activated for phase differences between these values but not for phase differences outside. See Figure 11:.

Change the *PhaseShift* setting to 350 deg. Change the phase angle between +35° and -55° and verify as above.

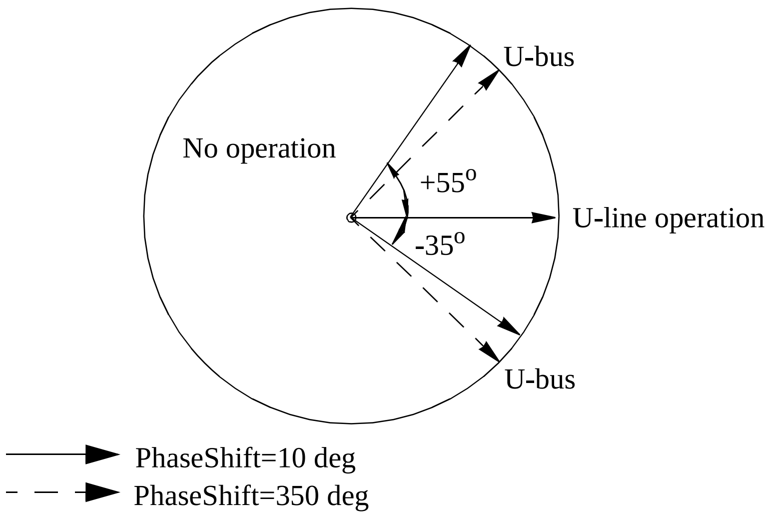


Figure 11: Test of shifted phase difference.

4.2.3 Test of frequency difference

The frequency difference is set at 50 mHz on the local HMI, and the test should verify that operation is achieved when the *FreqDiff* frequency difference is lower than 50 mHz.

1 Use the same settings as under “Test of phase difference” above.

2 **Test with FreqDiff = 0 mHz**
Apply voltages U-Line (UL1) equal to 100% of U1b and U-Bus (U5) equal to 100% of U1b, with a frequency difference equal to 0 mHz and a phase difference lower than 45°. Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.

3 **Test with FreqDiff = 1Hz**
Apply voltage to the U-line (UL1) equal to 100% of U1b with a frequency equal to 50 Hz and voltage U-bus (U5) equal to 100% of U1b, with a frequency equal to 49 Hz.
Check that the two outputs are **NOT** activated.

4 The test can be repeated with different frequency values to verify that the function operates for values lower than the set ones. If the FREJA program, *Test of synchronising relay*, is used the frequency can be changed continuously.

Note!! A frequency difference also implies a floating mutual-phase difference. So the SYN1-AUTOOK and SYN1-MANOK outputs might NOT be stable, even though the frequency difference is within set limits, because the phase difference is not stable!

4.2.4 Test of reference voltage

1 Use the same basic test connection as in Figure 9:. The *UDiff* between the voltage connected to U-bus and U-line should be 0%, so that the SYN1-AUTOOK and SYN1-MANOK outputs are activated first.
Change the U-Line voltage connection to UL2 without changing the setting on the HMI
Check that the two outputs are **NOT** activated.

2 The test can also be repeated by moving the U-line to the UL3 input.

4.3 Test of energising check

Use these voltage inputs:

U-line = UL1, UL2 or UL3 voltage input on the terminal.

U-bus = U5 voltage input on the terminal.

4.3.1 Dead-line-live-bus (DLLB)

The test should verify that the energising function operates for a low voltage on the U-Line and for a high voltage on the U-bus. This corresponds to an energising of a dead line to a live bus.

Use these settings during the test if the final setting is not determined.

1 Set these parameters accordingly:

Table 3: Test settings for DLLB

Parameter	Setting
Operation	On
InputPhase	UL1
USelection	SingleBus
PhaseShift	0 deg
URatio	1.00
AutoEnerg	DLLB
ManEnerg	DLLB
ManDBDL	Off
UHigh	80% U1b
ULow	40% U1b
FreqDiff	0.05 Hz
PhaseDiff	45 deg
UDiff	15% U1b
tAutoEnerg	0.5 s
tManEnerg	0.5 s

2 Apply a single-phase voltage 100% of U1b to the U-bus (U5), and a single-phase voltage 30% of U1b to the U-line (UL1).

3 Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.

4 Increase the U-Line (UL1) to 60% of U1b and U-Bus(U5) to be equal to 100% of U1b. The outputs should **NOT** be activated.

5 The test can be repeated with different values on the U-Bus and the U-Line.

4.3.2 Dead-bus-live-line (DBLL)

The test should verify that the energising function operates for a low voltage on the U-bus and for high voltage on the U-line. This corresponds to an energising of a dead bus from a live line.

1 Change the settings of *AutoEnerg* and *ManEnerg* to *DBLL*.

2 Apply a single-phase voltage of 30% of U1b to the U-bus (U5) and a single-phase voltage of 100% of U1b to the U-line (UL1).

3 Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.

4 Decrease the U-line to 60% of U1b and keep the U-bus equal to of 30% U1b.
The outputs should **NOT** be activated.

5 The test can be repeated with different values on the U-bus and the U-line.

4.3.3 Energising in both directions (DLLB or DBLL)

1 Change the settings of *AutoEnerg* and *ManEnerg* to *Both*.

2 Apply a single-phase voltage of 30% of U1b to the U-line (UL1) and a single-phase voltage of 100% of U1b to the U-bus (U5).

3 Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.

4 Change the connection so that the U-line (UL1) is equal to 100% of U1b and the U-bus (U5) is equal to 30% of U1b.

5 The outputs should still be activated.

6 The test can be repeated with different values on the U-bus and the U-line.

7 Restore the equipment to normal or desired settings.

4.3.4 Dead-bus-dead-line (DBDL)

The test should verify that the energising function operates for a low voltage on both the U-bus the U-line, i.e closing of the breaker in a non-energised system.

1 Set *AutoEnerg* to *Off* and *ManEnerg* to *DBLL*.

Set *ManDBDL* to *On*.

2 Apply a single-phase voltage of 30% of U1b to the U-bus (U5) and a single-phase voltage of 30% of U1b to the U-line (UL1).

3 Check that the SYN1-MANOK output is activated.

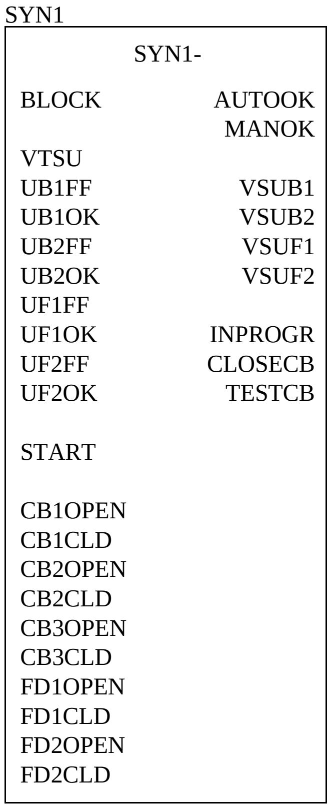
4 Increase the U-bus to 80% of U1b and keep the U-line equal to 30% of U1b.

The outputs should **NOT** be activated.

5 The test can be repeated with the *ManEnerg* set to *DLLB* and *Both*, and using different values on the U-bus and the U-line.

5 Appendix

5.1 Function block



5.2 Signal list

Block	Signal	Type	Description
SYN1-	BLOCK	IN	Block of synchro-check function 1
SYN1-	CB1CLD	IN	Breaker section 1 closed
SYN1-	CB1OPEN	IN	Breaker section 1 open
SYN1-	CB2CLD	IN	Breaker section 2 closed
SYN1-	CB2OPEN	IN	Breaker section 2 open
SYN1-	CB3CLD	IN	Breaker section 3 closed
SYN1-	CB3OPEN	IN	Breaker section 3 open
SYN1-	FD1CLD	IN	Feeder disconnector 1 closed
SYN1-	FD1OPEN	IN	Feeder disconnector 1 open
SYN1-	FD2CLD	IN	Feeder disconnector 2 closed
SYN1-	FD2OPEN	IN	Feeder disconnector 2 open
SYN1-	START	IN	Initiate phasing operation
SYN1-	UB1FF	IN	External voltage fuse failure, bus 1
SYN1-	UB1OK	IN	External voltage fuse healthy, bus 1
SYN1-	UB2FF	IN	External voltage fuse failure, bus 2
SYN1-	UB2OK	IN	External voltage fuse healthy, bus 2
SYN1-	UF1FF	IN	External voltage fuse failure, feeder 1
SYN1-	UF1OK	IN	External voltage fuse healthy, feeder 1
SYN1-	UF2FF	IN	External voltage fuse failure, feeder 2
SYN1-	UF2OK	IN	External voltage fuse healthy, feeder 2
SYN1-	VTSU	IN	Block from internal fuse failure supervision or from external fuse failure of the line voltage.
SYN1-	AUTOOK	OUT	Automatic synchronism/Energising check OK
SYN1-	CLOSECB	OUT	Close circuit breaker pulse
SYN1-	INPROGR	OUT	Phasing operation in progress
SYN1-	MANOK	OUT	Manual synchronism/energising check OK
SYN1-	TESTCB	OUT	Close circuit breaker test output
SYN1-	VSUB1	OUT	Voltage selection from bus 1
SYN1-	VSUB2	OUT	Voltage selection from bus 2
SYN1-	VSUF1	OUT	Voltage selection from feeder 1
SYN1-	VSUF2	OUT	Voltage selection from feeder 2

5.3 Setting table

Parameter	Range	Unit	Default	Parameter description
Operation	Off, Release, On		Off	Synchro-check function Off/Release/On
InputPhase	L1, L2, L3, L1-L2, L2-L3, L3-L1		L1	Select input voltage
UMeasure	Ph/N, Ph/Ph		Ph/N	Select input voltage Ph/N or Ph/Ph
PhaseShift	0-360	degrees	0	Phase shift between U-bus and U-line
URatio	0.20-5.00		1.00	Voltage ratio between U-bus and U-line
USelection	SingleBus, DbleBus		Single-Bus	Bus arrangement for voltage selection
AutoEnerg	Off, DLLB, DBLL, Both		Off	Auto energising/synchronising method
ManEnerg	Off, DLLB, DBLL, Both		Off	Manual energising/synchronising method
ManDBDL	Off, On		Off	Manual dead-bus and dead-line energising
UHigh	50-120	%	80	High voltage limit, as a percentage of Ub
ULow	10-100	%	40	Low voltage limit, as a percentage of Ub
FreqDiff	0.05-0.30	Hz	0.20	Frequency difference limit
PhaseDiff	5-75	degrees	20	Phase difference limit
UDiff	5-50	%	20	Voltage difference limit, as a percentage of Ub
tAutoEnerg	0.000-60.000	s	0.100	Auto energising time delay period
tManEnerg	0.000-60.000	s	0.100	Manual energising time delay period
Operation-Synch	Off, On		Off	Phasing function Off/On
ShortPulse	Off, On		Off	Short pulse Off/On
FreqDiff-Synch	0.05-0.50	Hz	00.30	Frequency diff limit for phasing
tPulse	0.000-60.000	s	0.200	Breaker closing pulse duration
tBreaker	0.02-0.50	s	0.20	Closing time of the breaker

1 Application

1.1 Phasing

The phasing function is used to close a circuit breaker when two asynchronous systems are going to be connected. The breaker close command is issued at the optimum time when conditions across the breaker are satisfied in order to avoid stress on the network and its components.

The systems are defined to be asynchronous when the frequency difference between bus and line is larger than an adjustable parameter. If the frequency difference is less than this threshold value the system is defined to have a parallel circuit and the synchro-check function is used.

The phasing function measures the difference between the U-line and the U-bus. It operates and issues a closing command to the circuit breaker when the calculated closing angle is equal to the measured phase angle and these conditions are simultaneously fulfilled.

- The voltages U-line and U-bus are higher than the set value for UHigh of the base voltage U1b.
- The difference in the voltage is smaller than the set value of UDiff.
- The difference in frequency is less than the set value of FreqDiffSynch and larger than the set value of FreqDiff. If the frequency is less than FreqDiff the synchro-check is used. The bus and line frequencies must also be within a range of ±5 Hz from the rated frequency.
- The frequency rate of change is less than 0.21 Hz/s for both U-bus and U-line.
- The closing angle is less than approx. 60 degrees.

The phasing function compensates for measured slip frequency as well as the circuit breaker closing delay. The phase advance is calculated continuously by the following formula:

$$\textit{Closing angle} = 360° \cdot \textit{Meas. freq. diff.} \cdot \textit{tBreaker} \qquad \text{(Equation 1)}$$

Closing angle is the change in angle during breaker closing delay.

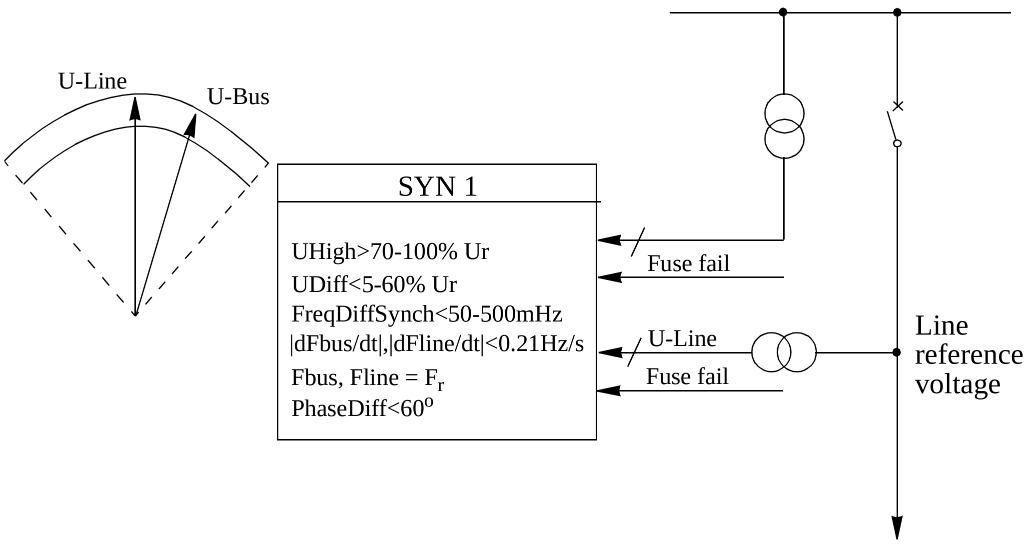


Figure 1: Phasing.

1.2 Synchrocheck

The synchrocheck function is used for controlled closing of a circuit in an interconnected network. When used, the function gives an enable signal at satisfied voltage conditions across the breaker to be closed. When there is a parallel circuit established, the frequency is normally the same at the two sides of the open breaker. At power swings, e.g. after a line fault, an oscillating difference can appear. Across the open breaker, there can be a phase angle and a voltage amplitude difference due to voltage drop across the parallel circuit or circuits. The synchrocheck function measures the difference between the U-line and the U-bus, regarding voltage (UDiff), phase angle (PhaseDiff), and frequency (FreqDiff). It operates and permits closing of the circuit breaker when these conditions are simultaneously fulfilled.

- The voltages U-line and U-bus are higher than the set value for UHigh of the base voltage U1b.
- The differences in the voltage and phase angles are smaller than the set values of UDiff and PhaseDiff.
- The difference in frequency is less than the set value of FreqDiff. The bus frequency must also be within a range of ±5 Hz from the rated frequency.

The function can be used as a condition to be fulfilled before the breaker is closed at manual closing and/or together with the auto-recloser function.

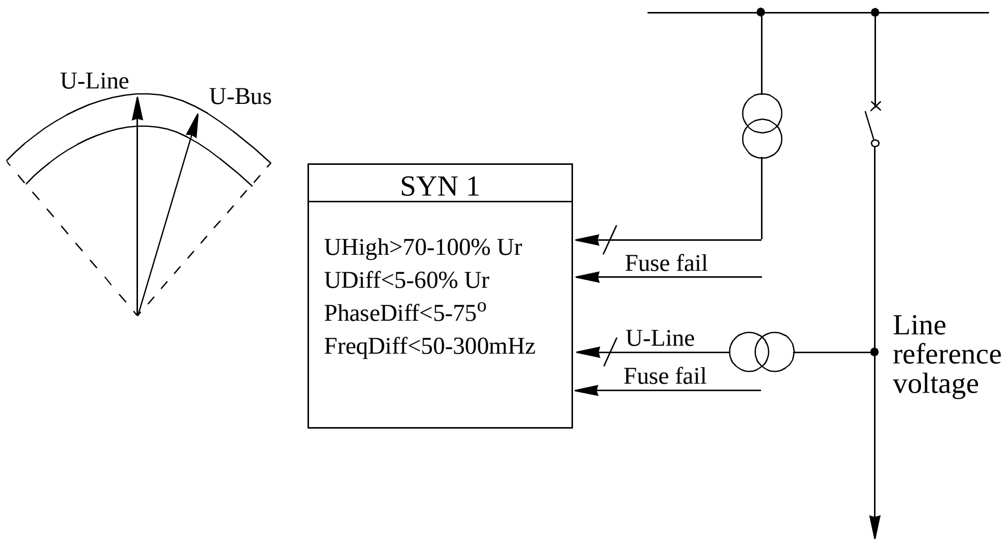


Figure 2: Synchrocheck.

The reference voltage can be single-phase L1, L2, L3 or phase-phase L1-L2, L2-L3, L3-L1. The U-bus voltage must then be connected to the same phase or phases as are chosen on the HMI. Figure 3: shows the voltage connection.

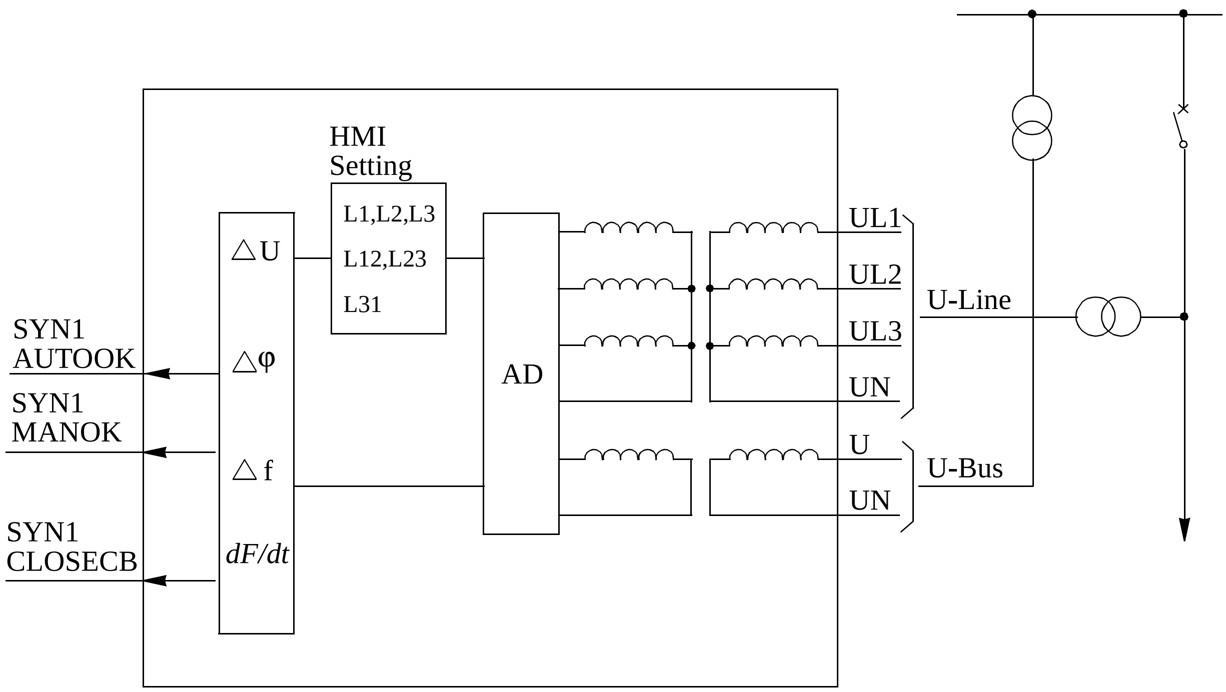


Figure 3: Connection of the phasing and synchrocheck function for one bay.

1.3 Energising check

The energising check is made when a disconnected line is to be connected to an energised section of a network, see Figure 4:. The check can also be set to allow energisation of the busbar or in both directions.

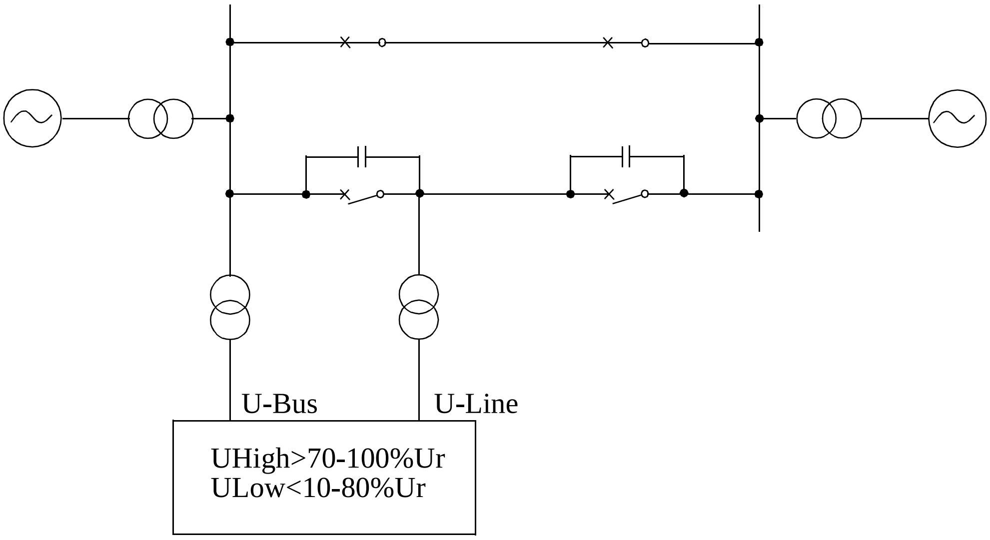


Figure 4: Principle for energising check.

The voltage level considered to be a non-energised bus or line is set on the HMI. An energising can occur — depending on the set direction of the energising function. There are separate setable limits for energised (live) condition, UHigh, and non-energised (dead) ULow conditions. The equipment is considered energised if the voltage is above the set value UHigh (e.g. 80% of base voltage), and non-energised if it is below the set value, ULow (e.g. 30% of the base voltage). The user can set the UHigh condition between 70-100% U1b and the ULow condition between 10-80% U1b.

A disconnected line can have a considerable potential due to, for instance, induction from a line running in parallel, or by being fed via the extinguishing capacitors in the circuit breakers. This voltage can be as high as 30% or more of the rated voltage of the line.

The energising operation can be set to operate in either direction over the circuit breaker, or it can be permitted to operate in both directions. Use the AutoEnerg and ManEnerg HMI setting to select the energising operation in:

- Both directions (Both)
- Dead line live bus (DLLB)
- Dead bus live line (DBLL)

The voltage check can also be set Off. A closing impulse is issued to the circuit breaker if one of the U-line or U-bus voltages is High and the other is Low, that is, when only one side is energised. The user can set AutoEnerg and ManEnerg to enable different conditions during automatic and manual closing of the circuit breaker.

In the manual mode it is also possible to allow closing when both sides of the breaker are dead. This is done by setting the parameter ManDBDL = “On” and ManEnerg to “DLLB”, “DBLL” or “Both”.

1.4 Voltage selection

The voltage selection function is used for the phasing and synchronism (SYN1) and energising check functions. When the terminal is used in a double bus, the voltage that should be selected depends on the positions of the breakers and/or disconnectors. By checking the position of the disconnectors and/or breakers auxiliary contacts, the terminal can select the right voltage for the synchronism and energising function. Select the type of voltage selection from the Synchro-check, Uselection, SingleBus or DbleBus on the HMI.

The configuration of internal signal inputs and outputs may be different for different busbar systems, and the actual configuration for the substation must be done during engineering of the terminal.

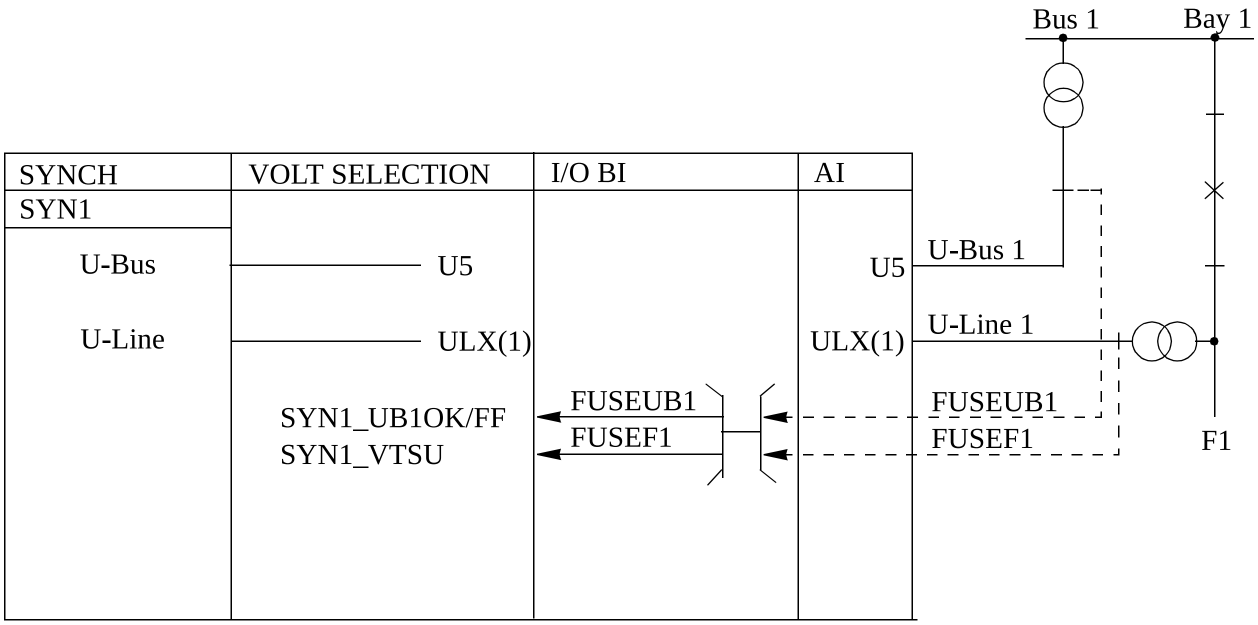


Figure 5: Voltage connection in a single busbar arrangement.

1.4.1 Voltage selection for a single busbar

Single bus is selected on the HMI. Figure 5: shows the principle for the connection arrangement. For the phasing, synchrocheck (SYN1) and energising check function, there is one voltage transformer at each side of the circuit breaker. The voltage transformer circuit connections are straight forward, no special voltage selection is needed.

For the phasing, synchrocheck and energising check, the voltage from Bus 1 (SYN1-U-Bus) is connected to the single phase analogue input (U5) on the terminal unit.

Fuse failure and Voltage OK signals

The external fuse-failure signals or signals from a tripped fuse switch/ MCB are connected to binary inputs configured to inputs of the synchro-check functions in the terminal. There are two alternative connection possibilities. Inputs named OK must be supplied if the voltage circuit is healthy. Inputs named FF must be supplied if the voltage circuit is faulty.

The SYN1-UB1OK and SYN1-UB1FF inputs are related to the busbar voltage. Configure them to the binary inputs that indicate the status of the external fuse failure of the busbar voltage. The SYN1-VTSU input is related to the line voltage from each line.

The user can use the FUSE-VTSU signal from the built-in optional selectable fuse-failure function as an alternative to the external fuse-failure signals.

In case of a fuse failure, the energising check (dead line check) is blocked via the inputs (SYN1-UB1OK/FF or SYN1-VTSU).

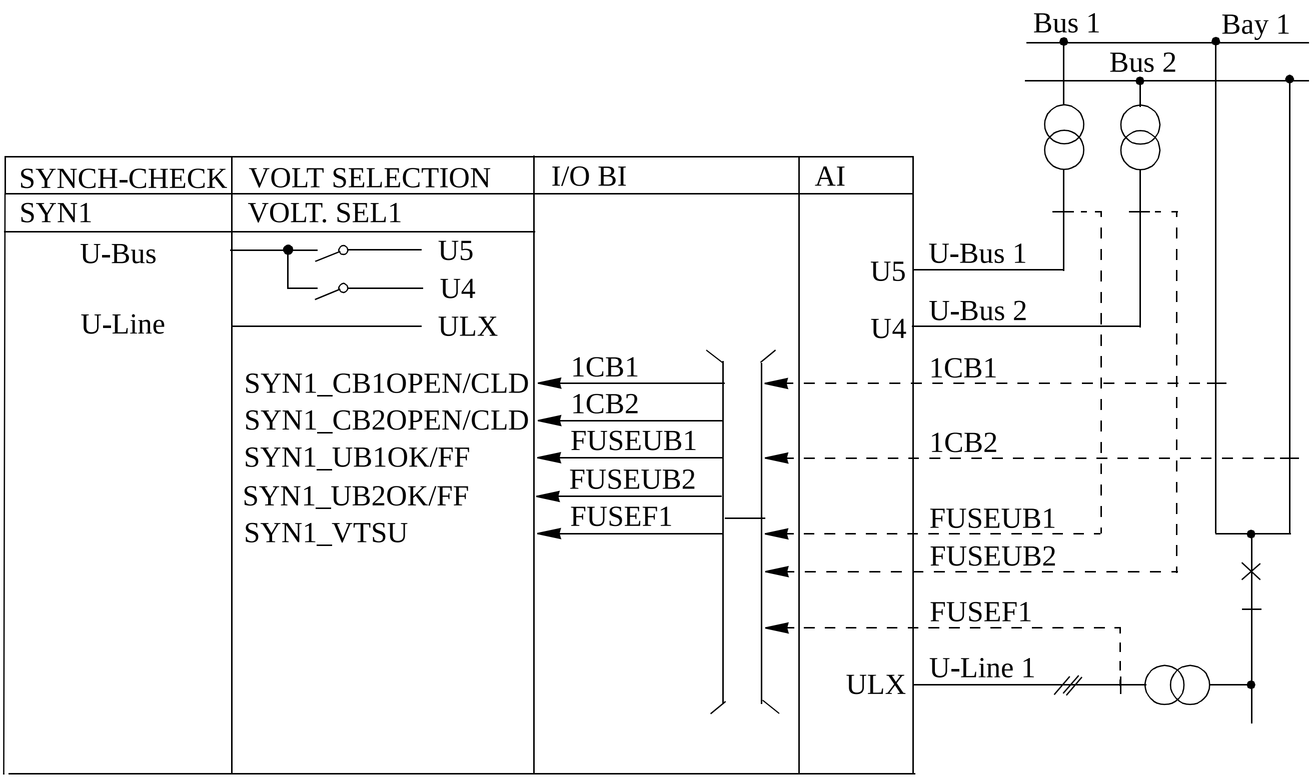


Figure 6: Voltage selection in a double bus arrangement.

1.4.2 Voltage selection for a double bus

Select DbleBus on the HMI. Figure 6: shows the principle for the connection arrangement. For the phasing and synchrocheck (SYN1) and energising check function, the voltages on the two busbars are selected by voltage selection (VOLT.SEL1) in the terminal unit. The bus voltage from

Bus 1 is fed to the U5 analogue single-phase input, and the bus voltage from Bus 2 is fed to the U4 analogue single-phase input. The line voltage transformers are connected as a three-phase voltage UL1, UL2, UL3 (ULx) to the input U-line.

The selection of the bus voltage is made by checking the position of the disconnectors' auxiliary contacts connected via binary inputs of the voltage selection logic inputs, SYN1-CB1OPEN (Disconnector section 1 open), SYN1-CB1CLD (Disconnector section 1 closed) and SYN1-CB2OPEN (Disconnector section 2 open), SYN1-CB2CLD (Disconnector section 2 closed).

1.4.2.1 Fuse failure and Voltage OK signals

The external fuse-failure signals or signals from a tripped fuse switch/ MCB are connected to binary inputs configured to inputs of the synchro-check functions in the terminal. There are two alternative connection possibilities. Inputs named OK must be supplied if the voltage circuit is healthy. Inputs named FF must be supplied if the voltage circuit is faulty.

The SYN1-UB1(2)OK and SYN1-UB1(2)FF inputs are related to each busbar voltage. The SYN1-VTSU input is related to each line voltage. Configure them to the binary inputs that indicate the status of the external fuse failure of the busbar respectively the line voltage. Only the fuse failure of a selected voltage causes a blocking of the relevant energising check unit.

The user can use the FUSE-VTSU signal from the built-in optional selectable fuse-failure function as an alternative to the external fuse-failure signals.

In case of a fuse failure, the energising check (dead line check) is blocked via the inputs (SYN1-UB1OK/FF, SYN1-UB2OK/FF or SYN1-VTSU).

2 Theory of operation

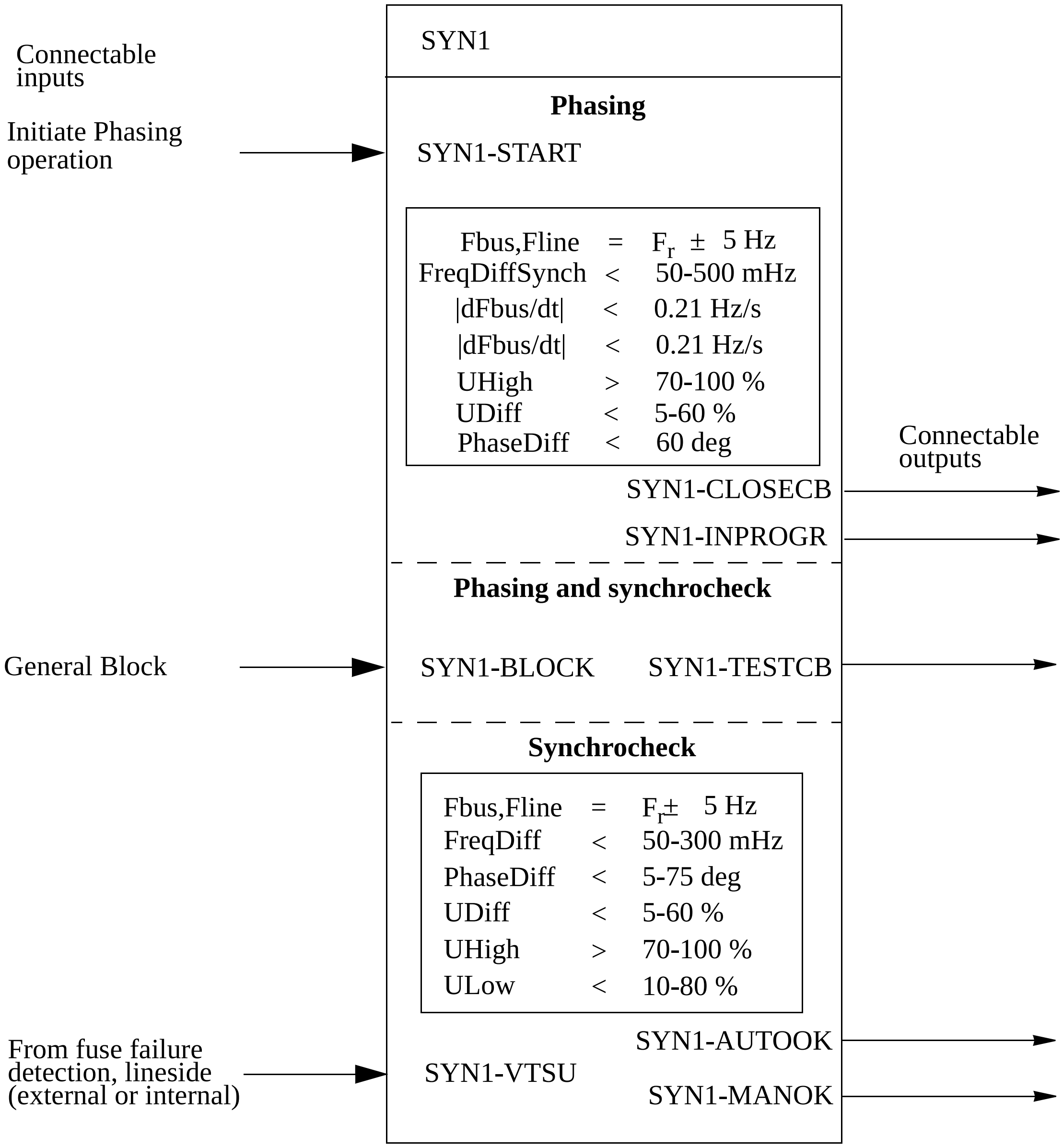


Figure 7: Input and output signals.

2.1 In- and output signals

Description of input and output signals for the phasing and synchrocheck function.

Input signals	Description
SYN1-BLOCK	General block input from any external condi tion, that should block the phasing and the synchrocheck.
SYN1-VTSU	The SYNC function cooperates with the FUSE-VTSU connected signal, which is the built-in optional fuse failure detection. It can also be

	connected to external condition for fuse failure. This is a blocking condition for the energising function.
SYN1-START	The signal initiates the phasing operation. When initiated the function continues until the SYN1-CLOSECB pulse is submitted or it is stopped by the SYN1-BLOCK signal. In test mode (SYN1-TESTCB) ends the phasing operation.

Output signals	**Description**
SYN1-TESTCB	Output when the function is in test mode. In test mode a complete phasing sequence is performed except for closing of the circuit breaker. The output signal SYN1-TESTCB indicates when the SYN1-CLOSECB signal would have been submitted from the phasing function or when the conditions for paralleling are fulfilled, from the synchro-check function
SYN1-CLOSECB	Close breaker command from phasing. Used to the circuit breaker or to be connected to the auto-reclosing function.
SYN1-INPROGR	The signal is high when a phasing operation is in progress, i.e from the moment a SYN1-START is received until the operation is terminated. The operation is teminated when SYN1-CLOSECB or SYN1-TESTCB has been submitted or if a SYN1-BLOCK is received.
SYN1-AUTOOK	Synchrocheck/energising OK. The output signal is high when the synchro-check conditions set on the HMI are fulfilled. It can also include the energising condition, if selected. The signal can be used to release the autorecloser before closing attempt of the circuit breaker. It can also be used as a free signal.
SYN1-MANOK	Same as above but with alternative settings of the direction for energising to be used during manual closing of the circuit breaker.

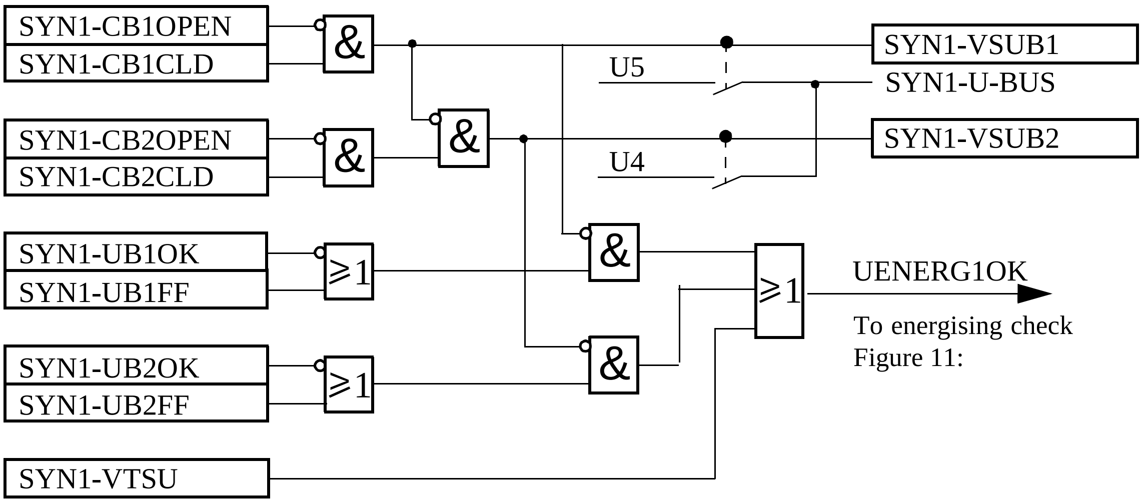


Figure 8: Simplified voltage selection logic in a double bus, single breaker arrangement.

Description of the input and output signals shown in the above simplified logic diagrams for voltage selection:

Input signal	**Description**
SYN1-CB1OPEN	Disconnector section 1 of Bay 1 open. Connected to the auxiliary contacts of a disconnector section in a double-bus, single breaker arrangement, to inform the voltage selection about the positions.
SYN1-CB1CLD	Disconnector section 1 of Bay 1 closed. Connected to the auxiliary contacts of a disconnector section in a double-bus, single breaker arrangement to inform the voltage selection about the positions.
SYN1-CB2OPEN	Same as above but for disconnector section 2.
SYN1-CB2CLD	Same as above but for disconnector section 2.
SYN1-UB1FF	External fuse failure input from busbar voltage Bus 1 (U5). This signal can come from a tripped fuse switch (MCB) on the secondary side of the voltage transformer. In case of a fuse failure, the energising check is blocked.
SYN1-UB1OK	No external voltage fuse failure (U5). Inverted signal.
SYN1-UB2FF	External fuse failure input from busbar voltage Bus 2 (U4). This signal can come from a tripped fuse switch (MCB) on the secondary side of the voltage transformer. In case of fuse failure, the energising check is blocked.

SYN1-UB2OK	No external voltage fuse failure (U4). Inverted signal.
SYN1-VTSU	Internal fuse failure detection or configured to a binary input indicating external fuse failure of the UL1, UL2, UL3 line-side voltage. Blocks the energising function.

Output signals	**Description**
SYN1-VSUB1	Signal for indication of voltage selection from Bus 1 voltage.
SYN1-VSUB2	Signal for indication of voltage selection from Bus 1 voltage.

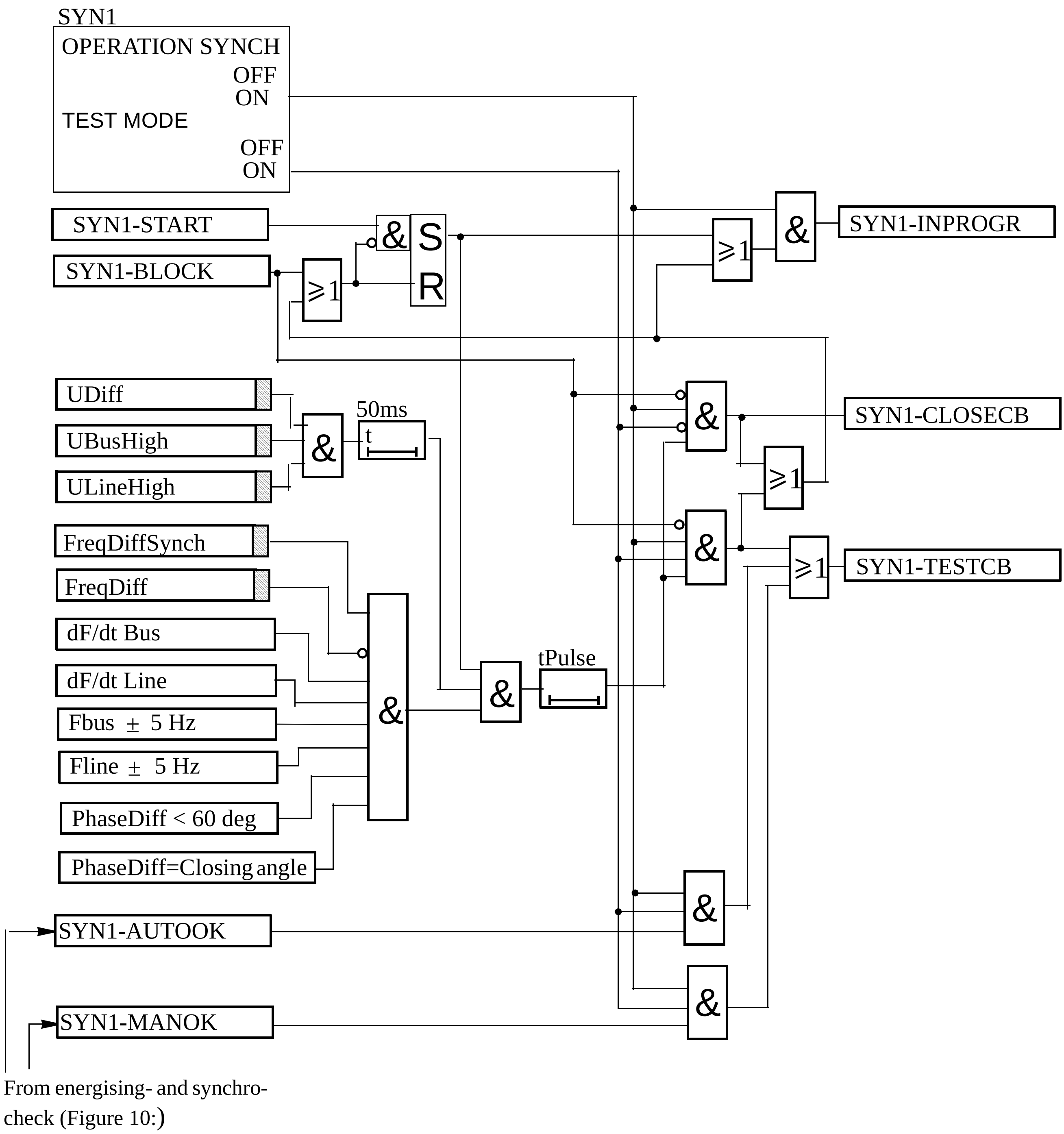


Figure 9: Simplified logic diagram - Phasing

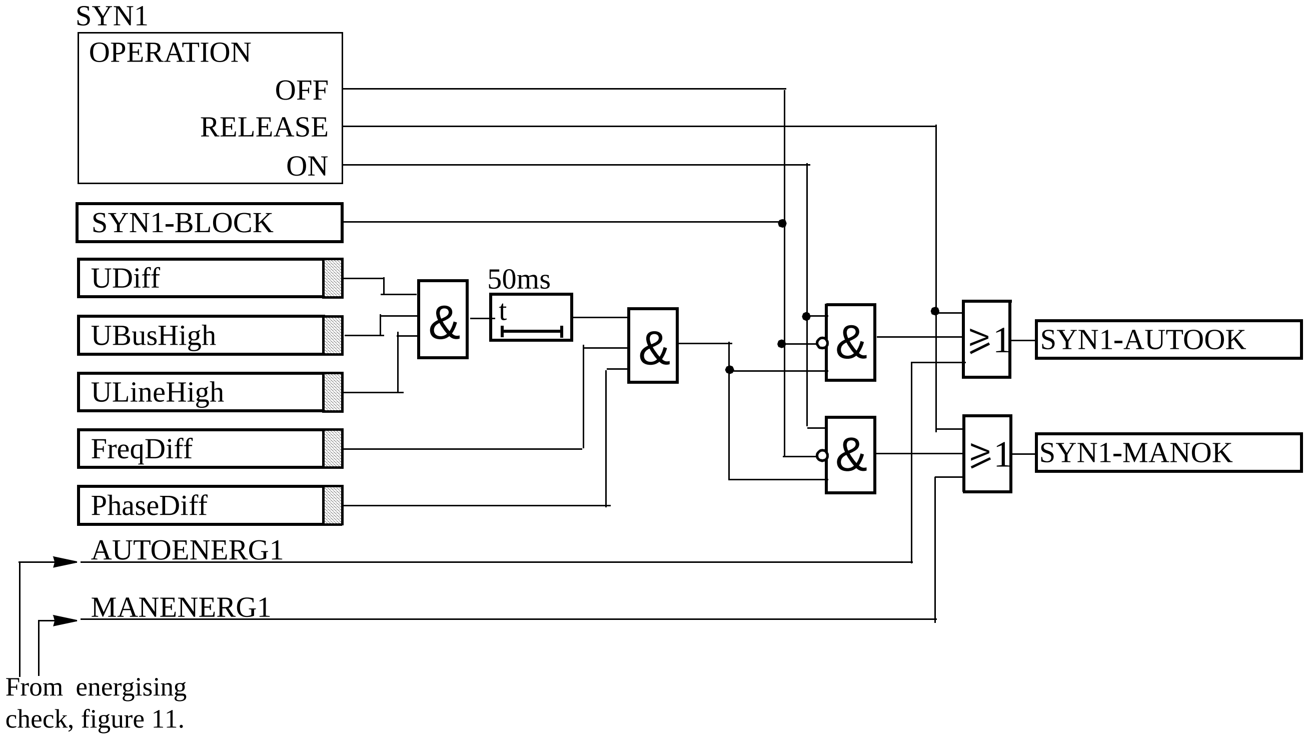


Figure 10: Simplified logic diagram - Synchrocheck

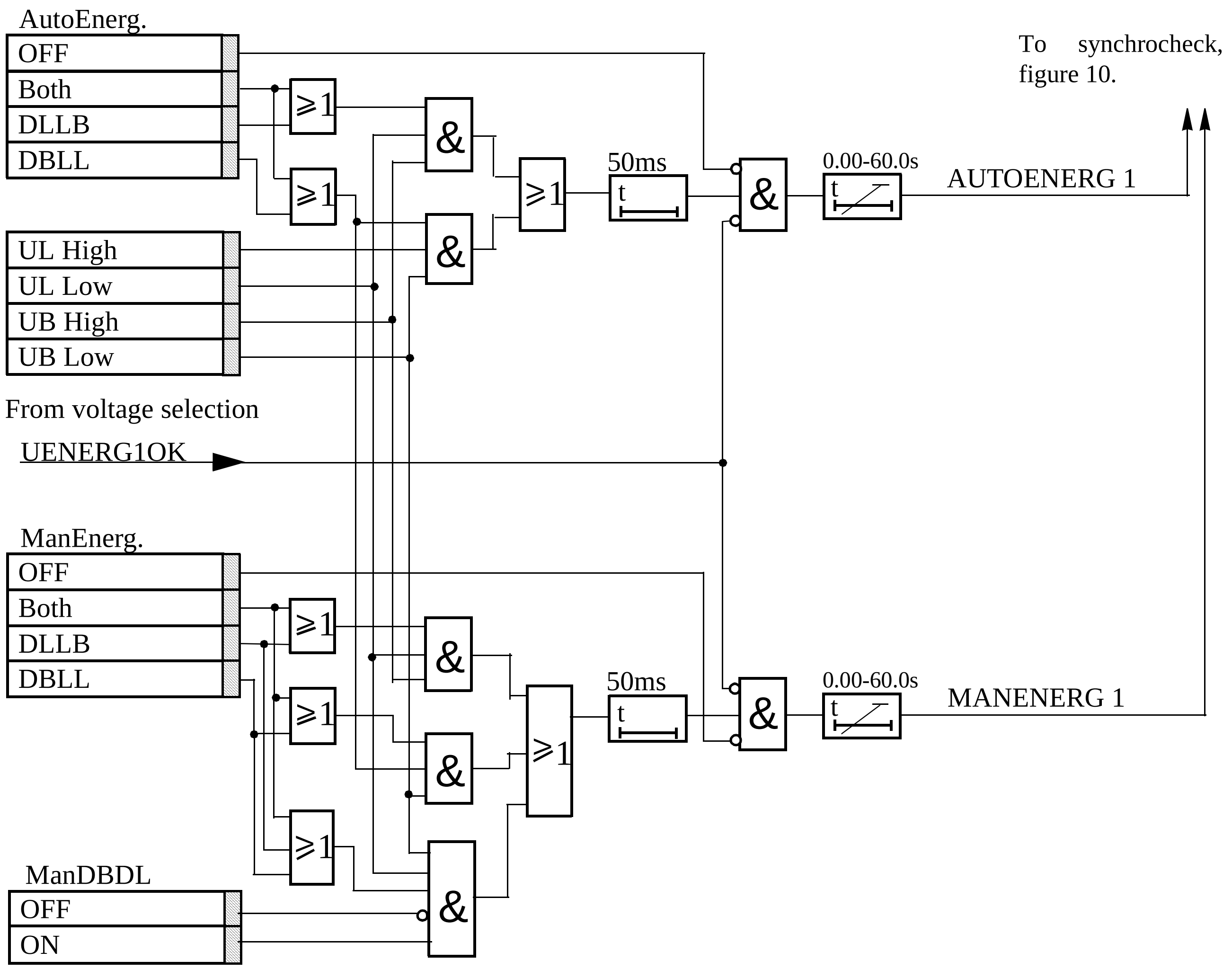


Figure 11: Simplified logic diagram - Energising check

3 Setting

The setting parameters are accessible through the HMI. The parameters for the phasing and synchrocheck function are found in the MMI tree under:

Settings
Functions
Group n (n=1-4)
SynchroCheck
SynchroCheck1

3.1 Operation

Off	The synchrocheck function is off and the output is low.
Release	There are fixed, high output signals SYN1-AUTOOK = 1 and SYN1-MANOK = 1.
On	The synchro-check function is in service and the output signal depends on the input conditions.

3.2 Input phase

The measuring phase of the UL1, UL2, UL3 line voltage, which can be of a single-phase (phase-neutral) or two-phases (phase-phase).

3.3 PhaseShift

This setting is used to compensate for a phase shift caused by a line transformer between the two measurement points for UBus and ULine. The set value is added to the measured phase difference. The bus voltage is reference voltage.

3.4 URatio

The URatio is defined as URatio=UBus/ULine. A typical use of the setting is to compensate for the voltage difference caused if wished to connect the UBus phase-phase and ULine phase-neutral. The “Input phase”-setting should then be set to phase-phase and the “URatio”-setting to sqr3=1.732. This setting scales up the line voltage to equal level with the bus voltage.

3.5 USelection

Selection of single or double bus voltage-selection logic.

3.6 AutoEnerg and ManEnerg

Two different settings can be used for automatic and manual closing of the circuit breaker.

Off	The energising condition is not used, only the synchro-check.
DLLB	The line voltage U-line is low, below (10-80% U1b) and the bus voltage U-bus is high, above (70-100% U1b).

DBLL	The bus voltage U-bus is low, below (10-80% U1b) and the line voltage U-line is high, above (70-100% U1b).
Both	Energising can be done in both directions, DLLB or DBLL.
tAutoEnerg	The required consecutive time of fulfillment of the energising condition to achieve SYN1-AUTOOK.
tManEnerg	The required consecutive time of fulfillment of the energising condition to achieve SYN1-MANOK.

3.7 ManDBDL

If the parameter is set to “On”, closing is enabled when Both U-Line and U-bus are below ULow and ManEnerg is set to “DLLB”, “DBLL” or “Both”.

3.8 OperationSynch

Off	The phasing function is off and all outputs are low.
On	The phasing function is in service and the output signals depends on the input conditions.

3.9 ShortPulse

Off	The closing pulse issued to the circuit breaker will be of length=tPulse.
On	The closing pulse issued to the circuit breaker will be of length=one cycle time in the internal logic.

4 Testing

At periodical checks, the functions should preferably be tested with the used settings. To test a specific function, it might be necessary to change some setting parameters, for example:

- AutoEnerg = On/Off/DLLB/DBLL/Both
- ManEnerg = Off
- Operation = Off, On

The tests explained in section “Synchrocheck tests” on page 171 describe the settings, which can be used as references during testing, are presented before the final settings are specified. After testing, restore the equipment to the normal or desired settings.

4.1 Test equipment

A secondary injection test set with the possibility to alter the phase angle by regulation of the resistive and reactive components is needed. Here, the phase angle meter is also needed. To perform an accurate test of the frequency difference, a frequency generator at one of the input voltages is needed. The tests can also be performed with the computer-aided test system FREJA.

FREJA has a specially designed program for evaluating the synchrocheck function. Figure 12: shows the general test connection principle, which can be used during testing. This description describes the test of the version intended for one bay.

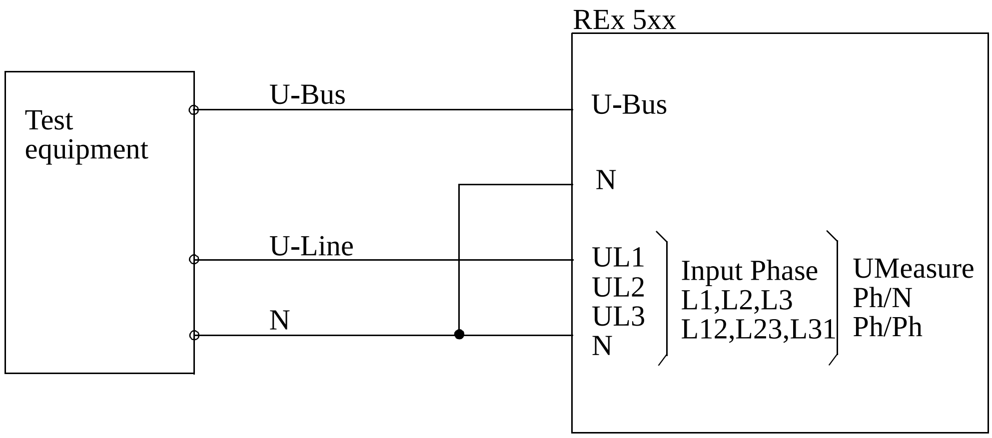


Figure 12: General test connection for phasing and synchrocheck with three-phase voltage connected to the line side.

4.2 Phasing tests

These voltage inputs are used:

U-line	UL1, UL2 or UL3 voltage input on the terminal.
U-bus	U5 voltage input on the terminal

These HMI settings can be used during the test if the final setting is not determined:

1 Set these HMI settings, which are found under:

Settings
Functions
Group n (n=1-4)
SynchroCheck
SynchroCheck1

Table 1: Test settings for phasing

Parameter:	Setting:
Operation	Off
InputPhase	UL1
USelection	SingleBus
PhaseShift	0 deg
URatio	1.00
AutoEnerg	Off
ManEnerg	Off
ManDBDL	Off
UHigh	70% U1b
ULow	40% U1b
FreqDiff	0.05 Hz
PhaseDiff	45°
UDiff	30% U1b
tAutoEnerg	0.5 s
tManEnerg	0.5 s
OperationSynch	On
ShortPulse	Off
FreqDiffSynch	0.40 Hz
tPulse	0.20 s
tBreaker	0.20 s

4.2.1 Test of frequency difference

The frequency difference is set at 0.40 Hz on the HMI, and the test should verify that operation is achieved when the FreqDiffSynch frequency difference is lower than 0.40 Hz.

- Apply voltages U-line (UL1) = 80% U1b, f-line=50.0 Hz and U-Bus (U5) = 80% U1b, f-bus=50.3 Hz
- Check that a closing pulse is submitted with length=0.20 sec. and at closing angle=360 * 0.20 * 0.40=29 deg
- Repeat with U-Bus (U5) = 80% U1b, f-bus=50.5 Hz to verify that the function doesn’t operate when freq.diff is above limit.
- Repeat with different settings on tBreaker and FreqDiffSynch. Make sure that the calculated closing angle is less than 60 deg. Verify that closing command is issued at the correct phase angle when the frequency difference is less than the set value.

4.3 Synchrocheck tests

4.3.1 Test of voltage difference

Set the voltage difference at 30% U1b on the HMI, and the test should check that operation is achieved when the voltage difference UDiff is lower than 30% U1b.

These voltage inputs are used:

U-line	UL1, UL2 or UL3 voltage input on the terminal.
U-bus	U5 voltage input on the terminal

These HMI settings can be used during the test if the final setting is not determined:

1 Set these HMI settings, which are found under:

Settings
Functions
Group n (n=1-4)
SynchroCheck
SynchroCheck1

Table 2: Test settings for voltage difference

Parameter:	Setting:
Operation	On
InputPhase	UL1
USelection	SingleBus
PhaseShift	0 deg
URatio	1.00
AutoEnerg	Off

Table 2: Test settings for voltage difference

ManEnerg	Off
ManDBDL	Off
UHigh	70% U1b
ULow	40% U1b
FreqDiff	0.05 Hz
PhaseDiff	45°
UDiff	30% U1b
tAutoEnerg	0.5 s
tManEnerg	0.5 s
OperationSynch	Off
ShortPulse	Off
FreqDiffSynch	0.4 Hz
tPulse	0.2 s
tBreaker	0.2 s

2 **Test with UDiff = 0%**

- Apply voltages U-line (UL1) = 80% U1b and U-Bus (U5) = 80% U1b.
- Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.
- The test can be repeated with different voltage values to verify that the function operates within UDiff <30%.

3 **Test with UDiff = 40%**

- Increase the U-bus (U5) to 120% U1b, and the U-line (UL1) = 80% U1b.
- Check that the two outputs are **NOT** activated.

4 **Test with UDiff = 20%, Uline < UHigh**

- Decrease the U-line (UL1) to 60% U1b and the U-bus (U5) to be equal to 80% U1b.
- Check that the two outputs are **NOT** activated.

5 **Test with URatio=0.20**

- Run the test under section 2 to 4 but with U-bus voltages 5 times lower.

6 **Test with URatio=5.00**

- Run the test under section 2 to 4 but with U-line voltages 5 times lower.

4.3.2 Test of phase difference

The phase difference is set at 45° on the HMI, and the test should verify that operation is achieved when the PhaseDiff (phase difference) is lower than 45°.

1 Set these HMI settings:

Table 3: Test settings for phase difference

PARAMETER:	SETTING:
Operation	On
InputPhase	UL1
USelection	SingleBus
PhaseShift	0 deg
URatio	1.00
AutoEnerg	Off
ManEnerg	Off
UHigh	70% U1b
ULow	40% U1b
FreqDiff	0.05 Hz
PhaseDiff	45°
UDiff	15% U1b
tAutoEnerg	0.5 s
tManEnerg	0.5 s
ManDBDL	Off
OperationSynch	Off
ShortPulse	Off
FreqDiffSynch	0.4 Hz
tPulse	0.2 s
tBreaker	0.2 s

2 **Test with PhaseDiff = 0°**
Apply voltages U-line (UL1) = 100% U1b and U-bus (U5) = 100% U1b, with a phase difference equal to 0° and a frequency difference that is lower than 50 mHz.
Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.

3 The test can be repeated with other PhaseDiff values to verify that the function operates for values lower than the set ones. By changing the phase angle on U1 connected to U-bus, between +/- 45°. The user can check that the two outputs are activated for a PhaseDiff lower than 45°. It should not operate for other values. See Figure 13:.

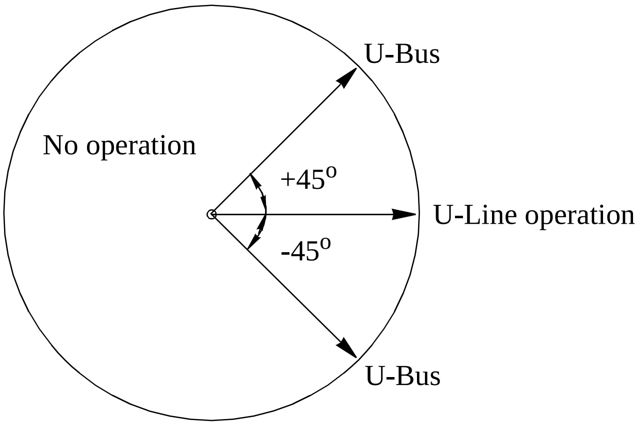


Figure 13: Test of phase difference.

4 Apply a PhaseShift setting of 10 deg. Change the phase angle between +55 and -35 and verify that the two outputs are activated for phase differences between these values but not for phase differences outside. See Figure 14:.

Change the PhaseShift setting to 350 deg. Change the phase angle between +35 and -55 and verify as above.

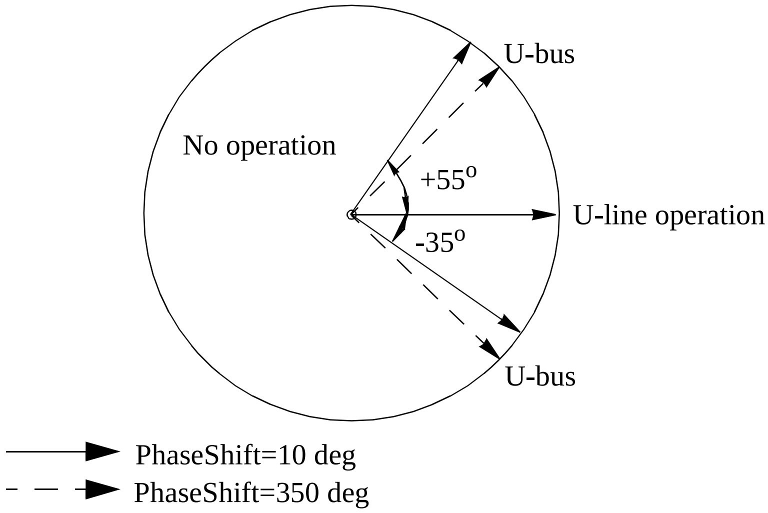


Figure 14: Test of phase difference.

4.3.3 Test of frequency difference

The frequency difference is set at 50 mHz on the HMI, and the test should verify that operation is achieved when the FreqDiff frequency difference is lower than 50 mHz.

1. Use the same HMI setting as in section “Test of phase difference” on page 172.

2. **Test with FreqDiff = 0 mHz**
   Apply voltages U-Line (UL1) equal to 100% U1b and U-Bus (U5) equal to 100% U1b, with a frequency difference equal to 0 mHz and a phase difference lower than 45°. Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.

3. **Test with FreqDiff = 1Hz**
   Apply voltage to the U-line (UL1) equal to 100% U1b with a frequency equal to 50 Hz and voltage U-bus (U5) equal to 100% U1b, with a frequency equal to 49 Hz.
   Check that the two outputs are **NOT** activated.

4. The test can be repeated with different frequency values to verify that the function operates for values lower than the set ones. If the FREJA program, *Test of synchronising relay*, is used the frequency can be changed continuously.

   Note! A frequency difference also implies a floating mutual-phase difference. So the SYN1-AUTOOK and SYN1-MANOK outputs might NOT be stable, even though the frequency difference is within set limits, because the phase difference is not stable!

4.3.4 Test of reference voltage

1. Use the same basic test connection as in Figure 12:. The UDiff between the voltage connected to U-bus and U-line should be 0%, so that the SYN1-AUTOOK and SYN1-MANOK outputs are activated first.
   Change the U-Line voltage connection to UL2 without changing the setting on the HMI
   Check that the two outputs are **NOT** activated.

2. The test can also be repeated by moving the U-line to the UL3 input.

4.4 Test of energising check

Use these voltage inputs:

U-line = UL1, UL2 or UL3 voltage input on the terminal.

U-bus = U5 voltage input on the terminal.

4.4.1 Test of dead line live bus (DLLB)

The test should verify that the energising function operates for a low voltage on the U-Line and for a high voltage on the U-bus. This corresponds to an energising of a dead line to a live bus.

Use these HMI settings during the test if the final setting is not determined.

1 Set these HMI settings:

Table 4: Test settings for DLLB

Parameter:	Setting:
Operation	On
InputPhase	UL1
PhaseShift	0 deg
URatio	1.00
USelection	SingleBus
AutoEnerg	DLLB
ManEnerg	DLLB
ManDBDL	Off
UHigh	80% U1b
ULow	40% U1b
FreqDiff	0.05 Hz
PhaseDiff	45°
UDiff	15% U1b
tAutoEnerg	0.5 s
tManEnerg	0.5 s
OperationSynch	Off
ShortPulse	Off
FreqDiffSynch	0.4 Hz
tPulse	0.2 s
tBreaker	0.2 s

2 Apply a single-phase voltage 100% U1b to the U-bus (U5), and a single-phase voltage 30% U1b to the U-line (UL1).

3 Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.

4 Increase the U-Line (UL1) to 60% U1b and U-Bus(U5) to be equal to 100% U1b. The outputs should **NOT** be activated.

5 The test can be repeated with different values on the U-Bus and the U-Line.

4.4.2 Dead bus live line (DBLL)

The test should verify that the energising function operates for a low voltage on the U-bus and for a high one on the U-line. This corresponds to an energising of a dead bus from a live line.

1 Change the HMI settings AutoEnerg and ManEnerg to DBLL**.**

2 Apply a single-phase voltage of 30% U1b to the U-bus (U5) and a single-phase voltage of 100% U1b to the U-line (UL1).

3 Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.

4 Decrease the U-line to 60% U1b and keep the U-bus equal to 30% U1b.
The outputs should **NOT** be activated.

5 The test can be repeated with different values on the U-bus and the U-line.

4.4.3 Energising in both directions (DLLB or DBLL)

1 Change the HMI settings AutoEnerg and ManEnerg to Both.

2 Apply a single-phase voltage of 30% U1b to the U-line (UL1) and a single-phase voltage of 100% U1b to the U-bus (U5).

3 Check that the “SYN1-AUTOOK” and “SYN1-MANOK” outputs are activated.

4 Change the connection so that the U-line (UL1) is equal to100% U1b and the U-bus (U5) is equal to 30% U1b.

5 The outputs should still be activated.

6 The test can be repeated with different values on the U-bus and the U-line.

7 Restore the equipment to normal or desired settings.

4.4.4 Dead bus Dead line (DBDL)

The test should verify that the energising function operates for a low voltage on both the U-bus the U-line, i.e closing of the breaker in a non energised system.

1 Set AutoEnerg to Off and ManEnerg to DBLL.

Set ManDBDL to On.

2 Apply a single-phase voltage of 30% U1b to the U-bus (U5) and a single-phase voltage of 30% U1b to the U-line (UL1).

3 Check that the SYN1-MANOK output is activated.

4 Increase the U-bus to 80% U1b and keep the U-line equal to 30% U1b.
The outputs should **NOT** be activated.

5 Repeat the test with ManEnerg set to DLLB and Both, and different values on the U-bus and the U-line.

4.4.5 Test of voltage selection

This test should verify that the correct voltage is selected for the measurement in the energising function used in a double-bus arrangement. Apply a single-phase voltage of 30% U1b to the U-line (UL1) and a single-phase voltage of 100% U1b to the U-bus (U5).

If the SYN1-UB1/2OK inputs for the fuse failure are used, normally they must be activated, thus activated and deactivated must be inverted in the description of tests below.

1 Set these HMI settings:

Table 5: Test settings for voltage selection

Parameter	Setting
Operation	On
InputPhase	UL1
USelection	DbleBus
PhaseShift	0 deg
URatio	1.00
AutoEnerg	Both
ManEnerg	Both
ManDBDL	Off
UHigh	80% U1b
ULow	40% U1b
FreqDiff	0,05 Hz
PhaseDiff	45°
UDiff	15% U1b
tAutoEnerg	0.5 s
tManEnerg	0.5 s
OperationSynch	Off
ShortPulse	Off
FreqDiffSynch	0.4 Hz
tPulse	0.2 s
tBreaker	0.2 s

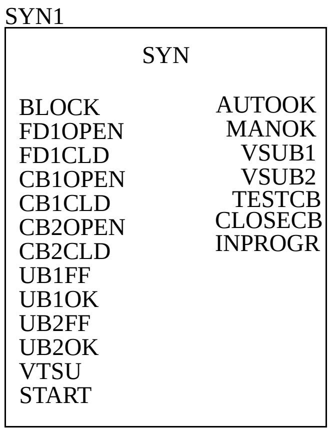
2 Connect the signals below to binary inputs and binary outputs. Apply signals according to the table and verify that correct output signals are generated.

Table 6: Signals

VOLTAGE FROM BUS1 U5	VOLTAGE FROM BUS2 U4	BINARY INPUTS	CB1OPEN	CB1CLD	CB2OPEN	CB2CLD	UB1FF	UB2FF	VTSU	BINARY OUTPUTS	AUTOOK	MANOK	VSUB1	VSUB2
1	0		1	0	1	0	0	0	0		1	1	1	0
1	0		0	1	1	0	0	0	0		1	1	1	0
1	0		0	1	1	0	1	0	0		0	0	1	0
1	0		0	1	1	0	0	1	0		1	1	1	0
1	0		0	1	1	0	0	0	1		0	0	1	0
1	0		0	1	0	1	0	0	0		1	1	1	0
1	0		1	0	0	1	0	0	0		0	0	0	1
0	1		0	1	1	0	0	0	0		0	0	1	0
0	1		0	1	0	1	0	0	0		0	0	1	0
0	1		1	0	0	1	0	0	0		1	1	0	1
0	1		1	0	0	1	1	0	0		1	1	0	1
0	1		1	0	0	1	0	1	0		0	0	0	1
0	1		1	0	0	1	0	0	1		0	0	0	1
0	1		0	1	0	1	0	0	0		0	0	1	0

5 Appendix

5.1 Function block



5.2 Signal list

Block	**Signal**	**Type**	**Description**
SYNx-	BLOCK	IN	Block of synchrocheck function x (x=1-4)
SYNx-	FD1OPEN	IN	Feeder disconnector 1 open
SYNx-	FD1CLD	IN	Feeder disconnector 1 closed
SYNx-	CB1OPEN	IN	Breaker section 1 open
SYNx-	CB1CLD	IN	Breaker section 1 closed
SYNx-	CB2OPEN	IN	Breaker section 2 open
SYNx-	CB2CLD	IN	Breaker section 2 closed
SYNx-	UB1FF	IN	External voltage fuse failure, bus 1
SYNx-	UB1OK	IN	External voltage fuse healthy, bus 1
SYNx-	UB2FF	IN	External voltage fuse failure, bus 2
SYNx-	UB2OK	IN	External voltage fuse healthy, bus 2
SYNx-	VTSU	IN	Block from internal fuse failure supervision or from external fuse failure of the line voltage.
SYNx-	START	IN	Initiate phasing operation
SYNx-	AUTOOK	OUT	Automatic synchronism/energising check OK
SYNx-	MANOK	OUT	Manual synchronism/energising check OK
SYNx-	VSUB1	OUT	Voltage selection from bus 1
SYNx-	VSUB2	OUT	Voltage selection from bus 2
SYNx-	TESTCB	OUT	Close circuit breaker test output
SYNx-	CLOSECB	OUT	Close circuit breaker pulse
SYNx-	INPROGR	OUT	Phasing operation in progress

5.3 Setting table

Parameter	Range	Unit	Default	Parameter description
Operation	Off, Release, On		Off	Synchrocheck function Off/Release/On
InputPhase	L1, L2, L3, L1-L2, L2-L3, L3-L1		L1	Select input voltage
UMeasure	Ph/N, Ph/Ph		Ph/N	Select input voltage Ph/N or Ph/Ph
PhaseShift	0-360	degrees	0	Phase shift between U-bus and U-line
URatio	0.20-5.00		1.00	Voltage ratio between U-bus and U-line
USelection	SingleBus, DbleBus		Single-Bus	Bus arrangement for voltage selection
AutoEnerg	Off, DLLB, DBLL, Both		Off	Auto energising/synchronising method
ManEnerg	Off, DLLB, DBLL, Both		Off	Manual energising/synchronising method
ManDBDL	Off, On		Off	Manual dead-bus and dead-line energising
UHigh	50-120	%	80	High voltage limit, as a percentage of Ub
ULow	10-100	%	40	Low voltage limit, as a percentage of Ub
FreqDiff	0.05-0.30	Hz	0.20	Frequency difference limit
PhaseDiff	5-75	degrees	20	Phase difference limit
UDiff	5-50	%	20	Voltage difference limit, as a percentage of Ub
tAutoEnerg	0.000-60.000	s	0.100	Auto energising time delay period
tManEnerg	0.000-60.000	s	0.100	Manual energising time delay period
Operation-Synch	Off, On		Off	Phasing function Off/On
ShortPulse	Off, On		Off	Short pulse Off/On
FreqDiff-Synch	0.05-0.50	Hz	00.30	Frequency diff limit for phasing
tPulse	0.000-60.000	s	0.200	Breaker closing pulse duration
tBreaker	0.02-0.50	s	0.20	Closing time of the breaker

1 Application

1.1 Phasing

The phasing function is used to close a circuit breaker when two asynchronous systems are going to be connected. The close breaker command is issued at the optimum time when conditions across the breaker are satisfied in order to avoid stress on the network and its components.

The systems are defined to be asynchronous when the frequency difference between bus and line is larger than an adjustable parameter. If the frequency difference is less than this treshold value the system is defined to have a parallel circuit and the synchro-check function is used.

The phasing function measures the difference between the U-line and the U-bus. It operates and issues a closing command to the circuit breaker when the calculated closing angle is equal to the measured phase angle and these conditions are simultaneously fulfilled.

- The voltages U-line and U-bus are higher than the set value for UHigh of the base voltage U1b.
- The difference in the voltage is smaller than the set value of UDiff.
- The difference in frequency is less than the set value of FreqDiff-Synch and larger than the set value of FreqDiff. If the frequency is less than FreqDiff the synchro-check is used. The bus and line frequencies must also be within a range of ±5 Hz from the rated frequency.
- The frequency rate of change is less than 0.21 Hz/s for both U-bus and U-line.
- The closing angle is less than approx. 60 degrees.

The phasing function compensates for measured slip frequency as well as the circuit breaker closing delay. The phase advance is calculated continuously by the following formula:

$$\textit{Closing angle} = 360^\circ \cdot \textit{Meas. freq. diff.} \cdot \textit{tBreaker} \qquad \text{(Equation 1)}$$

Closing angle is the change in angle during breaker closing delay.

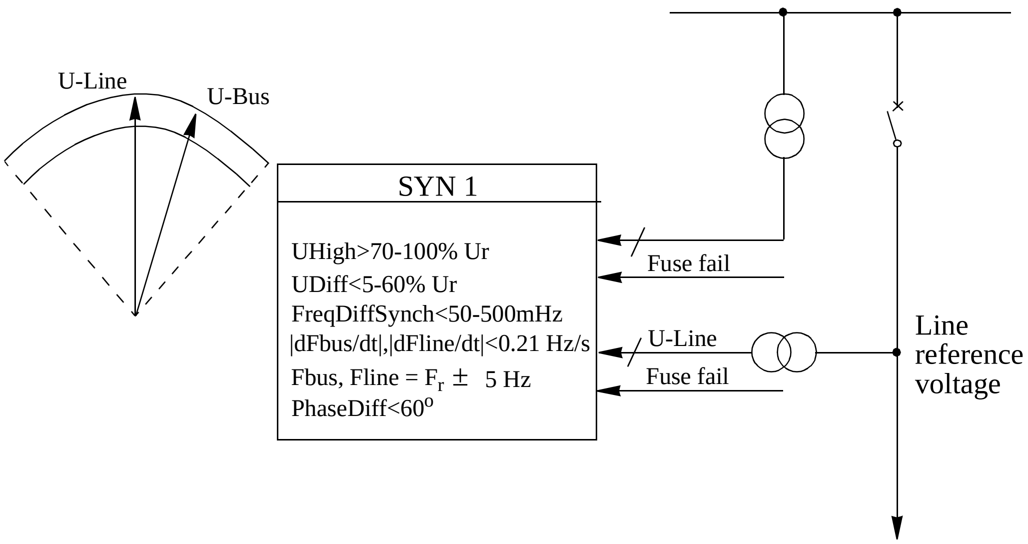


Figure 1: Phasing.

1.2 Synchrocheck

The synchrocheck function is used for controlled closing of a circuit in an interconnected network. When used, the function gives an enable signal at satisfied voltage conditions across the breaker to be closed. When there is a parallel circuit established, the frequency is normally the same at the two sides of the open breaker. At power swings, e.g. after a line fault, an oscillating difference can appear. Across the open breaker, there can be a phase angle and a voltage amplitude difference due to voltage drop across the parallel circuit or circuits. The synchrocheck function measures the difference between the U-line and the U-bus, regarding voltage (UDiff), phase angle (PhaseDiff), and frequency (FreqDiff). It operates and permits closing of the circuit breaker when these conditions are simultaneously fulfilled.

- The voltages U-line and U-bus are higher than the set value for UHigh of the base voltage U1b.
- The differences in the voltage and phase angles are smaller than the set values of UDiff and PhaseDiff.
- The difference in frequency is less than the set value of FreqDiff. The bus frequency must also be within a range of ±5 Hz from the rated frequency.

The function can be used as a condition to be fulfilled before the breaker is closed at manual closing and/or together with the autorecloser function.

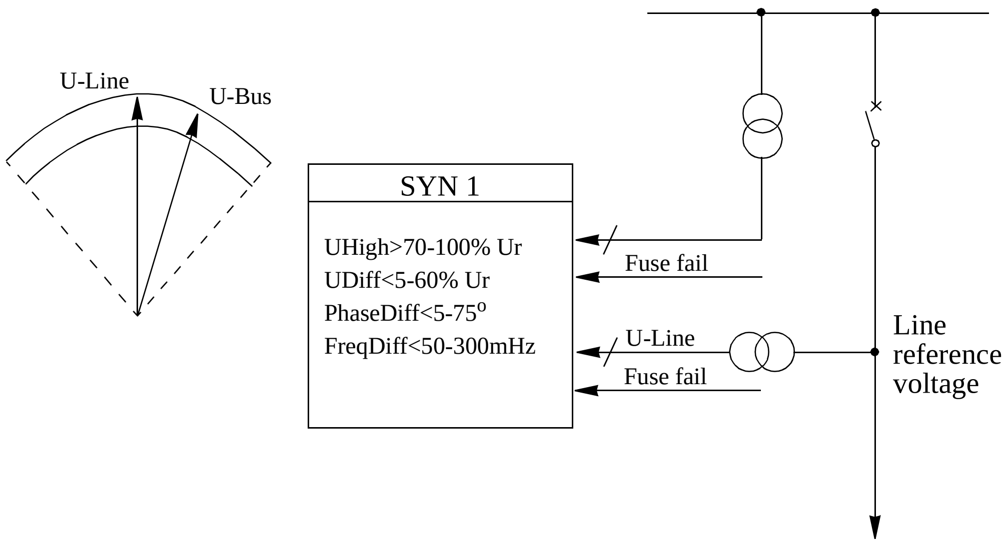


Figure 2: Synchrocheck

The voltage circuits are arranged differently depending on the number of synchrocheck functions that are included in the terminal.

The reference voltage can be single-phase L1, L2, L3 or phase-phase L1-L2, L2-L3, L3-L1. The U-bus voltage must then be connected to the same phase or phases as are chosen on the HMI. Figure 3: shows the voltage connection.

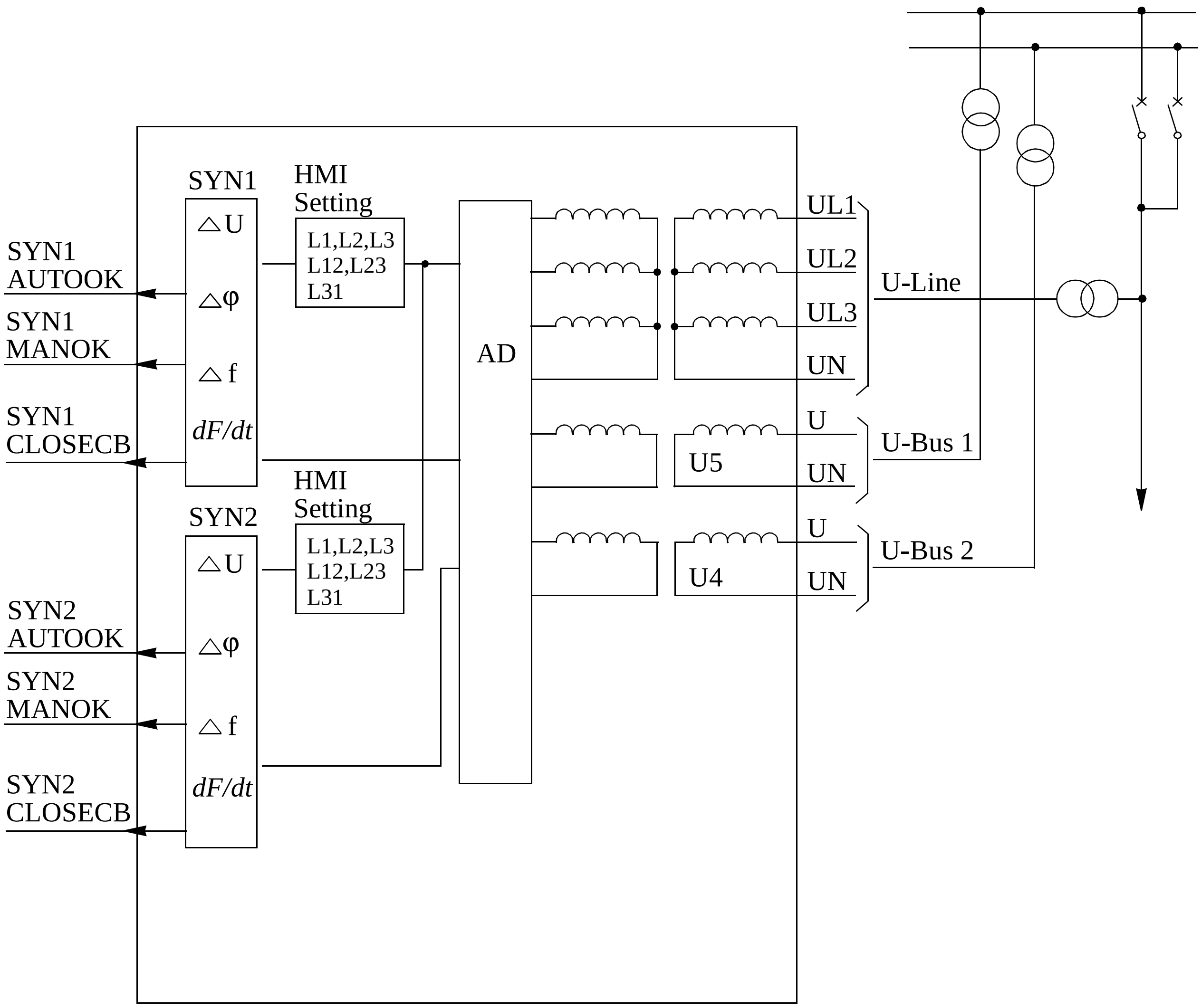


Figure 3: Connection of the phasing and synchrocheck function for one bay.

1.3 Energising check

The energising check is made when a disconnected line is to be connected to an energised section of a network, see Figure 4:. The check can also be set to allow energisation of the busbar or in both directions.

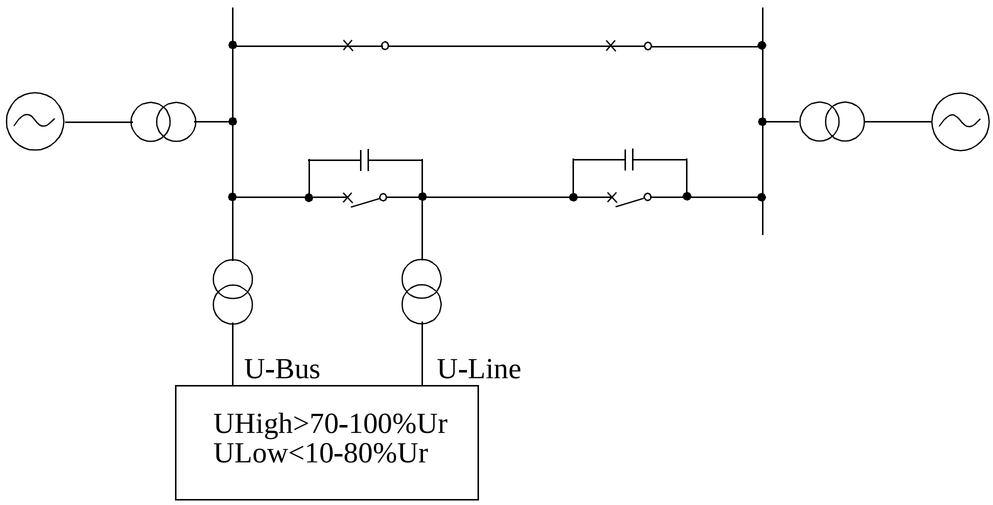


Figure 4: Principle for energising check.

The voltage level considered to be a non-energised bus or line is set on the HMI. An energising can occur — depending on the set direction of the energising function. There are separate settable limits for energised (live) condition, UHigh, and non-energised (dead) ULow conditions. The equipment is considered energised if the voltage is above the set value UHigh (e.g. 80% of base voltage), and non-energised if it is below the set value, ULow (e.g. 30% of the base voltage) The user can set the UHigh condition between 70-100% U1b and the ULow condition between 10-80% U1b.

A disconnected line can have a considerable potential due to, for instance, induction from a line running in parallel, or by being fed via the extinguishing capacitors in the circuit breakers. This voltage can be as high as 30% or more of the rated voltage of the line.

The energising operation can be set to operate in either direction over the circuit breaker, or it can be permitted to operate in both directions. Use the AutoEnerg and ManEnerg HMI setting to select the energising operation in:

- Both directions (Both)
- Dead line live bus (DLLB)
- Dead bus live line (DBLL)

The voltage check can also be set Off. A closing impulse is issued to the circuit breaker if one of the U-line or U-bus voltages is High and the other is Low, that is, when only one side is energised. The user can set AutoEnerg and ManEnerg to enable different conditions during automatic and manual closing of the circuit breaker.

In the manual mode it is also possible to allow closing when both sides of the breaker are dead. This is done by setting the parameter ManDBDL = “On” **and** ManEnerg to “DLLB”, “DBLL” or “Both”.

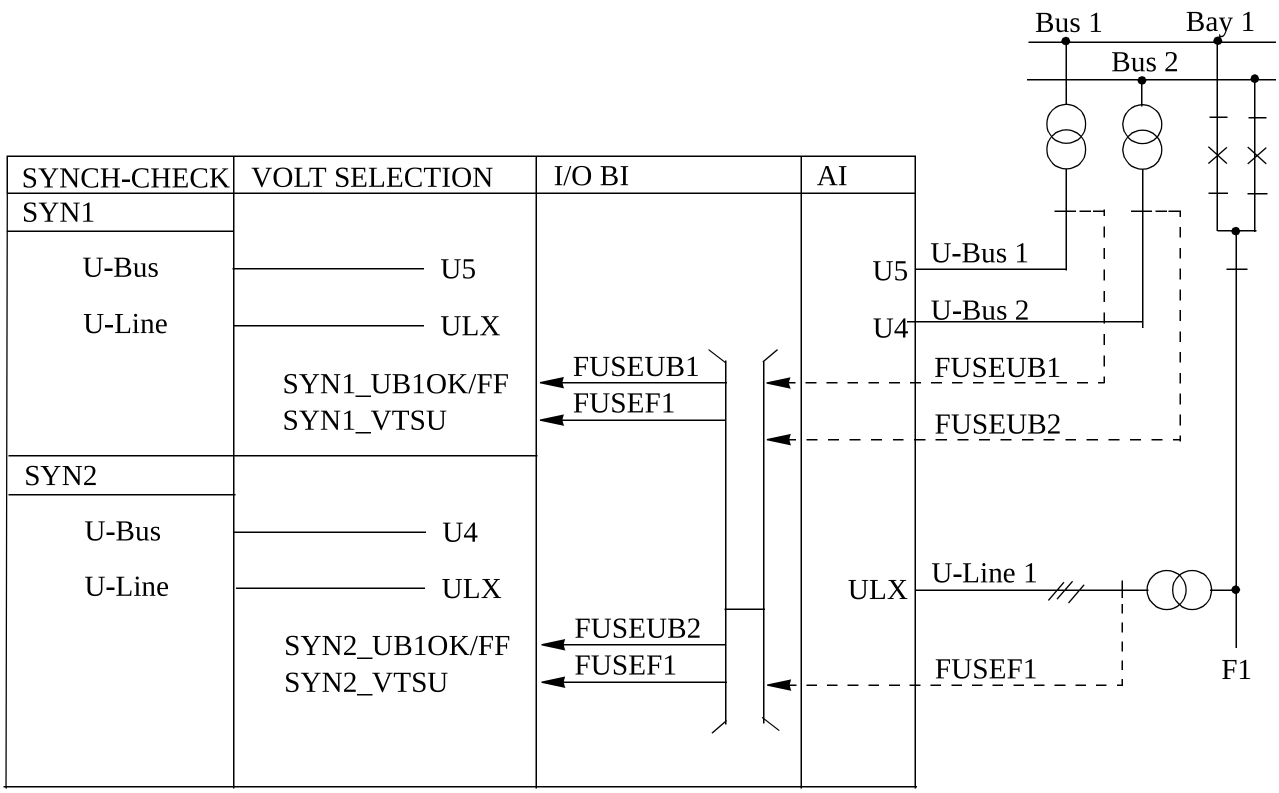


Figure 5: Voltage connection in a double busbar double breaker arrangement.

1.4 Voltage connection

The princip for the connection arrangement is shown in Figure 5:. One terminal unit is used for the two circuit breakers in one bay. There is one voltage transformer at each side of the circuit breaker, and the voltage transformer circuit connections are straight forward, without any special voltage selection.

For the synchrocheck and energising check, the voltage from Bus 1 (SYN1-U-bus) is connected to the single-phase analogue input (U5) on the terminal and the voltage from Bus 2 (SYN2-U-bus) is connected to the single-phase analogue input (U4).

The line voltage transformers are connected as a three-phase voltage to the analogue inputs UL1, UL2, UL3 (SYN1(2)-U-Line) voltage.

The synchronism condition is set on the HMI of the terminal unit, and the voltage is taken from Bus 1 and the Line or from Bus 2 and the Line (U-line). This means that the two synchro-check units are operating without any special voltage selection, but with the same line (U-line) voltage.

The configuration of internal signals, inputs, and outputs may be different for different busbar systems, and the actual configuration for the substation must be done during engineering of the terminal.

1.4.1 Fuse failure and Voltage OK signals

The external fuse-failure signals or signals from a tripped fuse switch/ MCB are connected to binary inputs configured to inputs of the synchro-check functions in the terminal. There are two alternative connection possibilities. Inputs named OK must be supplied if the voltage circuit is healthy. Inputs named FF must be supplied if the voltage circuit is faulty.

The SYNx-UB1OK and SYNx-UB1FF inputs are related to the busbar voltage. Configure them to the binary inputs that indicate the status of the external fuse failure of the busbar voltage. The SYNx-VTSU input is related to the line voltage from each line.

The user can use the FUSE-VTSU signal from the built-in optional selectable fuse-failure function as an alternative to the external fuse-failure signals.

In case of a fuse failure, the energising check (dead line- check) is blocked via the input (SYN1-UB1OK/FF or SYN1-VTSU).

2 Theory of operation

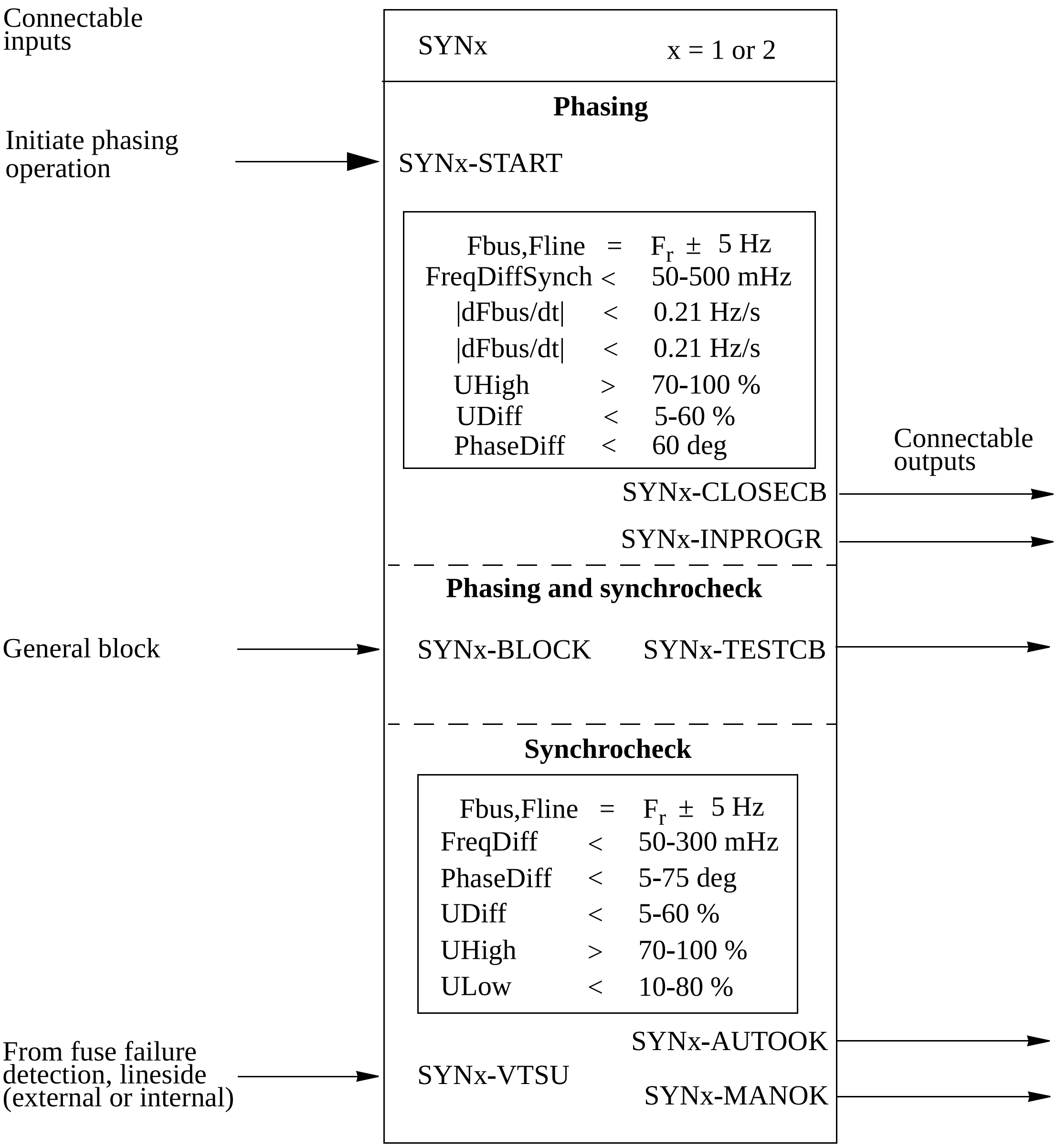


Figure 6: Input and output signals.

2.1 Input and output signals

Description of input and output signals for the phasing and synchro-check function.

Input signals	Description
SYNx-BLOCK	General block input from any external condi tion, that should block the phasing and the synchrocheck.
SYNx-VTSU	The SYNC function cooperates with the FUSE-VTSU connected signal, which is the built-in optional fuse failure detection. It can also be

	connected to external condition for fuse failure. This is a blocking condition for the energising function.
SYNx-UB1FF	External fuse failure input from busbar voltage Bus 1 (U5). This signal can come from a tripped fuse switch (MCB) on the secondary side of the voltage transformer. In case of a fuse failure the energising check is blocked.
SYNx-UB1OK	No external voltage fuse failure (U5). Inverted signal.
SYNx-START	The signal initiates the phasing operation. When initiated the function continues until the SYNx-CLOSECB pulse is submitted or it is stopped by the SYNx-BLOCK signal. In test mode SYNx-TESTCB ends the phasing operation.

Output signals	**Description**
SYNx-TESTCB	Output when the function is in test mode. In test mode a complete phasing sequence is performed except for closing of the circuit breaker. The output signal SYNx-TESTCB indicates when the SYNx-CLOSECB signal would have been submitted from the phasing function or when the conditions for paralleling are fulfilled, from the synchro-check function.
SYNx-CLOSECB	Close breaker command from phasing. Used to control the circuit breaker or to be connected to the auto-reclosing function.
SYNx-INPROGR	The signal is high when a phasing operation is in progress, i.e from the moment a SYNx-START is received until the operation is terminated. The operation is teminated when SYNx-CLOSECB or SYNx-TESTCB has been submitted or if a SYNx-BLOCK is received.
SYNx-AUTOOK	Synchrocheck/energising OK. The output signal is high when the synchrocheck conditions set on the HMI are fulfilled. It can also include the energising condition, if selected. The signal can be used to release the autorecloser before closing attempt of the circuit breaker. It can also be used as a free signal.
SYNx-MANOK	Same as above but with alternative settings of the direction for energising to be used during manual closing of the circuit breaker.

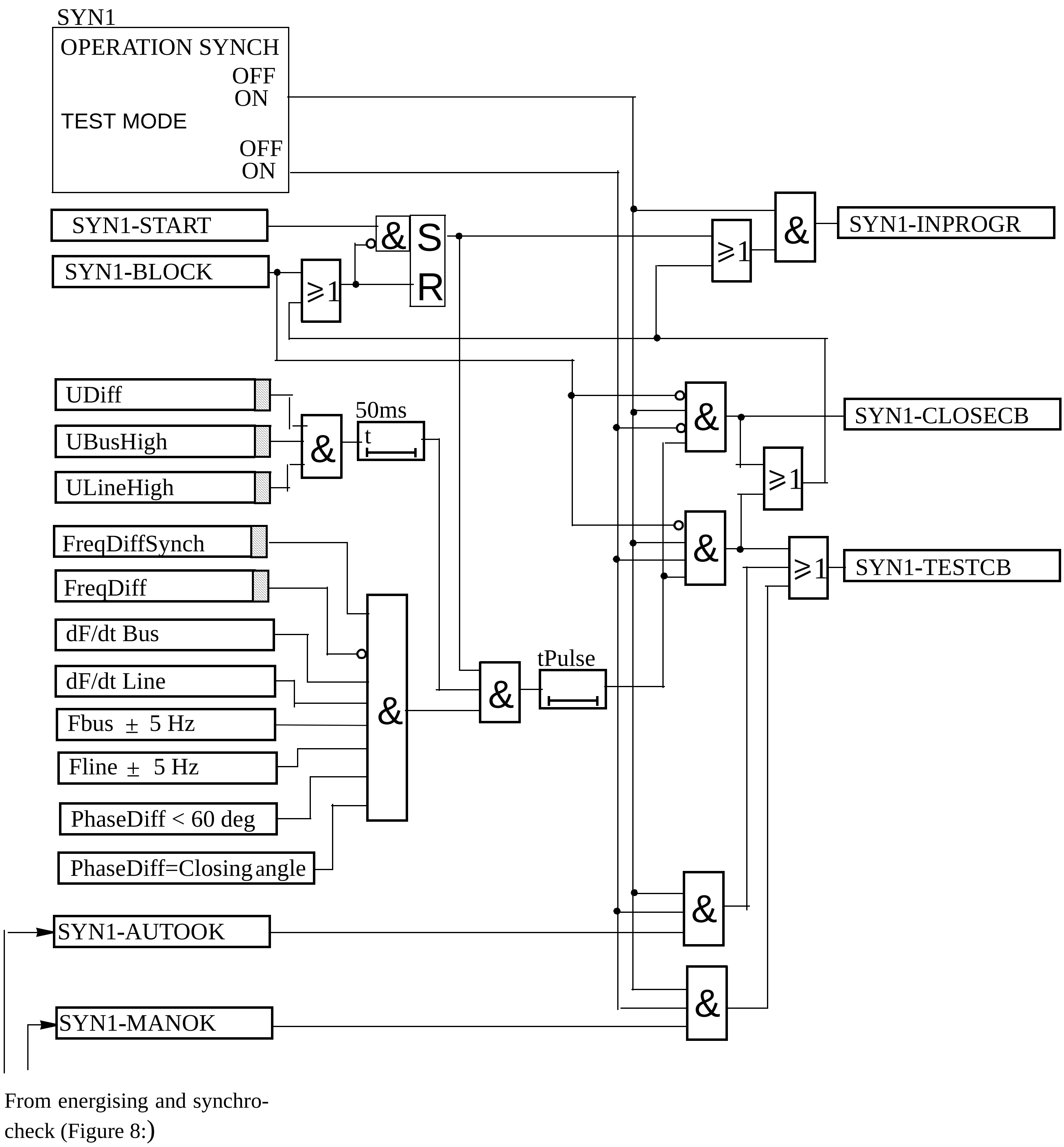


Figure 7: Simplified logic diagram - Phasing

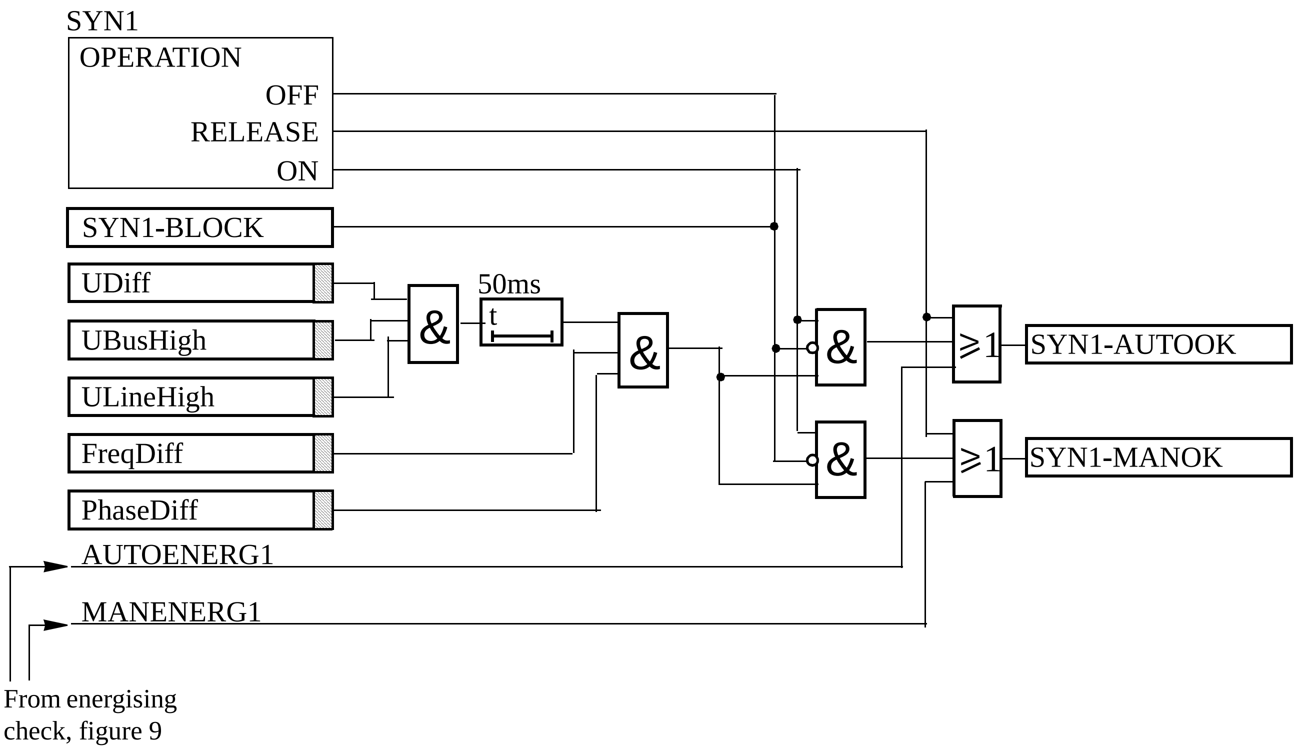


Figure 8: Simplified logic diagram - Synchrocheck

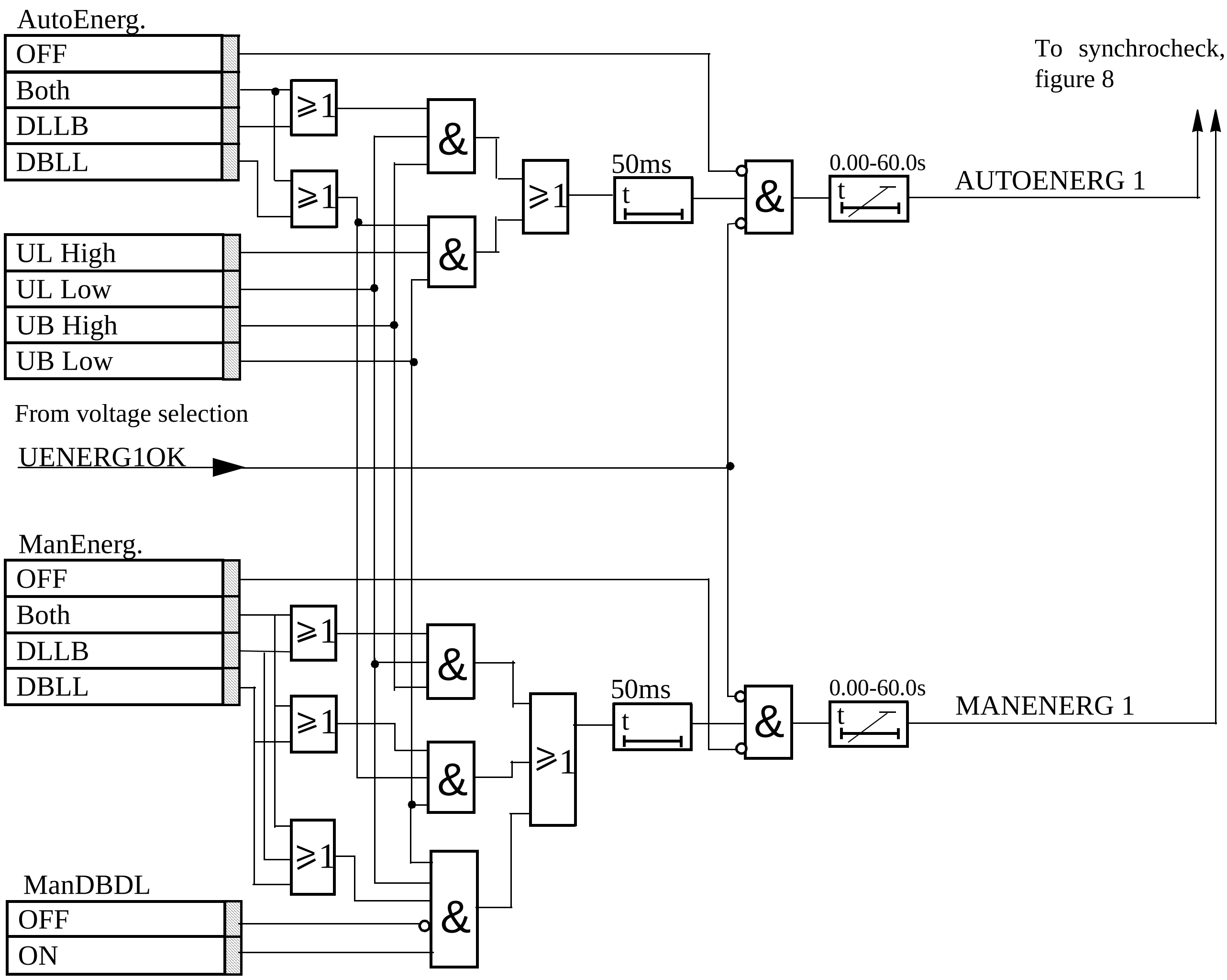


Figure 9: Simplified logic diagram - Energising check.

3 Setting

The setting parameters are accessible through the HMI. The parameters for the synchro-check function are found in the MMI tree under:

Settings
Functions
Group n (n=1-4)
SynchroCheck
SynchroCheck1 (and 2)

3.1 Operation

Off	The function is off and the output is low.
Release	There are fixed, high output signals SYN1-AUTOOK = 1 and SYN1-MANOK = 1.
On	The function is in service and the output signal depends on the input conditions.

3.2 Input phase

The measuring phase of the UL1, UL2, UL3 line voltage, which can be of a single-phase (phase-neutral) or two-phases (phase-phase).

3.3 PhaseShift

This setting is used to compensate for a phase shift caused by a line transformer between the two measurement points for UBus and ULine. The set value is added to the measured phase difference. The bus voltage is reference voltage.

3.4 URatio

The URatio is defined as URatio=UBus/ULine. A typical use of the setting is to compensate for the voltage difference caused if wished to connect the UBus phase-phase and ULine phase-neutral. The “Input phase”-setting should then be set to phase-phase and the “URatio”-setting to sqr3=1.732. This setting scales up the line voltage to equal level with the bus voltage.

3.5 AutoEnerg and ManEnerg

Two different settings can be used for automatic and manual closing of the circuit breaker.

Off	The energising condition is not used only the synchro-check.
DLLB	The line voltage U-line is low, below (10-80% U1b) and the bus voltage U-bus is high, above (70-100% U1b).
DBLL	The bus voltage U-bus is low, below (10-80% U1b) and the line voltage U-line is high, above (70-100% U1b).
Both	Energising can be done in both directions, DLLB or DBLL.

tAutoEnerg	The required consecutive time of fulfilment of the energising condition to achieve SYN1-AUTOOK.
tManEnerg	The required consecutive time of fulfilment of the energising condition to achieve SYN1-MANOK.

3.6 ManDBDL

If the parameter is set to “On”, closing is enabled when Both U-Line and U-bus are below ULow and ManEnerg is set to “DLLB”, “DBLL” or “Both”.

3.7 OperationSynch

Off	The phasing function is off and all outputs are low.
On	The phasing function is in service and the output signals depends on the input conditions.

3.8 ShortPulse

Off	The closing pulse issued to the circuit breaker will be of length=tPulse.
On	The closing pulse issued to the circuit breaker will be of length=one cycle time in the internal logic.

4 Testing

At periodical checks, the functions should preferably be tested with the used settings. To test a specific function, it might be necessary to change some setting parameters, for example:

- AutoEnerg = On/Off/DLLB/DBLL/Both
- ManEnerg = Off
- Operation = Off, On

The tests explained in section “Synchrocheck tests” on page 199“ describe the settings, which can be used as references during testing, are presented before the final settings are specified. After testing, restore the equipment to the normal or desired settings.

4.1 Test equipment

A secondary injection test set with the possibility to alter the phase angle by regulation of the resistive and reactive components is needed. Here, the phase angle meter is also needed. To perform an accurate test of the frequency difference, a frequency generator at one of the input voltages is needed. The tests can also be performed with the computer-aided test system FREJA.

FREJA has a specially designed program for evaluating the synchrocheck function. Figure 10: shows the general test connection principle, which the user can use during testing. This description describes the test of the version intended for one bay.

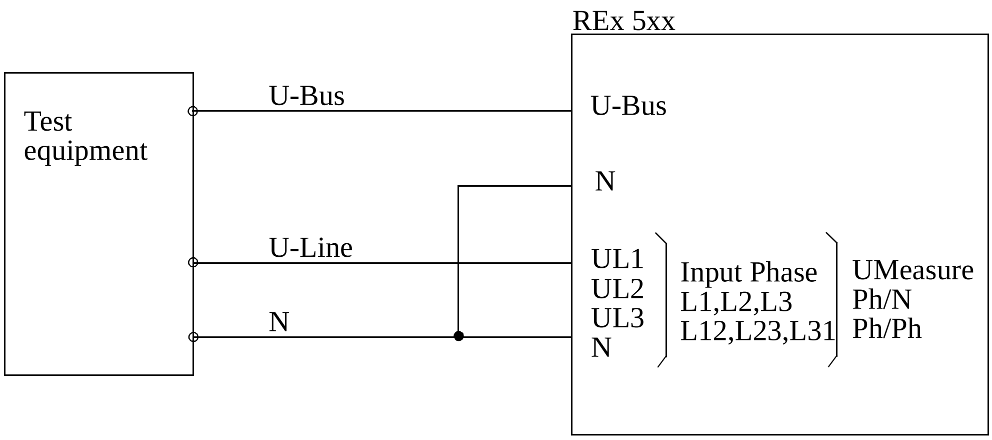


Figure 10: General test connection for synchrocheck with three-phase voltage connected to the line side.

4.2 Phasing tests

These voltage inputs are used:

U-line UL1, UL2 or UL3 voltage input on the terminal.

U-bus U5 voltage input on the terminal

These HMI settings can be used during the test if the final setting is not determined:

1 Set these HMI settings, which are found under:

Settings
Functions
Group n (n=1-4)
SynchroCheck
SynchroCheck1 (and 2)

Table 1: Test settings for phasing

PARAMETER:	SETTING:
Operation	Off
InputPhase	UL1
USelection	SingleBus
PhaseShift	0 deg
URatio	1.00
AutoEnerg	Off
ManEnerg	Off
ManDBDL	Off
UHigh	70% U1b
ULow	40% U1b
FreqDiff	0.05 Hz
PhaseDiff	45°
UDiff	30% U1b
tAutoEnerg	0.5 s
tManEnerg	0.5 s
OperationSynch	On
ShortPulse	Off
FreqDiffSynch	0.40 Hz
tPulse	0.20 s
tBreaker	0.20 s

4.2.1 Test of frequency difference

The frequency difference is set at 0.40 Hz on the HMI, and the test should verify that operation is achieved when the FreqDiffSynch frequency difference is lower than 0.40 Hz.

- Apply voltages U-line (UL1) = 80% U1b, f-line=50.0 Hz and U-Bus (U5) = 80% U1b, f-bus=50.3 Hz.
- Check that a closing pulse is submitted with length=0.20 sec. and at closing angle=360 * 0.20 * 0.40=29 deg.
- Repeat with U-Bus (U5) = 80% U1b, f-bus=50.5 Hz to verify that the function does not operate when freq.diff is above limit.
- Repeat with different settings on tBreaker and FreqDiffSynch. Make sure that the calculated closing angle is less than 60 deg. Verify that closing command is issued at the correct phase angle when the frequency difference is less than the set value.

4.3 Synchrocheck tests

4.3.1 Test of voltage difference

Set the voltage difference at 30% U1b on the HMI, and the test should check that operation is achieved when the voltage difference UDiff is lower than 30% U1b.

These voltage inputs are used:

U-line	UL1, UL2 or UL3 voltage input on the terminal.
U-bus	U5 voltage input on the terminal

These HMI settings can be used during the test if the final setting is not determined:

1 Set these HMI settings, which are found under:

Settings
　Functions
　　Group n (n=1-4)
　　　SynchroCheck
　　　　SynchroCheck1 (and 2)

Table 2: Test settings for voltage difference

Parameter	Setting
Operation	On
InputPhase	UL1
USelection	SingleBus
PhaseShift	0 deg
URatio	1.00
AutoEnerg	Off

Table 2: Test settings for voltage difference

ManEnerg	Off
ManDBDL	Off
UHigh	70% U1b
ULow	40% U1b
FreqDiff	0.05 Hz
PhaseDiff	45°
UDiff	30% U1b
tAutoEnerg	0.5 s
tManEnerg	0.5 s
OperationSynch	Off
ShortPulse	Off
FreqDiffSynch	0.4 Hz
tPulse	0.2 s
tBreaker	0.2 s

2 **Test with UDiff = 0%**

- Apply voltages U-line (UL1) = 80% U1b and U-Bus (U5) = 80% U1b, with no frequency or phase difference.
- Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.
- The test can be repeated with different voltage values to verify that the function operates within UDiff <30%.

3 **Test with UDiff = 40%**

- Increase the U-bus (U5) to 120% U1b, and the U-line (UL1) = 80% U1b.
- Check that the two outputs are **NOT** activated.

4 **Test with UDiff = 20%, Uline < UHigh**

- Decrease the U-line (UL1) to 60% U1b and the U-bus (U5) to be equal to 80% U1b.
- Check that the two outputs are **NOT** activated.

5 **Test with URatio=0.20**

- Run the test under section 2 to 4 but with U-bus voltages 5 times lower.

6 **Test with URatio=5.00**

- Run the test under section 2 to 4 but with U-line voltages 5 times lower.

4.3.2 Test of phase difference

The phase difference is set at 45° on the HMI, and the test should verify that operation is achieved when the PhaseDiff (phase difference) is lower than 45°.

1 Set these HMI settings:

Table 3: Test settings for phase difference

Parameter	**Setting**
Operation	On
InputPhase	UL1
USelection	SingleBus
PhaseShift	0 deg
URatio	1.00
AutoEnerg	Off
ManEnerg	Off
ManDBDL	Off
UHigh	70% U1b
ULow	40% U1b
FreqDiff	0,05 Hz
PhaseDiff	45°
UDiff	15% U1b
tAutoEnerg	0.5 s
tManEnerg	0.5 s
OperationSynch	Off
ShortPulse	Off
FreqDiffSynch	0.4 Hz
tPulse	0.2 s
tBreaker	0.2 s

2 **Test with PhaseDiff = 0°**
Apply voltages U-line (UL1) = 100% U1b and U-bus (U5) = 100% U1b, with no frequency or phase difference.
Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.

3 The test can be repeated with other PhaseDiff values to verify that the function operates for values lower than the set ones. By changing the phase angle on U1 connected to U-bus, between +/- 45°. The user can check that the two outputs are activated for a PhaseDiff lower than 45°. It should not operate for other values. See figure 11.

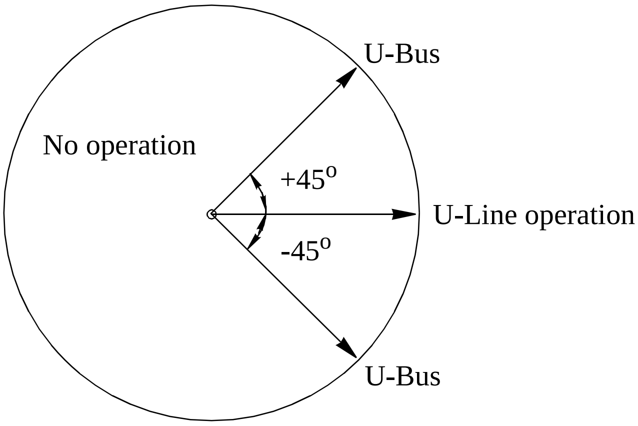


Figure 11: Test of phase difference.

4 Apply a PhaseShift setting of 10 deg. Change the phase angle between +55 and -35 and verify that the two outputs are activated for phase differences between these values but not for phase differences outside. See Figure 12:.

Change the PhaseShift setting to 350 deg. Change the phase angle between +35 and -55 and verify as above.

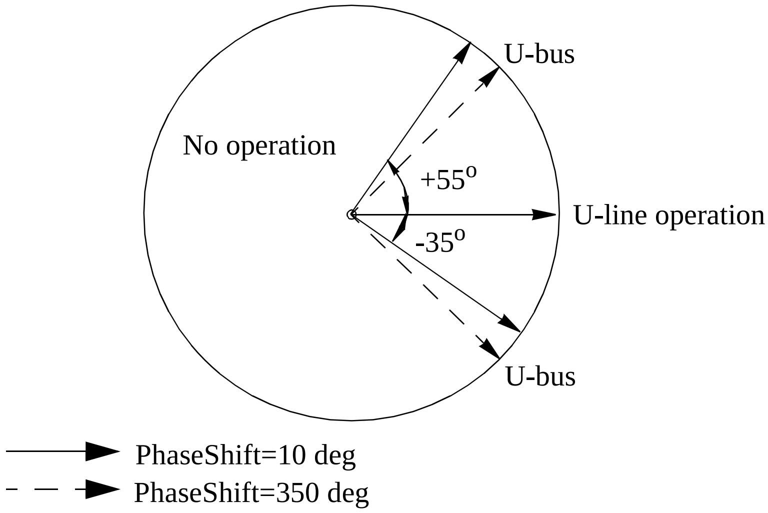


Figure 12: Test of phase difference.

4.3.3 Test of frequency difference

The frequency difference is set at 50 mHz on the HMI, and the test should verify that operation is achieved when the FreqDiff frequency difference is lower than 50 mHz.

1 Use the same HMI setting as in section “Test of phase difference” on page 200.

2 **Test with FreqDiff = 0 mHz**
Apply voltages U-Line (UL1) equal to 100% U1b and U-Bus (U5) equal to 100% U1b, with a frequency difference equal to 0 mHz and a phase difference lower than 45°. Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.

3 **Test with FreqDiff = 1Hz**
Apply voltage to the U-line (UL1) equal to 100% U1b with a frequency equal to 50 Hz and voltage U-bus (U5) equal to 100% U1b, with a frequency equal to 49 Hz.
Check that the two outputs are **NOT** activated.

4 The test can be repeated with different frequency values to verify that the function operates for values lower than the set ones. If the FREJA program, *Test of synchronising relay*, is used the frequency can be changed continuously.

Note! A frequency difference also implies a floating mutual-phase difference. So the SYN1-AUTOOK and SYN1-MANOK outputs might NOT be stable, even though the frequency difference is within set limits, because the phase difference is not stable!

4.3.4 Test of reference voltage

1 Use the same basic test connection as in Figure 10:. The UDiff between the voltage connected to U-bus and U-line should be 0%, so that the SYN1-AUTOOK and SYN1-MANOK outputs are activated first.
Change the U-Line voltage connection to UL2 without changing the setting on the HMI.
Check that the two outputs are **NOT** activated.

2 The test can also be repeated by moving the U-line to the UL3 input.

4.4 Test of energising check

Use these voltage inputs:

U-line = UL1, UL2 or UL3 voltage input on the terminal.

U-bus = U5 voltage input on the terminal.

4.4.1 Test of dead line live bus (DLLB)

The test should verify that the energising function operates for a low voltage on the U-Line and for a high voltage on the U-bus. This corresponds to an energising of a dead line to a live bus.

Use these HMI settings during the test if the final setting is not determined.

1 Set these HMI settings:

Table 4: Test settings for DLLB

Parameter	Setting
Operation	On
InputPhase	UL1
USelection	SingleBus
PhaseShift	0 deg
URatio	1.00
AutoEnerg	DLLB
ManEnerg	DLLB
ManDBDL	Off
UHigh	80% U1b
ULow	40% U1b
FreqDiff	0,05 Hz
PhaseDiff	45°
UDiff	15% U1b
tAutoEnerg	0.5 s
tManEnerg	0.5 s
OperationSynch	Off
ShortPulse	Off
FreqDiffSynch	0.4 Hz
tPulse	0.2 s
tBreaker	0.2 s

2 Apply a single-phase voltage 100% U1b to the U-bus (U5), and a single-phase voltage 30% U1b to the U-line (UL1).

3 Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.

4 Increase the U-Line (UL1) to 60% U1b and U-Bus(U5) to be equal to 100% U1b. The outputs should **NOT** be activated.

5 The test can be repeated with different values on the U-Bus and the U-Line.

4.4.2 Dead bus live line (DBLL)

The test should verify that the energising function operates for a low voltage on the U-bus and for a high one on the U-line. This corresponds to an energising of a dead bus from a live line.

1. Change the HMI settings AutoEnerg and ManEnerg to DBLL**.**
2. Apply a single-phase voltage of 30% U1b to the U-bus (U5) and a single-phase voltage of 100% U1b to the U-line (UL1).
3. Check that the SYN1-AUTOOK and SYN1-MANOK outputs are activated.
4. Decrease the U-line to 60% U1b and keep the U-bus equal to 30% U1b.
   The outputs should **NOT** be activated.
5. The test can be repeated with different values on the U-bus and the U-line.

4.4.3 Energising in both directions (DLLB or DBLL)

1. Change the HMI settings AutoEnerg and ManEnerg to Both.
2. Apply a single-phase voltage of 30% U1b to the U-line (UL1) and a single-phase voltage of 100% U1b to the U-bus (U5).
3. Check that the “SYN1-AUTOOK” and “SYN1-MANOK” outputs are activated.
4. Change the connection so that the U-line (UL1) is equal to100% U1b and the U-bus (U5) is equal to 30% U1b.
5. The outputs should still be activated.
6. The test can be repeated with different values on the U-bus and the U-line.
7. Restore the equipment to normal or desired settings.

4.4.4 Dead bus Dead line (DBDL)

The test should verify that the energising function operates for a low voltage on both the U-bus the U-line, i.e closing of the breaker in a non energised system.

1. Set AutoEnerg to Off and ManEnerg to DBLL.

   Set ManDBDL to On.
2. Apply a single-phase voltage of 30% U1b to the U-bus (U5) and a single-phase voltage of 30% U1b to the U-line (UL1).
3. Check that the SYN1-MANOK output is activated.

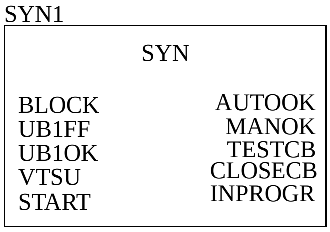
4 Increase the U-bus to 80% U1b and keep the U-line equal to 30% U1b.

   The outputs should **NOT** be activated.

5 Repeat the test with ManEnerg set to DLLB and Both, and different values on the U-bus and the U-line.

5 Appendix

5.1 Function block



5.2 Signal list

Block	Signal	Type	Description
SYNx-	BLOCK	IN	Block of synchro- and energising check function x (x=1-2)
SYNx-	UB1FF	IN	External voltage fuse failure, bus 1
SYNx-	UB1OK	IN	External voltage fuse healthy, bus 1
SYNx-	VTSU	IN	Block from internal fuse failure supervision or from external fuse failure of the line voltage.
SYNx-	START	IN	Initiation of phasing operation
SYNx-	AUTOOK	OUT	Automatic synchro-/energising check OK
SYNx-	MANOK	OUT	Manual synchronism/energising check OK
SYNx-	TESTCB	OUT	Output from phasing and synchrocheck when SYNx is in test mode
SYNx-	CLOSECB	OUT	Close circuit breaker pulse from phasing
SYNx-	INPROGR	OUT	Phasing operation in progress

5.3 Setting table

Parameter	Range	Unit	Default	Parameter description
Operation	Off, Release, On		Off	Synchrocheck function Off/Release/On
InputPhase	L1, L2, L3, L1-L2, L2-L3, L3-L1		L1	Select input voltage
PhaseShift	0-360	degrees	0	Phase shift between U-bus and U-line
URatio	0.20-5.00		1.00	Voltage ratio between U-bus and U-line
AutoEnerg	Off, DLLB, DBLL, Both		Off	Auto energising/synchronising method
ManEnerg	Off, DLLB, DBLL, Both		Off	Manual energising/synchronising method
ManDBDL	Off, On		Off	Manual dead-bus and dead-line energising
UHigh	50-120	%	80	High voltage limit, as a percentage of Ub
ULow	10-100	%	40	Low voltage limit, as a percentage of Ub
FreqDiff	0.05-0.30	Hz	0.20	Frequency difference limit
PhaseDiff	5-75	degrees	20	Phase difference limit
UDiff	5-50	%	20	Voltage difference limit, as a percentage of Ub
tAutoEnerg	0.000-60.000	s	0.100	Auto energising time delay period
tManEnerg	0.000-60.000	s	0.100	Manual energising time delay period
Operation-Synch	Off, On		Off	Phasing function Off/On
ShortPulse	Off, On		Off	Short pulse Off/On
FreqDiff-Synch	0.05-0.50	Hz	00.30	Frequency diff limit for phasing
tPulse	0.000-60.000	s	0.200	Breaker closing pulse duration
tBreaker	0.02-0.50	s	0.20	Closing time of the breaker

1 Application

Automatic reclosing (AR) is a well-established method to restore the service of a power line after a transient line fault. The majority of line faults are flashover arcs, which are transient by nature. When the power line is switched off by operation of line protection and line breakers, the arc deionises and recovers voltage withstand at a somewhat variable rate. So a certain line *dead time* is needed. But then line service can resume by the auto-reclosing of the line breakers. Select the length of the dead time to enable good probability of fault arc de-ionisation and successful reclosing.

For the individual line breakers and auto-reclosing equipment, the Auto-reclose open time (AR open time) expression is used.
At simultaneous tripping and reclosing at the two line ends, Auto-reclose open time equals the dead time of the line. Otherwise these two times may differ.

In case of a permanent fault, the line protection trips again at reclosing to clear the fault. Figure 1: shows the operation sequence and some expressions.

The reclosing function can be selected to perform single-phase, two-phase and/or three-phase reclosing from six single-shot to multiple-shot reclosing programs. The three-phase auto-reclose open time can be set to give either high-speed auto-reclosing (HSAR) or delayed auto-reclosing (DAR).

Three-phase auto-reclosing can be performed with or without the use of synchro-check and energising check.

Single-phase tripping and single-phase reclosing is a way to limit the effect of a single-phase line fault to system operation. Especially at the higher voltages, the majority of line faults are of the single-phase type. The method is of particular value to maintain system stability in systems with limited meshing or parallel routing. It requires individual operation of each phase of the breakers, which is most common at the higher transmission voltages.

A somewhat longer dead time may be required at single-phase reclosing compared to high-speed three-phase reclosing, due to influence on the fault arc of the non-tripped phases.

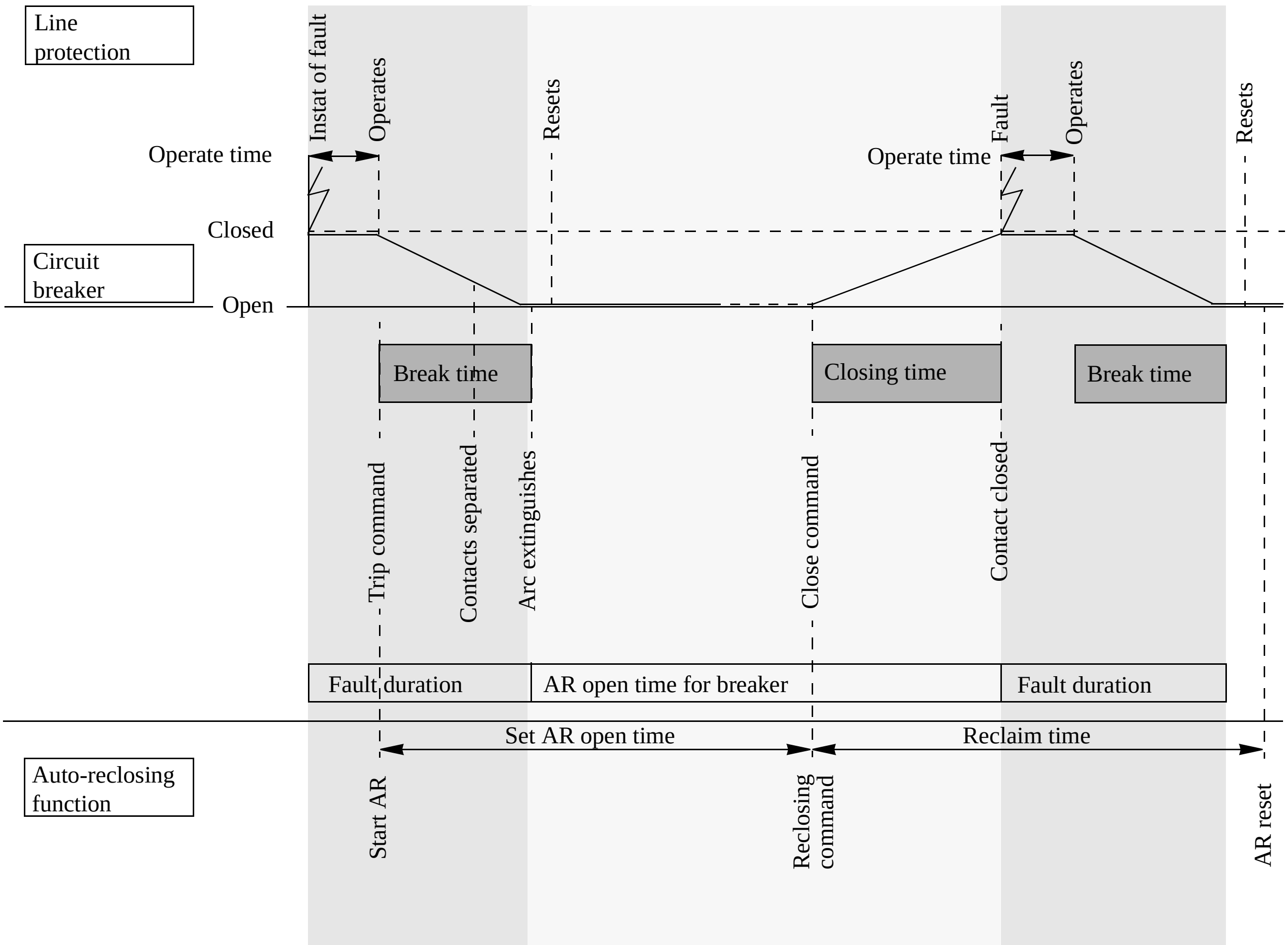


Figure 1: Single-shot auto-reclosing at a permanent fault.

2 Theory of operation

The auto-reclosing function first co-operates with the line protection functions, the trip function, the circuit-breaker and the synchro-check function. It can also be influenced by other protection functions such as shunt reactor protection through binary input signals and AR On/Off manual control. It can provide information to the disturbance and service report functions, event recording, indications, and reclosing operation counters.

The reclosing function outputs and counters can be viewed and reset on the local HMI at:

ServiceReport
Functions
AutoRecloser
AutoRecloser n

The auto-reclosing is a pure logical function that works with logical or binary signals, logical operations and timers.

2.1 Input and output signals, single breaker arrangement

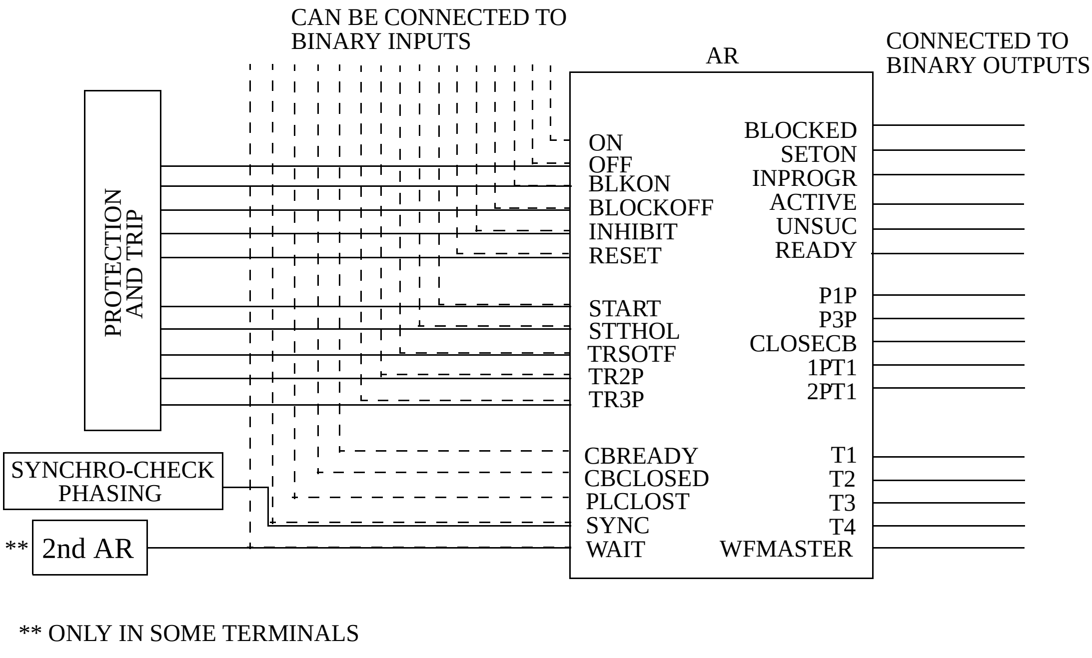


Figure 2: Single-, two- and three-phase auto-reclosing; input and output signals.

The input signals can be connected to binary inputs or internal functions of the terminal. The output signals can be connected to binary output relays. It is also possible to connect the signals to free logic functions, for example OR-gates, and in that way add connection links.

The input and output signals which can be interfaced with the auto-recloser 1 are presented in this document. Data is the same for other auto-recloser functions (2 to 6) with signal prefix AR02- to AR06-.

Input signals:

AR01-ON	Switches the auto-reclosing On (at Operation = Stand-by).
AR01-OFF	Switches the auto-reclosing Off (at Operation =Stand-by).
AR01-BLKON	Sets the auto-recloser in blocked state.
AR01-BLOCKOFF	Releases the auto-recloser from the blocked state.
AR01-INHIBIT	Inhibits an auto-reclosing cycle. Interrupts and blocks auto-reclosing. The input can, for example, be activated by a shunt reactor, delayed back-up protection or breaker-failure protection. There is a tInhibit reset timer to ensure blocking during a few seconds after the signal is removed.
AR01-RESET	Resets the auto-recloser.
AR01-START	Auto-reclosing start by a protection trip signal. It also makes the reclosing program continue at a repeated trip, if multi-shot reclosing is selected.
AR01-STTHOL	Start of thermal overload protection. Will block the auto-reclosing.
AR01-TRSOTF	Protection trip switch-onto-fault. This signal alone does not start reclosing. But at a reclosing onto a permanent fault it may appear and let the function move on to AR01-UNSUC (unsuccessful) or second-shot reclosing as programmed.
AR01-TR2P	Two-phase trip. Status signal to the auto-reclosing function that a two-phase tripping occurred.
AR01-TR3P	Three-phase trip. Status signal to the auto-reclosing function that a three-phase tripping occurred.
AR01-CBREADY	A condition for the start of a reclosing cycle. The circuit breaker must have its operating gear ready (manoeuvre spring charged) for a Close-Open (CO) or an Open-Close-Open (OCO) operations to allow the start of an auto-reclosing cycle. This input can also be connected to circuits that monitor the breaker pressure. If it is not ready at start, it is unlikely that it is ready by the end of the AR open time.
AR01-CBCLOSED	Circuit breaker closed. A condition for the start of a reclosing cycle. The circuit breaker (CB) must be closed at least for five seconds to allow a new AR cycle to start. It prevents start at closing onto a fault. It also prevents the reclosing of a breaker that is open at the protection trip, which is possible in a multiple breaker arrangement.

AR01-PLCLOST	Power line carrier or other form of permissive signal lost. An optional input signal at loss of a communication channel in a permissive line protection scheme. Can extend the AR open time.
AR01-SYNC	Synchro-check fulfilled from the internal synchro-check/phasing function or an external device required for three-phase auto-reclosing.

Output signals:

AR01-BLOCKED	The auto-recloser is in blocked state.
AR01-SETON	Indicates that the AR operation is switched on, operative.
AR01-INPROGR	Auto-reclosing attempt in progress. Activated during the AR open time.
AR01-ACTIVE	Auto-reclosing cycle in progress.
AR01-UNSUC	Auto-reclosing unsuccessful. Activated at a new trip after the last programmed shot (selected number of reclosing shots), or at trip while reclosing is blocked. The output resets after the reclaim time.
AR01-READY	Indicates that the AR function is ready for a new AR cycle. It is On but not started or blocked. This output is high when the function is On, at rest, and prepared for operation. The signal can be used by a protection function to extend the reach before reclosing, when required.
AR01-P1P	Permit single-phase trip. Inverse signal to AR01-P3P.
AR01-P3P	Prepare three-phase trip. Control of the next trip operation.
AR01-CLOSECB	Close circuit-breaker command.
AR01-1PT1	Single-phase reclosing in progress.
AR01-2PT1	Two-phase reclosing in progress.
AR01-T1(T2 - T4)	Three-phase reclosing, Shot 1(2 - 4) in progress.

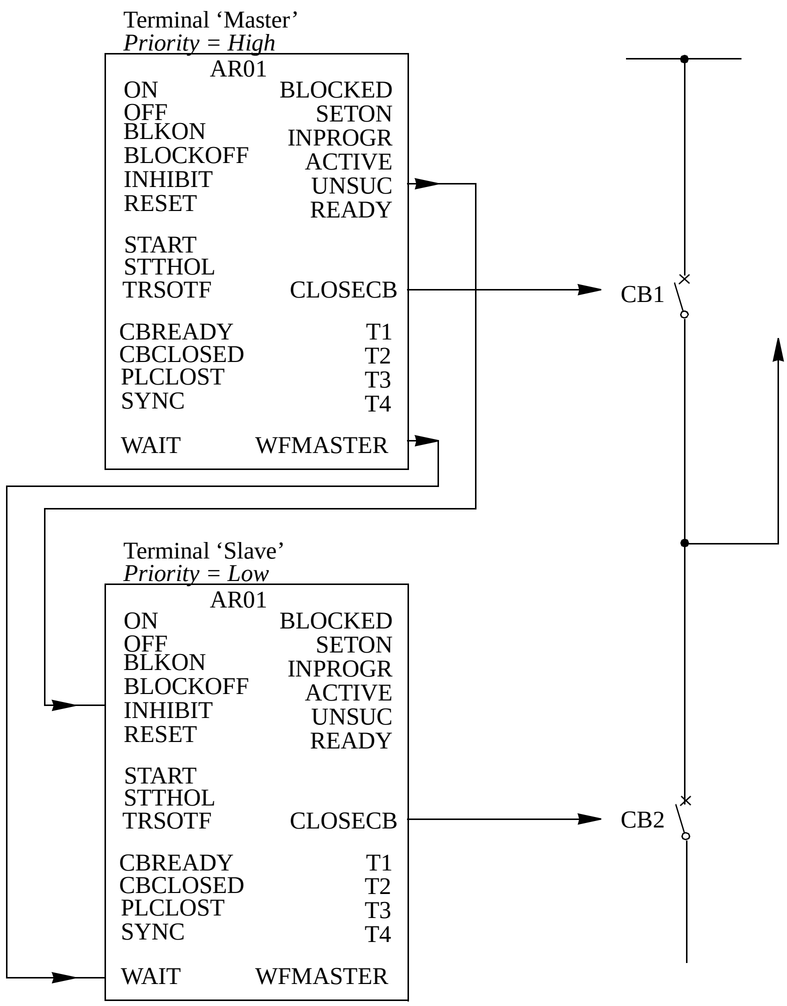
2.2 Multi-breaker arrangement

In stations with a 1 1/2-breaker, double breaker or ring bus arrangement, there are two breakers which switch that end of the line. The reclosing of the line breakers can be made in a sequential order. One breaker is reclosed first, and if the reclosing is successful, the second breaker is reclosed as well. In the case of a permanent fault, the second breaker need not to be reclosed. By fitting one REx 5xx terminal for each line breaker, and by a few interconnections between them, sequential reclosing can be achieved. See Figure 3:.

One terminal is selected as *Master* and given *high* reclosing *priority.* At line protection trip, the two reclosing functions are started, but the master issues a *Wait For Master* signal to the *Slave* (with *low* reclosing *priority*). At unsuccessful reclosing by the master, an *Inhibit* reclosing signal is sent to the slave terminal to interrupt and reset the reclosing function.

AR01-WAIT — Signal to the low priority auto-reclosing function from the master in multi-breaker arrangements for sequential reclosing.

AR01-WFMASTER — Wait for master. Issued by the high priority unit for sequential reclosing.



*) Other input/output signals as in previous single breaker arrangement.

Figure 3: Additional input and output signals at multi-breaker arrangement.

2.3 AR Operation

The user can control the auto-reclosing function from the local HMI. Use the parameter *Operation*, which can be set to Off, Stand-by or On. See Figure 6:.

Off deactivates the auto-recloser. *On* activates automatic reclosing. Stand-by enables On and Off Operation via input signal pulses.

3 Design

3.1 Start and control of the auto-reclosing

The automatic operation of the auto-reclosing function is controlled by the parameter *Operation* and the input signals as described above. When it is on, the AR01-SETON output is high (active). See Figure 6:.

The auto-reclosing function is activated at a protection trip by the AR01-START input signal. At repeated trips, this signal is activated again to make the reclosing program continue.

There are a number of conditions for the start to be accepted and a new cycle started. After these checks, the start signal is latched in and the *Started* state signal is activated. It can be interrupted by certain events.

3.2 Extended AR open time, shot 1

The purpose of this function is to adapt the length of the AR Open time to the possibility of non-simultaneous tripping at the two line ends. If a permissive communication scheme is used and the permissive communication channel (for example, PLC, power-line carrier) is out of service at the fault, there is a risk of sequential non-simultaneous tripping. To ensure a sufficient line dead time, the AR open time is extended by 0.4 s. The input signal AR01-PLCLOST is checked at tripping. See figure 7. Select this function (or not) by setting the Extended t1 parameter to On (or Off).

3.3 Long trip signal

During normal circumstances, the trip command resets quickly due to fault clearing. The user can set a maximum trip pulse duration by tTrip. At a longer trip signal, the AR open dead time is extended by Extend_t1. If the Extended t1 = Off, a long trip signal interrupts the reclosing sequence in the same way as AR01-INHIBIT.

3.4 Reclosing programs

The reclosing programs can be performed with up to maximum four reclosing attempts (shots), selectable with the NoOfReclosing parameter. The first program is used at pure 3-phase trips of breakers and the other programs are used at 1-, 2- or 3-phase trips of breakers.

The following reclosing programs can be selected through the parameter *FirstShot*, to fit actual application:

3ph 3-phase reclosing, one to four attempts.

1/2/3ph 1-phase, 2-phase or 3-phase reclosing (shot 1) followed by 3-phase reclosing (shot 2 - 4) if selected.

1/2ph 1-phase or 2-phase reclosing (shot 1) followed by 3-phase reclosing (shot 2 - 4) if selected. If the first trip is a 3-phase trip (TR3P high), the AR will be blocked.

1ph + 1*2ph 1-phase or 2-phase reclosing (shot 1). The 1-phase reclosing attempt can be followed by 3-phase reclosing (shot 2 - 4) if selected. A failure of a 2-phase reclosing attempt will block the AR. If the first trip is a 3-phase trip (TR3P high), the AR will be blocked.

1/2ph + 1*3ph 1-phase, 2-phase or 3-phase reclosing (shot 1). The 1-phase and 2-phase reclosing attempts can be followed by 3-phase reclosing (shot 2 - 4) if selected. A failure of a 3-phase reclosing attempt (at shot 1) will block the AR.

1ph + 1*2/3ph 1-phase, 2-phase or 3-phase reclosing (shot 1). The 1-phase reclosing attempt can be followed by 3-phase reclosing (shot 2 - 4) if selected. A failure of the 2-phase and 3-phase reclosing attempts will block the AR.

Below is a description of a *one-shot reclosing for single-phase, two-phase or three-phase*. The other programs are thereafter described more briefly.

3.4.1 1/2/3ph reclosing

For the example, one-shot reclosing for 1-phase, 2-phase or 3-phase, see Figures 6 and 12. Here, the AR function is assumed to be On and Ready. The breaker is closed and the operation gear ready (manoeuvre spring charged etc.). Only the 1-phase and 3-phase cases are described.

AR01-START is received and sealed-in at operation of the line protection. The AR01-READY output is reset (Ready for a new AR cycle).

If AR01-TR2P (2-phase trip) is low and AR01-TR3P (3-phase trip) is...

low, the timer for 1-phase reclosing open time t1 1Ph is started and the AR01-1PT1 output (auto-reclosing 1-phase, shot 1, in progress) is activated.
It can be used to suppress Pole disagreement and Earth-fault protection during the 1-phase open interval.

high, the timer for 3-phase AR open time, t1, is started (instead of t1 1Ph) and AR01-T1 is set (auto-reclosing 3-phase, shot 1, in progress). While either t1 1Ph or t1 is running, the output AR01-INPROGR is activated.

Immediately after the start-up of the reclosing and tripping of the breaker, the input (in Figure 6:) AR01-CBCLOSED is low (possibly also AR01-CBREADY at type OCO). The AR Open-time timer, t1 1Ph or t1, keeps on running.
At the end of the set AR open time, t1 1Ph or t1, the respective SPTO or TPTO (single-phase or three-phase AR time-out, Figure 9:) is activated and goes on to the output module for further checks and to give a closing command to the circuit breaker.

3.5 Evolving fault

A single-phase fault can result in a single-phase trip and start of t1 1Ph. The fault may evolve into another phase. At such an evolving fault, the protection must issue a three-phase trip at the second trip.

When the AR01-P3P appears, the t1 1Ph-timer is stopped and the timer for t1, the three-phase AR open time, starts.

3.6 AR01-P3P, Prepare three-phase trip

This output signal ensures that a possible coming trip operation is a three-phase operation. This is, for example, the case if the AR is set off, or blocked, or if it has performed the first reclosing shot.

Usually, the signal is reset when the reclaim time after a reclosing has expired and the function is once more ready for a single-phase reclosing, Permit single-phase trip (P1P). It is the inverse of P3P and should be connected to a binary output relay. Should the unit with the auto-reclosing be inoperative, single-phase trip is thus not released. The external circuit can be connected to a make or break contact of an output relay depending on what is required: Permit single-phase or Prepare three-phase trip.

3.7 Blocking of a new reclosing cycle

A new start of a reclosing cycle is blocked for the reclaim time after the selected number of reclosing attempts are performed.

3.8 Reclosing checks and Reclaim timer

An AR open-time time-out signal is received from a program module.
At three-phase reclosing, a synchro-check and/or energising check or voltage check can be used. It is possible to use an internal or an external synchro-check function, configured to AR01-SYNC.
If a reclosing without check is preferred, configure the input AR01-SYNC to FIXD-ON (set to 1).

Another possibility is to set the output from the internal synchro-check function to a permanently active signal. Set Operation = Release in the synchro-check function. Then AR01-SYNC is configured to SYNx-AUTOOK.

At confirmation from the synchro-check or if the reclosing is of single-phase type, the signal passes on.

At AR01-CBREADY signal of the Close-Open (CO) type, it is checked that this signal is present to allow a reclosing.

The synchronising and energising check must be fulfilled within a certain period of time, tSync. If it does not, or if the other conditions are not fulfilled, the reclosing is interrupted and blocked.

The Reclaim-timer defines a period from the issue of a reclosing command, after which the reclosing function is reset. Should a new trip occur within this time, it is treated as a continuation of the first fault.
When a closing command is given (Pulse AR), the reclaim timer is started.

There is an AR State Control, Figure 9:, to track the actual state in the reclosing sequence.

3.9 Pulsing of CB closing command

The circuit breaker closing command, AR01-CLOSECB, is made as a pulse with a duration, set by the tPulse parameter. For circuit breakers without an anti-pumping function, the closing-pulse-cutting described below can be used. It is selected by means of the CutPulse parameter (set to On). In case of a new trip pulse, the closing pulse will be cut (interrupted). But the minimum length of the closing pulse is always 50 ms.

At the issue of a reclosing command, the associated reclosing operation counter is also incremented.
There is a counter for each type of reclosing and one for the total number of reclosings. See Figure 10:.

3.10 Transient fault

After the reclosing command, the reclaim timer keeps running for the set time. If no tripping occurs within this time, tReclaim, the auto-reclosing function will be reset. The circuit breaker remains closed and the operating gear ready (manoeuvre spring is recharged). AR01-CBCLOSED = 1 and AR01-CBREADY = 1.

After the reclaim time, the AR state control resets to original rest state, with AR01-SETON = 1, AR01-READY = 1 and AR01-P1P = 1 (depending on the selected program). The other AR01 outputs = 0.

3.11 Unsuccessful signal

Normally the signal AR01-UNSUC appears when a new start is received after the last reclosing attempt has been made. See Figure 11:. It can be programmed to appear at any stage of a reclosing sequence by setting the parameter *UnsucMode* = On. The UNSUC signal is attained after the time tUnsuc.

3.12 Permanent fault

If a new trip takes place after a reclosing attempt and a new AR01-START or AR01-TRSOTF signal appears, the AR01-UNSUC (Reclosing unsuccessful) is activated. The timers for the first reclosing attempt (t1 1Ph, t1 2Ph and t1) cannot be started (Figure 9:).

Depending on the PulseCut parameter setting, the closing command may be shortened at the second trip command.

After time-out of the reclaim timer, the auto reclosing function resets, but the circuit breaker remains open (AR01-CBCLOSED = 0, AR01-CBREADY = 1). Thus the reclosing function is not ready for a new reclosing cycle. See Figure 6: and Figure 12:.

3.13 Automatic confirmation of programmed reclosing attempts

The auto-recloser can be programmed to continue with reclosing attempts two to four (if selected) even if the start signals are not received from the protection functions, but the breaker is still not closed. See figure 8. This is done by setting the parameter *AutoCont* = On and the wait time *tAutoWait* to desired length.

3.14 More about reclosing programs

The reclosing programs are briefly described below concerning type of reclosing and number of attempts for different trips. Also see Table 1 in the end of this section.

3ph
3-phase reclosing, one to four attempts (NoOfReclosing parameter).
The output AR01-P3P is always high (=1).

A trip operation is made as a three-phase trip at all types of fault.
The reclosing is as a three-phase reclosing in program **1/2/3ph**, described above.

All signals, blockings, inhibits, timers, requirements etc. are the same as for the above described example.

1/2/3ph
1-phase, 2-phase or 3-phase reclosing in the first shot.

At any kind of trip, the operation is as already described, program **1/2/3ph**. If the first reclosing attempt fails, a 3-phase trip will be issued and 3-phase reclosings can follow, if selected. Maximum three additional attempts can be done (according to the NoOfReclosing parameter).

All signals, blockings, inhibits, timers, requirements etc. are the same as for the above described example.

1/2ph
1-phase or 2-phase reclosing in the first shot.

At 1-phase or 2-phase trip, the operation is as in above described example, program **1/2/3ph**. If the first reclosing attempt fails, a 3-phase trip will be issued and 3-phase reclosings can follow, if selected. Maximum three additional attempts can be done (according to the NoOfReclosing parameter).

At 3-phase trip, TR2P low and TR3P high, the AR will be blocked and no reclosing takes place.

All signals, blockings, inhibits, timers, requirements etc. are the same as for the above described example.

1ph + 1*2ph
1-phase or 2-phase reclosing in the first shot.

At 1-phase trip (TR2P low and TR3P low), the operation is as in above described example, program **1/2/3ph**. If the first reclosing attempt fails, a 3-phase trip will be issued and 3-phase reclosings can follow, if selected. Maximum three additional attempts can be done (according to the NoOfReclosing parameter).

At 2-phase trip (TR2P high and TR3P low), the operation is similar as above. But, if the first reclosing attempt fails, a 3-phase trip will be issued and the AR will be blocked. No more attempts take place!

At 3-phase trip, TR2P low and TR3P high, the AR will be blocked and no reclosing takes place.

All signals, blockings, inhibits, timers, requirements etc. are the same as for the above described example.

1/2ph + 1*3ph
1-phase, 2-phase or 3-phase reclosing in the first shot.

At 1-phase or 2-phase trip, the operation is as described above. If the first reclosing attempt fails, a 3-phase trip will be issued and 3-phase reclosings can follow, if selected. Maximum three additional attempts can be done (according to the NoOfReclosing parameter).

At 3-phase trip, the operation is similar as above. But, if the first reclosing attempt fails, a 3-phase trip will be issued and the AR will be blocked. No more attempts take place!

All signals, blockings, inhibits, timers, requirements etc. are the same as for the above described example.

1ph + 1*2/3ph
1-phase, 2-phase or 3-phase reclosing in the first shot.

At 1-phase trip, the operation is as described above. If the first reclosing attempt fails, a 3-phase trip will be issued and 3-phase reclosings can follow, if selected. Maximum three additional attempts can be done (according to the NoOfReclosing parameter).

At 2-phase or 3-phase trip, the operation is similar as above. But, if the first reclosing attempt fails, a 3-phase trip will be issued and the AR will be blocked. No more attempts take place!

All signals, blockings, inhibits, timers, requirements etc. are the same as for the above described example.

Table 1: Type of reclosing for different programs

Program	**1st attempt**	**2-4th attempt**
3ph	3ph	3ph
1/2/3ph	1ph	3ph
	2ph	3ph
	3ph	3ph
1/2ph	1ph	3ph
	2ph	3ph
	No 3ph reclosing	No 3ph reclosing
1ph + 1*2ph	1ph	3ph
	2ph	No
	No 3ph reclosing	No 3ph reclosing
1/2ph + 1*3ph	1ph	3ph
	2ph	3ph
	3ph	No
1ph + 1*2/3ph	1ph	3ph
	2ph	No
	3ph	No

4 Configuration and setting

The signals are configured in the CAP 531 configuration tool.

The parameters for the auto-reclosing function are set through the local HMI at:

Settings
Functions
Group n
AutoRecloser
AutoRecloser n

4.1 Recommendations for input signals

See Figure 4: and the default configuration for examples.

AR01-ON and AR01-OFF
may be connected to binary inputs for external control.

AR01-START
should be connected to the protection function trip output which shall start the auto-recloser. It can also be connected to a binary input for start from an external contact. A logical OR gate can be used to multiply the number of start sources.

AR01-INHIBIT
can be connected to binary inputs, to block the AR from a certain protection, such as a line connected shunt reactor, transfer trip receive or back-up protection or breaker-failure protection.

AR01-CBCLOSED and **AR01-CBREADY**
must be connected to binary inputs, for pick-up of the breaker signals. If the external signals are of Breaker-not-ready type, uncharged etc., an inverter can be configured before CBREADY.

AR01-SYNC
is connected to the internal synchro-check function if required. It can also be connected to a binary input. If neither internal nor external synchronising or energising check (dead line check) is required, it can be connected to a permanent 1 (high), by connection to FIXD-ON.

AR01-PLCLOST
can be connected to a binary input, when required.

AR01-TRSOTF
can be connected to the internal line protection, distance protection, trip switch-onto-fault.

AR01-STTHOL
Start of thermal overload protection signal. Can be connected to OVLD-TRIP to block the AR at overload.

AR01-TR2P and AR01-TR3P
are connected to the function block TRIP or to binary inputs. The protection functions that give two-phase or three-phase trips are supposed to be routed via that function.

Other
The other input signals can be connected as required.

4.2 Recommendations for output signals

See Figure 4: and the default configuration for examples.

AR01-READY
can be connected to the Zone extension of a line protection. It can also be used for indication, if required.

AR01-1PT1 and 2PT1
1-phase and 2-phase reclosing in progress is used to temporarily block an Earth-fault protection and/or a Pole disagreement function during the 1-phase or 2-phase open intervals.

AR01-CLOSECB
connect to a binary output relay for circuit breaker closing command.

AR01-P3P
prepare 3-phase trip: Connect to TRIP-P3PTR.

AR01-P1P
permit 1-phase trip: Can be connected to a binary output for connection to external protection or trip relays. In case of total loss of auxiliary voltage, the output relay drops and does not allow 1-phase trip. If needed to invert the signal, it can be made by a breaking contact of the output relay.

Other
The other output signals can be connected for indication, disturbance recording etc., as required.

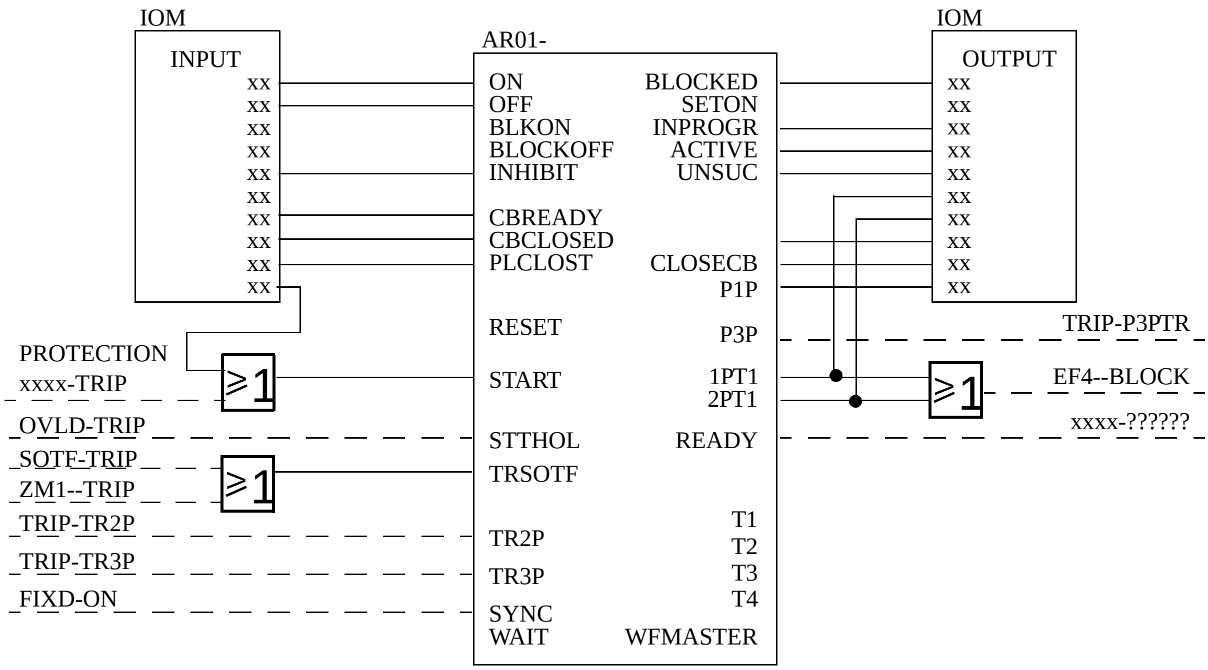


Figure 4: Recommendations for I/O-signal connections.

4.3 Recommendations for multi-breaker arrangement

Sequential reclosing at multi-breaker arrangement is achieved by giving the two line breakers different priorities. Refer to Figure 3:. At single breaker application, *Priority* is set to *No*, and this has no influence on the function. The signal *Started* is sent to the next function module. At double breaker and similar applications, *Priority* is set *High* for the Master terminal and *Priority = Low* for the Slave.

While reclosing is in progress in the master, it issues the signal -WFMASTER. A reset delay ensures that the -WAIT signal is kept high for the breaker closing time. After an unsuccessful reclosing, it is also maintained by the signal -UNSUC. For the slave terminal, the input signal -WAIT holds back a reclosing operation. A time *tWait* sets a maximum waiting time for the reset of the Wait signal. At time-out, it interrupts the reclosing cycle by a WM-INH, wait for master inhibit, signal.

5 Testing

The user can test the auto-reclosing function, for example, during commissioning or after a reconfiguration. The test can be performed with protection and trip functions, as the synchro-check function (with energising check), applied.

Figure 5: illustrates a recommended testing scenario, where the circuit breaker is simulated by an external bistable relay (BR), e.g. an RXMVB2 or an RXMVE1. These manual switches are available:

- Switch close (SC)
- Switch trip (ST)
- Switch ready (SRY).

SC and ST can be push-buttons with spring return. If no bistable relay is available, replace it with two self-reset auxiliary relays as in Figure 5:.

Use a secondary injection relay test set to operate the protection function. It is possible to use the BR to control the injected analogue quantities so that the fault only appears when the BR is picked up—simulating a closed breaker position.

To make the arrangement more elaborate, include the simulation of the operation gear condition, AR01-CBREADY, for the sequences Close-Open (CO) and Open-Close-Open (OCO).

The AR01-CBREADY condition at the CO sequence type is usually low for a recharging time of 5-10 s after a closing operation. Then it is high. The example shows that it is simulated with SRY, a manual switch.

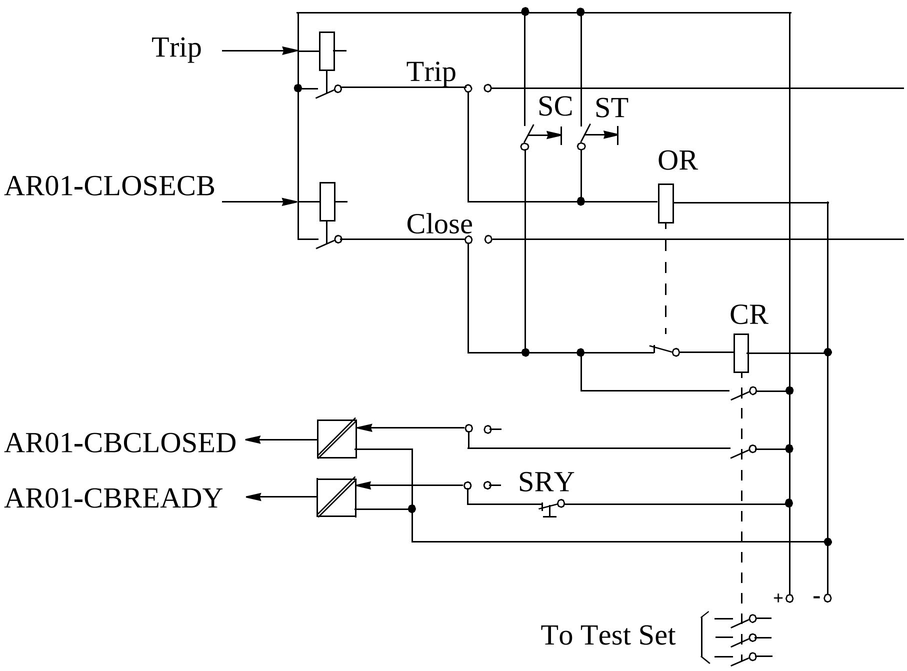


Figure 5: Simulating breaker operation with two auxiliary relays.

5.1 Suggested testing procedure

5.1.1 Preparations

1.1 Check the settings of the auto-reclosing (AR) function. The operation can be set at Stand-by (Off).

HMI tree:

Settings
  Functions
    Group n
      AutoRecloser
        AutoRecloser n

If any timer setting is changed so as to speed-up or facilitate the testing, they must be set to normal after the testing. A verification test has to be done afterwards.

1.2 Read and note the reclosing operate counters from the HMI tree:

ServiceReport
  Functions
    AutoRecloser
      AutoRecloser n
        Counters

1.3 Do the testing arrangements outlined above, for example, as in Figure 5:.

1.4 The AR01-CBCLOSED breaker position, the commands Trip and Closing, AR01-CLOSECB, and other signals should preferably be arranged for event recording provided with time measurements. Otherwise, a separate timer or recorder can be used to check the AR open time and other timers.

5.1.2 Check the AR functionality

2.1 Ensure that the voltage inputs to Synchro-check gives accepted conditions at open breaker (BR). They can, for example, be Live busbar and Dead line.

2.2 Set the operation at On.

2.3 Make a BR pickup by a closing pulse, the SC-pulse.

2.4 Close SRY, Breaker ready and leave it closed.

2.5 Inject AC quantities to give a trip and start AR.
Observe or record the BR operation. The BR relay should trip and reclose. After the closing operation, the SRY switch could be opened for about 5 s and then closed.
The AR open time and the operating sequence should be checked, for example, in the event recording.
Check the operate indications and the operate counters.

Should the operation not be as expected, the reason must be investigated. It could be due to an AR Off state or wrong program selection, or not accepted synchro-check conditions.

2.6 A few fault cases may be checked, for example, single-phase, two-phase and three-phase trips, transient, and permanent fault. The signal sequence diagrams in Figure 12: and 13 can be of guidance for the checking.

5.1.3 Check the reclosing requirements

The number of cases can be varied according to the application. Examples of selection cases are:

3.1 Inhibit input signal: Check that the function is operative and that the breaker conditions are okay. Apply an AR01-INHIBIT input signal and start the reclosing function. *No reclosing!*

3.2 Breaker open, closing onto a fault: Set the breaker simulating relay, BR, in position open. Then close it with the SC switch and start the AR within one second. *No reclosing!*

3.3 Breaker not ready: Close the BR breaker relay and see that everything except for AR01-CBREADY is in normal condition (SRY is open). Start the AR function. *No reclosing!*

3.4 Lack of verification from synchro-check: Check the function at non-acceptable voltage conditions. Wait for the time out, >5 s. *No reclosing!*

3.5 Operation Stand-by and Off: Check that no reclosing can occur with the function in Off state.

3.6 Depending on the program selection and the selected fault types that start and inhibit reclosing, a check of no unwanted reclosing can be made. For example, if only single-phase reclosing is selected, a test can verify that there is no reclosing after two-phase and three-phase trips.

5.1.4 Test of Master-Slave

If a multi-breaker arrangement is used for the application and priorities are given for the master (high) and slave (low) terminals, test that correct operation takes place and that correct signals are issued. The signals WFMASTER, UNSUC, WAIT and INHIBIT should be involved.

5.1.5 Termination of the test

After the test, restore the equipment to normal or desired state.

Especially check these items:

4.1 Reclosing operate counters: Check and record the counter contents. (Reset if it is the user's preference.)

HMI tree:

ServiceReport
Functions
AutoRecloser
AutoRecloser n
Counters
Clear Counters

4.2 Setting parameters and the Operation parameter as required.

4.3 Test switch or disconnected links of connection terminals.

4.4 Normal indications.

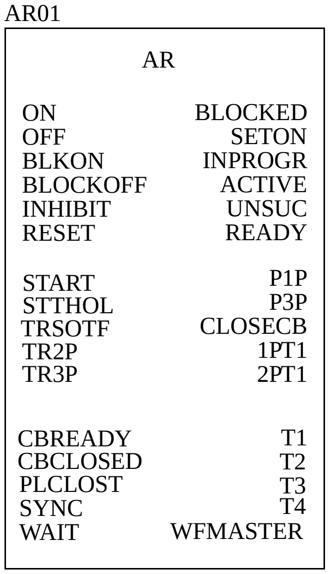
(If so preferred, the disturbance report may be cleared.)

HMI tree:

DisturbReport
ClearDistRep

6 Appendix

6.1 Function block



6.2 Function block diagrams

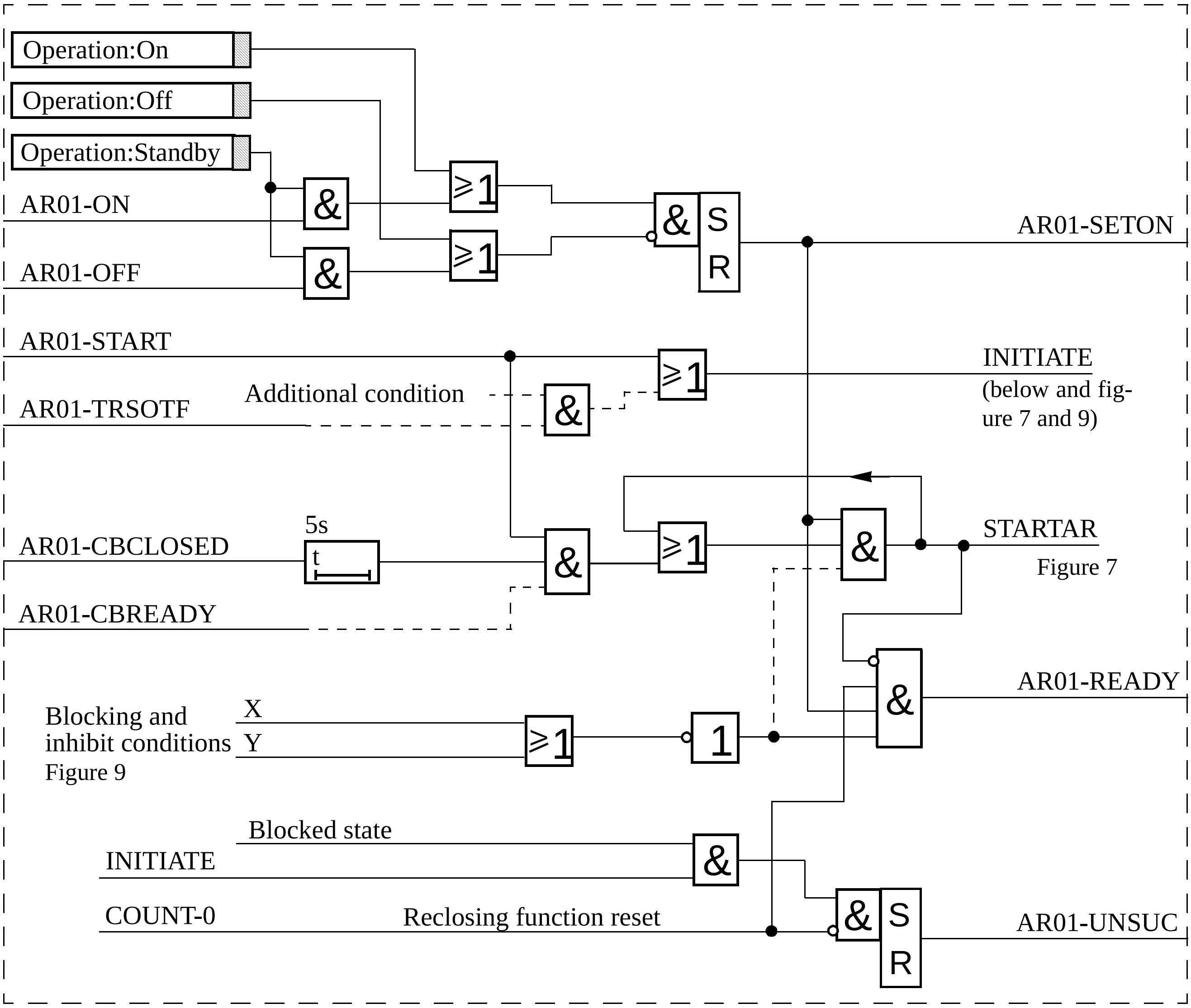


Figure 6: Auto-reclosing on/off control and start

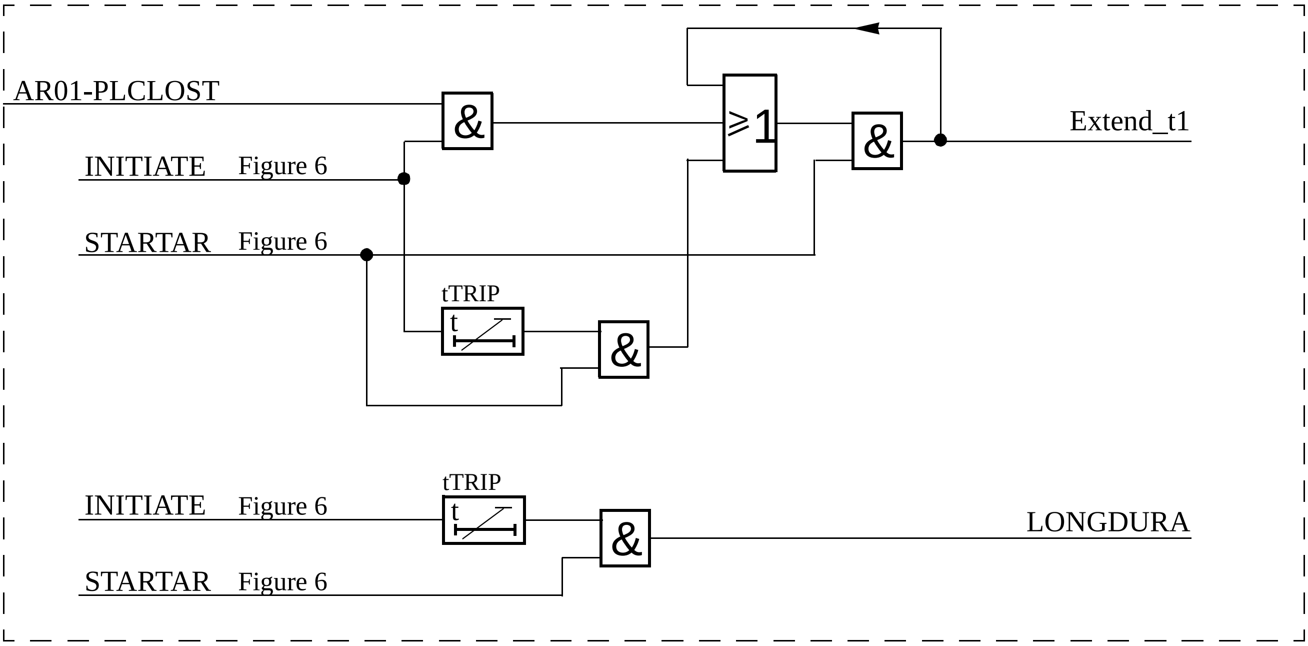


Figure 7: Control of extended AR open time, shot 1

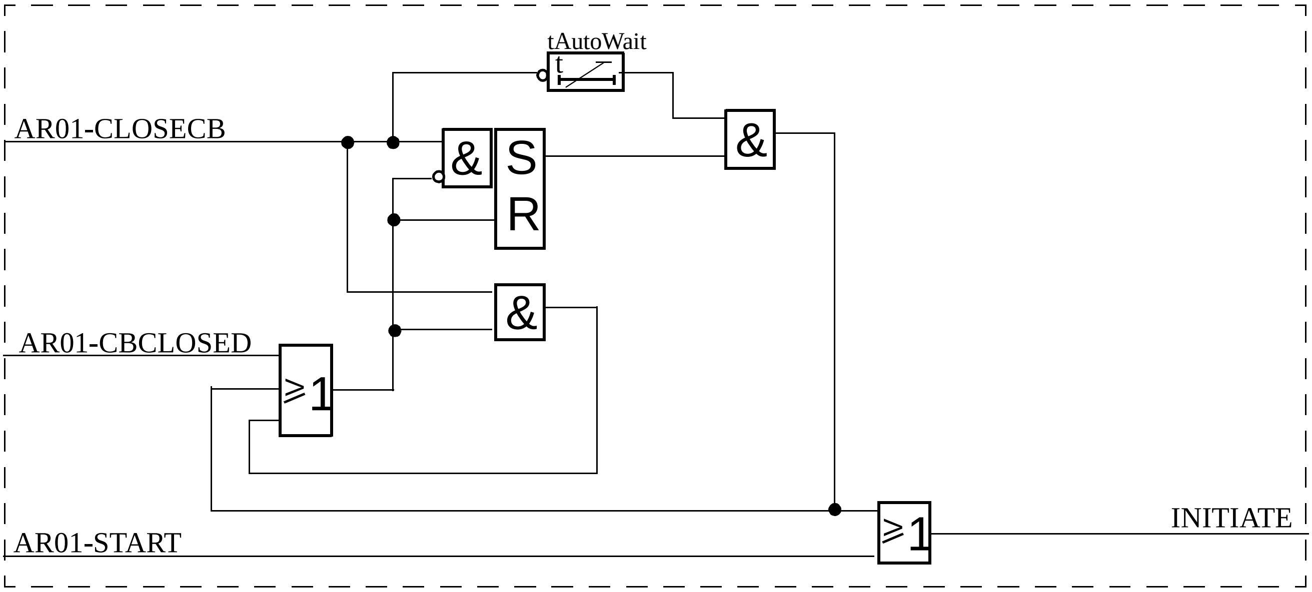


Figure 8: Automatic proceeding of shot 2 to 4

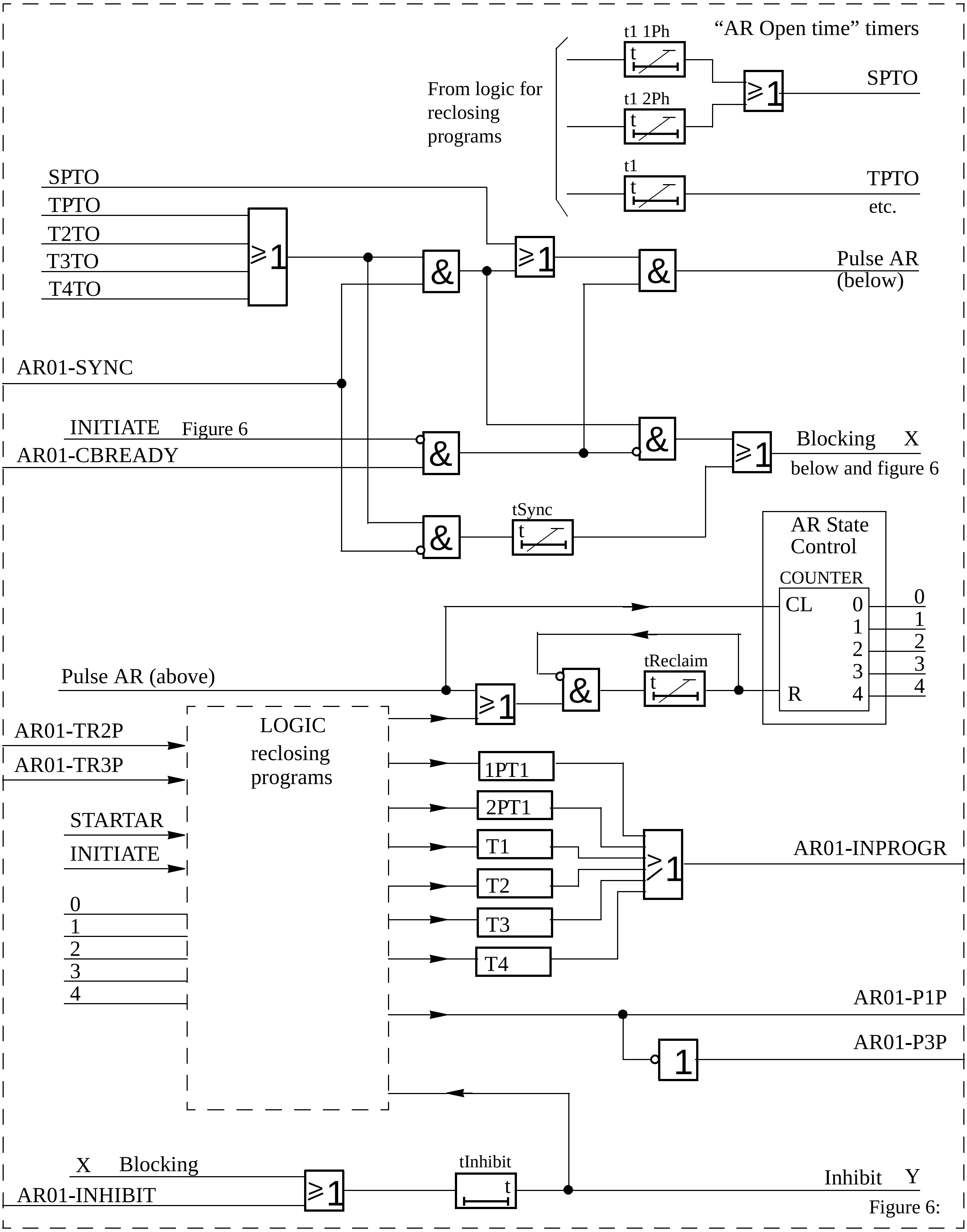


Figure 9: Reclosing checks and "Reclaim" and "Inhibit" timers.

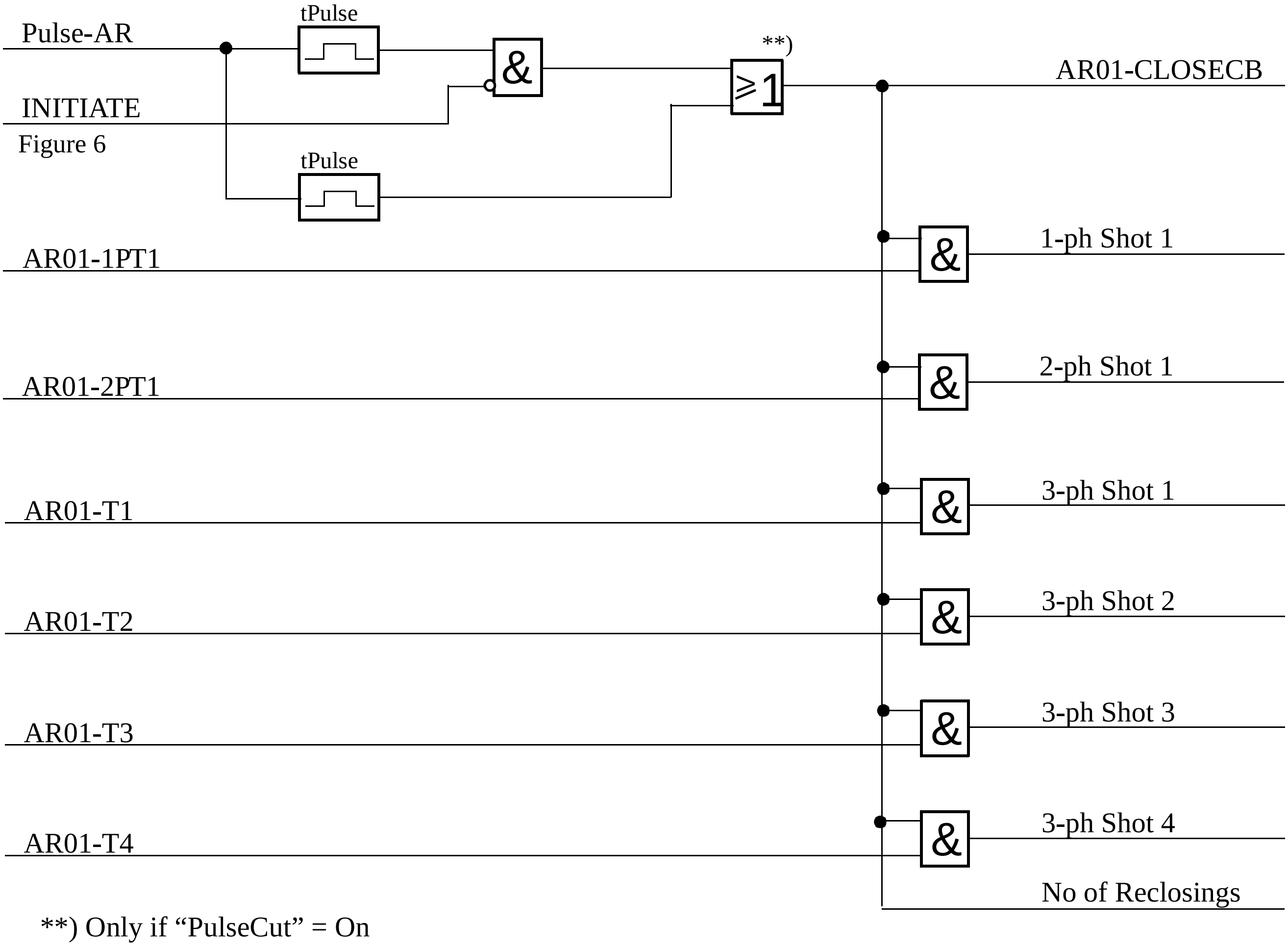


Figure 10: Pulsing of close command and driving of operation counters

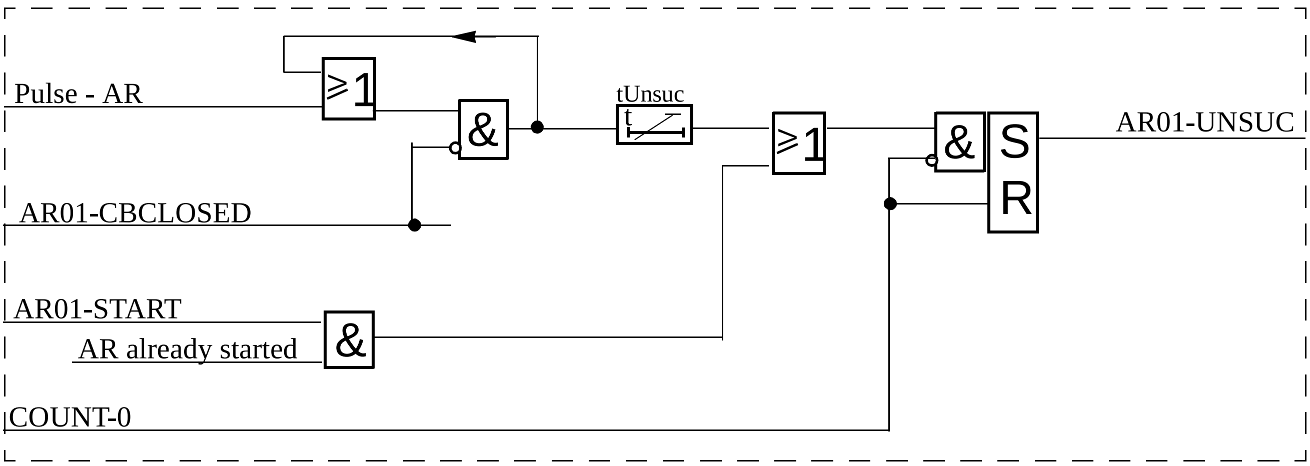


Figure 11: Issuing of the AR01-UNSUC signal

6.3 Sequence examples

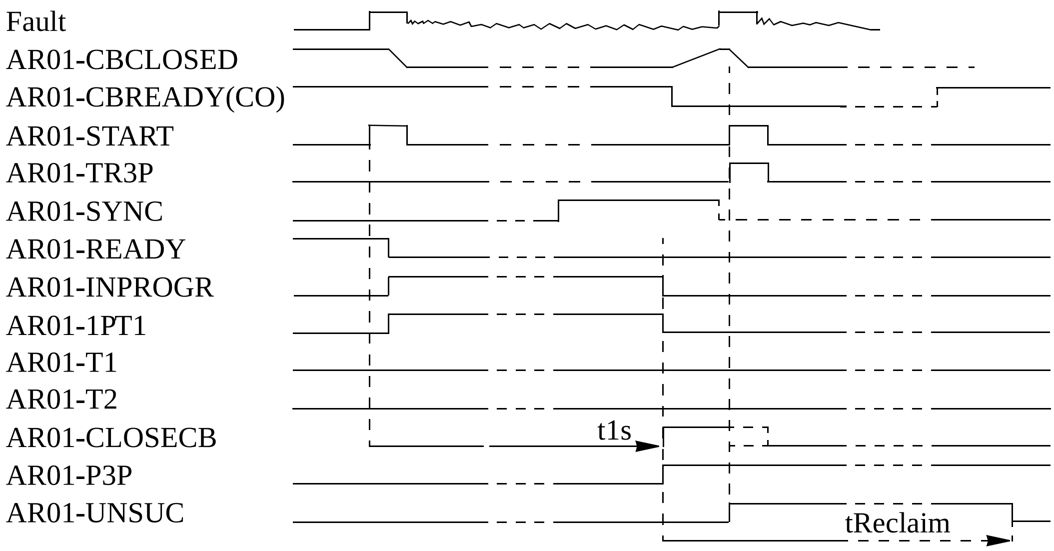


Figure 12: Permanent single-phase fault. Program 1/2/3ph, single-phase single-shot reclosing.

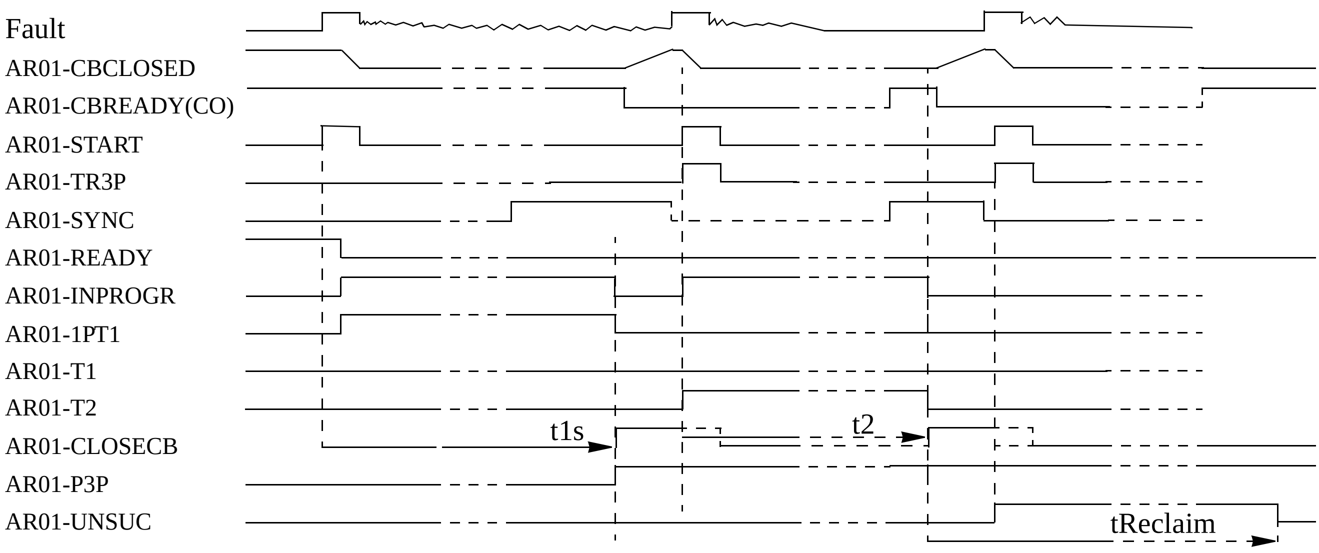


Figure 13: Permanent single-phase fault. Program 1ph + 3ph or 1/2ph + 3ph, two-shot reclosing.

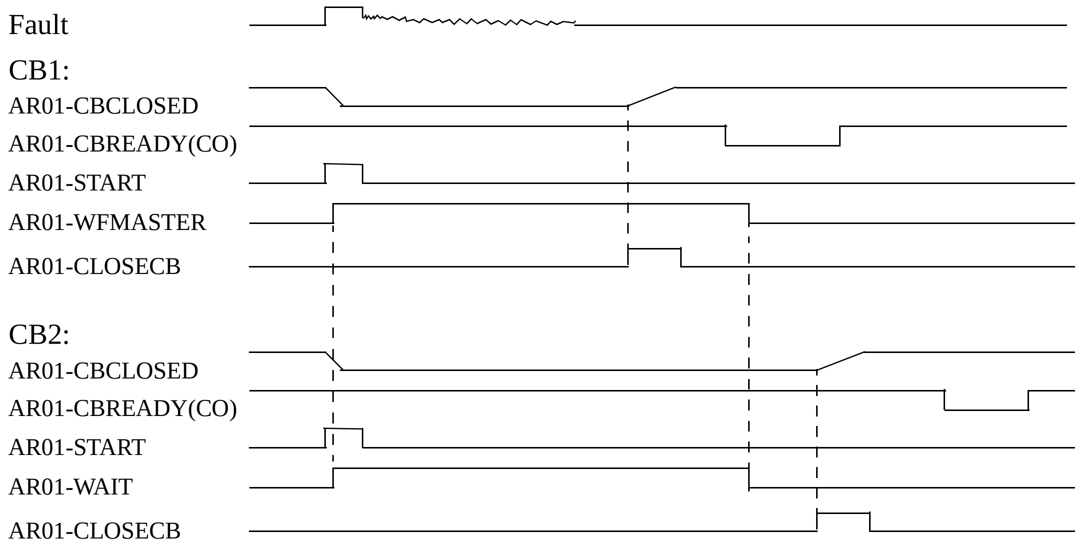


Figure 14: Sequential reclosing of two line breakers with priority.

6.4 Signal list

The signal list shows the input and output signals which can be interfaced with the auto-recloser 1. Data is same for other auto-recloser functions (2 to 6) with signal prefix AR02- to AR06-.

Table 2:

Block	Signal	Type	Description
AR01-	ON	IN	Enable auto-recloser operation
AR01-	OFF	IN	Disable auto-recloser operation
AR01-	BLKON	IN	Set auto-recloser in blocked state
AR01-	BLOCKOFF	IN	Release of auto-recloser in blocked state
AR01-	INHIBIT	IN	Inhibit auto-reclosing cycle
AR01-	RESET	IN	Resets auto-recloser
AR01-	START	IN	Start of auto-reclosing cycle
AR01-	STTHOL	IN	Start of thermal overload protection
AR01-	TRSOTF	IN	Start of auto-reclosing cycle from switch-onto-fault
AR01-	TR2P	IN	Two-phase trip
AR01-	TR3P	IN	Three-phase trip
AR01-	CBREADY	IN	Circuit breaker ready for operation
AR01-	CBCLOSED	IN	Circuit breaker closed
AR01-	PLCLOST	IN	Permissive communication channel out of service
AR01-	SYNC	IN	OK from external synchronising/energising unit
AR01-	WAIT	IN	Wait from master for sequential tripping
AR01-	BLOCKED	OUT	Auto-recloser in blocked state
AR01-	SETON	OUT	Auto-recloser switched on
AR01-	INPROGR	OUT	Auto-reclosing attempt in progress
AR01-	ACTIVE	OUT	Auto-reclosing cycle in progress
AR01-	UNSUC	OUT	Unsuccessful auto-reclosing
AR01-	READY	OUT	Auto-recloser prepared for reclose cycle
AR01-	P1P	OUT	Permit single-phase trip
AR01-	P3P	OUT	Prepare three-phase trip
AR01-	CLOSECB	OUT	Closing command for circuit breaker
AR01-	1PT1	OUT	Single-phase reclosing in progress
AR01-	2PT1	OUT	Two-phase reclosing in progress
AR01-	T1	OUT	Three-phase reclosing, shot 1 in progress
AR01-	T2	OUT	Three-phase reclosing, shot 2 in progress
AR01-	T3	OUT	Three-phase reclosing, shot 3 in progress
AR01-	T4	OUT	Three-phase reclosing, shot 4 in progress
AR01-	WFMASTER	OUT	Wait from master for sequential tripping

6.5 Setting table

Parameter	Range	Unit	Default	Parameter description
Operation	Off, Stand-by, On		Off	Auto-recloser Off/Stand-by/On
NoOfRe-closing	1-4		1	Maximum number of reclosing attempts
FirstShot	3 ph, 1/2/3 ph, 1/2 ph, 1 ph+1*2 ph, 1/2+1*3 ph, 1 ph+1*2/3 ph		3 ph	Restriction of fault type for first reclosing attempt
Extended t1	Off, On		Off	Extended dead time for loss of permissive channel
t1 1Ph	0.000-60.000	s	1.000	Open time for first auto-reclosing at single-phase
t1 2Ph	0.000-60.000	s	1.000	Open time for first auto-reclosing at two-phase
t1	0.000-60.000	s	1.000	Open time for first auto-reclosing at three-phase
t2	0.0-9000.0	s	30.0	Open time for second auto-reclosing
t3	0.0-9000.0	s	30.0	Open time for third auto-reclosing
t4	0.0-9000.0	s	30.0	Open time for fourth auto-reclosing
tSync	0.0-9000.0	s	2.0	Auto-recloser maximum wait time for sync
tPulse	0.000-60.000	s	0.200	Circuit breaker closing pulse length
CutPulse	Off, On		Off	Shorten closing pulse at a new trip
tReclaim	0.0-9000.0	s	60.0	Auto-recloser reclaim time
tInhibit	0.000-60.000	a	5.000	Inhibit reset time
CB Ready	CO, OCO		CO	Select type of circuit breaker ready signal
tTrip	0.000-60.000	s	1.000	Block auto-reclosing for long trip duration
Priority	None, Low, High		None	Priority selection between adjacent terminals
tWaitFor-Master	0.0-9000.0	s	60.0	Maximum wait time for Master
AutoCont	Off, On		Off	Continue with next reclosing attempt if breaker not closes
BlockUnsuc	Off, On		Off	Block auto-recloser at unsuccessful auto-reclosing
tAutoWait	0.000-60.000	s	2.000	Maximum wait time between shots
UnsucMode	NoCBCheck, CBCheck		NOCB-Check	Unsuccessful-signal mode
tUnsuc	0.0-9000.0	s	30	CB Check time before unsuc

1 Application

Automatic reclosing (AR) is a well-established method to restore the service of a power line after a transient line fault. The majority of line faults are flashover arcs, which are transient by nature. When the power line is switched off by operation of line protection and line breakers, the arc de-ionises and recovers voltage withstand at a somewhat variable rate. So a certain line *dead time* is needed. But then line service can resume by the auto-reclosing of the line breakers. Select the length of the dead time to enable good probability of fault arc de-ionisation and successful reclosing.

For the individual line breakers and auto-reclosing equipment, the Auto-reclose open time (AR open time) expression is used.
At simultaneous tripping and reclosing at the two line ends, Auto-reclose open time equals the dead time of the line. Otherwise these two times may differ.

In case of a permanent fault, the line protection trips again at reclosing to clear the fault. Figure 1: shows the operation sequence and some expressions.

The reclosing function can be selected to perform three-phase reclosing from single-shot to multiple-shot reclosing program. The three-phase auto-reclose open time can be set to give either high-speed auto-reclosing (HSAR) or delayed auto-reclosing (DAR).

Three-phase auto-reclosing can be performed with or without the use of synchro-check and energising check.

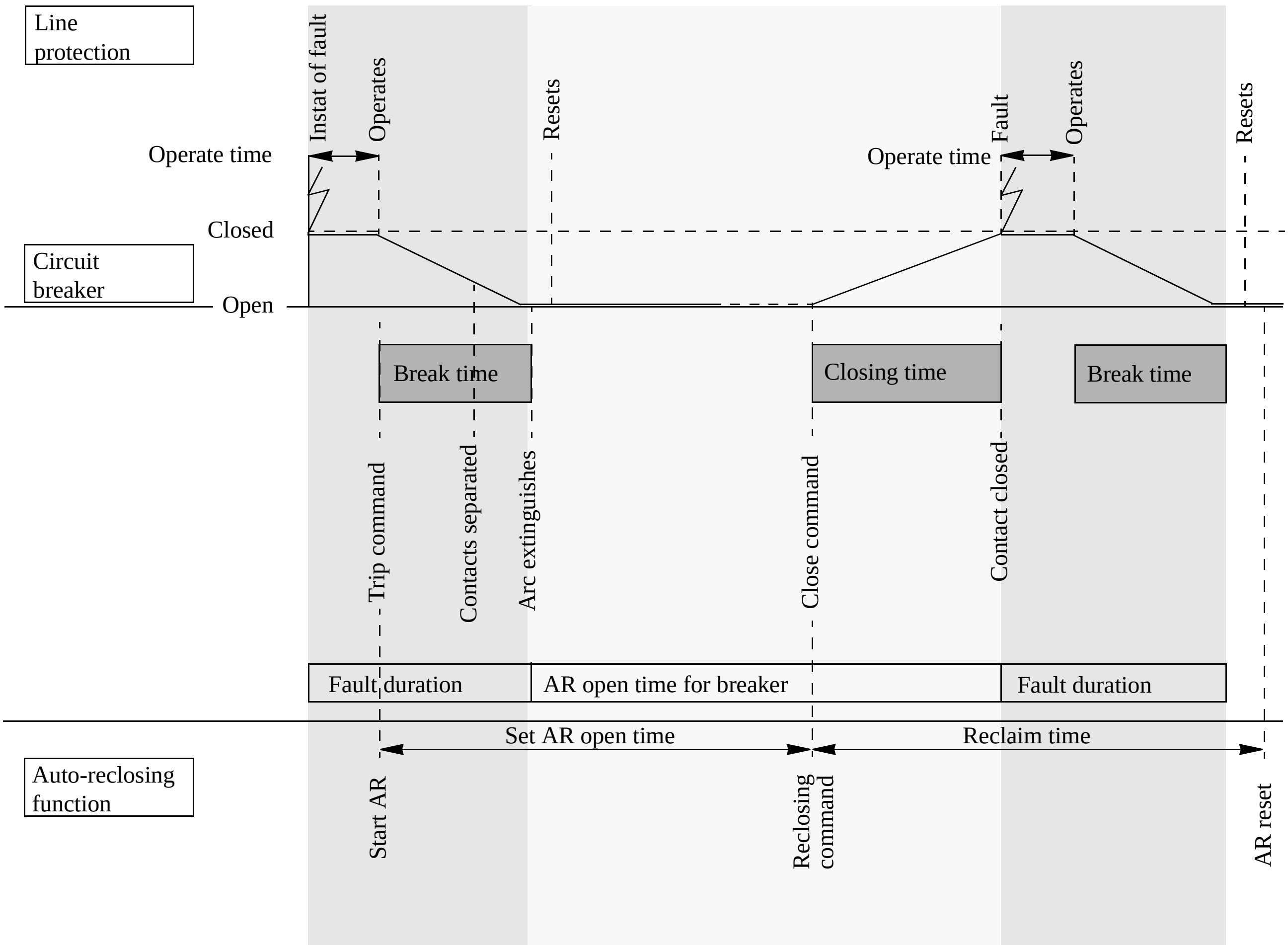


Figure 1: Single-shot auto-reclosing at a permanent fault.

2 Theory of operation

The auto-reclosing function first co-operates with the line protection functions, the trip function, the circuit-breaker and the synchro-check function. It can also be influenced by other protection functions such as shunt reactor protection through binary input signals and AR On/Off manual control. It can provide information to the disturbance and service report functions, event recording, indications, and reclosing operation counters.

The reclosing function outputs and counters can be viewed and reset on the local HMI at:

ServiceReport
Functions
AutoRecloser
AutoRecloser n

The auto-reclosing is a pure logical function that works with logical or binary signals, logical operations and timers.

2.1 Input and output signals, single breaker arrangement

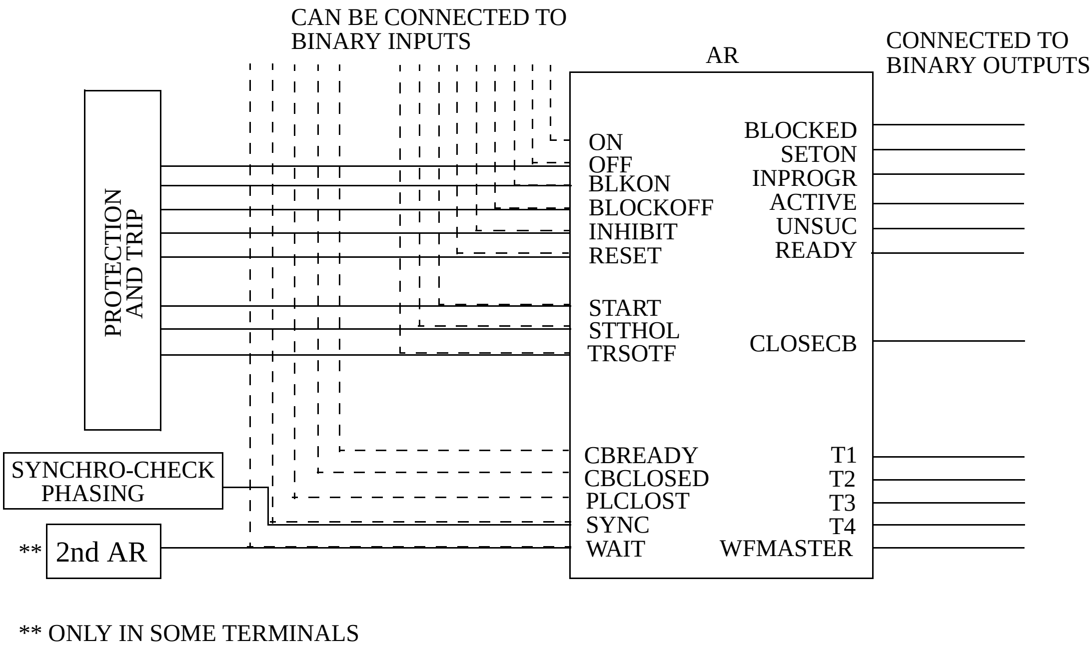


Figure 2: Three-phase auto-reclosing; input and output signals.

The input signals can be connected to binary inputs or internal functions of the terminal. The output signals can be connected to binary output relays. It is also possible to connect the signals to free logic functions, for example OR-gates, and in that way add connection links.

The input and output signals which can be interfaced with the auto-recloser 1 are presented in this document. Data is the same for other auto-recloser functions (2 to 6) with signal prefix AR02- to AR06-.

Input signals:

AR01-ON	Switches the auto-reclosing On (at Operation = Stand-by).
AR01-OFF	Switches the auto-reclosing Off (at Operation =Stand-by).
AR01-BLKON	Sets the auto-recloser in blocked state.
AR01-BLOCKOFF	Releases the auto-recloser from the blocked state.
AR01-INHIBIT	Inhibits an auto-reclosing cycle. Interrupts and blocks auto-reclosing. The input can, for example, be activated by a shunt reactor, delayed back-up protection or breaker-failure protection. There is a tInhibit reset timer to ensure blocking during a few seconds after the signal is removed.
AR01-RESET	Resets the auto-recloser.
AR01-START	Auto-reclosing start by a protection trip signal. It also makes the reclosing program continue at a repeated trip, if multi-shot reclosing is selected.
AR01-STTHOL	Start of thermal overload protection. Will block the auto-reclosing.
AR01-TRSOTF	Protection trip switch-onto-fault. This signal alone does not start reclosing. But at a reclosing onto a permanent fault it may appear and let the function move on to AR01-UNSUC (unsuccessful) or second-shot reclosing as programmed.
AR01-CBREADY	A condition for the start of a reclosing cycle. The circuit breaker must have its operating gear ready (manoeuvre spring charged) for a Close-Open (CO) or an Open-Close-Open (OCO) operations to allow the start of an auto-reclosing cycle. This input can also be connected to circuits that monitor the breaker pressure. If it is not ready at start, it is unlikely that it is ready by the end of the AR open time.
AR01-CBCLOSED	Circuit breaker closed. A condition for the start of a reclosing cycle. The circuit breaker (CB) must be closed at least for five seconds to allow a new AR cycle to start. It prevents start at closing onto a fault. It also prevents the reclosing of a breaker that is open at the protection trip, which is possible in a multiple breaker arrangement.
AR01-PLCLOST	Power line carrier or other form of permissive signal lost. An optional input signal at loss of a communication channel in a permissive line protection scheme. Can extend the AR open time.

AR01-SYNC	Synchro-check fulfilled from the internal synchro-check/phasing function or an external device required for three-phase auto-reclosing.

Output signals:

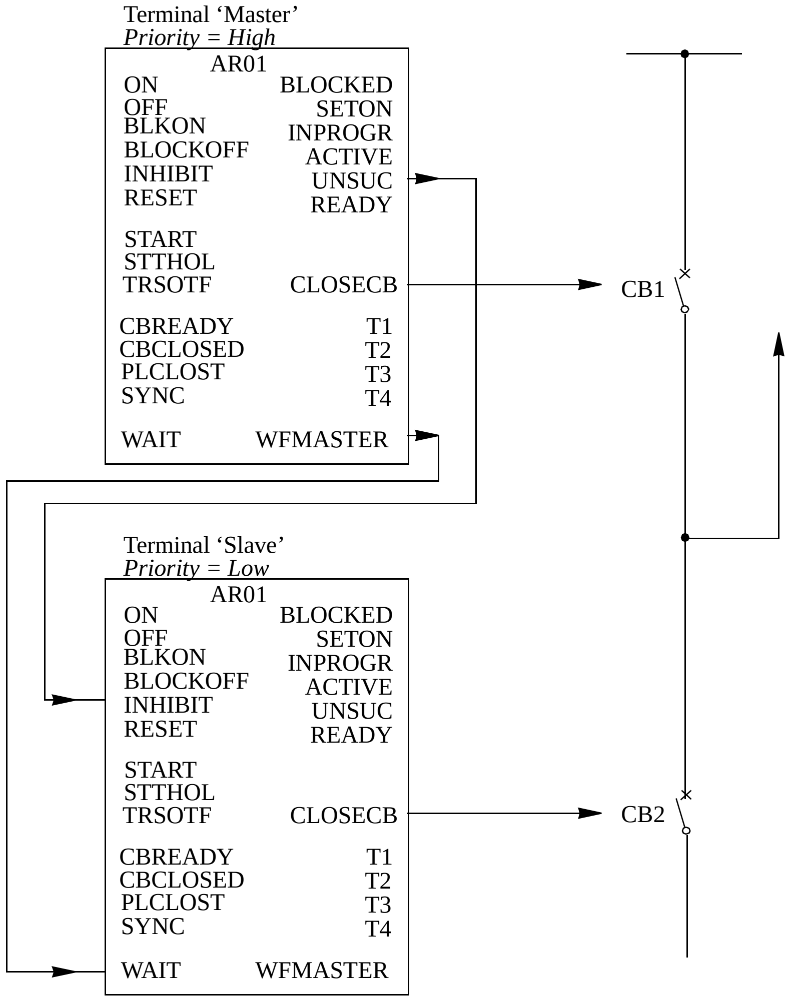
AR01-BLOCKED	The auto-recloser is in blocked state.
AR01-SETON	Indicates that the AR operation is switched on, operative.
AR01-INPROGR	Auto-reclosing attempt in progress. Activated during the AR open time.
AR01-ACTIVE	Auto-reclosing cycle in progress.
AR01-UNSUC	Auto-reclosing unsuccessful. Activated at a new trip after the last programmed shot (selected number of reclosing shots), or at trip while reclosing is blocked. The output resets after the reclaim time.
AR01-READY	Indicates that the AR function is ready for a new AR cycle. It is On but not started or blocked. This output is high when the function is On, at rest, and prepared for operation. The signal can be used by a protection function to extend the reach before reclosing, when required.
AR01-CLOSECB	Close circuit-breaker command.
AR01-T1(T2 - T4)	Three-phase reclosing, Shot 1(2 - 4) in progress.

2.2 Multi-breaker arrangement

In stations with a 1 1/2-breaker, double breaker or ring bus arrangement, there are two breakers which switch that end of the line. The reclosing of the line breakers can be made in a sequential order. One breaker is reclosed first, and if the reclosing is successful, the second breaker is reclosed as well. In the case of a permanent fault, the second breaker need not to be reclosed. By fitting one REx 5xx terminal for each line breaker, and by a few interconnections between them, sequential reclosing can be achieved. See Figure 3:.

One terminal is selected as *Master* and given *high* reclosing *priority.* At line protection trip, the two reclosing functions are started, but the master issues a *Wait For Master* signal to the *Slave* (with *low* reclosing *priority*). At unsuccessful reclosing by the master, an *Inhibit* reclosing signal is sent to the slave terminal to interrupt and reset the reclosing function.

AR01-WAIT	Signal to the low priority auto-reclosing function from the master in multi-breaker arrangements for sequential reclosing.
AR01-WFMASTER	Wait for master. Issued by the high priority unit for sequential reclosing.



*) Other input/output signals as in previous single breaker arrangement.

Figure 3: Additional input and output signals at multi-breaker arrangement.

2.3 AR Operation

The user can control the auto-reclosing function from the local HMI. Use the parameter *Operation*, which can be set to Off, Stand-by or On. See Figure 6:.

Off deactivates the auto-recloser. *On* activates automatic reclosing. Stand-by enables On and Off Operation via input signal pulses.

3 Design

3.1 Start and control of the auto-reclosing

The automatic operation of the auto-reclosing function is controlled by the parameter *Operation* and the input signals as described above. When it is on, the AR01-SETON output is high (active). See Figure 6:.

The auto-reclosing function is activated at a protection trip by the AR01-START input signal. At repeated trips, this signal is activated again to make the reclosing program continue.

There are a number of conditions for the start to be accepted and a new cycle started. After these checks, the start signal is latched in and the *Started* state signal is activated. It can be interrupted by certain events.

3.2 Extended AR open time, shot 1

The purpose of this function is to adapt the length of the AR Open time to the possibility of non-simultaneous tripping at the two line ends. If a permissive communication scheme is used and the permissive communication channel (for example, PLC, power-line carrier) is out of service at the fault, there is a risk of sequential non-simultaneous tripping. To ensure a sufficient line dead time, the AR open time is extended by 0.4 s. The input signal AR01-PLCLOST is checked at tripping. See Figure 7:. Select this function (or not) by setting the Extended t1 parameter to On (or Off).

3.3 Long trip signal

During normal circumstances, the trip command resets quickly due to fault clearing. The user can set a maximum trip pulse duration by tTrip. At a longer trip signal, the AR open dead time is extended by Extend_t1. If the Extended t1 = Off, a long trip signal interrupts the reclosing sequence in the same way as AR01-INHIBIT.

3.4 Reclosing program

The three-phase reclosing program can be performed with up to maximum four reclosing attempts (shots), selectable with the NoOfReclosing parameter.

For the example (see Figures 6 and 12), the AR function is assumed to be *On* and *Ready.* The breaker is closed and the operation gear ready, manoeuvre spring charged etc.

AR01-START is received and sealed-in at operation of the line protection. The AR01-READY output is reset (Ready for a new AR cycle).

Immediately after the start-up of the reclosing and tripping of the breaker, the input (in Figure 6:) AR01-CBCLOSED is low (possibly also AR01-CBREADY at type OCO). The AR Open-time timer, t1, keeps on running.
At the end of the set AR open-time, the three-phase AR time-out (Figure 9:) is activated and goes on to the output module for further checks and to give a closing command to the circuit breaker.

3.5 Blocking of a new reclosing cycle

A new start of a reclosing cycle is blocked for the reclaim time after the selected number of reclosing attempts are performed.

3.6 Reclosing checks and Reclaim timer

An AR open-time time-out signal is received from a program module.
At three-phase reclosing, a synchro-check and/or energising check or voltage check can be used. It is possible to use an internal or an external synchro-check function, configured to AR01-SYNC.
If a reclosing without check is preferred, configure the input AR01-SYNC to FIXD-ON (set to 1).

Another possibility is to set the output from the internal synchro-check function to a permanently active signal. Set Operation = Release in the synchro-check function. Then AR01-SYNC is configured to SYNx-AUTOOK.

At confirmation from the synchro-check or if the reclosing is of single-phase type, the signal passes on.

At AR01-CBREADY signal of the Close-Open (CO) type, it is checked that this signal is present to allow a reclosing.

The synchronising and energising check must be fulfilled within a certain period of time, tSync. If it does not, or if the other conditions are not fulfilled, the reclosing is interrupted and blocked.

The Reclaim-timer defines a period from the issue of a reclosing command, after which the reclosing function is reset. Should a new trip occur within this time, it is treated as a continuation of the first fault.
When a closing command is given (Pulse AR), the reclaim timer is started.

There is an AR State Control, Figure 9:, to track the actual state in the reclosing sequence.

3.7 Pulsing of CB closing command

The circuit breaker closing command, AR01-CLOSECB, is made as a pulse with a duration, set by the tPulse parameter. For circuit breakers without an anti-pumping function, the closing-pulse-cutting described below can be used. It is selected by means of the CutPulse parameter (set to On). In case of a new trip pulse, the closing pulse will be cut (interrupted). But the minimum length of the closing pulse is always 50 ms.

At the issue of a reclosing command, the associated reclosing operation counter is also incremented.
There is a counter for each type of reclosing and one for the total number of reclosings. See Figure 10:.

3.8 Transient fault

After the reclosing command, the reclaim timer keeps running for the set time. If no tripping occurs within this time, tReclaim, the auto-reclosing function will be reset. The circuit breaker remains closed and the operating gear ready (manoeuvre spring is recharged). AR01-CBCLOSED = 1 and AR01-CBREADY = 1.

After the reclaim time, the AR state control resets to original rest state, with AR01-SETON = 1 and AR01-READY = 1. The other AR01 outputs = 0.

3.9 Unsuccessful signal

Normally the signal AR01-UNSUC appears when a new start is received after the last reclosing attempt has been made. See Figure 11:. It can be programmed to appear at any stage of a reclosing sequence by setting the parameter *UnsucMode* = On. The UNSUC signal is attained after the time tUnsuc.

3.10 Permanent fault

If a new trip takes place after a reclosing attempt and a new AR01-START or AR01-TRSOTF signal appears, the AR01-UNSUC (Reclosing unsuccessful) is activated. The timer for the first reclosing attempt, t1, cannot be started (Figure 9:).

Depending on the PulseCut parameter setting, the closing command may be shortened at the second trip command.

After time-out of the reclaim timer, the auto reclosing function resets, but the circuit breaker remains open (AR01-CBCLOSED = 0, AR01-CBREADY = 1). Thus the reclosing function is not ready for a new reclosing cycle. See Figure 6: and Figure 12:.

3.11 Automatic confirmation of programmed reclosing attempts

The auto-recloser can be programmed to continue with reclosing attempts two to four (if selected) even if the start signals are not received from the protection functions, but the breaker is still not closed. See Figure 8:. This is done by setting the parameter *AutoCont* = On and the wait time *tAutoWait* to desired length.

4 Configuration and setting

The signals are configured in the CAP 531 configuration tool.

The parameters for the auto-reclosing function are set through the local HMI at:

Settings
  Functions
    Group n
      AutoRecloser
        AutoRecloser n

4.1 Recommendations for input signals

See Figure 4: and the default configuration for examples.

AR01-ON and AR01-OFF
may be connected to binary inputs for external control.

AR01-START
should be connected to the protection function trip output which shall start the auto-recloser. It can also be connected to a binary input for start from an external contact. A logical OR gate can be used to multiply the number of start sources.

AR01-INHIBIT
can be connected to binary inputs, to block the AR from a certain protection, such as a line connected shunt reactor, transfer trip receive or back-up protection or breaker-failure protection.

AR01-CBCLOSED and **AR01-CBREADY**
must be connected to binary inputs, for pick-up of the breaker signals. If the external signals are of Breaker-not-ready type, uncharged etc., an inverter can be configured before CBREADY.

AR01-SYNC
is connected to the internal synchro-check function if required. It can also be connected to a binary input. If neither internal nor external synchronising or energising check (dead line check) is required, it can be connected to a permanent 1 (high), by connection to FIXD-ON.

AR01-PLCLOST
can be connected to a binary input, when required.

AR01-TRSOTF
can be connected to the internal line protection, distance protection, trip switch-onto-fault.

AR01-STTHOL
Start of thermal overload protection signal. Can be connected to OVLD-TRIP to block the AR at overload.

Other
The other input signals can be connected as required.

4.2 Recommendations for output signals

See Figure 4: and the default configuration for examples.

AR01-READY
can be connected to the Zone extension of a line protection. It can also be used for indication, if required.

AR01-CLOSECB
connect to a binary output relay for circuit breaker closing command.

Other
The other output signals can be connected for indication, disturbance recording etc., as required.

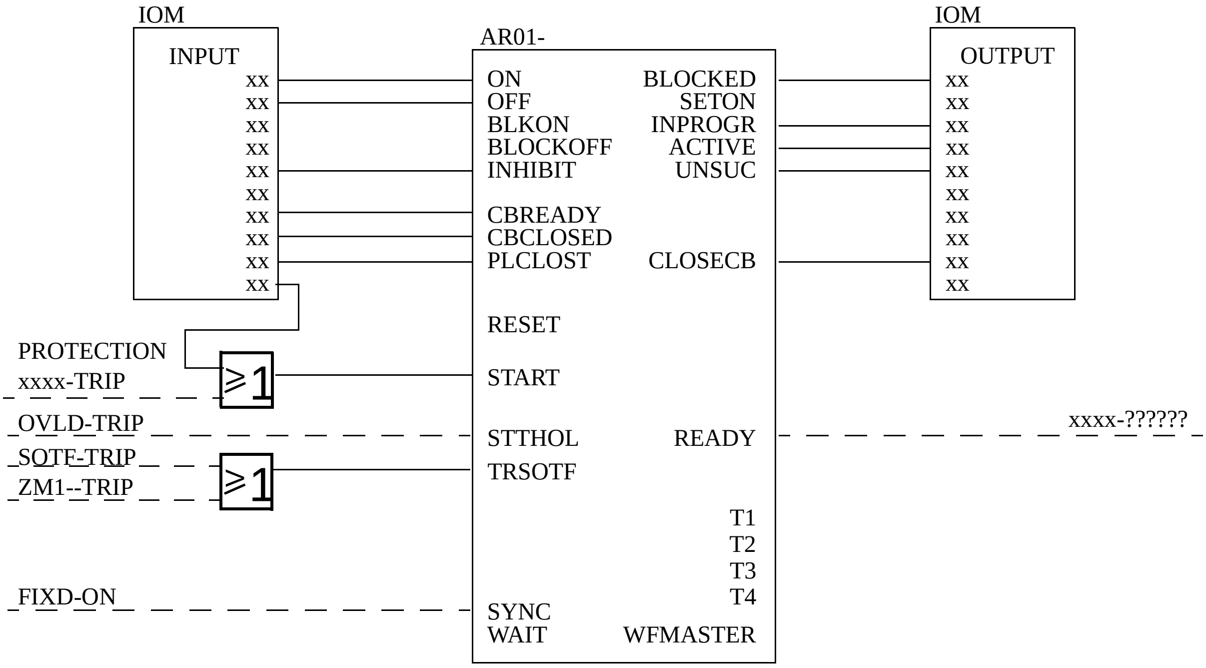


Figure 4: Recommendations for I/O-signal connections.

4.3 Recommendations for multi-breaker arrangement

Sequential reclosing at multi-breaker arrangement is achieved by giving the two line breakers different priorities. Refer to Figure 3:. At single breaker application, *Priority* is set to *No*, and this has no influence on the function. The signal *Started* is sent to the next function module. At double breaker and similar applications, *Priority* is set *High* for the Master terminal and *Priority* = *Low* for the Slave.

While reclosing is in progress in the master, it issues the signal -WFMASTER. A reset delay ensures that the -WAIT signal is kept high for the breaker closing time. After an unsuccessful reclosing, it is also maintained by the signal -UNSUC. For the slave terminal, the input signal -WAIT holds back a reclosing operation. A time *tWait* sets a maximum waiting time for the reset of the Wait signal. At time-out, it interrupts the reclosing cycle by a WM-INH, wait for master inhibit, signal.

5 Testing

The user can test the auto-reclosing function, for example, during commissioning or after a reconfiguration. The test can be performed with protection and trip functions, as the synchro-check function (with energising check), applied.

Figure 5: illustrates a recommended testing scenario, where the circuit breaker is simulated by an external bistable relay (BR), e.g. an RXMVB2 or an RXMVE1. These manual switches are available:

- Switch close (SC)
- Switch trip (ST)
- Switch ready (SRY).

SC and ST can be push-buttons with spring return. If no bistable relay is available, replace it with two self-reset auxiliary relays as in Figure 5:.

Use a secondary injection relay test set to operate the protection function. It is possible to use the BR to control the injected analogue quantities so that the fault only appears when the BR is picked up—simulating a closed breaker position.

To make the arrangement more elaborate, include the simulation of the operation gear condition, AR01-CBREADY, for the sequences Close-Open (CO) and Open-Close-Open (OCO).

The AR01-CBREADY condition at the CO sequence type is usually low for a recharging time of 5-10 s after a closing operation. Then it is high. The example shows that it is simulated with SRY, a manual switch.

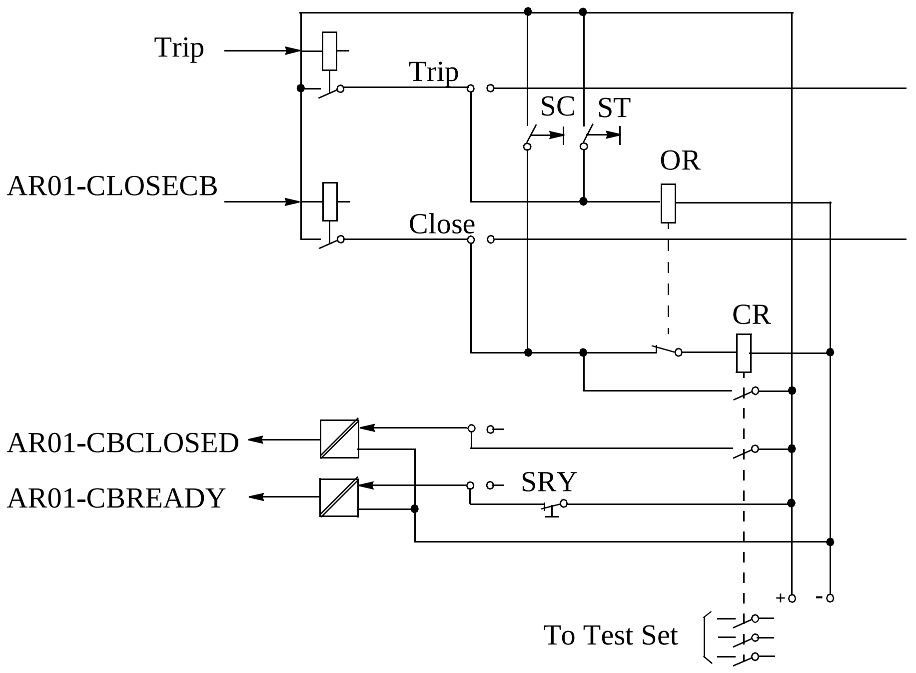


Figure 5: Simulating breaker operation with two auxiliary relays.

5.1 Suggested testing procedure

5.1.1 Preparations

1.1 Check the settings of the auto-reclosing (AR) function. The operation can be set at Stand-by (Off).

HMI tree:

Settings
Functions
Group n
AutoRecloser
AutoRecloser n

If any timer setting is changed so as to speed-up or facilitate the testing, they must be set to normal after the testing. A verification test has to be done afterwards.

1.2 Read and note the reclosing operate counters from the HMI tree:

ServiceReport
Functions
AutoRecloser
AutoRecloser n
Counters

1.3 Do the testing arrangements outlined above, for example, as in Figure 5:.

1.4 The AR01-CBCLOSED breaker position, the commands Trip and Closing, AR01-CLOSECB, and other signals should preferably be arranged for event recording provided with time measurements. Otherwise, a separate timer or recorder can be used to check the AR open time and other timers.

5.1.2 Check the AR functionality

2.1 Ensure that the voltage inputs to Synchro-check gives accepted conditions at open breaker (BR). They can, for example, be Live busbar and Dead line.

2.2 Set the operation at On.

2.3 Make a BR pickup by a closing pulse, the SC-pulse.

2.4 Close SRY, Breaker ready and leave it closed.

2.5 Inject AC quantities to give a trip and start AR.
Observe or record the BR operation. The BR relay should trip and reclose. After the closing operation, the SRY switch could be opened for about 5 s and then closed.
The AR open time and the operating sequence should be checked, for example, in the event recording.
Check the operate indications and the operate counters.

Should the operation not be as expected, the reason must be investigated. It could be due to an AR Off state or wrong program selection, or not accepted synchro-check conditions.

2.6 A few fault cases may be checked, for example, single-phase, two-phase and three-phase trips, transient, and permanent fault. The signal sequence diagrams in Figure 12: and fig12 can be of guidance for the checking.

5.1.3 Check the reclosing requirements

The number of cases can be varied according to the application. Examples of selection cases are:

3.1 Inhibit input signal: Check that the function is operative and that the breaker conditions are okay. Apply an AR01-INHIBIT input signal and start the reclosing function. *No reclosing!*

3.2 Breaker open, closing onto a fault: Set the breaker simulating relay, BR, in position open. Then close it with the SC switch and start the AR within one second. *No reclosing!*

3.3 Breaker not ready: Close the BR breaker relay and see that everything except for AR01-CBREADY is in normal condition (SRY is open). Start the AR function. *No reclosing!*

3.4 Lack of verification from synchro-check: Check the function at non-acceptable voltage conditions. Wait for the time out, >5 s. *No reclosing!*

3.5 Operation Stand-by and Off: Check that no reclosing can occur with the function in Off state.

3.6 Depending on the program selection and the selected fault types that start and inhibit reclosing, a check of no unwanted reclosing can be made. For example, if only single-phase reclosing is selected, a test can verify that there is no reclosing after two-phase and three-phase trips.

5.1.4 Test of Master-Slave

If a multi-breaker arrangement is used for the application and priorities are given for the master (high) and slave (low) terminals, test that correct operation takes place and that correct signals are issued. The signals WFMASTER, UNSUC, WAIT and INHIBIT should be involved.

5.1.5 Termination of the test

After the test, restore the equipment to normal or desired state.

Especially check these items:

4.1 Reclosing operate counters: Check and record the counter contents. (Reset if it is the user’s preference.)

HMI tree:

ServiceReport
Functions
AutoRecloser
AutoRecloser n
Counters
Clear Counters

4.2 Setting parameters and the Operation parameter as required.

4.3 Test switch or disconnected links of connection terminals.

4.4 Normal indications.

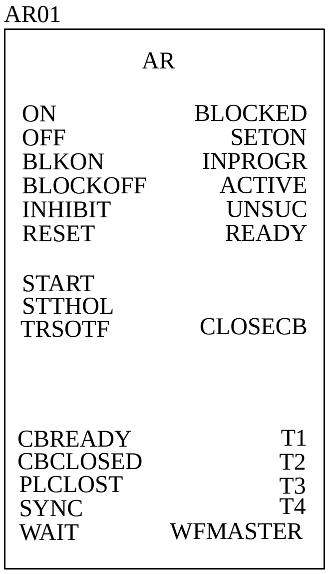
(If so preferred, the disturbance report may be cleared.)

HMI tree:

DisturbReport
ClearDistRep

6 Appendix

6.1 Function block



6.2 Function block diagrams

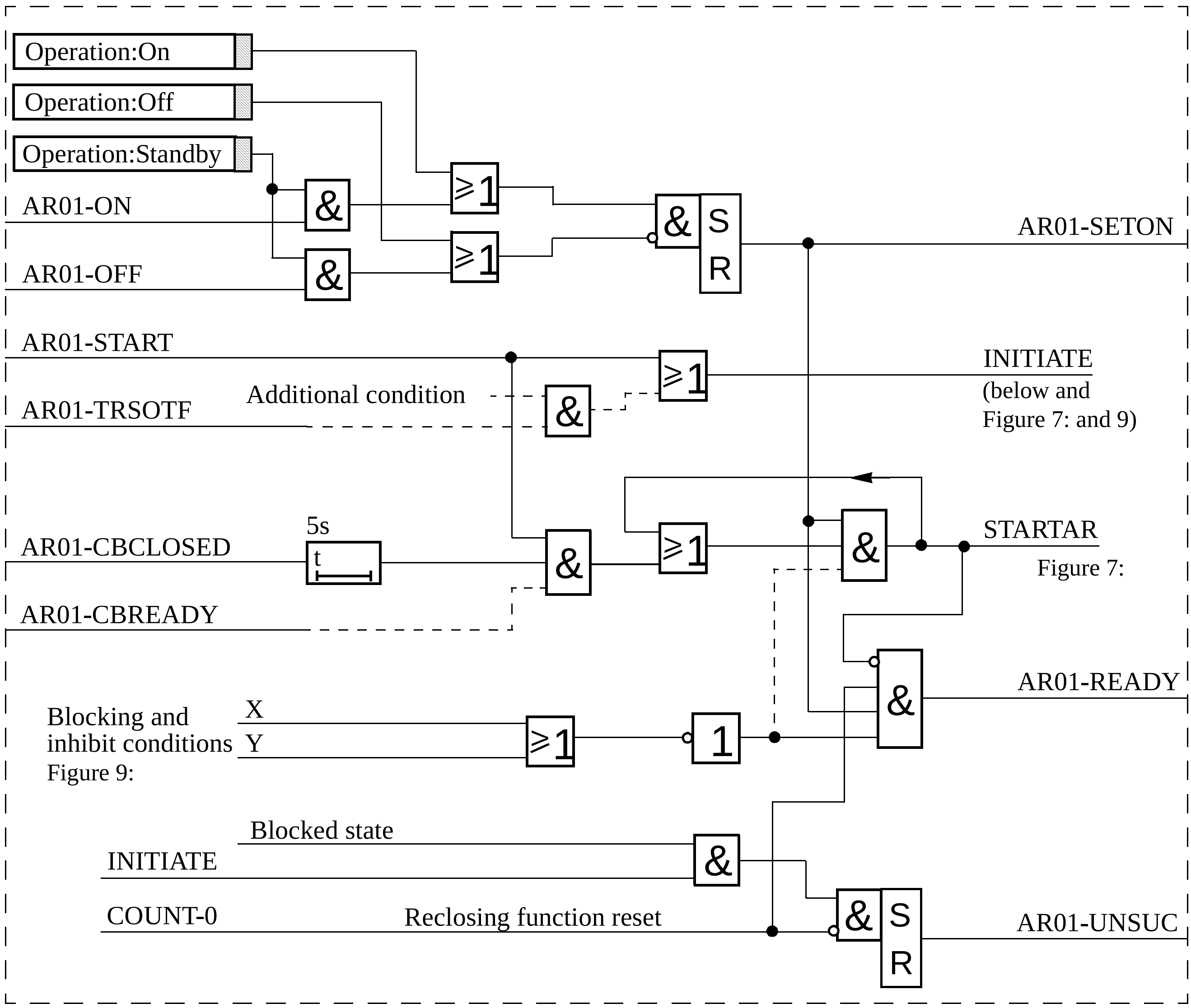


Figure 6: Auto-reclosing On/Off control and start. Simplified logic diagram.

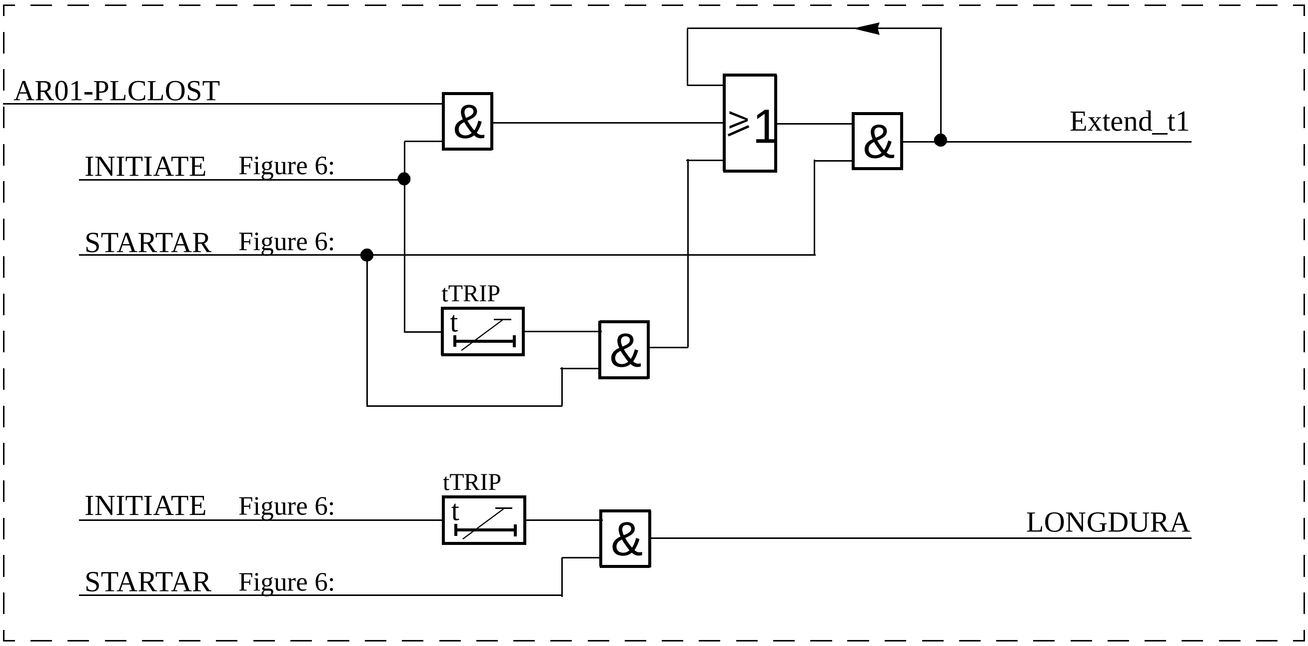


Figure 7: Control of extended “AR Open time, shot 1”. Simplified logic diagram.

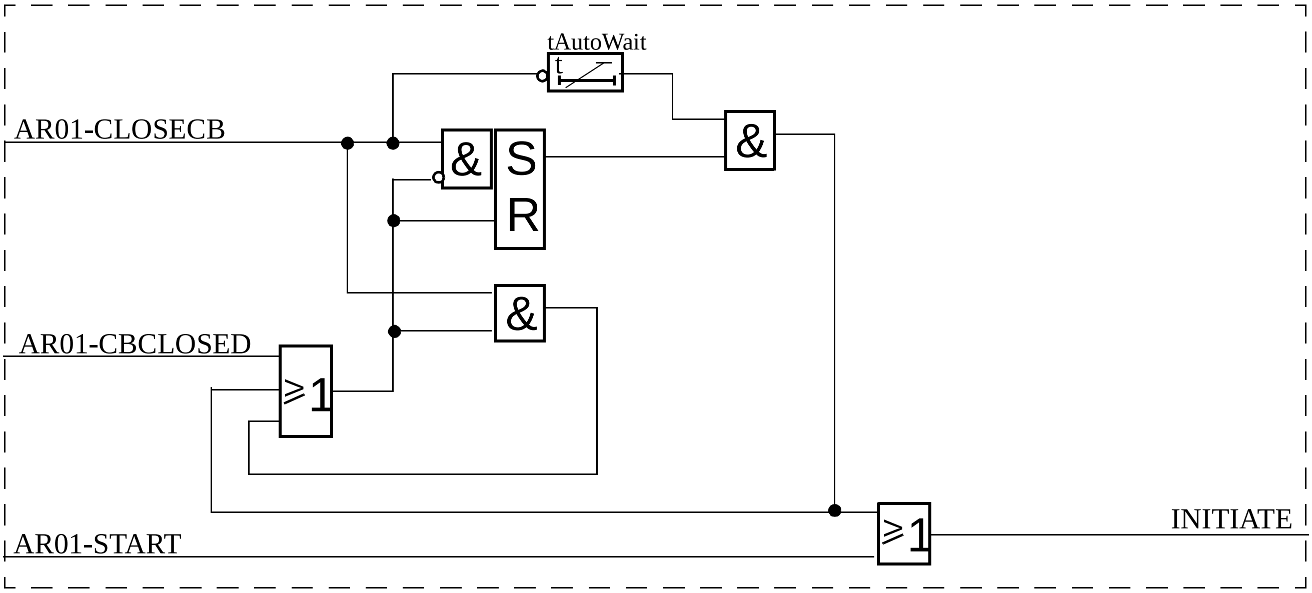


Figure 8: Automatic proceeding of shot two to four. Simplified logic diagram.

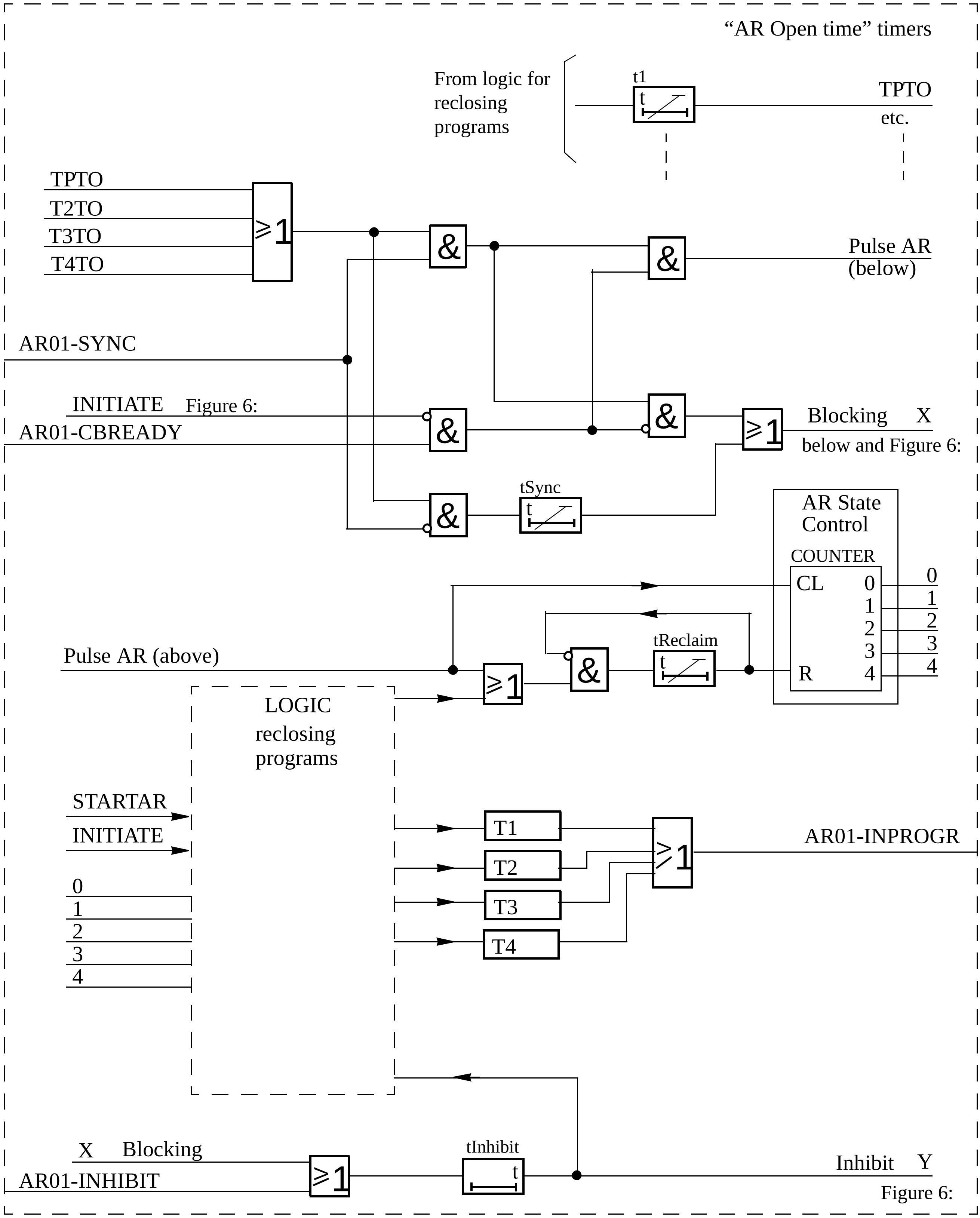


Figure 9: Reclosing checks and "Reclaim" and "Inhibit" timers. Simplified logic diagram.

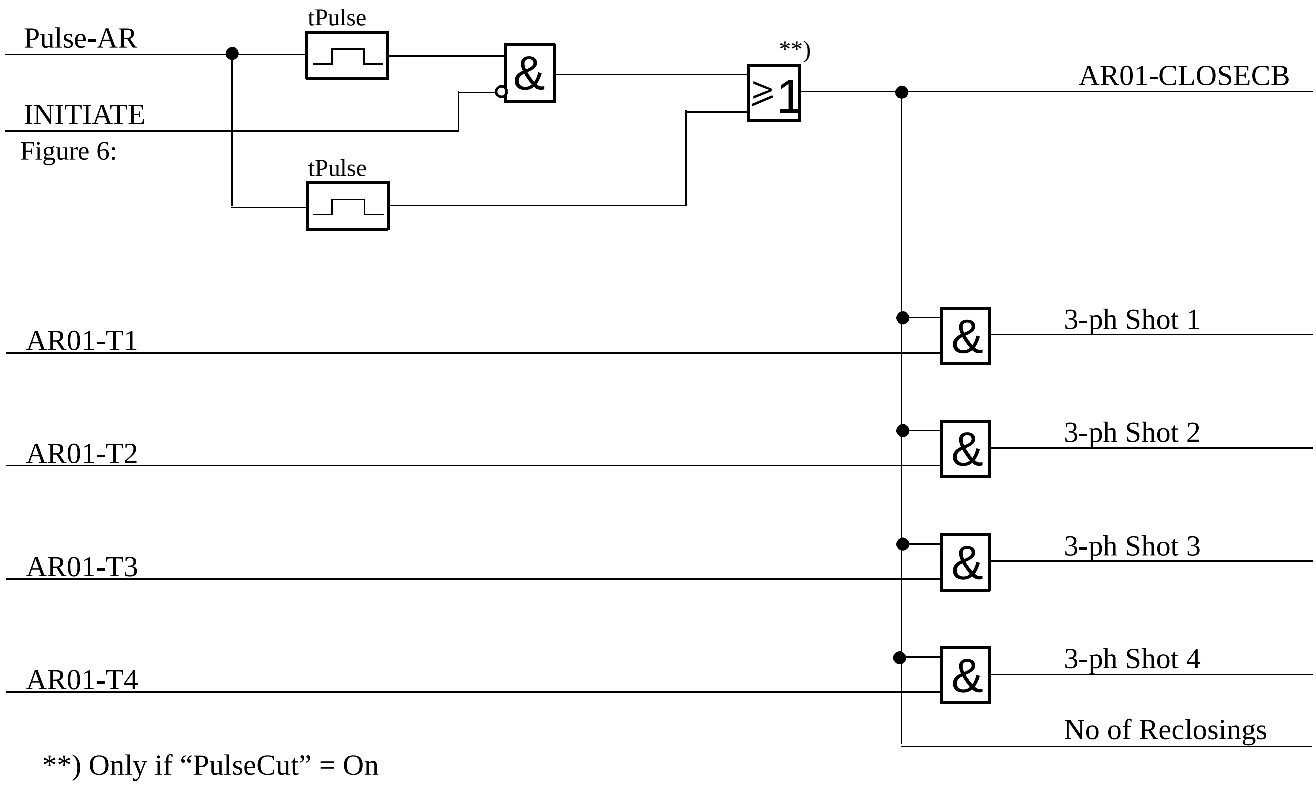


Figure 10: Pulsing of close command and driving of operation counters. Simplified logic diagram.

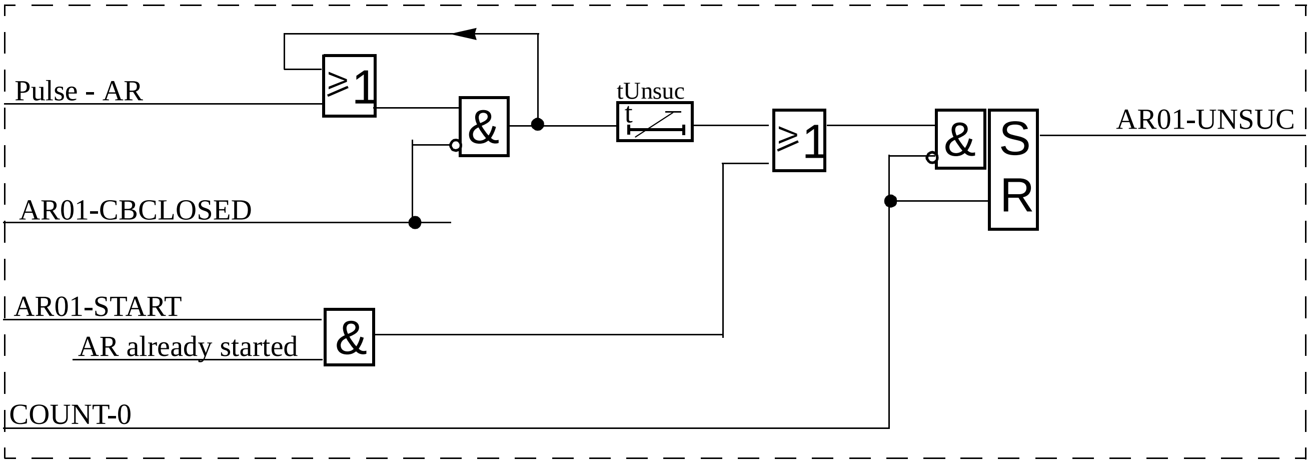


Figure 11: Issuing of the AR01-UNSUC signal. Simplified logic diagram.

6.3 Sequence examples

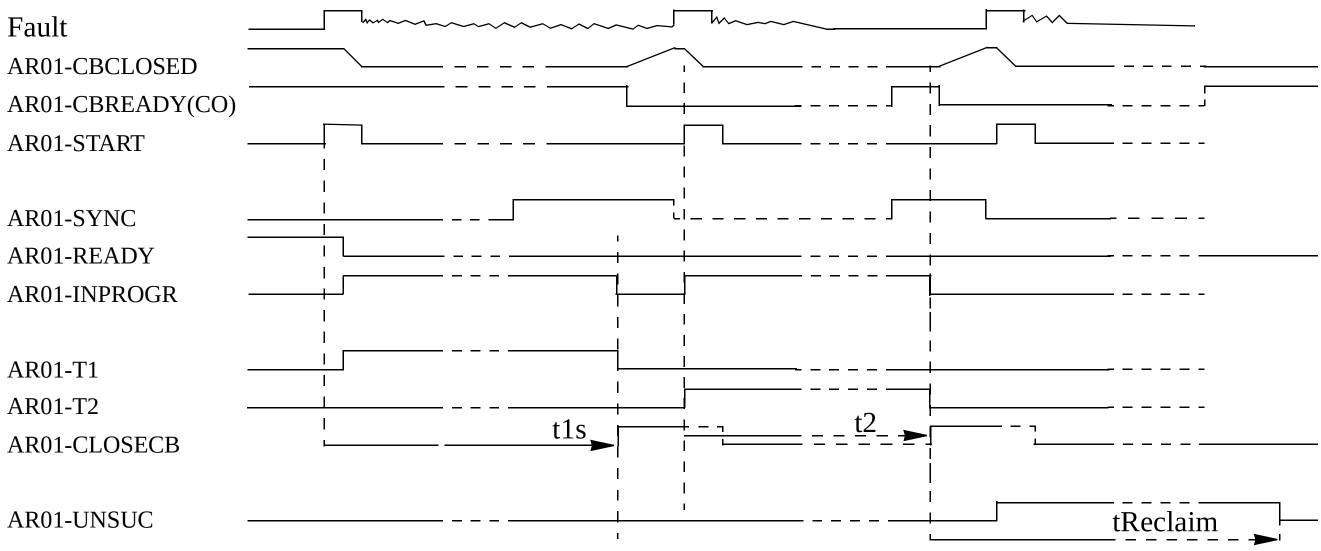


Figure 12: Example. Permanent three-phase fault, two-shot reclosing.

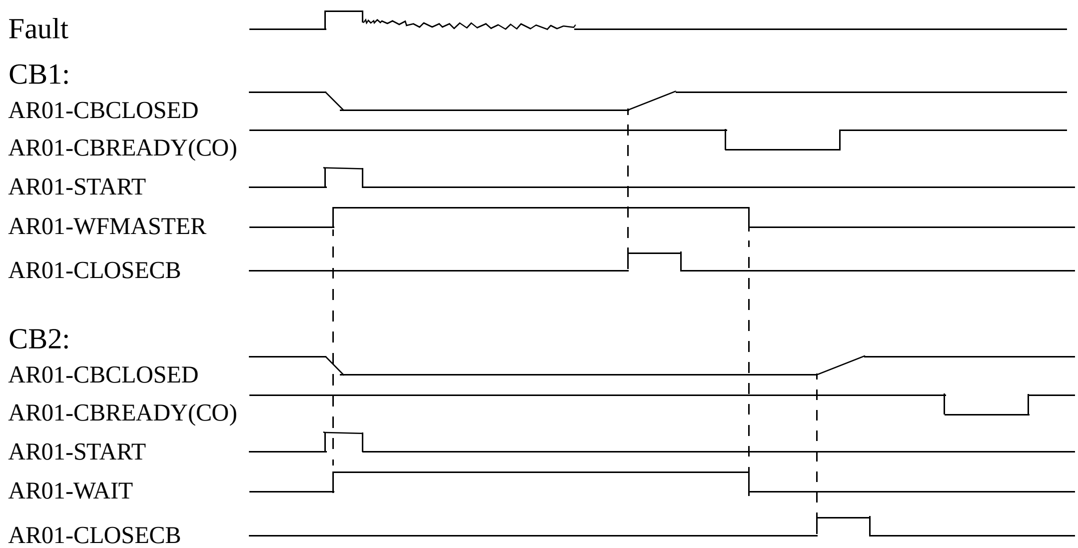


Figure 13: Sequential reclosing of two line breakers with priority.

6.4 Signal list

The signal list shows the input and output signals which can be interfaced with the auto-recloser 1. Data is same for other auto-recloser functions (2 to 6) with signal prefix AR02- to AR06-.

Table 1:

Block	Signal	Type	Description
AR01-	ON	IN	Enable auto-recloser operation
AR01-	OFF	IN	Disable auto-recloser operation
AR01-	BLKON	IN	Set auto-recloser in blocked state
AR01-	BLOCKOFF	IN	Release of auto-recloser in blocked state
AR01-	INHIBIT	IN	Inhibit auto-reclosing cycle
AR01-	RESET	IN	Resets auto-recloser
AR01-	START	IN	Start of auto-reclosing cycle
AR01-	STTHOL	IN	Start of thermal overload protection
AR01-	TRSOTF	IN	Start of auto-reclosing cycle from switch-onto-fault
AR01-	CBREADY	IN	Circuit breaker ready for operation
AR01-	CBCLOSED	IN	Circuit breaker closed
AR01-	PLCLOST	IN	Permissive communication channel out of service
AR01-	SYNC	IN	OK from external synchronising/energising unit
AR01-	WAIT	IN	Wait from master for sequential tripping
AR01-	BLOCKED	OUT	Auto-recloser in blocked state
AR01-	SETON	OUT	Auto-recloser switched on
AR01-	INPROGR	OUT	Auto-reclosing attempt in progress
AR01-	ACTIVE	OUT	Auto-reclosing cycle in progress
AR01-	UNSUC	OUT	Unsuccessful auto-reclosing
AR01-	READY	OUT	Auto-recloser prepared for reclose cycle
AR01-	CLOSECB	OUT	Closing command for circuit breaker
AR01-	T1	OUT	Three-phase reclosing, shot 1 in progress
AR01-	T2	OUT	Three-phase reclosing, shot 2 in progress
AR01-	T3	OUT	Three-phase reclosing, shot 3 in progress
AR01-	T4	OUT	Three-phase reclosing, shot 4 in progress
AR01-	WFMASTER	OUT	Wait from master for sequential tripping

6.5 Setting table

Parameter	Range	Unit	Default	Parameter description
Operation	Off, Stand-by, On		Off	Auto-recloser Off/Stand-by/On
NoOfRe-closing	1-4		1	Maximum number of reclosing attempts
Extended t1	Off, On		Off	Extended dead time for loss of permissive channel
t1	0.000-60.000	s	1.000	Open time for first auto-reclosing at three-phase
t2	0.0-9000.0	s	30.0	Open time for second auto-reclosing
t3	0.0-9000.0	s	30.0	Open time for third auto-reclosing
t4	0.0-9000.0	s	30.0	Open time for fourth auto-reclosing
tSync	0.0-9000.0	s	2.0	Auto-recloser maximum wait time for sync
tPulse	0.000-60.000	s	0.200	Circuit breaker closing pulse length
CutPulse	Off, On		Off	Shorten closing pulse at a new trip
tReclaim	0.0-9000.0	s	60.0	Auto-recloser reclaim time
tInhibit	0.000-60.000	a	5.000	Inhibit reset time
CB Ready	CO, OCO		CO	Select type of circuit breaker ready signal
tTrip	0.000-60.000	s	1.000	Block auto-reclosing for long trip duration
Priority	None, Low, High		None	Priority selection between adjacent terminals
tWaitFor-Master	0.0-9000.0	s	60.0	Maximum wait time for Master
AutoCont	Off, On		Off	Continue with next reclosing attempt if breaker not closes
BlockUnsuc	Off, On		Off	Block auto-recloser at unsuccessful auto-reclosing
tAutoWait	0.000-60.000	s	2.000	Maximum wait time between shots
UnsucMode	NoCBCheck, CBCheck		NOCB-Check	Unsuccessful-signal mode
tUnsuc	0.0-9000.0	s	30	CB Check time before unsuc

1 Application

The tripping logic in REx 5xx protection, control and monitoring terminals offers three different operating modes:

- Three-phase tripping for all kinds of faults (3ph operating mode)
- Single-phase tripping for single-phase faults and three-phase tripping for multi-phase and evolving faults (1ph/3ph operating mode). The logic also issues a three-phase tripping command when phase selection within the operating protection functions is not possible, or when external conditions request three-phase tripping.
- Single-phase tripping for single-phase faults, two-phase tripping for ph-ph and ph-ph-E faults and three-phase tripping for three-phase faults (1ph/2ph/3ph operating mode). The logic also issues a three-phase tripping command when phase selection within the operating protection functions is not possible or at evolving multi-phase faults.

2 Design

The function consists of the following basic logic parts:

- A three-phase front logic that is activated when the terminal is set into exclusive three-phase operating mode.
- A phase segregated front logic that is activated when the terminal is in 1ph/3ph or 1ph/2ph/3ph operating mode.
- An additional logic for evolving faults and three-phase tripping when the function operates in 1ph/3ph operating mode
- An additional logic for evolving faults and three-phase tripping when the function operates in 1ph/2ph/3ph operating mode.
- The final tripping circuits.

2.1 Three-phase front logic

Figure 1: shows a simplified block diagram of a three-phase front logic. Descriptions of different signals is available in signal list.

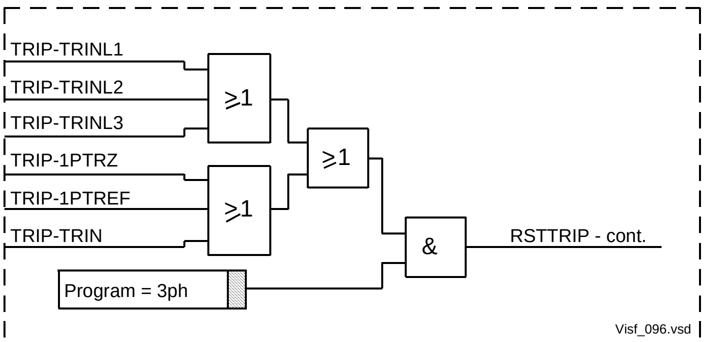


Figure 1: Three-phase front logic - simplified logic diagram

Any of active functional input signals activates the RSTTRIP internal signal, which influences the operation of the final tripping circuits.

2.2 Phase segregated front logic

The following input signals to the single-phase front logic influence the single-phase tripping of the terminal (see Figure 2:):

- Phase related tripping signals from different built-in protection functions that can operate on a phase segregated basis and are used in the terminal. The output signals of these functions should be configured to the TRIP-TRINLn (n = 1...3) functional inputs.
- Internal phase-selective tripping signals from different phase selection functions within the terminal, like PHS (phase selection for distance protection) or GFC (general fault criteria). The output signals of these functions should be configured to the TRIP-PSLn (n = 1...3) functional inputs. It is also possible to connect to these functional inputs different external phase selection signals.
- Single-phase tripping commands from line distance protection or carrier aided tripping commands from scheme communication logic for distance protection, which initiate single-phase tripping. These signals should be configured to the TRIP-1PTRZ functional input. It is also possible to configure a tripping output from an earth-fault overcurrent protection, to initiate the single-pole trip in connection with some external phase selection function. This signal should be configured to the TRIP-1PTREF functional input.

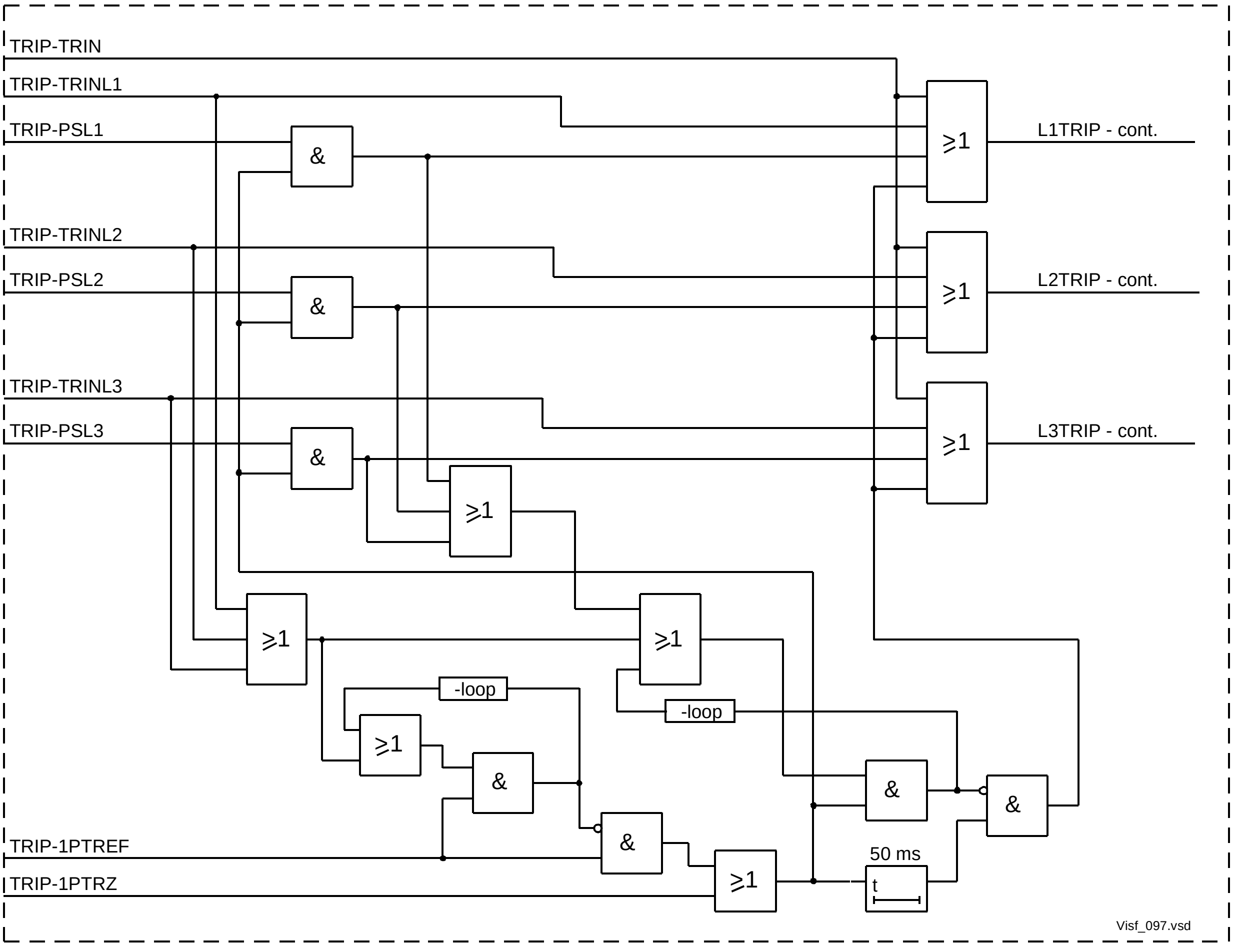


Figure 2: Phase segregated front logic

The TRIP-1PTRZ signal enables tripping corresponding to phase selection signals without any restriction while any phase selective external tripping signals prevent such tripping from the TRIP-1PTREF signal.

If any of these signals continues for more than 50 ms without the presence of any phase selection signals, three-phase tripping command is issued.

It is possible to configure the TRIP-1PTREF signal to the output signal of the EF---TRIP overcurrent, earth-fault, protection function (directional and nondirectional). This enables single-phase tripping when the faulty phase is detected by some other phase-selection element such as the phase selection in distance protection.

2.3 Additional logic for 1ph/3ph operating mode

Figure 3: presents the additional logic when the trip function is in 1ph/3ph operating mode. A TRIP-P3PTR functional input signal activates a three pole tripping if at least one phase within the front logic initiates a trip command.

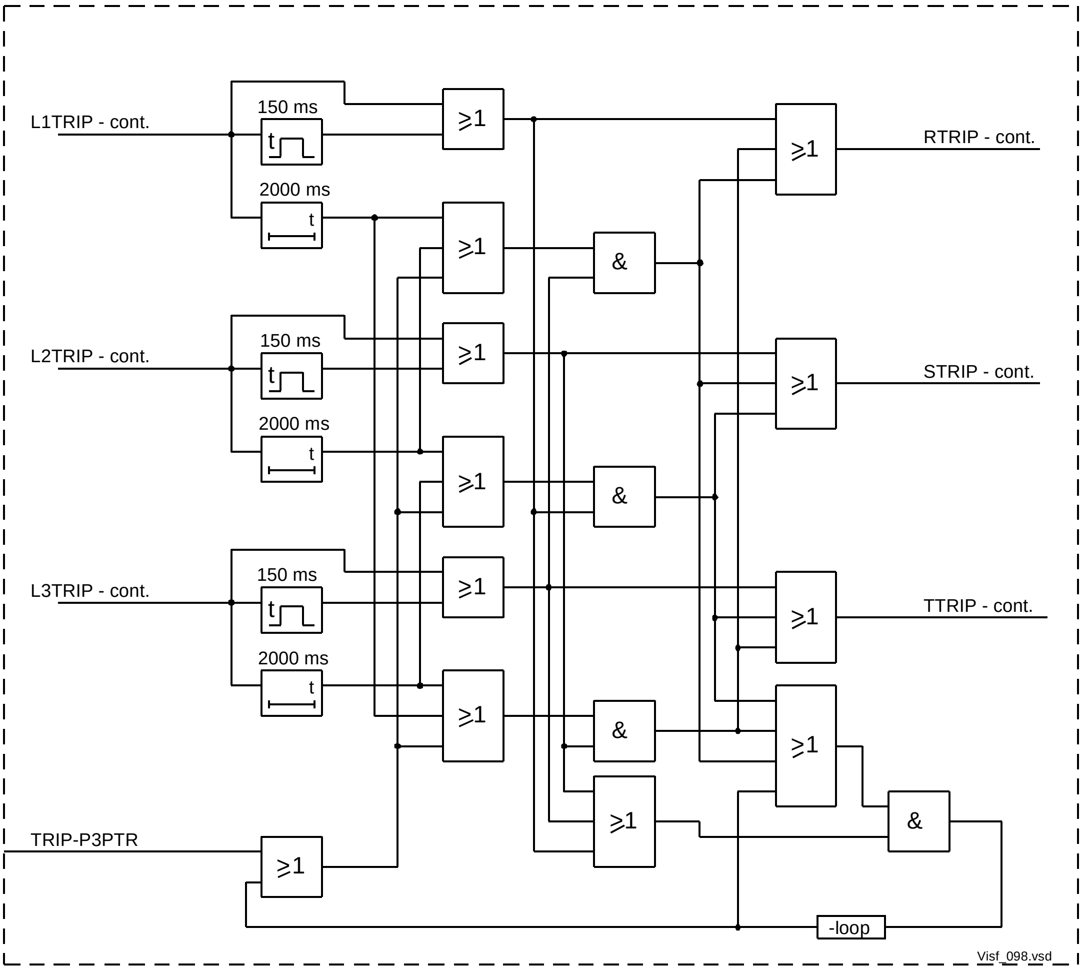


Figure 3: Additional logic for the 1ph/3ph operating mode

If only one of internal signals LnTRIP is present without the presence of a TRIP-P3PTR signal, a single pole tripping information is send to the final tripping circuits. A three-phase tripping command is initiated in all other cases.

Built-in drop-off delayed (two second) timers secure a three-phase tripping for evolving faults if the second fault occurs in different phase than the first one within a two second interval after initiation of a first tripping command.

2.4 Additional logic for 1ph/2ph/3ph operating mode

Figure 4: presents the additional logic, when the trip function is in 1ph/2ph/3ph operating mode. A TRIP-P3PTR functional input signal activates a three pole tripping if at least one phase within the front logic initiates a trip command.

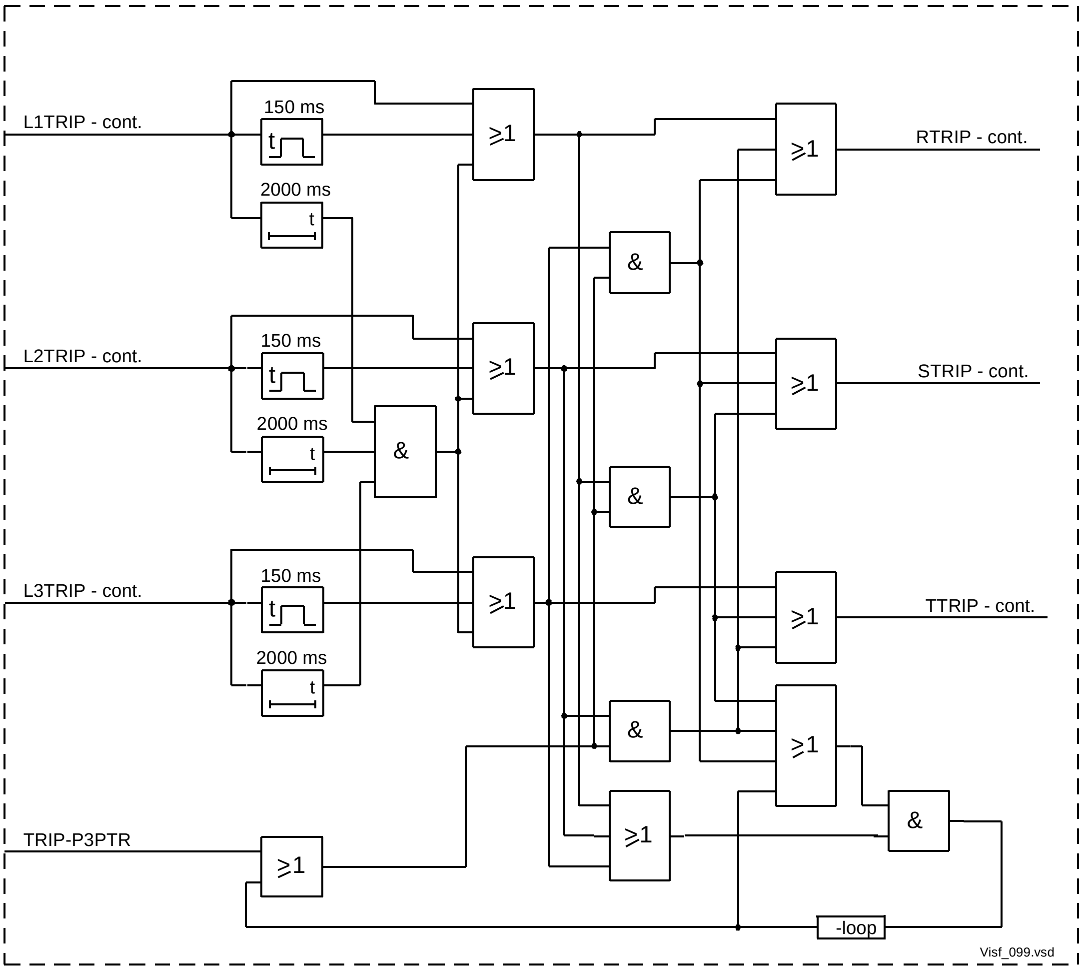


Figure 4: Additional logic for the 1ph/2ph/3ph operating mode

The logic initiates a single-phase tripping information to the final logic circuits, if only one of internal input signals (LnTRIP) is active. A two phase tripping information is send in case, when two out of three input signals LnTRIP are active. A three phase tripping information requires all three LnTRIP input signals to be active.

The built in drop-off delayed (two seconds) timers secure correct three-phase tripping information, when the faults are detected within two seconds in all three phases.

2.5 Final tripping circuits

Figure 5: present the final tripping circuits for a tripping function within the REx 5xx terminals. The TRIP-BLOCK functional input signal can block the operation of a function, so that no functional output signals become logical one. Detailed explanation of functional output signals is available in signal list.

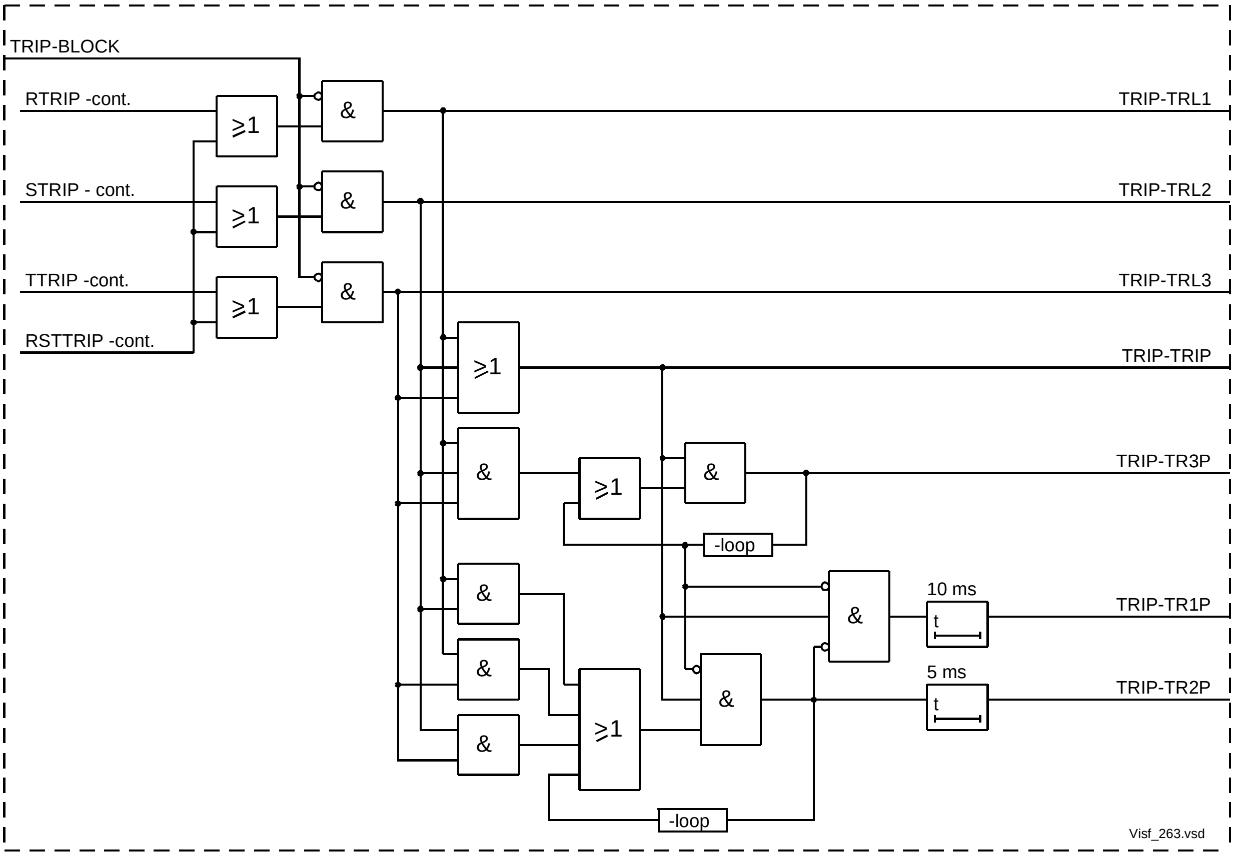


Figure 5: Final tripping circuits

3 Testing

The function can be disabled during the testing mode under these conditions:

- When the function is selected to be blocked under the testing conditions, select the functions, which should be blocked under the submenu:

  Test
  TestMode
  BlockFunctions

- Set the Operation parameter to On (Operation=On) to set the terminal in to testing mode. Select the operating mode under this submenu:

  Test
  TestMode
  Operation

- The terminal is switched to testing mode when the logical 1 is specified for the TEST-INPUT functional input.

Note: The function is blocked if the corresponding setting under the **BlockFunctions** submenu remains on and the TEST-INPUT signal remains active.

The function is tested functionally together with other protection functions (distance protection ZMn--, line differential protection DIFL-, earth-fault overcurrent protection IOC-- or TOC--, etc.) within the REx 5xx terminals. It is recommended to test the function together with the autoreclosing function, when built into the terminal or when a separate external unit is used for the reclosing purposes.

3.1 3ph operating mode

The function must issue a three-phase tripping in all cases, when tripping is initiated by any protection or some other built-in or external function. The following functional output signals must always appear simultaneously: TRIP-TRIP, TRIP-TRL1, TRIP-TRL2, TRIP-TRL3 and TRIP-TR3P.

3.2 1ph/3ph operating mode

The following tests should be carried out in addition to some other tests, which depends on the complete configuration of a terminal:

1.) Initiate one-by one different single-phase-to-earth faults. Consider sufficient time interval between the faults, to overcome a reclaim time of eventually activated autoreclosing function. Only a single-phase trip should occur for each separate fault and only one of the tripping outputs (TRIP-TRLn) should be activated at a time. Functional outputs TRIP-TRIP and TRIP-TR1P should be active at each fault. No other outputs should be active.

2.) Initiate different phase-to-phase and three-phase faults. Consider sufficient time interval between the faults, to overcome a reclaim time of eventually activated autoreclosing function. Only a three-phase trip should occur for each separate fault and all of the tripping outputs (TRIP-TRLn) should be activated at a time. Functional outputs TRIP-TRIP and TRIP-TR3P should be active at each fault. No other outputs should be active.

3.) Initiate a single-phase-to-earth fault and switch it off immediately when the tripping signal is issued for the corresponding phase. Initiate the same fault once again within the reclaim time of the used autoreclosing function. A three-phase tripping must be initiated for the second fault. Check that the corresponding tripping signals appear after both faults. If not the autoreclosing function is used the functional outputs TRIP-TRIP, TRIP-TR1P and the corresponding phase signal (TRIP-TRLn) should be active at each fault.

4.) Initiate a single-phase-to-earth fault and switch it off immediately when the tripping signal is issued for the corresponding phase. Initiate the second single-phase-to-earth fault in one of the remaining phases within the time interval, shorter than two seconds and shorter than the dead-time of the autoreclosing function, when included in protection scheme. Check that the second trip is a three-phase trip.

3.3 1ph/2ph/3ph operating mode

The following tests should be carried out in addition to some other tests, which depends on the complete configuration of a terminal:

1.) Initiate one-by one different single-phase-to-earth faults. Consider sufficient time interval between the faults, to overcome a reclaim time of eventually activated autoreclosing function. Only a single-phase trip should occur for each separate fault and only one of the tripping outputs (TRIP-TRLn) should be activated at a time. Functional outputs TRIP-TRIP and TRIP-TR1P should be active at each fault. No other outputs should be active.

2.) Initiate one-by one different phase-to-phase faults. Consider sufficient time interval between the faults, to overcome a reclaim time of eventually activated autoreclosing function. Only a two-phase trip should occur for each separate fault and only corresponding two tripping outputs (TRIP-TRLn) should be activated at a time. Functional outputs TRIP-TRIP and TRIP-TR2P should be active at each fault. No other outputs should be active.

3.) Initiate a three-phase fault. Consider sufficient time interval between the faults, to overcome a reclaim time of eventually activated autoreclosing function. Only a three-phase trip should occur for the fault and all tripping outputs (TRIP-TRLn) should be activated at the same time. Functional outputs TRIP-TRIP and TRIP-TR3P should be active at each fault. No other outputs should be active.

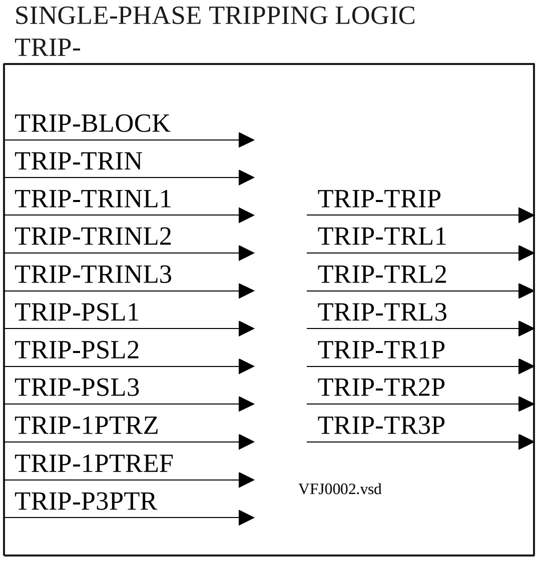
4.) Initiate a single-phase-to-earth fault and switch it off immediately when the tripping signal is issued for the corresponding phase. Initiate the same fault once again within the reclaim time of the used autoreclosing function. A three-phase tripping must be initiated for the second fault. Check that the corresponding tripping signals appear after both faults. If not the autoreclosing function is used the functional outputs TRIP-TRIP, TRIP-TR1P and the corresponding phase signal (TRIP-TRLn) should be active at each fault.

5.) Initiate a single-phase-to-earth fault and switch it off immediately when the tripping signal is issued for the corresponding phase. Initiate the second single-phase-to-earth fault in one of the remaining phases within the time interval, shorter than two seconds and shorter than the dead-time of the autoreclosing function, when included in protection scheme. Check that the second trip is a single-phase trip in a second initiated phase.

6.) Initiate a phase-to-phase fault and switch it off immediately when the tripping signal is issued for the corresponding two phases. Initiate another phase-to-phase fault (not between the same phases) within the time, shorter than 2 seconds. Check, that the output signals, issued for the first fault, correspond to two-phase tripping for included phases. The output signals for the second fault must correspond to the three-phase tripping action.

4 Appendix

4.1 Function block



4.2 Signal list

Block:	Signal:	Type	Description:
TRIP-	TRIP	OUT	General trip output signal
TRIP-	TRL1	OUT	Trip output signal in phase L1
TRIP-	TRL2	OUT	Trip output signal in phase L2
TRIP-	TRL3	OUT	Trip output signal in phase L3

Block:	Signal:	Type	Description:
TRIP-	TR1P	OUT	Single pole tripping
TRIP-	TR2P	OUT	Two pole tripping
TRIP-	TR3P	OUT	Three pole tripping
TRIP-	BLOCK	IN	Block of Trip
TRIP-	TRIN	IN	Trip all phases
TRIP-	TRINL1	IN	Trip phase L1
TRIP-	TRINL2	IN	Trip phase L2
TRIP-	TRINL3	IN	Trip phase L3
TRIP-	PSL1	IN	Functional input for phase selection in phase L1
TRIP-	PSL2	IN	Functional input for phase selection in phase L2
TRIP-	PSL3	IN	Functional input for phase selection in phase L3
TRIP-	1PTRZ	IN	Functional input for impedance single pole trip
TRIP-	1PTREF	IN	Functional input for earth fault single pole trip
TRIP-	P3PTR	IN	Functional input for preparing for three phase trip

4.3 Setting table

Parameter:	Range:	Unit:	Default:	Parameter description:
Operation	Off / On	-	Off	Operation of trip logic
Program	3ph - 1/3ph - 1/2/3ph	-	3ph	Operating mode of trip logic

1 Application

The binary signal transfer function is preferably used for sending communication scheme related signals, transfer trip and/or other binary signals required at the remote end. Up to 16 selectable binary send and 16 selectable binary recieve signals, internal or external to the terminal can be transmitted.

Together with the binary signals internal to the terminal, the function is utilising binary inputs and outputs. The function can be provided with various 56/64 kbit/s communication modules for fibre-optic or galvanic connection.

The communication can be done via direct galvanic communication line for shorter distances, via dedicated optical fibres up to around 30 km and via a communication scheme for longer distances.

2 Design

2.1 General

The Remote Terminal Communication module RTC1 can handle 16 inputs and 16 outputs. If additional inputs and outputs are required, an additional Remote Terminal Communication module RTC2 can be added.

The modules can be placed in applicable slots in the terminal. To add, remove or move moduls within the REx 5xx terminal, reconfiguration of the terminal is done from the graphical configuration tool, CAP 531.

If the user-entered configuration does not match the actual hardware position of the modules within the terminal, an error output is activated on the function block, which can be treated as an event or alarm.

All user defined names for inputs and outputs are input identities on the function blocks and are set from the configuration tool CAP 531.

2.2 Function block

Each corresponding Remote terminal communication function block has 16 inputs to handle information recieved from the remote end plus 16 outputs to send information to the remote end. See figure 1.

The function blocks has an input BLOCK, which is available to block the function. When the input is energised, all 16 binary signals (SEND01-16) will be sent as zeroes. Incoming signals are not affected.

An output COMFAIL is also available to announce an alarm when there is a failure in the communication via the Remote terminal communication module.

RTC1-

BLOCK	COMFAIL
SEND01	REC01
SEND02	REC02
SEND03	REC03
SEND04	REC04
SEND05	REC05
SEND06	REC06
SEND07	REC07
SEND08	REC08
SEND09	REC09
SEND10	REC10
SEND11	REC11
SEND12	REC12
SEND13	REC13
SEND14	REC14
SEND15	REC15
SEND16	REC16

Figure 1: Function block of RTC1- with input and output signals.

2.3 Human-machine interface (HMI)

The service reports of the function provides information of all functional outputs as well as function inputs ‘SEND01-16’ and can be viewed on the local HMI under:

ServiceReport
- **I/O**
  - **RemTermCom1**
  - **RemTermCom2**

Self-supervision is provided for the remote terminal communication and information is available on the local HMI under:

TerminalReport
- **SelfSuperv**
  - RemTermCom

3 Configuration

The configuration of input and output signals to the function block is done from the configuration tool CAP 531.

To configure the I/O-module from the graphical tool:

- First, set the function selector for the Remote Terminal Communication units, RTC1 used.
- Then connect the POSITION input of the logical I/O module to a slot output of the RTC function block.

Reconfiguration of the I/O-modules are also possible from the local HMI under the menus:

Configuration
  I/O-modules
    Operation
    Reconfigure
    Oscillation

4 Setting

Set the user defined names, parameters, for the binary inputs and outputs from the configuration tool CAP 531.

5 Testing

There are two types of internal self-supervision of the RTC.

The I/O-circuitboard is supervised as an I/O module. For example it gives ‘FAIL’ if the board is not inserted. I/O-modules not configured are neither supervised. When an RTC- module is configured as a logical I/O module it is also supervised.

Then there is also the communication supervision that gives ‘WARNING’ if one of the RTC-modules signals for ‘COMFAIL’. Each RTC-module has an error output (‘COMFAIL’) which is set to a logical 1 if anything is wrong with the communication through the actual module. Status for inputs and outputs as well as self-supervision status are available from the local HMI.

Test correct functionality by simulating different kind of faults. Also check that sent and received data is correct transmitted and read.

A test connection is showed in figure 2. A binary input (BI) is connected to a RTC function input in end1, for example RTC1-SEND01, and in the other end a binary output (BO) is connected to the received function output, for example RTC1-REC01. The binary signal is transfered to the remote end (end2) through a HDLC link.

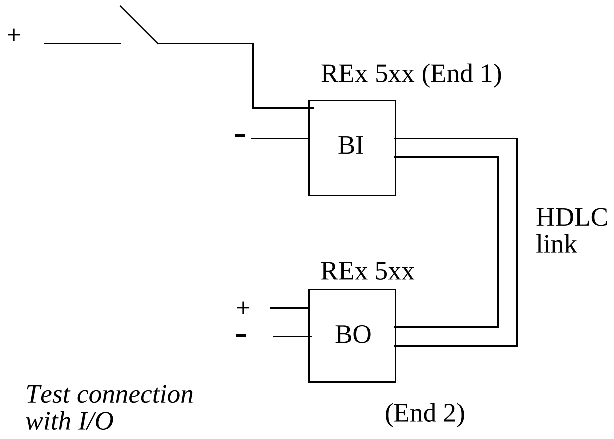


Figure 2: Test of RTC with I/O.

6 Appendix

6.1 Function block

RTC1-

BLOCK	COMFAIL
SEND01	REC01
SEND02	REC02
SEND03	REC03
SEND04	REC04
SEND05	REC05
SEND06	REC06
SEND07	REC07
SEND08	REC08
SEND09	REC09
SEND10	REC10
SEND11	REC11
SEND12	REC12
SEND13	REC13
SEND14	REC14
SEND15	REC15
SEND16	REC16

RC01NAME
RC02NAME
RC03NAME
RC04NAME
RC05NAME
RC06NAME
RC07NAME
RC08NAME
RC09NAME
RC10NAME
RC11NAME
RC12NAME
RC13NAME
RC14NAME
RC15NAME
RC16NAME
SD01NAME
SD02NAME
SD03NAME
SD04NAME
SD05NAME
SD06NAME
SD07NAME
SD08NAME
SD09NAME
SD10NAME
SD11NAME
SD12NAME
SD13NAME
SD14NAME
SD15NAME
SD16NAME

Figure 3: Terminal diagram of function block RTC1, parameters shown.

6.2 Signal list

Block	Signal	Type	Description
RTC1-	BLOCK	IN	Block of remote terminal communication function
RTC1-	SEND01	IN	Signal to remote terminal, input 1
RTC1-	SEND02	IN	Signal to remote terminal, input 2
RTC1-	SEND03	IN	Signal to remote terminal, input 3
RTC1-	SEND04	IN	Signal to remote terminal, input 4
RTC1-	SEND05	IN	Signal to remote terminal, input 5
RTC1-	SEND06	IN	Signal to remote terminal, input 6
RTC1-	SEND07	IN	Signal to remote terminal, input 7
RTC1-	SEND08	IN	Signal to remote terminal, input 8
RTC1-	SEND09	IN	Signal to remote terminal, input 9
RTC1-	SEND10	IN	Signal to remote terminal, input 10
RTC1-	SEND11	IN	Signal to remote terminal, input 11
RTC1-	SEND12	IN	Signal to remote terminal, input 12
RTC1-	SEND13	IN	Signal to remote terminal, input 13
RTC1-	SEND14	IN	Signal to remote terminal, input 14
RTC1-	SEND15	IN	Signal to remote terminal, input 15
RTC1-	SEND16	IN	Signal to remote terminal, input 16
RTC1-	COMFAIL	OUT	Communication failure
RTC1-	REC01	OUT	Signal from remote terminal, input 1
RTC1-	REC02	OUT	Signal from remote terminal, input 2
RTC1-	REC03	OUT	Signal from remote terminal, input 3
RTC1-	REC04	OUT	Signal from remote terminal, input 4
RTC1-	REC05	OUT	Signal from remote terminal, input 5
RTC1-	REC06	OUT	Signal from remote terminal, input 6
RTC1-	REC07	OUT	Signal from remote terminal, input 7
RTC1-	REC08	OUT	Signal from remote terminal, input 8
RTC1-	REC09	OUT	Signal from remote terminal, input 9
RTC1-	REC10	OUT	Signal from remote terminal, input 10
RTC1-	REC11	OUT	Signal from remote terminal, input 11
RTC1-	REC12	OUT	Signal from remote terminal, input 12
RTC1-	REC13	OUT	Signal from remote terminal, input 13
RTC1-	REC14	OUT	Signal from remote terminal, input 14
RTC1-	REC15	OUT	Signal from remote terminal, input 15
RTC1-	REC16	OUT	Signal from remote terminal, input 16

6.3 Setting table

Parameter	Range	Unit	Default	Parameter description
RC01NAME	0-13		RTC1-REC01	Remote Terminal Communication 1, Name for Input 1
RC02NAME	0-13		RTC1-REC02	Remote Terminal Communication 1, Name for Input 2
RC03NAME	0-13		RTC1-REC03	Remote Terminal Communication 1, Name for Input 3
RC04NAME	0-13		RTC1-REC04	Remote Terminal Communication 1, Name for Input 4
RC05NAME	0-13		RTC1-REC05	Remote Terminal Communication 1, Name for Input 5
RC06NAME	0-13		RTC1-REC06	Remote Terminal Communication 1, Name for Input 6
RC07NAME	0-13		RTC1-REC07	Remote Terminal Communication 1, Name for Input 7
RC08NAME	0-13		RTC1-REC08	Remote Terminal Communication 1, Name for Input 8
RC09NAME	0-13		RTC1-REC09	Remote Terminal Communication 1, Name for Input 9
RC10NAME	0-13		RTC1-REC10	Remote Terminal Communication 1, Name for Input 10
RC11NAME	0-13		RTC1-REC11	Remote Terminal Communication 1, Name for Input 11
RC12NAME	0-13		RTC1-REC12	Remote Terminal Communication 1, Name for Input 12
RC13NAME	0-13		RTC1-REC13	Remote Terminal Communication 1, Name for Input 13
RC14NAME	0-13		RTC1-REC14	Remote Terminal Communication 1, Name for Input 14
RC15NAME	0-13		RTC1-REC15	Remote Terminal Communication 1, Name for Input 15
RC16NAME	0-13		RTC1-REC16	Remote Terminal Communication 1, Name for Input 16
SD01NAME	0-13		RTC1-SEND01	Remote Terminal Communication 1, Name for Output 1
SD02NAME	0-13		RTC1-SEND02	Remote Terminal Communication 1, Name for Output 2
SD03NAME	0-13		RTC1-SEND03	Remote Terminal Communication 1, Name for Output 3
SD04NAME	0-13		RTC1-SEND04	Remote Terminal Communication 1, Name for Output 4
SD05NAME	0-13		RTC1-SEND05	Remote Terminal Communication 1, Name for Output 5
SD06NAME	0-13		RTC1-SEND06	Remote Terminal Communication 1, Name for Output 6
SD07NAME	0-13		RTC1-SEND07	Remote Terminal Communication 1, Name for Output 7

Parameter	Range	Unit	Default	Parameter description
SD08NAME	0-13		RTC1-SEND08	Remote Terminal Communication 1, Name for Output 8
SD09NAME	0-13		RTC1-SEND09	Remote Terminal Communication 1, Name for Output 9
SD10NAME	0-13		RTC1-SEND10	Remote Terminal Communication 1, Name for Output 10
SD11NAME	0-13		RTC1-SEND11	Remote Terminal Communication 1, Name for Output 11
SD12NAME	0-13		RTC1-SEND12	Remote Terminal Communication 1, Name for Output 12
SD13NAME	0-13		RTC1-SEND13	Remote Terminal Communication 1, Name for Output 13
SD14NAME	0-13		RTC1-SEND14	Remote Terminal Communication 1, Name for Output 14
SD15NAME	0-13		RTC1-SEND15	Remote Terminal Communication 1, Name for Output 15
SD16NAME	0-13		RTC1-SEND16	Remote Terminal Communication 1, Name for Output 16

1 Application

The serial communication can be used for different purposes, which enable better access to the information stored in the terminals. The serial communication is also used for communication directly between terminals (bay-to-bay communication).

The serial communication can be used with a station monitoring system (SMS), via a substation automation system (SCS) or a SCADA system. Normally, SPA communication is used for SMS and SCS; LON communication is used for SCS. SPA communication is also applied when using the front communication port, but for this purpose, no special serial communication function is required in the terminal. Only the software in the PC and a special cable for front connection is needed.

As an alternative to the rear SPA communication port, a port intended for the IEC 870-5-103 is available. IEC 870-5-103 is a standard protocol for protection functions.

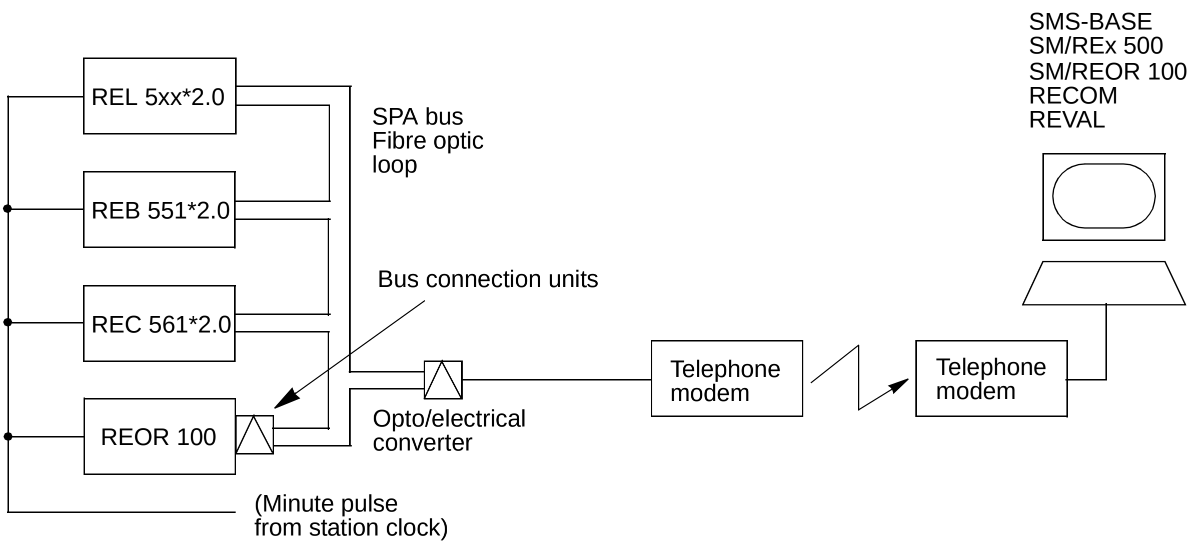


Figure 1: Example of SPA communication structure for a station monitoring system

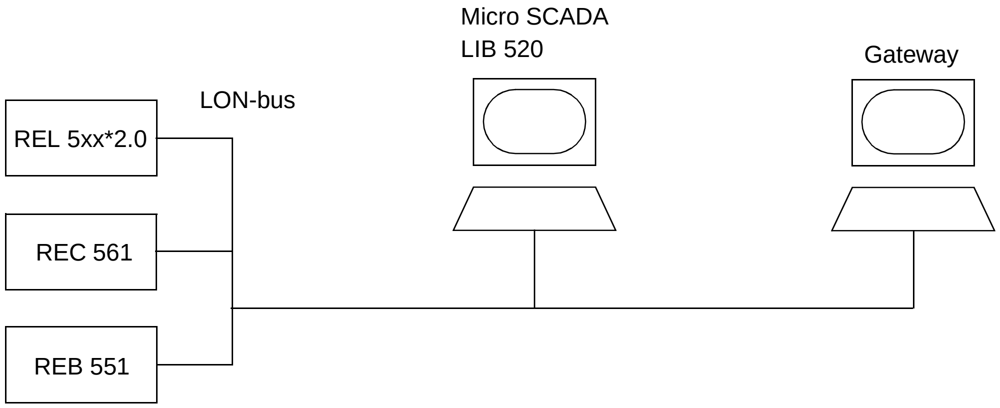


Figure 2: Example of LON communication structure for substation automation

2 Theory of operation

All serial communication to and from the terminal (including the front PC port communication) uses either the SPA-bus V 2.4 protocol, IEC 870-5-103 or the LonTalk protocol.

2.1 SPA operation

The SPA protocol is an ASCII-based protocol for serial communication. The communication is based on a master-slave principle, where the terminal is a slave, and the PC is the master. Only one master can be applied on each fibre optic loop. A program is needed in the master computer for interpretation of the SPA-bus codes, and for translation of the settings sent to the terminal. This program is called SMS-BASE with the SM/REx 500-module.

2.2 LON operation

The LON protocol is specified in the *LonTalkProtocol Specification Version 3* from Echelon Corporation. This protocol is designed for communication in control networks and is a peer-to-peer protocol where all the devices connected to the network can communicate with each other directly. For more information of the bay-to-bay communication, refer to the documents *Event function* and *Binary signal interbay communication*.

2.3 IEC 870-5-103 operation

The IEC 870-5-103 is an unbalanced (master-slave) protocol for coded-bit serial communication exchanging information with a control system. In IEC terminology a primary station is a master and a secondary station is a slave. The communication is based on a point to point principle. The master must have a program that can interpret the IEC 870-5-103 communication messages. For detailed information about IEC 870-5-103, refer to the part 5: Transmission protocols, and to the section 103: Companion standard for the informative interface of protection equipment, in the IEC 870 standard.

3 Design

The serial communication use optical fibres for transfer of data within a station. For this purpose, a fibre optic bus input can be available on the rear of the terminal, one for LON communication, and one for SPA or IEC communication. The principle of two independent communication ports is used.

3.1 SPA design

When communicating locally with a Personal Computer (PC) in the station, using the rear SPA port, the only hardware needed for a station monitoring system is:

- Optical fibres
- Opto/electrical converter for the PC
- PC

When communicating remotely with a PC using the rear SPA port, the same hardware is needed plus telephone modems.

The software needed in the PC, either local or remote, is:

- SMS-BASE (Ver. 2.0 or higher)
- SM/REx 500 for terminals ver. 2.0
- RECOM (Ver 1.3 or higher) if disturbance recorder data is transferred to a PC
- REVAL (Ver 1.1 or higher) for evaluation of this disturbance recorder data

When communicating to a front-connected PC, the only hardware required is the special front-connection cable. The software needed in a front connected PC is:

- SMS-BASE (Ver 2.0 or higher)
- SM/REx 500 for terminals ver. 2.0. The SM/REx 500 includes one small part of RECOM, which lets you collect disturbance recorder data via the front port.
- REVAL (Ver 1.1 or higher) is also required if the same PC is used for evaluation of the disturbance recorder data.

3.2 LON design

The hardware needed for applying LON communication depends on the application, but one very central unit needed is the LON Star Coupler and optic fibres connecting the star coupler to the terminals. To communicate with the terminals from MicroSCADA, the application library LIB 520 is needed.

The HV/Control and the HV/REx 500 software modules are included in the LIB 520 high-voltage process package, which is a part of the Application Software Library within MicroSCADA applications.

The HV/Control software module is intended to be used for control functions in REx 5xx terminals. This module contains the process picture, dialogues and process database for the control application in the MicroSCADA.

The HV/REx 500 software module is used to present Station Monitoring information on the MicroSCADA screen.

3.3 IEC 870-5-103 design

3.3.1 General

The protocol implementation in REx 5xx consists of these functions:

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

3.3.2 Hardware

When communicating locally with a Personal Computer (PC) or a Remote Terminal Unit (RTU) in the station, using the IEC port, the only hardware needed is:

- Optical fibres, glass/plastic
- Opto/electrical converter for the PC/RTU
- PC/RTU

3.3.3 Events

The events created in the terminal available for the IEC 870-5-103 protocol are based on the event function EV01 - EV06 available in the terminal. These event function blocks include the function type and the information number for each event input, which can be found in the IEC-document. See also document *Event function.*

3.3.4 Measurands

The measurands can be included as type 3.1, 3.2, 3.3, 3.4 and type 9 according to the standard.

3.3.5 Fault location

The fault location is expressed in reactive ohms. In relation to the line length in reactive ohms, it gives the fault distance in percent. The data is available and reported when the fault locator function is included in the terminal.

3.3.6 Commands

The commands defined in the IEC 870-5-103 protocol are represented in a dedicated function block. This block has output signals according to the protocol for all commands. The function block for the IEC commands can be found in the appendix.

3.3.7 File transfer

As for file transfer functionality it is based on the *Disturbance recorder function*. The analog and binary signals recorded will be reported to the master. The eight last disturbances that is recorded is available for transfer to the master. Though a file is transferred and acknowledged by the master it cannot be transferred again.

The analog channels that are reported are the first four current inputs and the first four voltage inputs.

4 Setting

The SPA and the IEC use the same rear communication port. To define the protocol to be used, a setting is done on the local HMI under the menu:

Configuration
  TerminalCom
    SPA-IECPort

When the type of communication protocol is defined, the power to the terminal has to be switched off and on.

4.1 SPA setting

The most important settings in the terminal for SPA communication are the slave number and baud rate (communication speed). These settings are absolutely essential for all communication contact to the terminal.

These settings can **only** be done on the local HMI for rear channel communication at:

Configuration
  TerminalCom
    SPAComm
      Rear

and for front connection at:

Configuration
  TerminalCom
    SPAComm
      Front

The slave number can be set to any value from 1 to 899, as long as the slave number is unique within the used SPA loop.

The baud rate, which is the communication speed, can be set to between 300 and 38400 bits/s. The baud rate should be the same for the whole station, although different baud rates in a loop are possible. If different baud rates in the same fibre optical loop are used, consider this when making the communication setup in the communication master, the PC. The maximum baud rate of the front connection is limited to 9600 bit/s.

For local communication, 19200 or 38400 bit/s is the normal setting. If telephone communication is used, the communication speed depends on the quality of the connection and on the type of modem used. But remember that the terminal does not adapt its speed to the actual communication conditions, because the speed is set on the HMI of the terminal.

4.2 LON setting

Use the LNT, LON Network Tool to set the LON communication. This is a software tool applied as one node on the LON bus. In order to communicate via LON, the terminals need to know which node addresses the other connected terminals have, and which network variable selectors should be used. This is organised by the LNT.

The node address is transferred to the LNT via the local HMI at:

Configuration
  TerminalCom
    LONComm
      ServicePinMsg

By setting YES, the node address is sent to the LNT via the LON bus. Or, the LNT can scan the network for new nodes.

The speed of the LON bus is set to the default of 1.25 MHz. This can be changed by the LNT.

If the LON communication from the terminal stops, caused by setting of illegal communication parameters (outside the setting range) or by another disturbance, it is possible to reset the LON port of the terminal. This is performed at the local HMI at:

Configuration
  TerminalCom
    LONComm
      LONDefault

By setting YES, the LON communication is reset in the terminal, and the addressing procedure can start from the beginning again.

There are a number of session timers which can be set via the local HMI. These settings are only for advanced use and should only be changed after recommendation from ABB Network Partner AB. The time values below are the default settings. The settings can be found at:

Configuration
  TerminalCom
    LONComm
      SessionTimers

4.3 IEC 870-5-103 setting

4.3.1 Settings from the local HMI

The settings for IEC 870-5-103 communication are the following:

- Individually blocking of commands
- Setting of measurand type
- Setting of main function type and activation of main function type
- Settings for slave number and baud rate (communication speed)
- Command for giving Block of information command

The settings for individually blocking of commands can be found on the local HMI at:

Configuration
  TerminalCom
    IECCom
      Commands

Each command has its own blocking setting and the state can be set to OFF or ON. The OFF state corresponds to non-blocked state and ON corresponds to blocked state.

The settings for type of measurand can be found on the local HMI at:

Configuration
TerminalCom
IECCom
Measurands

The type of measurands can be set to report standardised types, Type 3.1, Type 3.2, Type 3.3, Type 3.4 or Type 9.

The use of main function type is to facilitate the engineering work of the terminal. The settings for main function type and the activation of main function type can be found on the local HMI at:

Configuration
TerminalCom
IECCom
FunctionType

The main function type can be set to values according to the standard, this is, between 1 and 255. The value zero is used as default and corresponds to not used.

The setting for activation of main function type can be set to OFF or ON. The OFF state corresponds to non-activated state and ON corresponds to activated state. Upon activated the main function type overrides all other settings for function type within the terminal, that is, function type settings for event function and disturbance recorder function. When set to OFF, function type settings for event function and disturbance recorder function use their own function type settings made on the function blocks for the event function and disturbance recorder respectively. Though for all other functions they use the main function type even when set to OFF.

The settings for communication parameters slave number and baud rate can be found on the local HMI at:

Configuration
TerminalCom
IECCom
Communication

The slave number can be set to any value between 0 to 255.

The baud rate, the communication speed, can be set either to 9600 bits/s or 19200 bits/s.

The settings for issuing a block-of-information command can be found on the local HMI at:

Configuration
TerminalCom
IECCom
BlockOfInfo

Issuing the BlockOfInformation command with the value *one (1)* blocks all information sent to the master and abort any GI procedure or any file transfer in process. Thus issuing the command with the value set to *zero (0)* will allow information to be polled by the master.

The dialogue to operate the output from the BlockOfInformation command function is performed from different state as follows:

1. Selection active; select the:
   - C button, and then the No box activates.
   - Up arrow, and then New: 0 changes to New: 1. The up arrow changes to the down arrow.
   - E button, and then the Yes box activates.

2. Yes box active; select the:
   - C button to cancel the action and return to the BlockOfInfo window.
   - E button to confirm the action and return to the BlockOfInfo window.
   - Right arrow to activate the No box.

3. No box active; select the:
   - C button to cancel the action and return to the BlockOfInfo window.
   - E button to confirm the action and return to the BlockOfInfo window.
   - Left arrow to activate the Yes box.

4.3.2 Settings from the CAP 531 tool

4.3.2.1 Event

For each input of the *Event function* there is a setting for the information number of the connected signal. The information number can be set to any value between 0 and 255. In order to get proper operation of the sequence of events the event masks in the event function shall be set to ON_CHANGE. For single-command signals, the event mask shall be set to ON_SET.

In addition there is a setting on each event block for function type. Refer to description of the Main Function type set on the local HMI.

4.3.2.2 Commands

As for the commands defined in the protocol there is a dedicated function block with eight output signals. The configuration of these signals are made by using the CAP 531 tool.

To realise the BlockOfInformation command, which is operated from the local HMI, the output BLKINFO on the IEC command function block ICOM has to be connected to an input on an event function block. This input shall have the information number 20 (monitor direction blocked) according to the standard.

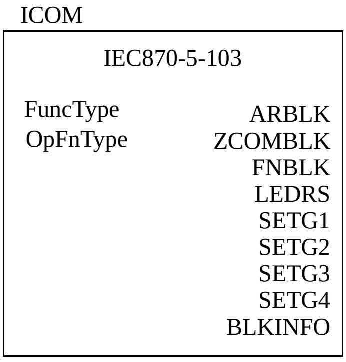
4.3.2.3 File transfer

For each input of the *Disturbance recorder function* there is a setting for the information number of the connected signal. The information number can be set to any value between 0 and 255.

Furthermore there is a setting on each input of the *Disturbance recorder function* for the function type. Refer to description of Main Function type set on the local HMI.

5 Appendix

5.1 Function block



5.2 Signal list

Block	Signal	Type	Description
ICOM-	ARBLK	OUT	Output from ARBLK command, to be used for switching autorecloser on/off.
ICOM-	FNBLK	OUT	Output from FNBLK command, to be used for switching protection on/off.
ICOM-	BLKINFO	OUT	Output from BLKINFO command. Signal to block all information sent to master.
ICOM-	LEDRS	OUT	Output from LEDRS command, to be used for resetting the LEDs.
ICOM-	SETG1	OUT	Output from SETG1 command, to be used for activation of setting group 1.
ICOM-	SETG2	OUT	Output from SETG2 command, to be used for activation of setting group 2.
ICOM-	SETG3	OUT	Output from SETG3 command, to be used for activation of setting group 3.
ICOM-	SETG4K	OUT	Output from SETG4 command, to be used for activation of setting group 4.
ICOM-	ZCOMBLK	OUT	Output from ZCOMBLK command, to be used for switching teleprotection on/off.

5.3 Setting table

Table 1: Setting table for the IEC 870-5-103 command function block ICOM

Parameter	Range	Unit	Default	Parameter description
FuncType	0-255		0	Main function type for terminal
OpFnType	Off, On		Off	Main function type operation for terminal

Table 2: Setting table for SPA communication

PARAMETER	SETTING RANGE	DESCRIPTION
Rear comm. port:		
SlaveNo	(1 - 899)	SPA-bus identification number
BaudRate	300, 1200, 2400, 4800, 9600, 19200, 38400 Baud	Communication speed
RemoteChActgrp	Open, Block	Open=Access right to change between active groups (both rear ports)
RemoteChSet	Open, Block	Open=Access right to change any parameter (both rear ports)
Front comm. port:		
SlaveNo	(1 - 899)	SPA-bus identification number
BaudRate	300, 1200, 2400, 4800, 9600 Baud	Communication speed

1 Application

The REx 5xx terminals may be provided with output functions that can be controlled either from a Substation Control System or from other terminals via the LON bus. Together with the configuration logic circuits, the user can govern pulses or steady output signals for control purposes within the terminal or via binary outputs. Command function blocks for 16 binary signals are used to receive information over the LON bus from the operator station and from other REx 5xx terminals. The other terminals must have a corresponding event function block to send the information.

2 Design

2.1 General

One multiple command function block with fast execution time and/or 79 multiple command function blocks with slower execution time are available in the REx 5xx terminals as options.

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

0=Off sets all outputs to 0, independent of the values sent from the station level, that is, the operator station or remote-control gateway.

1=Steady sets the outputs to a steady signal 0 or 1, depending on the values sent from the station level.

2=Pulse gives a pulse with one execution cycle duration, if a value sent from the station level is changed from 0 to 1. That means that the configured logic connected to the command function blocks may not have a cycle time longer than the execution cycle time for the command function block.

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

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

2.2 Binary signal interbay communication

The multiple command function block can also be used to receive information over the LON bus from other REx 5xx terminals. The most common use is to transfer interlocking information between different bays. That can be performed by an Event function block as the send block and with a multiple command function block as the receive block. The configuration for the communication between terminals is made by the LON Network Tool.

The MODE input is set to Steady at communication between terminals and then the data are mapped between the terminals.

The command function also has a supervision function, which sets the output VALID to 0 if the block did not receive data within an INTERVAL time, that could be set. This function is applicable only during communication between terminals over the LON bus. The INTERVAL input time is set a little bit longer than the interval time set on the Event function block (see the document *Event function*). If INTERVAL=0, then VALID will be 1, that is, not applicable.

3 Configuration

The configuration of the signal outputs from the multiple command function in REx 5xx is made by the CAP 531 configuration tool.

4 Setting

The setting parameters for the multiple command function are set from the CAP 531 configuration tool.

The multiple command function has a common name setting (CmdOut) for the block. The MODE input sets the outputs to be one of the types Off, Steady, or Pulse. INTERVAL is used for the supervision of the cyclical receiving of data.

The appendix shows the parameters and their setting ranges.

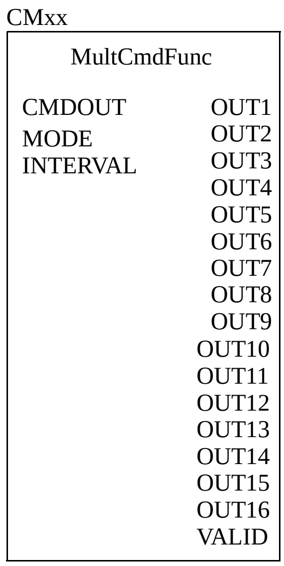
5 Testing

Test of the multiple command function block is recommended to be performed in a system, that is, either in a complete delivery system as an acceptance test (FAT/SAT) or as parts of that system, because the command function blocks are connected in a delivery-specific way between bays and the station level.

Command function blocks included in the operation of different built-in functions must be tested at the same time as their corresponding functions.

6 Appendix

6.1 Function block



6.2 Signal list

Block	Signal	Type	Description
CMxx- (xx=01-80)	OUTy	OUT	Command output y (y=1-16)
CMxx-	VALID	OUT	Received data. 0: invalid, 1: valid
CMxx-	CMDOUT		See settings table
CMxx-	INTERVAL		See settings table
CMxx-	MODE		See settings table

6.3 Setting table

Parameter	Range	Unit	Default	Parameter description
CMDOUT	User def. string	String	CMxx-CMD-OUT	User defined common name for all outputs of function block CMxx (xx=01-80).String length up to 19 characters. Can only be set from CAP 531 configuration tool
INTERVAL	0-60	s	0	Time interval for supervision of recieved data. Can only be set from CAP 531 configuration tool
MODE	0, 1, 2		0	Operation mode. 0: Off, 1: Not pulsed (steady), 2: Pulsed. Can only be set from CAP 531 configuration tool

1 Application

Many applications in secondary systems require testing of different functions with confirmed information on successfully completed test. **C**arrier **ch**annel **t**est (CCHT) function serves primarily testing of communication (power line carrier) channels in applications, where continuous monitoring by some other means is not possible due to technical or economical reasons.

The logic initiates sending of some impulse (carrier send signal), which starts the operation of different functions outside the logic, and checks the feedback from the external function. It reports the successful or non-successful response on initiated test. It is also possible to abort the test with some external signal, which overrules all internal process.

It is possible to initiate the logic manually or automatically. Manual starts are possible by means of external push-button, connected to the binary input of a terminal. Automatic starts are possible in long time intervals with their duration dependent on setting of the corresponding timer.

2 Design

Figure 1: presents a simplified logic diagram for the CCHT function. Logical one on CCHT-BLOCK functional input disables completely the operation of the logic.

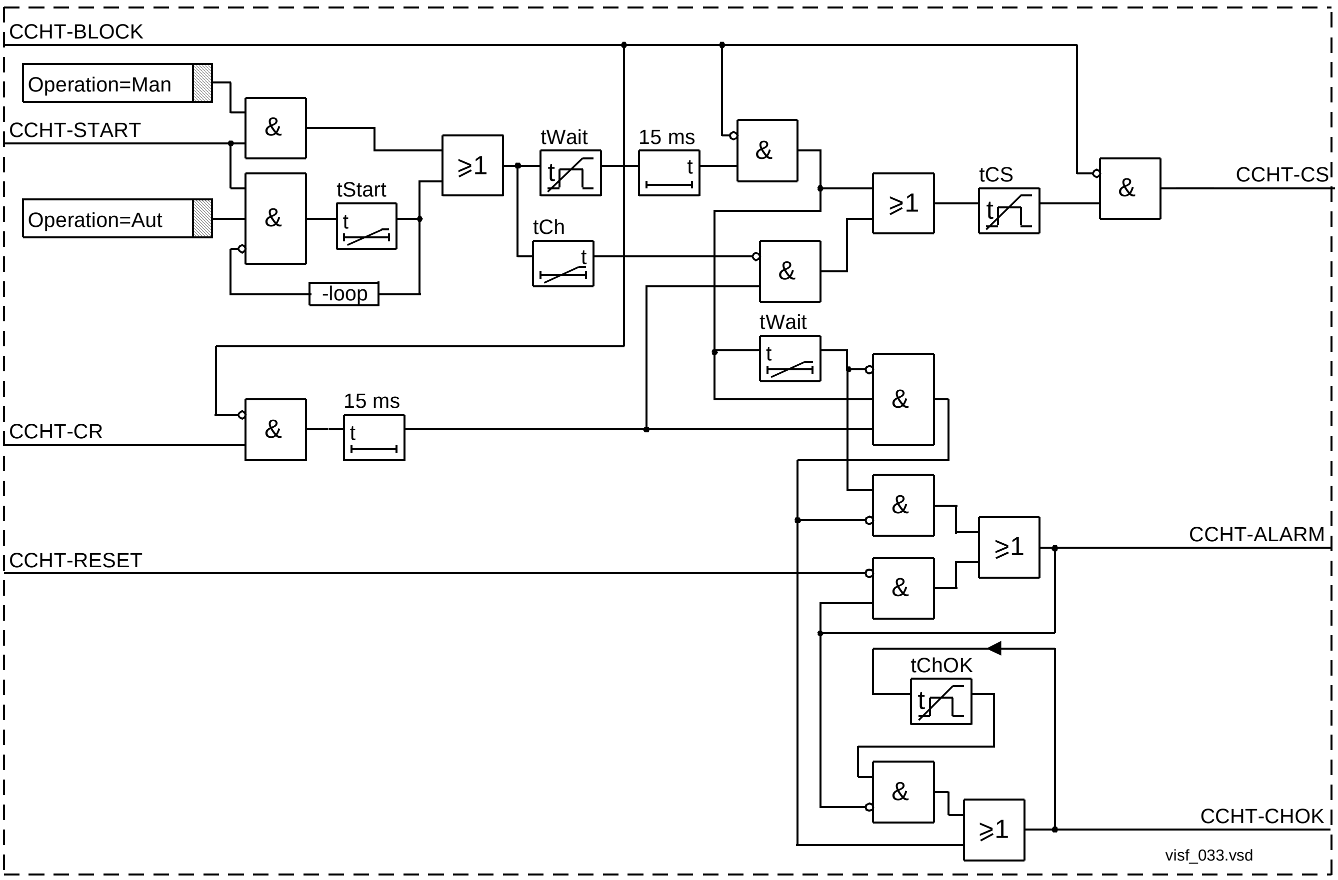


Figure 1: Simplified logic diagram for the CCHT function

2.1 Selection of an operating mode

Selection of an operating mode, which determines the automatic (internal) or manual (external) start is possible by setting the “Operation = Aut” and “Operation = Man” respectively (see Figure 1:). The automatic starting requires continuous presence of logical one on CCHT-START functional input. Setting of the tStart timer determines the time intervals for the automatic starts logic.

Any presence of the logical one signal on the CCHT-START functional input starts the function, when in manual operating mode.

2.2 Operation at sending end

Manual or automatic start initiates the pulse, which is for 15 ms longer than the time set on a tWait timer. This pulse initiates the CCHT-CS functional output signal in duration as set on a tCS pulse timer.The same pulse starts also the time measurement by the tWait timer. The CCHT-ALARM output signal appears, if the CCHT-CR input does not become logical one within the time interval, as set on the tWait timer. The appearance of the CCHT-CR signal is safeguarded by a 15 ms timer, to prevent influence of the disturbances on a communication link.

The appearance of the CCHT-CR signal within the tWait time interval activates the CCHT-CHOK output signal. It remains active for the period as set on the timer tChOK or until the CCHT-ALARM appears at new start of a CCHT function.

The tCh timer, which is delayed on drop-off, prevents ringing of a complete system. It is possible to reset the CCHT-ALARM output signal by activating the CCHT-RESET functional input.

2.3 Operation at receiving end

Activation of a CCHT-CR functional input activates instantaneously the CCHT-CS functional output, if the timer tCh has not been activated or the function has not been blocked by the active CCHT-BLOCK functional input. Duration of the CCHT-CR input signal must be longer than 15 ms to avoid operation at different disturbances on communication link.

3 Setting instructions

Settings for the CCHT function relates mostly to time co-ordination between settings of different timers.

3.1 tInh timer

The CCHT function remains blocked as long as the CCH-BLOCK functional input is active. The time delay set on tInh timer determines the time interval, which takes for the logic to start its normal operation after the CCHT-BLOCK functional input has been set to logical zero. It is recommended to set it to some longer time delay, 30 seconds for example.

3.2 tCh timer

The tCh timer determines the time interval after the activation of the CCHT-START functional input, during which it is not possible to activate the CCHT-CS functional output by activating the CCHT-CR functional input. It prevents ringing of the function. Setting of 60s is recommended.

3.3 tCS timer

It determines the duration at which the CCHT-CS functional output is activated (logical one). The CCHT-CS signal should be active long enough, to reliably activate the operation of the tested function. Too long activation is not recommended.

3.4 tWait timer

The tWait timer determines the maximum time interval, within which the CCHT-CR functional input must become active after the CCHT-CS signal has been initiated. It must include double transmission time to the tested equipment, the reaction time of the tested equipment, and some additional margin of at least 20%.

3.5 tChOK timer

The tChOK timer determines the duration of a CCHT-CHOK functional input. Its setting depends on the signalling equipment and purposes within the secondary system in substation.

3.6 tStart timer

The tStart timer determines the duration of regular time intervals, when the function starts automatically. Eight hour time intervals are usually recommended, when used for testing the carrier communication channels.

4 Basic configuration possibilities

Logical one on functional input signal CCHT-BLOCK blocks instantaneously and completely the operation of a function. The input should be configured to the output of some OR gates, which have connected on their inputs operating (starting) signals from different protection functions, like:

- operation of a line distance protection in forward and reverse direction
- operation of the overvoltage and the undervoltage protection functions
- operation of the overcurrent (phase and earth fault) protection functions, etc.

The CCHT-START functional input initiates the operation of a CCHT function. It is possible to configure it to the binary input of a terminal and start the function manually by connecting the dc voltage for a short time via some normally opened contact. It must be connected to a constantly active FIXD-ON signal, if the automatic mode of operation is selected.

CCHT-CR functional input brings back to the logic the response of a tested object. It is possible to configure it to some terminal binary input. Configure it to the same binary input as a carrier receive signal for the scheme communication logic, used together with the distance protection, if the CCHT function is used for testing the communication channel associated with the distance protection function.

CCHT-RESET functional input resets the ALARM functional output. Configure it normally to some terminal binary input and connect the later one to some external reset push-button with normally opened contact.

The signal obtained on CCHT-CS functional output is supposed to start some external activities. It is possible to configure it to some binary output of a terminal, or to the same binary output as the carrier send signal for the distance protection function (via some OR gates), if the CCHT function is intended for testing the communication channel associated with a distance protection communication logic.

CCHT-ALARM and CCHT-CHOK functional outputs bring information on successful or non-successful result of an activity, started by the logic. They are supposed to be configured to the binary outputs of a terminal and used for the initiation of some external alarming and signalling facilities.

5 Testing

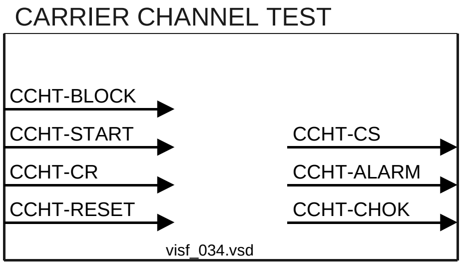
Check that all functional inputs and outputs are connected to the corresponding binary inputs and outputs of a terminal. In the opposite case, configure them for the testing purposes.

Check the operation of a logic according to Figure 1: by applying a dc voltage on the corresponding binary inputs and checking the response on the binary outputs of a terminal.

Establish the correct configuration of a terminal after the tests have been completed.

6 Appendix

6.1 Function block



6.2 Function block diagram

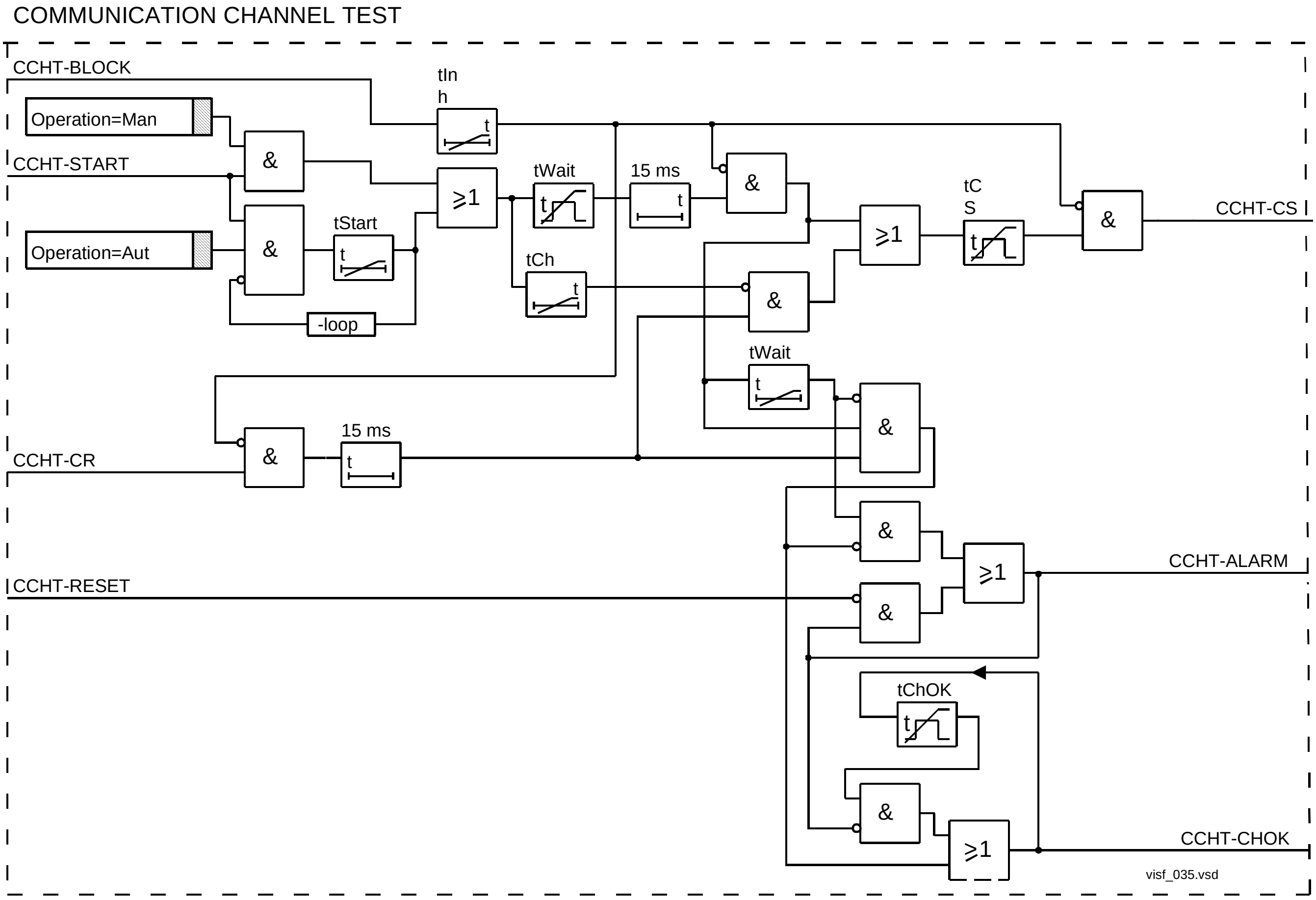


Figure 2: Function diagram for the CCHT function

6.3 Signal list

Block:	**Signal:**	**Type**	**Description:**
CCHT-	BLOCK	IN	Blocks the operation of a function and CCHT-CS output
CCHT-	START	IN	Starts the functional cycle at manual operating mode. To be connected to FIXD-ON at automatic operating mode.
CCHT-	CR	IN	Informs on completed operation of an external (tested) function.
CCHT-	RESET	IN	Resets the CCHT-ALARM output signal, when present.
CCHT-	CS	OUT	Initiates the operation of an external (tested) function.
CCHT-	ALARM	OUT	Informs on uncompleted (failed) test of an external function.
CCHT-	CHOK	OUT	Informs on successful (completed) test of an external function.

6.4 Setting table

Parameter:	**Range:**	**Unit:**	**Default:**	**Parameter description:**
Operation	Off, Manual, Automatic		Off	Operating mode of a function
tStart	0 - 90000	s	28800	Time interval for outomatic start of testing cycle
tWait	0.000 - 60.000	s	0.1	Time interval available for successful test of an external function
tCh	0.000 - 60.000	s	30	Minimum time interval for repeated tests of an external function
tCS	0.000 - 60.000	s	0.04	Duration of CCHT-CS functional output signal, which initiates testing of an external function
tChOK	0 - 90000	s	10	Duration of a CCHT-CHOK functional output signal
tInh	0.000 - 60.000	s	30	Diration of an inhibit condition after the CCHT-BLOCK input signal resets

1 General overview

The aim of the disturbance report is to contribute to the highest possible quality of electrical supply. This is done by a continuous collection of system data and, upon occurrence of a fault, by storing a certain amount of pre-fault, fault, and post-fault data.

The stored data can be used for analysis and decision making to find and eliminate possible system and equipment weaknesses.

The disturbance report is a common name for several facilities to supply the operator with more information about the disturbances and the system. Some of the facilities are basic and some are optional in the different products. For some products not all facilities are available.

The facilities included in the disturbance report are:

- General disturbance information
- Indications
- Event recorder
- Fault locator
- Trip values (phase values)
- Disturbance recorder

The whole disturbance report can contain information for up to 10 disturbances, each with the data coming from all the parts mentioned above, depending on the options installed. All information in the disturbance report is stored in non-volatile flash memories. This implies that no information is lost in case of loss-of-power supply.

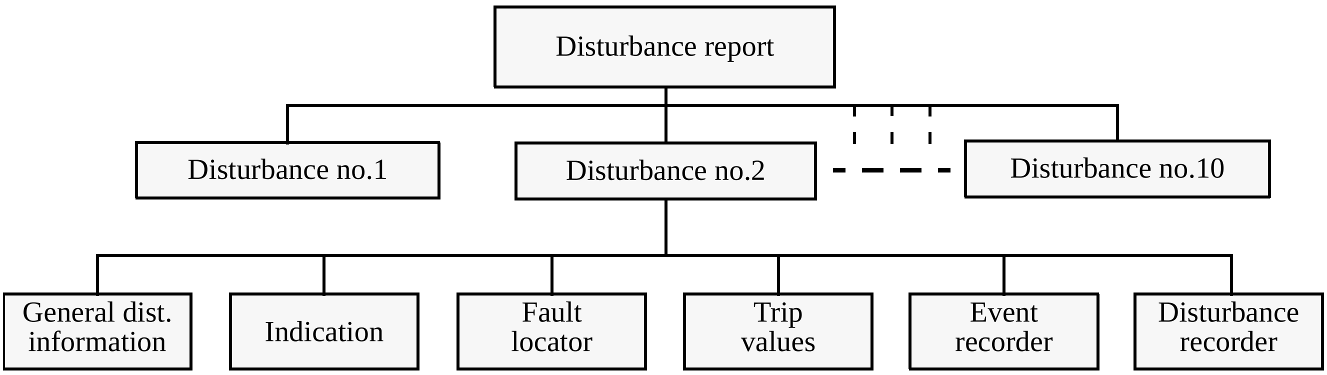


Figure 1: Disturbance report structure.

Up to 10 disturbances can always be stored. If a new disturbance is to be recorded when the memory is full, the oldest disturbance is over-written by the new one. The nominal memory capacity for the disturbance recorder is measured with 10 analogue and 48 binary signals recorded, which means that in the case of long recording times, fewer than 10 disturbances are stored. If fewer analogue signals are recorded, a longer total recording time is available. This memory limit does not affect the rest of the disturbance report.

1.1 General disturbance information

Disturbance overview is a summary of all the stored disturbances. The overview is available only on a front-connected PC or via the Station Monitoring System (SMS). The overview contains:

- Disturbance index
- Date and time
- Trip signals
- Trig signal that activated the recording
- Distance to fault (requires Fault locator)
- Fault loop selected by the Fault locator (requires Fault locator)

Disturbance Summary is automatically scrolled on the human-machine interface (HMI). Here the two latest disturbances (DisturbSummary 1, which is the latest and DisturbSummary 2 which is the second latest) are presented with:

- Date and time
- Selected indications (set with the Indication mask)
- Distance to fault and fault loop selected by the Fault locator

Disturbance data on the HMI is presented at:

DisturbReport
  Disturbances
    Disturbance n (1 - 10)

The date and time of the disturbance, the trig signal, the indications, the fault locator result and the trip values are available, provided that the corresponding functions are installed.

1.2 Indications

Indications is a list of signals that were activated during the fault time of the disturbance. A part (or all) of these signals are automatically scrolled on the local HMI after a disturbance.

1.3 Event recorder

The event recorder contains an event list with time-tagged events. In the Station Monitoring System, this list is directly connected to a disturbance.

1.4 Fault locator

The fault locator contains information about the distance to the fault and about the measuring loop that was selected for the calculation. After changing the system parameters in the terminal, a recalculation of the distance to the fault can be made in the protection.

1.5 Trip values

Trip values includes phasors of currents and voltages before the fault and during the fault.

1.6 Disturbance recorder

The disturbance recorder records analogue and binary signal data before, during and after the fault.

On the local HMI, the indications, the fault locator result (when applicable), and the trip values are available. For a complete disturbance report, front communication with a PC or remote communication with SMS is required.

2 Recording times

The recording times are valid for the whole disturbance report. The disturbance recorder and the event recorder register disturbance data and events during *tRecording*, the total recording time. However, indications are only registered during the fault time.

The total recording time, *tRecording*, of a recorded disturbance is:

tRecording = tPre + tFault + tPost, or tPre + tLim, depending on which criterion stops the current disturbance recording.

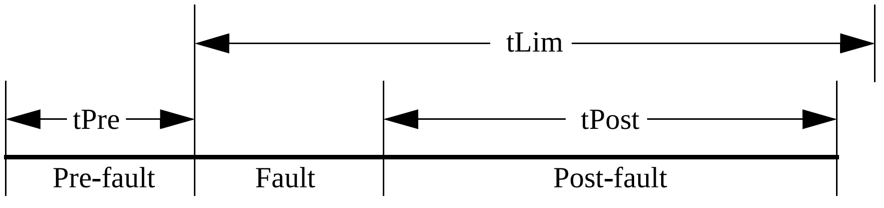


Figure 2: Recording times relationship.

The different time periods are described below:

Period	**Is the ...**
tPre	Pre-fault recording time. More correctly it should be called pre-triggering time, because it consists of not only a pre-fault time but also the operating time for the trigger itself.
tFault	Fault time of the recording. The fault time cannot be set and continues as long as any valid trigger condition, binary or analogue, persists (unless limited by tLim the limit time, see below).
tPost	Post-fault recording time. When all activated triggers during the fault time are reset, the current disturbance recording continues according to the set post-fault time.
tLim	Limit time, which is the maximum recording time after the disturbance recording was triggered. The limit time is used to eliminate the consequences of a faulty trigger that does not reset within a reasonable time interval. It limits the maximum recording time of a recording and prevents subsequent overwriting of already stored disturbances.

3 Analogue signals

Up to 10 analogue signals (five voltages and five currents from the transformer module) can be selected for recording and trig if the disturbance recorder function is installed. If fewer than 10 signals are selected, the maximum storing capacity in the flash memories, regarding total recording time are increased.

A user-defined name for each of the signals can be programmed in the terminal.

For each of the 10 analogue signals, *Operation* = *On* means that it is recorded by the disturbance recorder. The triggering itself is independent of the setting of *Operation*, and triggers even if operation is set to *Off*. Both undervoltage and overvoltage can be used as trig condition. The same applies for the current signals.

The check of the trig condition is based on peak-to-peak values. When this is found, the absolute average value of these two peak values is calculated. If the average value is above the threshold level for an overvoltage or overcurrent trig, this trig is indicated with a greater than (>) sign with the user-defined name.

If the average value is below the set threshold level for an undervoltage or undercurrent trig, this trig is indicated with a less than (<) sign with its name. The procedure is separately performed for each channel.

This method of checking the analogue start conditions gives a function which is insensitive to DC offset in the signal. The operating time for this start is typically in the range of one cycle, 20 ms for a 50 Hz network.

The analogue signals are presented only in the disturbance recording, but they affect the entire disturbance report when being used for triggering.

4 Binary signals

Up to 48 binary signals can be selected from the signal list, where all available signals are grouped under each function. The 48 signals can be selected from among internal logical signals and binary input signals. For each of the 48 signals, it is also possible to select if the signal is to be used as a trigger of the disturbance report, and if the trig should be activated on a 1 or a 0. A binary signal can be selected to activate the red LED on the local HMI.

A user-defined name for each of the signals can be programmed in the terminal.

The selected 48 signals are presented in the event list and the disturbance recording. But they affect the whole disturbance report when they are used for triggering.

The indications, that are to be automatically scrolled on the HMI when a disturbance has been recorded are also selected from these 48 signals with the HMI Indication Mask.

4.1 Trig signals

The trig conditions affect the entire disturbance report. As soon as a trig condition is fulfilled, a complete disturbance report is recorded. On the other hand, if no trig condition is fulfilled, there is no disturbance report, no calculation of distance to fault, no indications, and so on. This implies the importance of choosing the right signals as trig conditions.

A trig can be of type:

- Manual trig
- Binary-signal trig
- Analogue-signal trig (over/under function)

4.1.1 Manual trig

Manual trig starts from the local HMI or from a front-connected PC (or SMS). This is found on the HMI menu tree at:

DisturbReport
    ManualTrig

4.1.2 Binary trig

A trig on a binary signal can be activated on either a logical 1 or a logical 0. When a binary input is used as trig, the signal must stay for at least 15 ms to be picked up.

Note that when a binary signal is programmed to trig on a logical 0, this signal is not presented as an indication in the disturbance report.

4.1.3 Analogue trig

All analogue signals are available for trigger purposes, no matter if they are recorded in the disturbance recorder or not. But the disturbance recorder function must be installed in the terminal.

1 Introduction

The main part of the settings for the Disturbance Report is found on the local human-machine interface (HMI) at:

Settings
  DisturbReport

The settings include:

Operation	Disturbance Report (On/Off)
	Re-trig during post-fault state (On/Off)
SequenceNo	Sequence number (0-255) (normally not necessary to set)
RecordingTimes	Recording times for the Disturbance Report and the event/indication logging, including pre-fault time, post-fault time, and limit time for the entire disturbance
BinarySignals	Selection of binary signals, trig conditions, HMI indication mask and HMI red LED option
AnalogSignals	Recording mask and trig conditions
FaultLocator	Distance measurement unit (km/miles/%)

User-defined names of analogue signals can be set at:

Configuration
  AnalogInputs

The user-defined names of binary signals can be set at:

Configuration
  DisturbReport
    Input n (n=1-48)

The analogue and binary signals appear with their user-defined names.

1.1 Settings during normal conditions

Table 1: How the settings affect different functions in the disturbance report

HMI Setting menu	Function	Disturbance summary (on HMI)	Disturbance recorder	Indica-tions	Event list (SMS)	Trip values	Fault locator
Operation	Operation (On/Off)	Yes	Yes	Yes	Yes	Yes	Yes
Recording times	Recording times (tPre, tPost, tLim)	No	Yes	No	Yes	No	No
Binary signals	Trig operation and trig level	Yes	Yes	Yes	Yes	Yes	Yes
	Indication mask (for automatic scrolling)	Yes	No	No	No	No	No
Analogue signals	Operation (On/Off)	No	Yes	No	No	Yes	Yes
	Trig over/under function	Yes	Yes	Yes	Yes	Yes	Yes
Fault Locator	Fault locator set-tings (Distance Unit)	No	No	No	No	No	Yes

2 Operation

HMI submenu:

Settings
DisturbReport
Operation

Operation can be set to *On* or *Off*. If *Off* is selected, note that no disturbance report is registered, including indications, fault locator, event recorder, and disturbance recorder.

Operation = Off:

- Disturbances are not stored.
- LED information (yellow - start, red - trip) is not stored or changed.
- No disturbance summary is scrolled on the local HMI.

Operation = On:

- Disturbances are stored, disturbance data can be read from the local HMI and from a front-connected PC or Station Monitoring System (SMS).
- LED information (yellow - start, red - trip) is stored.
- The disturbance summary is automatically scrolled on the local HMI for the two latest registered disturbances, until cleared.

Post re-trig can be set to On or Off

Postretrig = On:
Re-trig during the set post-fault time is enabled.

Postretrig = Off
Re-trig during the set post fault time is not accepted.

2.1 Sequence number

HMI submenu:

Settings
  DisturbReport
    SequenceNo

Normally, this setting option is seldom used. Each disturbance is assigned a number in the disturbance report. The first disturbance each day normally receives *SequenceNo = 0*. The value of *SequenceNo* that can be read in the service report is the number that will be assigned to the next disturbance registered during that day.

In normal use, the sequence number is increased by one for each new disturbance until it is reset to zero each midnight.

2.2 Recording times

HMI submenu:

Settings
  DisturbReport
    RecordingTimes

Under this submenu, the different recording times for the disturbance report are set (the pre-fault time, post-fault time, and limit time). These recording times affect the disturbance recorder and event recorder functions. The total recording time, *tRecording*, of a recorded disturbance is:

tRecording = tPre + tFault + tPost, or tPre + tLim, depending on which criterion stops the current disturbance recording.

2.3 Binary signals

HMI submenu:

Configuration
  DisturbReport
    Input n (n=1-48)

Up to 48 binary signals can be selected from the signal list, where all available signals are grouped function by function. The 48 signals can be selected among internal logical signals and binary input signals. Each selected signal is registered by the disturbance recorder, event recorder, and indication functions during a recording.

A user-defined name for each of the signals can be entered. This name can comprise up to 13 characters.

HMI submenu:

Settings
DisturbReport
BinarySignals

For each of the 48 signals, it is also possible to select if the signal is to be used as a trigger for the start of the disturbance report (*TrigOperation*), and if the trig should be activated at a logical 1 or 0 level (*TrigLevel*).

The indications in the disturbance summary, that are automatically scrolled on the HMI when a disturbance is registered, are also selected from these 48 signals using the indication mask.

2.4 Analogue signals

HMI-submenu:

Settings
DisturbReport
AnalogSignals

This HMI submenu is only available when the disturbance recorder option is installed.
For each of the 10 analogue signals (five voltages and five currents), *Operation* = *On* means that it is recorded by the disturbance recorder. If fewer than 10 signals are selected, the maximum storing capacity in the flash memories for total recording time becomes longer.

Both undervoltage and overvoltage can be used as triggering condition. The same applies for the current signals. The triggering is independent of the setting of *Operation* and triggers even if *Operation* = *Off*.

A user-defined name for each of the signals can be entered. It can consist of up to 13 characters. It is found at:

Configuration
AnalogInputs

3 Settings during test

3.1 Test mode

During testing, the operation of the disturbance report is required. The setting of this operation is found at the HMI submenu:

Test
  Test Mode
    DisturbReport
      Operation, DisturbSummary

When *TestMode* is set to *On* (Operation = On), the setting of the disturbance report parameters have the following impact:

Operation = Off DisturbSummary = Off

- Disturbances are not stored.
- LED information is not shown on the HMI and not stored.
- No Disturbance Summary is scrolled on the HMI.

Operation = Off DisturbSummary = On

- Disturbances are not stored.
- LED information (yellow - start, red - trip) are shown on the local HMI, but not stored in the terminal.
- Disturbance summary is automatically scrolled on the local HMI for the two latest registered disturbances, until cleared. The information is not stored in the terminal.

Operation = On DisturbSummary = Off or On

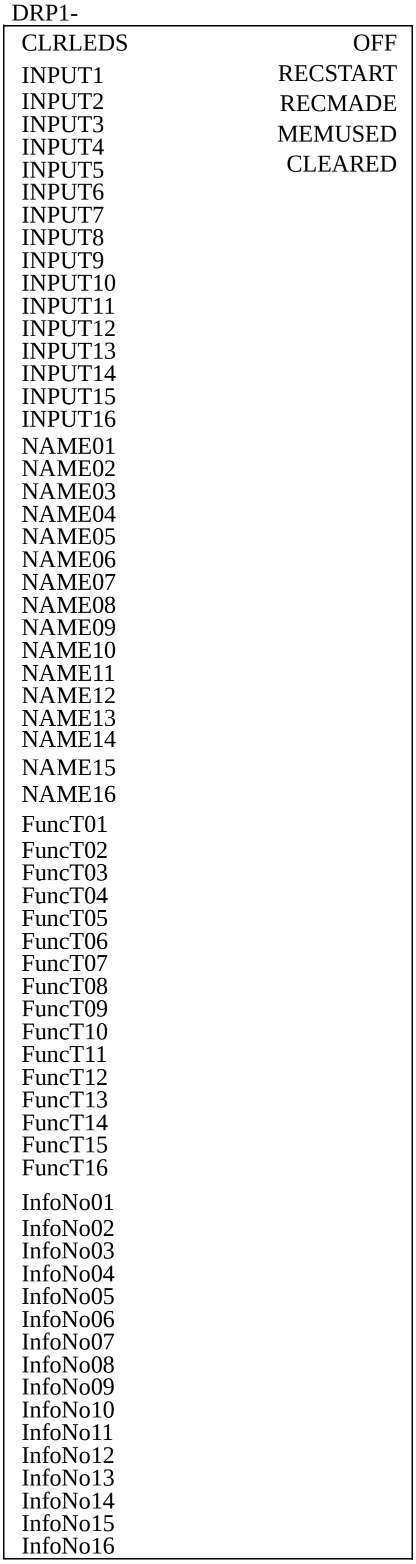
- The disturbance report works as in normal mode.
- Disturbances are stored. Data can be read from the local HMI, a front-connected PC, or SMS.
- LED information (yellow - start, red - trip) is stored.
- Disturbance summary is automatically scrolled on the local HMI for the two latest registered disturbances, until cleared.
- All disturbance data stored during test mode remains in the terminal when returning to normal mode.

3.2 Activation of manual triggering

A disturbance report can be manually triggered from the local HMI, a front-connected PC, or SMS. When the trig is activated, the manual trig signal is generated. This feature is especially useful for testing.

4 Appendix

4.1 Function block



There are three different disturbance function blocks. The diagram above shows the first one, DRP1-. The other two (DRP2- and DRP3-) only contains the inputs, numbered 17 to 32 and 33 to 48 respectively.

4.2 Signal list

Block	Signal	Type	Description
DRP1-	CLRLEDS	IN	Disturbance Report-Clear front panel LEDs
DRP1-	INPUT1	IN	Select binary signal to be recorded as signal no. 1.
DRP1-	INPUT2	IN	Select binary signal to be recorded as signal no. 2.
DRP1-	INPUT3	IN	Select binary signal to be recorded as signal no. 3.
DRP1-	INPUT4	IN	Select binary signal to be recorded as signal no. 4.
DRP1-	INPUT5	IN	Select binary signal to be recorded as signal no. 5.
DRP1-	INPUT6	IN	Select binary signal to be recorded as signal no. 6.
DRP1-	INPUT7	IN	Select binary signal to be recorded as signal no. 7.
DRP1-	INPUT8	IN	Select binary signal to be recorded as signal no. 8.
DRP1-	INPUT9	IN	Select binary signal to be recorded as signal no. 9.
DRP1-	INPUT10	IN	Select binary signal to be recorded as signal no. 10.
DRP1-	INPUT11	IN	Select binary signal to be recorded as signal no. 11.
DRP1-	INPUT12	IN	Select binary signal to be recorded as signal no. 12.
DRP1-	INPUT13	IN	Select binary signal to be recorded as signal no. 13.
DRP1-	INPUT14	IN	Select binary signal to be recorded as signal no. 14.
DRP1-	INPUT15	IN	Select binary signal to be recorded as signal no. 15.
DRP1-	INPUT16	IN	Select binary signal to be recorded as signal no. 16.
DRP1-	NAME01-16	IN	See the setting table
DRP1-	FuncT01-16	IN	See the setting table
DRP1-	InfoNo01-16	IN	See the setting table
DRP1-	CLEARED	OUT	All disturbances in Disturbance Report cleared
DRP1-	MEMUSED	OUT	More than 80% of recording memory used
DRP1-	OFF	OUT	Disturbance Report function turned off
DRP1-	RECMADE	OUT	Disturbance recording made
DRP1-	RECSTART	OUT	Disturbance recording started

4.3 Setting table

Parameter	Range	Unit	Default	Parameter description
Disturbance report				
Operation	Off, On		On	Disturbance report deactivated/activated (off/on)
PostRetrig	Off, On		Off	Postfault retrig off/on
RecordingTime				
tPre	0.05 - 0.30	s	0.10	Prefault recording time
tPost	0.1 - 3.0	s	0.5	Postfault recording time
tLim	0.5 - 4.0	s	1.0	Fault recording time limit
Binary signals (x=1-48) (Settings to be set for each input)				
TrigOperation	Off, On		Off	On/Off: The binary signal is used as recordning trigger (On) or not used (Off)
TrigLevel	High-to-low, Low-to-high		High-to-low	Selects the signal transition used for triggering. From-1-to-0 or from-0-to-1
IndicationMask	Hide, show		Hide	Show: The signal is displayed (and automatically scrolled) on the local HMI
SetLed	Off, On		Off	On: When trigger conditions is satisfied, the red HMI LED is lit
NAMEx	Usr def. string		Input x	User defined name of binary input. The name can only be set using the CAP 531 configuration tool
Analogue voltage signals (U1b-U5b) (Settings to be set for each input)				
Operation	Off, On		On	On: The signal is recorded in the disturbance recorder (if present)
<TrigLevel	0-110	%	90	Undervoltage (U<) trigger level in % of voltage signal (U1b-U5b)
>TrigLevel	0-200	%	110	Overvoltage (U>) trigger level in % of voltage signal (U1b-U5b)
<TrigOperation	Off, On		Off	On: Undervoltage recording trigger is active
>TrigOperation	Off, On		Off	On: Overvoltage recording trigger is active
Analogue current signals (I1b-I5b) (Settings to be set for each input)				
Operation	Off, On		On	On: The signal is recorded in the disturbance recorder (if present)
<TrigLevel	0-200	%	50	Undercurrent (I<) trigger level in % of current signal (I1b-I5b)
>TrigLevel	0-5000	%	200	Overcurrent (I>) trigger level in % of current signal (I1b-I5b)
<TrigOperation	Off, On		Off	On: Undercurrent recording trigger is active
>TrigOperation	Off, On		Off	On: Overcurrent recording trigger is active
Sequence number				

Parameter	Range	Unit	Default	Parameter description
Sequen-ceNo	0 - 255		0	Disturbance sequence number
Function block setting inputs				
FuncT01	0-255		0	Function type 1
FuncT02	0-255		0	Function type 2
FuncT03	0-255		0	Function type 3
FuncT04	0-255		0	Function type 4
FuncT05	0-255		0	Function type 5
FuncT06	0-255		0	Function type 6
FuncT07	0-255		0	Function type 7
FuncT08	0-255		0	Function type 8
FuncT09	0-255		0	Function type 9
FuncT10	0-255		0	Function type 10
FuncT11	0-255		0	Function type 11
FuncT12	0-255		0	Function type 12
FuncT13	0-255		0	Function type 13
FuncT14	0-255		0	Function type 14
FuncT15	0-255		0	Function type 15
FuncT16	0-255		0	Function type 16
InfoNo01	0-255		0	Information number 1
InfoNo02	0-255		0	Information number 2
InfoNo03	0-255		0	Information number 3
InfoNo04	0-255		0	Information number 4
InfoNo05	0-255		0	Information number 5
InfoNo06	0-255		0	Information number 6
InfoNo07	0-255		0	Information number 7
InfoNo08	0-255		0	Information number 8
InfoNo09	0-255		0	Information number 9
InfoNo10	0-255		0	Information number 10
InfoNo11	0-255		0	Information number 11
InfoNo12	0-255		0	Information number 12
InfoNo13	0-255		0	Information number 13
InfoNo14	0-255		0	Information number 14
InfoNo15	0-255		0	Information number 15
InfoNo16	0-255		0	Information number 16
NAME01	0-13		Input1	Signal 1 user name 13 char. for disturbance presentations
NAME02	0-13		Input2	Signal 2 user name 13 char. for disturbance presentations
NAME03	0-13		Input3	Signal 3 user name 13 char. for disturbance presentations
NAME04	0-13		Input4	Signal 4 user name 13 char. for disturbance presentations
NAME05	0-13		Input5	Signal 5 user name 13 char. for disturbance presentations

Parameter	Range	Unit	Default	Parameter description
NAME06	0-13		Input6	Signal 6 user name 13 char. for disturbance presentations
NAME07	0-13		Input7	Signal 7 user name 13 char. for disturbance presentations
NAME08	0-13		Input8	Signal 8 user name 13 char. for disturbance presentations
NAME09	0-13		Input9	Signal 9 user name 13 char. for disturbance presentations
NAME10	0-13		Input10	Signal 10 user name 13 char. for disturbance presentations
NAME11	0-13		Input11	Signal 11 user name 13 char. for disturbance presentations
NAME12	0-13		Input12	Signal 12 user name 13 char. for disturbance presentations
NAME13	0-13		Input13	Signal 13 user name 13 char. for disturbance presentations
NAME14	0-13		Input14	Signal 14 user name 13 char. for disturbance presentations
NAME15	0-13		Input15	Signal 15 user name 13 char. for disturbance presentations
NAME16	0-13		Input16	Signal 16 user name 13 char. for disturbance presentations

1 Application

The indications from all the 48 selected binary signals are shown on the local human-machine interface (HMI) and on the Station Monitoring System (SMS) for each recorded disturbance in the disturbance report. The LEDs on the front of the terminal display start and trip indications.

2 Theory of operation

The indications shown on the HMI and SMS give an overview of the status of the 48 event signals during the fault. On the HMI, the indications for each recorded disturbance are presented at:

DisturbReport
  Disturbances
    Disturbance n (n=1-10)
      Indications

All selected signals can be internally produced signals or emerge from binary input channels.

The indications are registered only during the fault time of a recorded disturbance, as long as any trigger condition is activated. A part or all of these indications can be automatically scrolled on the local HMI after a disturbance is recorded, until acknowledged with the C button on the HMI. They are selected with the indication mask.

The signal name for internal logical signals presented on the screen follows the signal name, which can be found in the signal list in each function description of this user’s guide. Binary input signals are displayed with their user-defined names.

The LED indications display this information:

Green LED :

- Steady light In service
- Flashing light Internal fail, the INT--FAIL internal signal is high
- Dark No power supply

Yellow LED :

- Steady light A disturbance report is triggered
- Flashing light The terminal is in test mode or in configuration mode

Red LED :

- Steady light Trig on binary signal with HMI red LED option set.
- Flashing light The terminal is in configuration mode.

3 Setting

The signals to be displayed as indications are selected in the disturbance report setting. This can be found on the local HMI at:

Settings
DisturbReport
BinarySignals
Input n (n=1-48)

4 Testing

If TestMode is activated and TestMode/DisturbReport/ is set to ...		**Then the disturbances ...**
Operation = On	DisturbSummary = On or Off	Are stored as usual in the terminal.
Operation = Off	DisturbSummary = On	Summary scrolls. No indications. No storage of LED information.
Operation = Off	DisturbSummary = Off	Are not stored. LED information not stored.

1 Application

The aim of disturbance recording is to provide a means for better understanding of the behaviour of the power network and related primary and secondary equipment during and after a disturbance. An analysis of the recorded data provides valuable information that can be used to improve existing equipment. This information can also be used when planning for and designing new installations.

Most of the built-in disturbance recorders offered by various manufacturers operate only in connection with the operation of the protective functions and they have a very limited capacity for recording times and the number of recordings.

This is not the case with the disturbance recorders built into the REx 5xx terminals. These disturbance recorders are characterised by great flexibility as far as starting conditions and recording times, and large storage capacity are concerned. Thus, the disturbance recorders are not dependent on the operation of protective functions, and they can record disturbances that were not discovered by protective functions for one reason or another.

The disturbance recording function in the REx 5xx terminals is fully adequate for the recording of disturbances for the protected object.

1.1 Recording capacity

The recording function can record all analogue inputs in the transformer module and up to 48 binary signals. To maximise the use of the memory, the number of analogue channels to be recorded is user-selectable by programming and can be set individually for each analogue input. The recorded binary signals can be either true binary input signals or internal logical signals created by the protective functions.

1.2 Memory capacity

The maximum number of recordings stored in the memory is 10. So depending on the set recording times and the recording of the enabled number of channels, the memory can contain a minimum of six and a maximum of 10 disturbance recordings comprising of both header part and data part. But the header part for the last 10 recordings is always available.

1.3 Recording times

The recording times for the pre- and post-fault period, tPre and tPost, are user-programmable with wide setting ranges.

To avoid uncontrolled recording and subsequent erasing of previous recordings, in case a trigger should not reset within a reasonable time, a limit time, tLim, can be set to limit the total duration of a recording.

1.4 Triggers

Any of the recorded binary signals can be programmed to act as a trigger. The analogue channels have programmable threshold levels for triggering. Both overlevels and underlevels are available. Manual triggering is also available. This provides a convenient test possibility.

1.5 Time tagging

The terminal has a built-in, real-time clock and calendar. This function is used for time tagging of the recorded disturbances. The time tagging refers to the activation of the trigger that starts the disturbance recording.

2 Theory of operation

Disturbance recording is based on the continuous collection of network data, currents and binary signals, in a cyclic buffer. The buffer operates according to the FIFO principle, old data will be overwritten as new data arrives when the buffer is full. The size of this buffer is determined by the set pre-fault recording time.

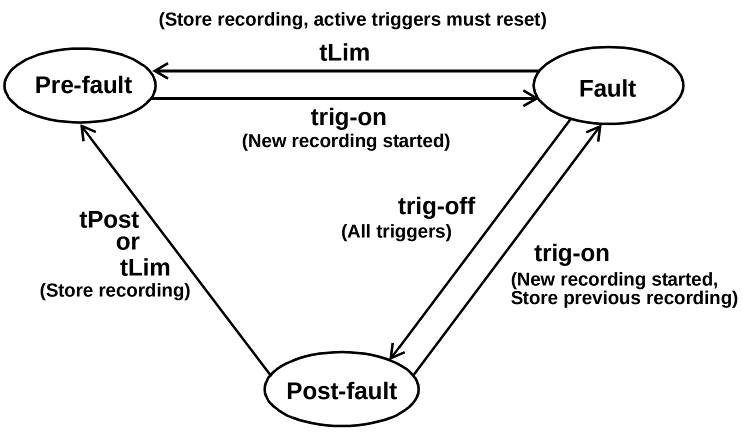


Figure 1: State transition diagram governing the recording modes.

Upon detection of a fault condition (triggering), the data storage continues in another part of the memory. The storing goes on as long as the fault condition prevails - plus a certain additional time. The length of this additional part is called the post-fault time and it can be set in the disturbance recorder. The above mentioned two parts form a disturbance recording. The whole memory acts as a cyclic buffer and when it is full, the oldest recording is overwritten.

The recordings can be retrieved to the PC with RECOM, the data collection software, and analysed and evaluated manually by using the REVAL evaluation software, which is also used for printouts of recorded disturbances. For automatic evaluation of the recordings, the RESDA software package is available.

The recordings can be divided into two parts, the header and the data part. The data part contains the numerical values for the recorded analogue and binary channels. The header contains clearly written basic information on the disturbance. A part of this information is also used by REVAL to reproduce the analogue and binary signals in a correct and user-friendly way. Such information is, primary and secondary instrument transformer ratings.

This information is included in the header:

Table 1: Contents of the header

Type of information Parameter	Stored in parameter database	Stored with disturbance
General		
Station, object & unit ID	x	-
Date and time	-	x
Sequence number	-	x
CT earthing	x	-
Time synchronisation source	x	-
Recording times tPre, tPost, tLim	-	x
Pre-fault Uph-ph, I (RMS)	-	x
Trig signal and test mode flag	-	x
Analogue signals		
Signal name	x	-
Primary and secondary instr. transformer rating	x	-
Undertrig: level and operation	x	-
Overtrig: level and operation	x	-
Undertrig status at time of trig	-	x
Overtrig status at time of trig	-	x
Instantaneous Uph-0 at time of trig	-	x
Instantaneous Iph-0 at time of trig	-	x
Uph-0/Iph-0 (RMS) before trig (pre-fault)	-	x
Uph-0/Iph-0 (RMS) after trig (fault)	-	x
Binary signals		

Table 1: Contents of the header

Type of information Parameter	**Stored in parameter database**	**Stored with disturbance**
Signal name	-	x
Type of contact (trig level)	x	-
Trig operation	x	-
Signal status at time of trig	-	x
Trig status at time of trig	-	x

Table 1 is a summary. For detailed information, see the *“User’s Guide for REVAL”*.

3 Design

The disturbance recording function is an optional function in the REx 5xx terminals. The processing of analogue signals is handled by a dedicated DSP (digital signal processor). Other functions are implemented in the main CPU. The memory is shared with other functions.

The numerical signals coming from the A/D conversion module in serial form are converted to parallel form in a dedicated DSP. The analogue trig conditions are also checked in the DSP.

A check of the start conditions is performed by searching for a maximum value. This is a positive peak. The function also seeks a minimum value, which is the negative peak.

When this is found, the absolute average value is calculated. If this value is above the set threshold level for the *overfunction* on the channel in question, an *overfunction* start on that channel is indicated. The *overfunction* is indicated with a greater than (>) sign.

Similarly, if the average value is below the set threshold level for *underfunction* on the channel in question, an *underfunction* start on that channel is indicated. The *underfunction* is indicated with a less than (<) sign.

The procedure is separately performed for each channel. This method of checking the analogue start conditions gives a function that is insensitive to DC offset in the signal. The operating time for this start is typically in the range of one cycle, 20 ms in a 50 Hz network.

The numerical data, along with the result of the trigger condition evaluation, are transmitted to the main CPU. The main CPU handles these functions:

- Evaluation of the manual start condition
- Evaluation of the binary start condition, both for true binary input signals and for internally created logical signals
- Storage of the numerical values for the analogue channels

The numerical data for the analogue channels are stored in a cyclic pre-fault buffer in a RAM. When a trigger is activated, the data storage is moved to another area in the RAM, where the data for the fault and the subsequent post-fault period are stored. Thus, a complete disturbance recording comprises the stored data for the pre-fault, fault, and post-fault period.

The RAM area for temporary storage of recorded data is divided into subareas, one for each recording. The size of a subarea is governed by the sum of the set pre-fault (tPre) and maximum post-triggering (tLim) time. There is a sufficient memory capacity for at least four consecutive recordings with a maximum number of analogue channels recorded and with maximum time settings. Should no such area be free at the time of a new triggering, the oldest recording stored in the RAM is overwritten.

When a recording is completed, a post recording processing occurs.

This post-recording processing comprises:

- Merging the data for analogue channels with corresponding data for binary signals stored in an event buffer
- Compression of the data, which is performed without losing any data accuracy
- Storing the compressed data in a non-volatile memory (flash memory)

The recorded disturbance is now ready for retrieval and evaluation. The recording comprises the stored and time-tagged disturbance data along with relevant data from the database for configuration and parameter set-up.

Some parameters in the header of a recording are stored with the recording, and some are retrieved from the parameter database in connection with a disturbance. Table 1 indicates where the various parameters are stored. This means that if a parameter that is retrieved from the parameter database was changed between the time of recording and retrieval, the collected information is not correct in all parts. For this reason, all recordings should be transferred to the Station Monitoring System (SMS) workstation and then deleted in the terminal before any such parameters are changed.

4 Setting

The setting parameters specific for the disturbance recording function are available in the menu tree under:

Settings
 DisturbReport
  Operation
  SequenceNo
  RecordingTimes
  BinarySignals
  AnalogSignals

The list of parameters in the appendix attached to the document “Disturbance report - Settings”, explains the meaning of the abbreviations used in connection with setting ranges.

Remember that values of parameters set elsewhere in the menu tree are linked to the information on a recording. Such parameters are, for example, station and object identifiers, CT and PT ratios.

The sequence number of the recordings is a specific parameter for the disturbance recorder and is used to identify the different recordings. By combining the date and the sequence number for a recording, the recording can be uniquely identified. The sequence number is also shown under:

ServiceReport
 DisturbReport
  SequenceNo

The read value on the local human-machine interface (HMI) display is the sequence number that the next recorded disturbance receives. The number is automatically increased by one for each new recording and is reset to zero at each midnight. The sequence number can also be set manually.

5 Testing

Evaluation of the results from the disturbance recording function requires access to an SMS workstation either permanently connected to the terminal or temporarily connected to the serial port on the front. The following software packages must be installed in the workstation:

Package:	**For:**
SMS-BASE	Common functions
RECOM	Collection of the disturbance data
REVAL	Evaluation and printouts of the recorded data

It could be useful to have a printer for hard copies. The behavior of the disturbance recording function can be checked when protective functions of the terminal are tested.

When the terminal is set to operate in test mode, there is a separate setting for operation of the disturbance report, which also affects the disturbance recorder.

A manual trig can be started any time. This results in a *snap-shot* of the actual values of all recorded channels.

1 Application

When using a front-connected PC or Station Monitoring System (SMS), an event list can be available for each of the recorded disturbances in the disturbance report. Each list can contain up to 150 time-tagged events. These events are logged during the total recording time, which depends on the set recording times (pre-fault, post-fault and limit time) and the actual fault time. During this time, the first 150 events for all the 48 selected binary signals are logged and time tagged. This list is a useful instrument for evaluating a fault and is a complement to the disturbance recorder.

To obtain this event list, the event recorder function (basic in some terminals and optional in others) must be installed.

2 Theory of operation

When one of the trig conditions for the disturbance report is activated, the events are collected by the main processing unit, from the 48 selected binary signals. The events can come from both internal logical signals and binary input channels. The internal signals are time tagged in the main processing module, while the binary input channels are time tagged directly on each I/O module. The events are collected during the total recording time, *tRecording*, and they are stored in the disturbance report memory at the end of each recording.

The name of the binary input signal that appears in the event list is the user-defined name that can be programmed in the terminal.

The time tagging of events emerging from internal logical signals and binary input channels have a resolution of 1 ms.

3 Setting

The settings of the event recorder consist of the signal selection and the recording times. It is possible to select up to 48 binary signals, either internal signals or signals coming from binary input channels. These signals coincide with the binary signals recorded by the disturbance recorder. The disturbance summary indications that are to scroll automatically on the local human-machine interface (HMI), can only be selected from these 48 event channels.

The signal selection is found at:

Settings
  DisturbReport
    BinarySignals
      Input n (n=1-48)

Each of the up to 48 event channels can be selected from the signal list, consisting of all available internal logical signals and all binary input channels.

For each of the binary input and output signals, a user-defined name can be programmed at:

Configuration

I/O

Slotnn-XXXX (ex. Slot15-BOM3)

4 Testing

During testing, the event recorder can be switched off if desired. This is found in the SMS or Substation Control System (SCS).

1 Application

The main objective of line protection and monitoring terminals is fast, selective and reliable operation for faults on a protected object. Besides this, information on the values of the currents and voltages before and during the fault is valuable to understand the severity of the fault.

The trip value recorder in the REx 5xx series of terminals provides this information. The function is an optional software module in the terminal.

The function calculates the pre-fault and fault values of currents and voltages and presents them as phasors with amplitude and argument.

2 Design

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

When the disturbance report function is triggered, the trip value recorder function starts to calculate the frequency of the analogue channel U1. If the calculation fails, a default frequency is read from database to ensure further execution of the function.

Then the sample for the fault interception is looked for by checking the non-periodic changes. The channel search order is U1, U2, U3, I1, I2, I3, I4, I5 and U5.

If no error sample is found, the trig sample is used as the start sample for the Fourier estimation of the complex values of currents and voltages. The estimation uses samples during one period before the trig sample. In this case the calculated values are used both as pre-fault and fault values.

If an error sample is found the Fourier estimation of the prefault values starts 1.5 period before the fault sample. The estimation uses samples during one period. The postfault values are calculated using the Recursive Least Squares (RLS) method. The calculation starts a few samples after the fault sample and uses samples during 1/2 - 2 periods depending on the shape of the signals.

The pre-fault time (tPre) should be at least 0.1 s to ensure enough samples for the estimation of pre-fault trip values.

3 Displaying pre-fault and fault phasors of the currents and voltages

When the Trip value recorder function is built into the REx 5xx terminals, it records and displays:

- The pre-fault phasors
- The fault phasors

Figure 1: shows typical examples of the corresponding data windows. The appendix in this document contains explanations of the different parameter names.

a)	b)
.TripVal/PreFlt U1= 57.35 kV 0.00 deg	.TripVal/Flt I1= 4560 A 87.0 deg

Figure 1: Typical data windows, which display the phasors of voltages and currents.

The phasors of the pre-fault and fault voltages and currents are available under the menu:

DisturbReport
Disturbances
Disturbance n (n=1-10)
TripValues
PreFault (Fault)

Figure 1:a and 1b shows typical data windows. The first row indicates if the pre-fault or the fault value of the phasor is presented. The name of the phasor is located in the second row. Its RMS value appears in the third row, while the fourth row displays information about the relative phase position compared, as a reference, to the voltage in the L1 phase.

3.1 Setting of the user-defined names for phasors

Customer specific names for all the ten analogue inputs (five currents and five voltages) can be entered. Each name can have up to 13 alphanumeric characters. These names are common for all functions within the disturbance report functionality. See the document “*Terminal identification*” for further description and settings of the analogue inputs.

The user-defined names for the analogue inputs are set under the menu:

Configuration
AnalogInputs
U1 (U2..U5, I1..I5)

4 Appendix

Table 1: List of phasors

Default parameter:	**Description:**
	Phasors of the pre-fault primary voltages and currents for the disturbance n = 1 to 10; **Menu tree:** Disturb.Report—Disturbances—Disturbance n—TripValues—PreFault
U1	Phase value of the phase L1 voltage—RMS value and relative phase angle
U2	Phase value of the phase L2 voltage—RMS value and relative phase angle
U3	Phase value of the phase L3 voltage—RMS value and relative phase angle
U4	Residual voltage 3Uo—RMS value and relative phase angle
U5	Phase value of the busbar voltage, used for the purposes of synchro-check and dead-line-check function—RMS value and relative phase angle
I1	Phase value of the phase L1 current—RMS value and relative-phase angle
I2	Phase value of the phase L2 current—RMS value and relative-phase angle
I3	Phase value of the phase L3 current—RMS value and relative-phase angle
I4	Residual current 3Io - RMS value and relative-phase angle
I5	Residual current 3Io from the parallel line for the fault location function only—RMS value and relative-phase angle
Frequency	Frequency before the disturbance
	Phasors of the fault primary voltages and currents for the disturbance n = 1 to 10; **Menu tree:** Disturb.Report—Disturbances—Disturbance n—TripValues—Fault
U1	Phase value of the phase L1 voltage—RMS value and relative-phase angle
U2	Phase value of the phase L2 voltage—RMS value and relative-phase angle
U3	Phase value of the phase L3 voltage—RMS value and relative-phase angle
U4	Residual voltage 3Uo—RMS value and relative phase angle
U5	Phase value of the busbar voltage, used for the purposes of synchro-check and dead-line-check function—RMS value and relative phase angle
I1	Phase value of the phase L1 current—RMS value and relative-phase angle
I2	Phase value of the phase L2 current—RMS value and relative-phase angle
I3	Phase value of the phase L3 current—RMS value and relative-phase angle
I4	Residual current 3Io—RMS value and relative-phase angle
I5	Residual current 3Io from the parallel line for the purposes of a fault location function only—RMS value and relative-phase angle

1 Application

Fast, reliable supervision of different analogue quantities is of vital importance during the normal operation of a power system.

Operators in the control centres can, for example:

- Continuously follow active and reactive power flow in the network
- Supervise the busbar voltage level and frequency

Different measuring methods are available for different quantities. Current and voltage instrument transformers provide the basic information on measured phase currents and voltages in different points within the power system. At the same time, currents and voltages serve as the input measuring quantities to power and energy meters, protective devices and so on.

Further processing of this information occurs within different control, protection, and monitoring terminals and within the higher hierarchical systems in the secondary power system.

The REx 5xx protection, control, and monitoring terminals have a built-in option to measure and further process information about up to five input currents and five input voltages. The number of processed alternate measuring quantities depends on the type of terminal and built-in options. Additional information are also available:

- Mean values of measured currents I in the first, three current-measuring channels
- Mean values of measured voltages U in the first, three voltage-measuring channels
- Three-phase active power P as measured by the first, three current- and voltage-measuring channels
- Three-phase reactive power Q as measured by the first, three current- and voltage-measuring channels
- Frequency f

The accuracy of measurement depends on the requirements. Basic accuracy satisfies the operating (information) needs. An additional calibration of measuring channels is necessary and must be ordered separately when the requirements on accuracy of the measurement are higher. Refer to the technical data and ordering particulars, for the particular terminal.

The information on measured quantities are then available to the user on different locations:

- Locally by means of the local human-machine interface (HMI) unit
- Locally by means of a front-connected personal computer (PC)
- Remotely over the LON bus to the station control system (SCS)
- Remotely over the SPA port to the station monitoring system (SMS)

1.1 User-defined measuring ranges

Each measuring channel has an independent measuring range from the others. This allows the users to select the most suitable measuring range for each measuring quantity on each monitored object of the power system. In doing so, they optimize the functionality of the power system.

1.2 Continuous monitoring of the measured quantity

Users can continuously monitor the measured quantity in each channel by means of four built-in operating thresholds (figure 1). The monitors operate in two different modes of operation:

- Overfunction, when the measured current exceeds the **HiWarn** or **HiAlarm** pre-set values
- Underfunction, when the measured current decreases under the **LowWarn** or **LowAlarm** pre-set values

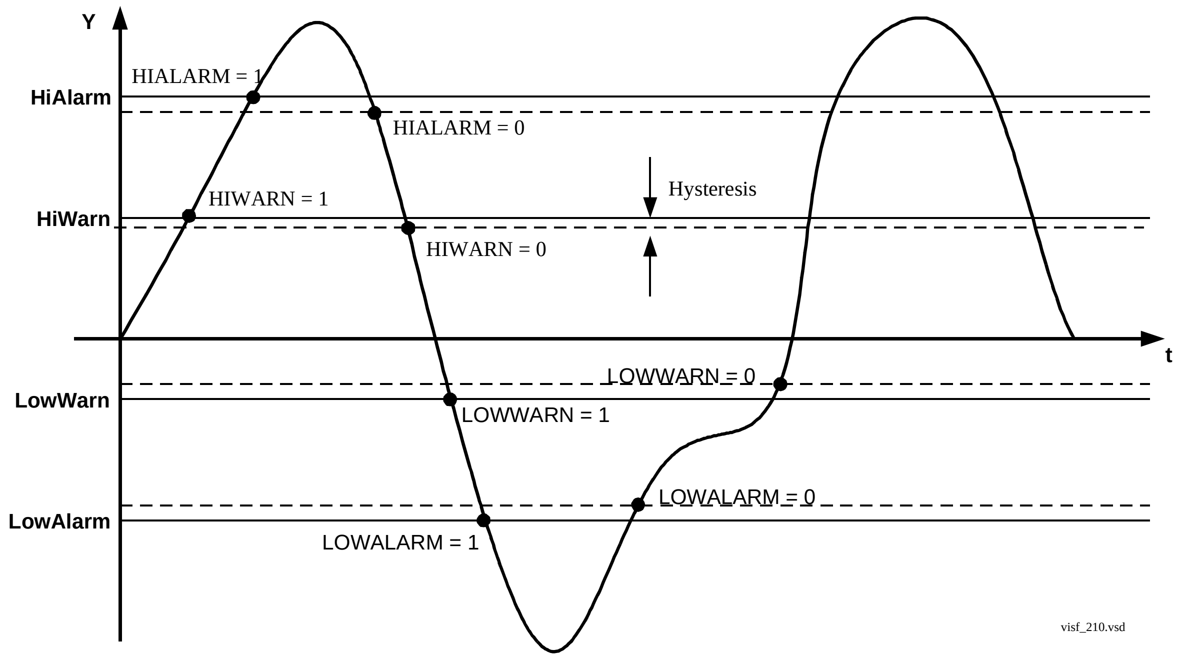


Figure 1: Presentation of the operating limits

Each operating level has its corresponding functional output signal:

- HIWARN
- HIALARM
- LOWWARN
- LOWALARM

The logical value of the functional output signals changes according to figure 1.

The user can set the hysteresis, which determines the difference between the operating and reset value at each operating point, in wide range for each measuring channel separately. The hysteresis is common for all operating values within one channel.

1.3 Continuous supervision of the measured quantity

The actual value of the measured quantity is available locally and remotely. The measurement is continuous for each channel separately, but the reporting of the value to the higher levels (control processor in the unit, HMI and SCS) depends on the selected reporting mode. The following basic reporting modes are available:

- Periodic reporting
- Periodic reporting with dead-band supervision in parallel
- Periodic reporting with dead-band supervision in series
- Dead-band reporting

Users can select between two types of dead-band supervision:

- Amplitude dead-band supervision (ADBS)
- Integrating dead-band supervision (IDBS)

1.3.1 Amplitude dead-band supervision

If the changed value —compared to the last reported value— is larger than the ± ΔY predefined limits that are set by users, and if this is detected by a new measuring sample, then the measuring channel reports the new value to a higher level. This limits the information flow to a minimum necessary. Figure 2 shows an example of periodic reporting with the amplitude dead-band supervision. The picture is simplified: the process is not continuous but the values are evaluated with a time interval of one second from each others.

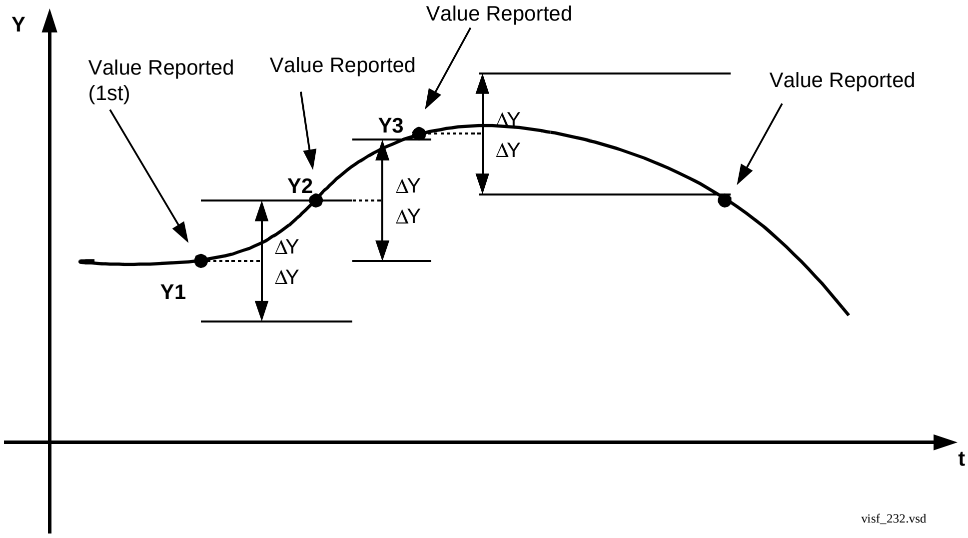


Figure 2: Amplitude dead-band supervision reporting

After the new value is reported, the new ± ΔY limits for dead-band are automatically set around it. The new value is reported only if the measured quantity changes more than defined by the new ±ΔY set limits.

1.3.2 Integrating dead-band supervision

The measured value is updated if the time integral of all changes exceeds the pre-set limit (figure 3), where an example of reporting with integrating dead-band supervision is shown. The picture is simplified: the process is not continuous but the values are evaluated with a time interval of one second from each others.

The last value reported (Y1 in figure 3) serves as a basic value for further measurement. A difference is calculated between the last reported and the newly measured value during new sample and is multiplied by the time increment (discrete integral). The absolute values of these products are added until the pre-set value is exceeded. This occurs with the value Y2 that is reported and set as a new base for the following measurements (as well as for the values Y3, Y4 and Y5).

The integrating dead-band supervision is particularly suitable for monitoring signals with low variations that can last for relatively long periods.

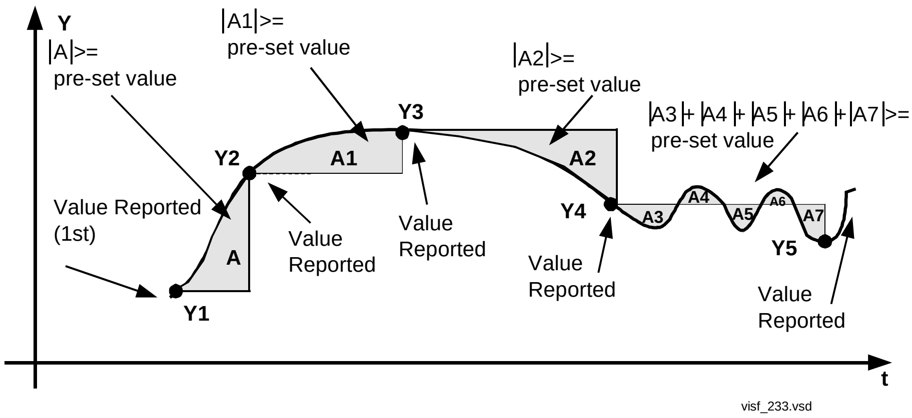


Figure 3: Reporting with integrating dead-band supervision

1.3.3 Periodic reporting

The user can select the periodic reporting of measured value in time intervals between 1 and 3600 s. The measuring channel reports the value even if it has not changed for more than the set limits of amplitude or integrating dead-band supervision. To disable periodic reporting, set the reporting time interval to 0 s (figure 4).

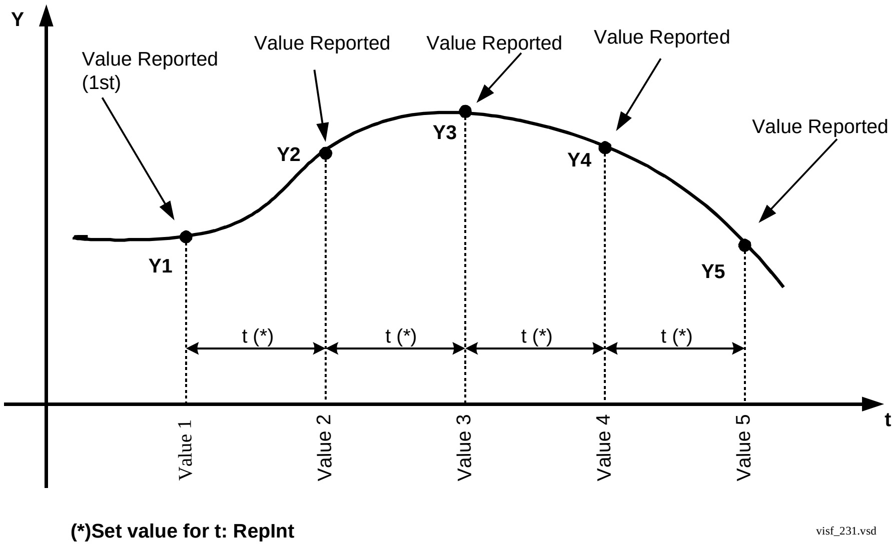


Figure 4: Periodic reporting

1.3.4 Periodic reporting with parallel dead-band supervision

The newly measured value is reported:

- After each time interval for the periodic reporting expired, **OR**
- When the new value is detected by the dead-band supervision function

The amplitude dead-band and the integrating dead-band can be selected. The periodic reporting can be set in time intervals between 1 and 3600 seconds.

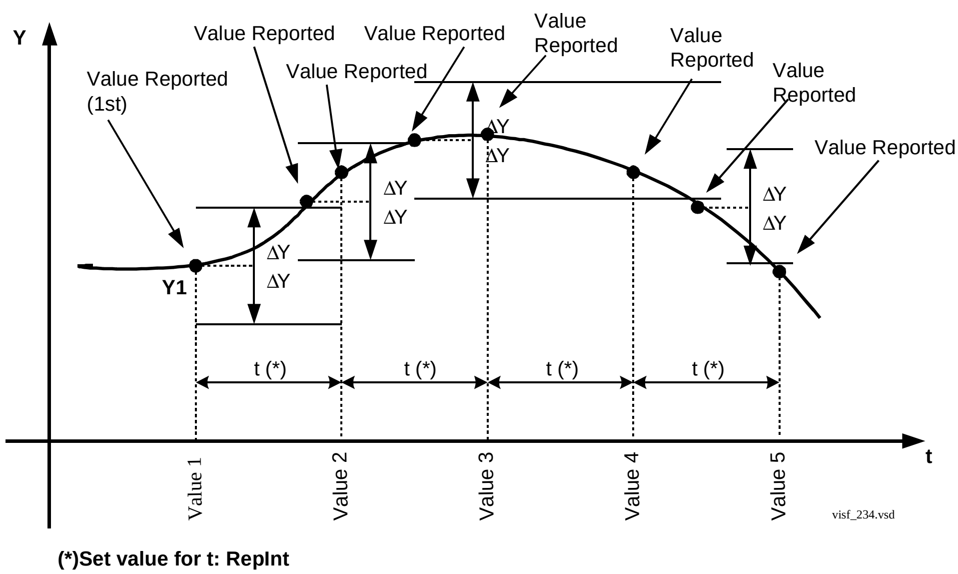
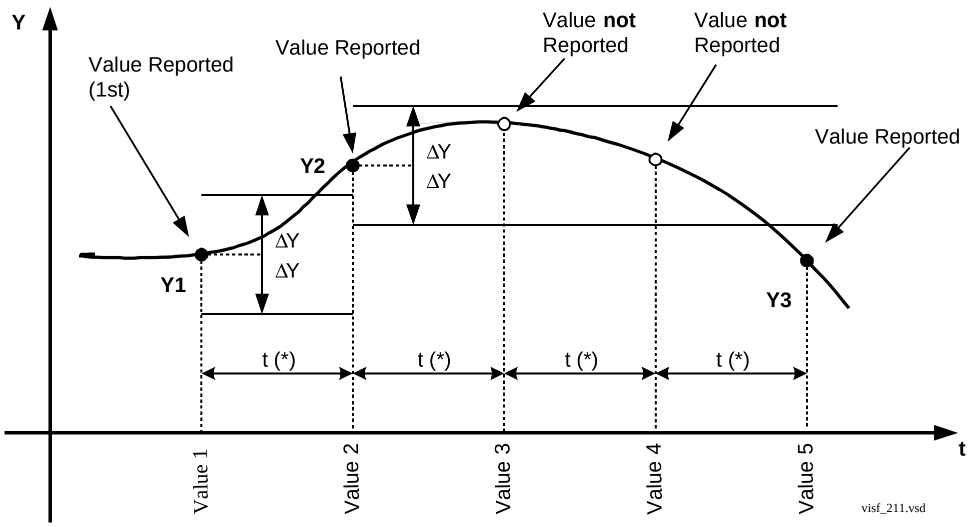


Figure 5: Periodic reporting with amplitude dead-band supervision in parallel

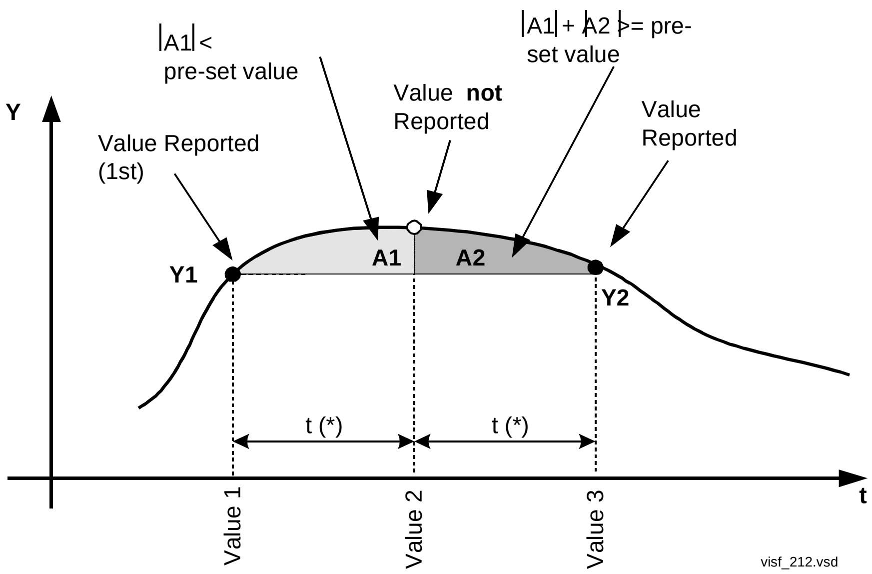
1.3.5 Periodic reporting with serial dead-band supervision

Periodic reporting can operate serially with the dead-band supervision. This means that the new value is reported only if the set time period expired **AND** if the dead-band limit was exceeded during the observed time (figures 6 and 7). The amplitude dead-band and the integrating dead-band can be selected. The periodic reporting can be set in time intervals between 1 and 3600 seconds.



(*)Set value for t: RepInt

Figure 6: Periodic reporting with amplitude dead-band supervision in series



(*)Set value for t: RepInt

Figure 7: Periodic reporting with integrating dead-band supervision in series

1.3.6 Combination of periodic reportings

The reporting of the new value depends on setting parameters for the dead-band and for the periodic reporting. Table 1 presents the dependence between different settings and the type of reporting for the new value of a measured quantity.

Table 1: Dependence of reporting on different setting parameters:

EnDeadB*	EnIDeadB*	EnDeadBP*	RepInt*	Reporting of the new value
Off	Off	Off	0	No measured values is reported
Off	On	On	t>0	The new measured value is reported only if the time t period expired and if, during this time, the integrating dead-band limits were exceeded (periodic reporting with integrating dead-band supervision in series)
On	Off	On	t>0	The new measured value is reported only if the time t period has expired and if, during this time, the amplitude dead-band limits were exceeded (periodic reporting with amplitude dead-band supervision in series)
On	On	On	t>0	The new measured value is reported only if the time t period expired and if at least one of the dead-band limits were exceeded (periodic reporting with dead-band supervision in series)
Off	On	Off	0	The new measured value is reported only when the integrated dead-band limits are exceeded
On	Off	Off	0	The new measured value is reported only when the amplitude dead-band limits were exceeded
On	On	Off	0	The new measured value is reported only if one of the dead-band limits was exceeded
x	x	Off	t>0	The new measured value is updated at least after the time t period expired. If the dead-band supervision is additionally selected, the updating also occurs when the corresponding dead-band limit was exceeded (periodic reporting with parallel dead-band supervision)

* please, refer to the setting table for the explanation

2 Theory of operation and Design

The design of the alternating quantities measuring function follows the design of all REx 5xx-series protection, control, and monitoring terminals that have distributed functionality, where the decision levels are placed as closely as possible to the process.

The measuring function uses the same input current and voltage signals as other protection and monitoring functions within the terminals (figure 8 on page 346). The number of input current and voltage transformers depends on the type of terminal and options included. The maximum possible configuration comprises five current and five voltage input channels.

Measured input currents and voltages are first filtered in analogue filters and then converted to numerical information by an A/D converter, which operates with a sampling frequency of 2 kHz.

The numerical information on measured currents and voltages continues over a serial link to one of the built-in digital signal processors (DSP). An additional Fourier filter numerically filters the received information, and the DSP calculates the corresponding values for the following quantities:

- Five input measured voltages (U1, U2, U3, U4, U5). RMS values
- Five input measured currents (I1, I2, I3, I4, I5). RMS Values
- Mean RMS value, U, of the three phase-to-phase voltages calculated from the first three phase-to-earth voltages U1, U2 and U3
- Mean RMS value, I, of the first three measured RMS values I1, I2, and I3
- Three-phase active power, P, related to the first three measured currents and voltages (I1, U1, I2, U2, I3, U3)
- Three-phase, reactive power, Q, related to the first three measured currents and voltages (I1, U1, I2, U2, I3, U3)
- Mean value of frequencies, f, as measured with voltages U1, U2, and U3

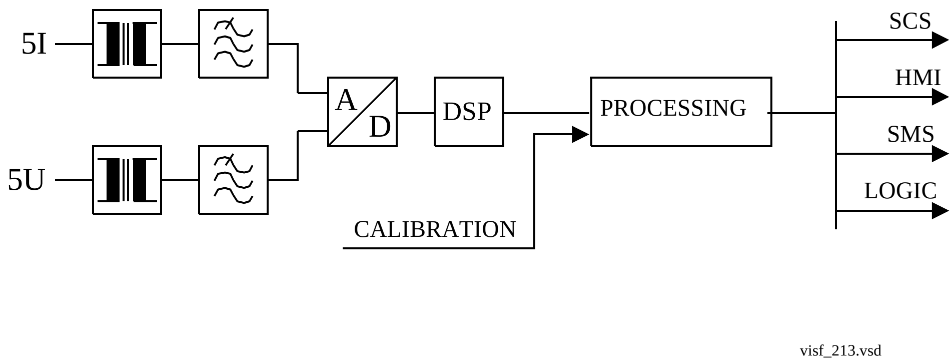


Figure 8: Simplified diagram for the function

This information is available to the user for operational purposes.

3 Setting instructions

The basic terminal parameters can be set from the HMI under the submenu:

Configuration
AnalogInputs
General
fr, CTEarth

So users can determine the rated parameters for the terminal:

- Rated frequency fr
- Position of the earthing point of the main CTs (CTEarth), which determines whether the CT earthing point is towards the protected object or the busbar.

The other basic terminal parameters, related to any single analog input, can be set under the submenu:

Configuration
AnalogInputs
U1, U2, U3, U4, U5, I1, I2, I3, I4, I5, U, I, P, Q, f

So the users can determine the base values, the primary CTs and VTs ratios, and the user-defined names for the analog inputs of the terminal.

Under U1:

- ac voltage base value for analog input U1: U1b
- voltage transformer input U1 nominal primary to secondary scale value: U1Scale
- Name (of up to 13 characters) of the analog input U1: Name

Under U2:

- ac voltage base value for analog input U2: U2b
- voltage transformer input U2 nominal primary to secondary scale value: U2Scale
- Name (of up to 13 characters) of the analog input U2: Name

Under U3:

- ac voltage base value for analog input U3: U3b
- voltage transformer input U3 nominal primary to secondary scale value: U3Scale
- Name (of up to 13 characters) of the analog input U3: Name

Under U4:

- ac voltage base value for analog input U4: U4b
- voltage transformer input U4 nominal primary to secondary scale value: U4Scale
- Name (of up to 13 characters) of the analog input U4: Name

Under U5:

- ac voltage base value for analog input U5: U5b
- voltage transformer input U5 nominal primary to secondary scale value: U5Scale
- Name (of up to 13 characters) of the analog input U5: Name

Under I1:

- ac current base value for analog input I1: I1b
- current transformer input I1 nominal primary to secondary scale value: I1Scale
- Name (of up to 13 characters) of the analog input I1: Name

Under I2:

- ac current base value for analog input I2: I2b
- current transformer input I2 nominal primary to secondary scale value: I2Scale
- Name (of up to 13 characters) of the analog input I2: Name

Under I3:

- ac current base value for analog input I3: I3b
- current transformer input I3 nominal primary to secondary scale value: I3Scale
- Name (up to 13 characters) of the analog input I3: Name

Under I4:

- ac current base value for analog input I4: I4b
- current transformer input I4 nominal primary to secondary scale value: I4Scale
- Name (of up to 13 characters) of the analog input I4: Name

Under I5:

- ac current base value for analog input I5: I5b
- current transformer input I5 nominal primary to secondary scale value: I5Scale
- Name (up to 13 characters) of the analog input I5: Name

Under U:

- Name (up to 13 characters) of the phase to phase voltage U: Name

Under I:

- Name (up to 13 characters) of the average current I: Name

Under P:

- Name (up to 13 characters) of the active power P: Name

Under Q:

- Name (up to 13 characters) of the reactive power Q: Name

Under f:

- Name (up to 13 characters) of the frequency value f: Name

The names of the first 10 quantities automatically appears in the REVAL evaluation program for each reported disturbance.

SMS and the CAP 531 configuration tool have to be used in order to set all remaining parameters that are related to different alternating measuring quantities.

In the settings menu it is possible to set all monitoring operating values and the hysteresis directly in the basic units of the measured quantities for each channel and for each quantity:

Settings
  DisturbReport
    AnalogSignals

The dead-band limits can be set directly in the corresponding units of the observed quantity for the:

- Amplitude dead-band supervision (ADBS)
- Integrating dead-band supervision (IDBS)

The IDBS area is defined by the following formula:

$$IDBS = \frac{IDeadB}{ReadFreq} = IDeadB \cdot ts \quad \text{(Equation 1)}$$

where:

$IDeadB$ is a set operating value for IDBS in corresponding unit

$ReadFreq$ is the reading frequency. It has a constant value of 1Hz

$ts = \frac{1}{ReadFreq}$ is the time between two samples (fixed to 1s).

The setting value for IDBS is IDeadB, and is expressed in the measuring unit of the monitored quantity (kV, A, MW, Mvar or Hz). The value is reported if the time integral area is greater than the value IDBS.

If a 0.1 Hz variation in the frequency for 10 minutes (600 s) is the event that should cause the reporting of the frequency monitored value, than the set value for IDeadB is 60 Hz.

The hysteresis can be set under the setting Hysteres.

Alarm and warning thresholds have to be set respectively under the settings HiAlarm (LowAlarm) and HiWarn (LowWarn).

The setting table lists all the setting parameters.

Note: It is important to set the time for periodic reporting and deadband in an optimised way to minimise the load on the station bus.

4 Testing

Stabilized ac current and voltage generators and corresponding current, voltage, power and frequency meters with very high accuracy are necessary for testing the alternating quantity measuring function. The operating ranges of the generators must correspond to the rated alternate current and voltage of each terminal.

Connect the generators and instruments to the corresponding input terminals of a unit under test. Check that the values presented on the HMI unit correspond to the magnitude of input measured quantities within the limits of declared accuracy. The mean service values are available under the submenu:

Service Report
    ServiceValues

The phasors of up to five input currents and voltages are available under the submenu:

Service Report
    Phasors
        Primary

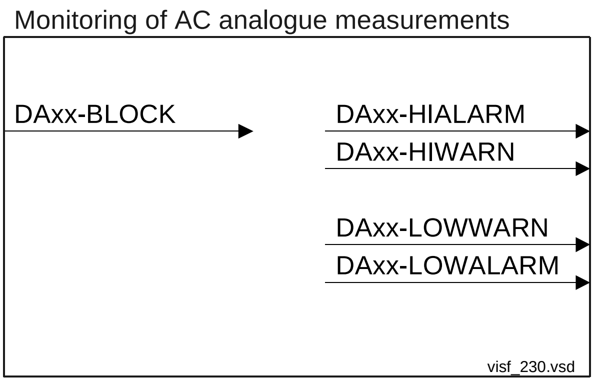
The operation of ADBS or IDBS function can be checked separately with the RepInt = 0 setting. The value on the HMI follows the changes in the input measuring quantity continuously.

Configure the monitoring output signals (see the signal list) to the corresponding output relays. Check the operating monitoring levels by changing the magnitude of input quantities and observing the operation of the corresponding output relays.

The output contact changes its state when the changes in the input measuring quantity are higher than the set values HIWARN, HIALARM, or lower than the set values LOWWARN, LOWALARM.

5 Appendix

5.1 Function block



5.2 Signal list

Table 2:

Block	Signal	Type	Description
DAxx-	BLOCK	IN	Block updating of value for U1
DAxx-	HIALARM	OUT	High Alarm U1
DAxx-	HIWARN	OUT	High Warning U1
DAxx-	LOWALARM	OUT	Low Alarm U1
DAxx-	LOWWARN	OUT	Low Warning U1

*1) The xx within the signal name corresponds to the following measuring quantities:

xx = 01 input measuring voltage U1

xx = 02 input measuring voltage U2

xx = 03 input measuring voltage U3

xx = 04 input measuring voltage U4

xx = 05 input measuring voltage U5

xx = 06 input measuring current I1

xx = 07 input measuring current I2

xx = 08 input measuring current I3

xx = 09 input measuring current I4

xx = 10 input measuring current I5

xx = 11 mean value U of the three phase to phase voltages calculated from the first three phase voltages U1, U2 and U3

xx = 12 mean value I of first three currents I1, I2 and I3

xx = 13 three phase active power P measured by first three voltage and current inputs

xx = 14 three phase reactive power Q measured by first three voltage and current inputs

xx = 15 mean value of frequency f as measured by first three voltage inputs U1, U2 and U3

5.3 Setting table

Table 3:

Parameter	Range	Unit	Default	Parameter description
				For each voltage input channels U1 - U5:
Operation	Off, On		Off	Direct Analogue Input U1 - U5 Off/On
Hysteres	0.0-1999.9	kV	5.0	Alarm hysteresis for U1 - U5 in kV
EnAlRem	Off, On		On	Immediate event when an alarm is disabled for U1 - U5 (produces an immediate event at reset of any alarm monitoring element, when On)

Table 3:

Parameter	**Range**	**Unit**	**Default**	**Parameter description**
EnAlarms	Off, On		On	Set to ’On’ to activate alarm supervision for U1 - U5 (produces an immediate event at operation of any alarm monitoring element, when On)
HiAlarm	0.0-1999.9	kV	220.0	High Alarm level for U1 - U5 in kV
HiWarn	0.0-1999.9	kV	210.0	High Warning level for U1 - U5 in kV
LowWarn	0.0-1999.9	kV	170.0	Low Warning level for U1 - U5 in kV
LowAlarm	0.0-1999.9	kV	160.0	Low Alarm level for U1 - U5 in kV
RepInt	0-3600	s	0	Time between reports for U1 - U5 in seconds. Zero = Off (duration of time interval between two reports at periodic reporting function. Setting to 0 disables the periodic reporting)
EnDeadB	Off, On		Off	Enable amplitude dead band supervision for U1 - U5
DeadBand	0.0-1999.9	kV	5.0	Amplitude dead band for U1 - U5 in kV
EnIDeadB	Off, On		Off	Enable integrating dead band supervision for U1 - U5
IDeadB	0.0-1999.9	kV	10.0	Integrating dead band for U1 - U5 in kV
EnDeadBP	Off, On		Off	Enable periodic dead band reporting U1 - U5
				For each voltage input channels I1 - I5:
Operation	Off, On		Off	Direct Analogue Input I1 - I5 Off/On
Hysteres	0-99999	A	50	Alarm hysteresis for I1 - I5 in A
EnAlRem	Off, On		On	Immediate event when an alarm is disabled for I1 - I5 (produces an immediate event at reset of any alarm monitoring element, when On)
EnAlarms	Off, On		Off	Set to ’On’ to activate alarm supervision for I1 - I5 (produces an immediate event at operation of any alarm monitoring element, when On)
HiAlarm	0-99999	A	900	High Alarm level for I1 - I5 in A
HiWarn	0-99999	A	800	High Warning level for I1 - I5 in A
LowWarn	0-99999	A	200	Low Warning level for I1 - I5 in A
LowAlarm	0-99999	A	100	Low Alarm level for I1 - I5 in A
RepInt	0-3600	s	0	Time between reports for I1 - I5 in seconds. Zero = Off (duration of time interval between two reports at periodic reporting function. Setting to 0 disables the periodic reporting)
EnDeadB	Off, On		Off	Enable amplitude dead band supervision for I1 - I5
DeadBand	0-99999	A	50	Amplitude dead band for I1 - I5 in A
EnIDeadB	Off, On		Off	Enable integrating dead band supervision for I1 - I5
IDeadB	0-99999	A	10000	Integrating dead band for I1 - I5 in A
EnDeadBP	Off, On		Off	Enable periodic dead band reporting I1 - I5
				Mean phase-to-phase voltage measuring channel U:
Operation	Off, On		Off	Direct Analogue Input U Off/On
Hysteres	0.0-1999.9	kV	5.0	Alarm hysteresis for U in kV

Table 3:

Parameter	Range	Unit	Default	Parameter description
EnAlRem	Off, On		On	Immediate event when an alarm is disabled for U (produces an immediate event at reset of any alarm monitoring element, when On)
EnAlarms	Off, On		On	Set to ’On’ to activate alarm supervision for U (produces an immediate event at operation of any alarm monitoring element, when On)
HiAlarm	0.0-1999.9	kV	220.0	High Alarm level for U in kV
HiWarn	0.0-1999.9	kV	210.0	High Warning level for U in kV
LowWarn	0.0-1999.9	kV	170.0	Low Warning level for U in kV
LowAlarm	0.0-1999.9	kV	160.0	Low Alarm level for U in kV
RepInt	0-3600	s	0	Time between reports for U in seconds. Zero = Off (duration of time interval between two reports at periodic reporting function. Setting to 0 disables the periodic reporting)
EnDeadB	Off, On		Off	Enable amplitude dead band supervision for U
DeadBand	0.0-1999.9	kV	5.0	Amplitude dead band for U in kV
EnIDeadB	Off, On		Off	Enable integrating dead band supervision for U
IDeadB	0.0-1999.9	kV	10.0	Integrating dead band for U in kV
EnDeadBP	Off, On		Off	Enable periodic dead band reporting U
				Mean current measuring channel I:
Operation	Off, On		Off	Direct Analogue Input I Off/On
Hysteres	0-99999	A	50	Alarm hysteresis for I in A
EnAlRem	Off, On		On	Immediate event when an alarm is disabled for I (produces an immediate event at reset of any alarm monitoring element, when On)
EnAlarms	Off, On		Off	Set to ’On’ to activate alarm supervision for I (produces an immediate event at operation of any alarm monitoring element, when On)
HiAlarm	0-99999	A	900	High Alarm level for I in A
HiWarn	0-99999	A	800	High Warning level for I in A
LowWarn	0-99999	A	200	Low Warning level for I in A
LowAlarm	0-99999	A	100	Low Alarm level for I in A
RepInt	0-3600	s	0	Time between reports for I in seconds. Zero = Off (duration of time interval between two reports at periodic reporting function. Setting to 0 disables the periodic reporting)
EnDeadB	Off, On		Off	Enable amplitude dead band supervision for I
DeadBand	0-99999	A	50	Amplitude dead band for I in A
EnIDeadB	Off, On		Off	Enable integrating dead band supervision for I
IDeadB	0-99999	A	10000	Integrating dead band for I in A
EnDeadBP	Off, On		Off	Enable periodic dead band reporting I
				Active power measuring channel P:
Operation	Off, On		Off	Direct Analogue Input P Off/On

Table 3:

Parameter	Range	Unit	Default	Parameter description
Hysteres	0.0-9999.9	MW	5.0	Alarm hysteresis for P in MW
EnAlRem	Off, On		On	Immediate event when an alarm is disabled for P (produces an immediate event at reset of any alarm monitoring element, when On)
EnAlarms	Off, On		Off	Set to 'On' to activate alarm supervision for P (produces an immediate event at operation of any alarm monitoring element, when On)
HiAlarm	0.0-9999.9	MW	300.0	High Alarm level for P in MW
HiWarn	0.0-9999.9	MW	200.0	High Warning level for P in MW
LowWarn	0.0-9999.9	MW	80.0	Low Warning level for P in MW
LowAlarm	0.0-9999.9	MW	50.0	Low Alarm level for P in MW
RepInt	0-3600	s	0	Time between reports for P in seconds. Zero = Off (duration of time interval between two reports at periodic reporting function. Setting to 0 disables the periodic reporting)
EnDeadB	Off, On		Off	Enable amplitude dead band supervision for P
DeadBand	0.0-9999.9	MW	1.0	Amplitude dead band for P in MW
EnIDeadB	Off, On		Off	Enable integrating dead band supervision for P
IDeadB	0.0-9999.9	MW	10.0	Integrating dead band for P in MW
EnDeadBP	Off, On		Off	Enable periodic dead band reporting P
				Reactive power measuring channel Q:
Operation	Off, On		Off	Direct Analogue Input Q Off/On
Hysteres	0.0-9999.9	Mvar	5.0	Alarm hysteresis for Q in Mvar
EnAlRem	Off, On		On	Immediate event when an alarm is disabled for Q (produces an immediate event at reset of any alarm monitoring element, when On)
EnAlarms	Off, On		Off	Set to 'On' to activate alarm supervision for Q (produces an immediate event at operation of any alarm monitoring element, when On)
HiAlarm	0.0-9999.9	Mvar	300.0	High Alarm level for Q in Mvar
HiWarn	0.0-9999.9	Mvar	200.0	High Warning level for Q in Mvar
LowWarn	0.0-9999.9	Mvar	80.0	Low Warning level for Q in Mvar
LowAlarm	0.0-9999.9	Mvar	50.0	Low Alarm level for Q in Mvar
RepInt	0-3600	s	0	Time between reports for Q in seconds. Zero = Off (duration of time interval between two reports at periodic reporting function. Setting to 0 disables the periodic reporting)
EnDeadB	Off, On		Off	Enable amplitude dead band supervision for Q
DeadBand	0.0-9999.9	Mvar	1.0	Amplitude dead band for Q in Mvar
EnIDeadB	Off, On		Off	Enable integrating dead band supervision for Q
IDeadB	0.0-9999.9	Mvar	10.0	Integrating dead band for Q in Mvar
EnDeadBP	Off, On		Off	Enable periodic dead band reporting Q
				Frequency measuring channel f:

Table 3:

Parameter	Range	Unit	Default	Parameter description
Operation	Off, On		Off	Direct Analogue Input f Off/On
Hysteres	0.0-99.9	Hz	1.0	Alarm hysteresis for f in Hz
EnAlRem	Off, On		On	Immediate event when an alarm is disabled for f (produces an immediate event at reset of any alarm monitoring element, when On)
EnAlarms	Off, On		Off	Set to ’On’ to activate alarm supervision for f (produces an immediate event at operation of any alarm monitoring element, when On)
HiAlarm	0.0-99.9	Hz	55.0	High Alarm level for f in Hz
HiWarn	0.0-99.9	Hz	53.0	High Warning level for f in Hz
LowWarn	0.0-99.9	Hz	47.0	Low Warning level for f in Hz
LowAlarm	0.0-99.9	Hz	45.0	Low Alarm level for f in Hz
RepInt	0-3600	s	0	Time between reports for f in seconds. Zero = Off (duration of time interval between two reports at periodic reporting function. Setting to 0 disables the periodic reporting)
EnDeadB	Off, On		Off	Enable amplitude dead band supervision for f
DeadBand	0.0-99.9	Hz	1.0	Amplitude dead band for f in Hz
EnIDeadB	Off, On		Off	Enable integrating dead band supervision for f
IDeadB	0.0-99.9	Hz	5	Integrating dead band for f in Hz
EnDeadBP	Off, On		Off	Enable periodic dead band reporting f
				Reporting of events to the station control system (SCS) through LON port
EventMask U1	No Events, Report Events			Enables (Report Events) or disables (No Events) the reporting of events from channel DA01 to the SCS
EventMask U2	No Events, Report Events			Enables (Report Events) or disables (No Events) the reporting of events from channel DA02 to the SCS
EventMask U3	No Events, Report Events			Enables (Report Events) or disables (No Events) the reporting of events from channel DA03 to the SCS
EventMask U4	No Events, Report Events			Enables (Report Events) or disables (No Events) the reporting of events from channel DA04 to the SCS
EventMask U5	No Events, Report Events			Enables (Report Events) or disables (No Events) the reporting of events from channel DA05 to the SCS
EventMask I1	No Events, Report Events			Enables (Report Events) or disables (No Events) the reporting of events from channel DA06 to the SCS
EventMask I2	No Events, Report Events			Enables (Report Events) or disables (No Events) the reporting of events from channel DA07 to the SCS
EventMask I3	No Events, Report Events			Enables (Report Events) or disables (No Events) the reporting of events from channel DA08 to the SCS
EventMask I4	No Events, Report Events			Enables (Report Events) or disables (No Events) the reporting of events from channel DA09 to the SCS
EventMask I5	No Events, Report Events			Enables (Report Events) or disables (No Events) the reporting of events from channel DA10 to the SCS

Table 3:

Parameter	Range	Unit	Default	Parameter description
EventMask U	No Events, Report Events			Enables (Report Events) or disables (No Events) the reporting of events from channel DA11 to the SCS
EventMask I	No Events, Report Events			Enables (Report Events) or disables (No Events) the reporting of events from channel DA12 to the SCS
EventMask P	No Events, Report Events			Enables (Report Events) or disables (No Events) the reporting of events from channel DA13 to the SCS
EventMask Q	No Events, Report Events			Enables (Report Events) or disables (No Events) the reporting of events from channel DA14 to the SCS
EventMask f	No Events, Report Events			Enables (Report Events) or disables (No Events) the reporting of events from channel DA15 to the SCS

1 Application

Fast, reliable supervision of different analogue quantities is of vital importance during the normal operation of a power system. Operators in the control centres can, for example:

- Continuously follow active and reactive power flow in the network
- Supervise the busbar voltages
- Check the temperature of power transformers, shunt reactors
- Monitor the gas pressure in circuit breakers

Different measuring methods are available for different quantities. Current and voltage instrument transformers provide the basic information on measured phase currents and voltages in different points within the power system. At the same time, currents and voltages serve as the input measuring quantities to power and energy meters.

Different measuring transducers provide information on electrical and non-electrical measuring quantities such as voltage, current, temperature, and pressure. In most cases, the measuring transducers change the values of the measured quantities into the direct current. The current value usually changes within the specified mA range—in proportion to the value of the measured quantity.

Further processing of the direct currents obtained on the outputs of different measuring converters occurs within different control, protection, and monitoring terminals and within the higher hierarchical systems in the secondary power system.

The REx 5xx control, protection and monitoring terminal have a built-in option to measure and further process information from 6 up to 36 different direct current information from different measuring transducers. Six independent measuring channels are located on each independent mA input module and the REx 5xx terminals can accept from one up to six independent mA input modules, depending on the case size. Refer to the technical data and ordering particulars for the particular terminal.

Information about the measured quantities are then available to the user on different locations:

- Locally by means of the local human-machine-interface (HMI)
- Locally by means of a front-connected personal computer (PC)
- Remotely over the LON bus to the station control system (SCS)
- Remotely over the SPA port to the station monitoring system (SMS)

1.1 User-defined measuring ranges

The measuring range of different direct current measuring channels is settable by the user independent on each other within the range between -25 mA and +25 mA in steps of 0.01 mA. It is only necessary to select the upper operating limit **I_max** higher than the lower one **I_min**.

The measuring channel can have a value of 2% of the whole range I_max - I_min above the upper limit I_max or below the lower limit I_min, before an out-of-range error occurs. This means that with a nominal range of 0-10 mA, no out-of-range event will occur with a value between -0.2 mA and 10.2 mA.

User can this way select for each measuring quantity on each monitored object of a power system the most suitable measuring range and this way optimise a complete functionality together with the characteristics of the used measuring transducer.

1.2 Continuous monitoring of the measured quantity

The user can continuously monitor the measured quantity in each channel by means of six built-in operating limits (figure 1). Two of them are defined by the operating range selection: **I_Max** as the upper and **I_Min** as the lower operating limit. The other four operating limits operate in two different modes:

- Overfunction, when the measured current exceeds the **HiWarn** or **HiAlarm** pre-set values
- Underfunction, when the measured current decreases under the **Low-Warn** or **LowAlarm** pre-set values

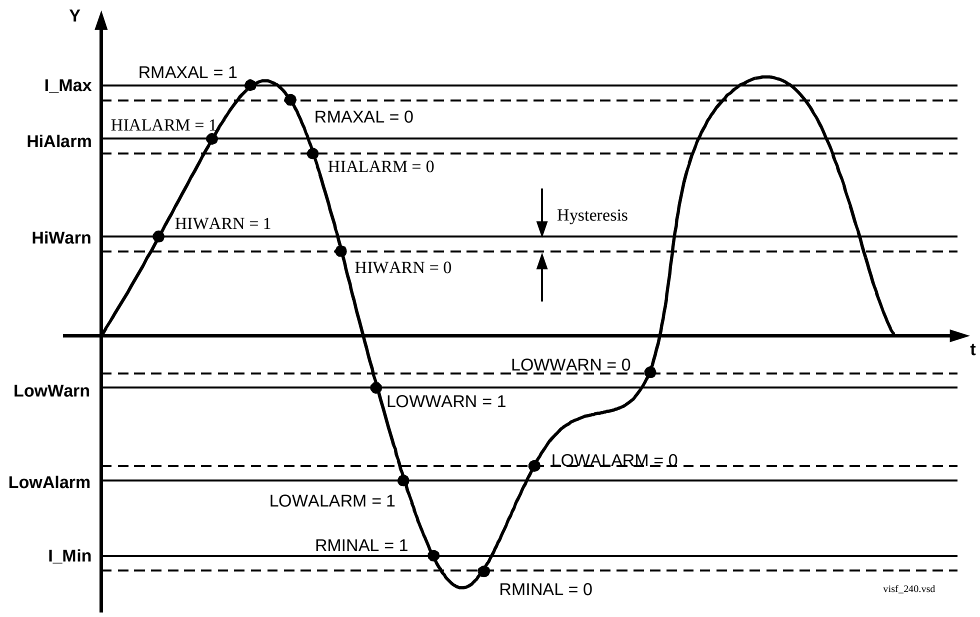


Figure 1: Presentation of the operating limits

Each operating level has its corresponding functional output signal:

- RMAXAL
- HIWARN
- HIALARM
- LOWWARN

- LOWALARM
- RMINAL

The logical value of the functional output signals changes according to figure 1 on page 358.

The user can set the hysteresis, which determines the difference between the operating and reset value at each operating point, in wide range for each measuring channel separately. The hysteresis is common for all operating values within one channel.

1.3 Continuous supervision of the measured quantity

The actual value of the measured quantity is available locally and remotely. The measurement is continuous for each channel separately, but the reporting of the value to the higher levels (control processor in the unit, HMI and SCS) depends on the selected reporting mode. The following basic reporting modes are available:

- Periodic reporting
- Periodic reporting with dead-band supervision in parallel
- Periodic reporting with dead-band supervision in series
- Dead-band reporting

Users can select between two types of dead-band supervision:

- Amplitude dead-band supervision (ADBS)
- Integrating dead-band supervision (IDBS)

1.3.1 Amplitude dead-band supervision

If the changed value —compared to the last reported value— is larger than the $\pm \Delta Y$ predefined limits that are set by users, and if this is detected by a new measuring sample, then the measuring channel reports the new value to a higher level. This limits the information flow to a minimum necessary. Figure 2 on page 360 shows an example of periodic reporting with the amplitude dead-band supervision.

The picture is simplified: the process is not continuous but the values are evaluated at a time intervals depending on the sampling frequency chosen by the user (SampRate setting).

After the new value is reported, the new $\pm \Delta Y$ limits for dead-band are automatically set around it. The new value is reported only if the measured quantity changes more than defined by the new $\pm\Delta Y$ set limits.

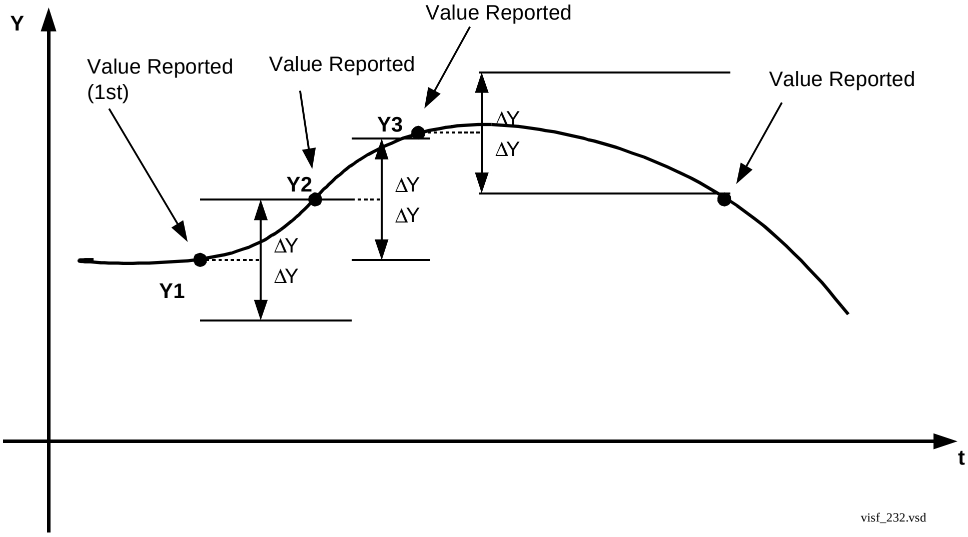


Figure 2: Amplitude dead-band supervision reporting

1.3.2 Integrating dead-band supervision

The measured value is updated if the time integral of all changes exceeds the pre-set limit (figure 3), where an example of reporting with integrating dead-band supervision is shown. The picture is simplified: the process is not continuous but the values are evaluated with a time interval of one second from each others.

The last value reported (Y1 in figure 3) serves as a basic value for further measurement. A difference is calculated between the last reported and the newly measured value during new sample and is multiplied by the time increment (discrete integral). The absolute values of these products are added until the pre-set value is exceeded. This occurs with the value Y2 that is reported and set as a new base for the following measurements (as well as for the values Y3, Y4 and Y5).

The integrating dead-band supervision is particularly indicate for monitoring signals with low variations that can last for relatively long periods.

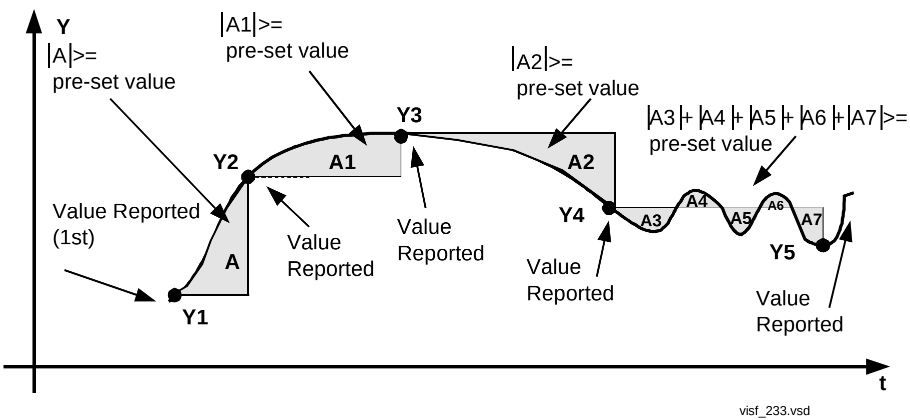
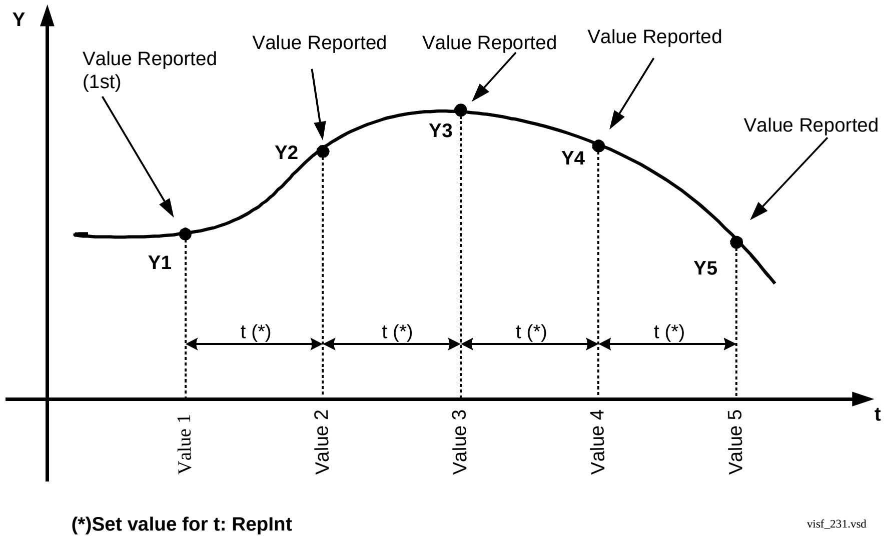


Figure 3: Reporting with integrating dead-band supervision

1.3.3 Periodic reporting

The user can select the periodic reporting of measured value in time intervals between 1 and 3600 s (setting RepInt). The measuring channel reports the value even if it has not changed for more than the set limits of amplitude or integrating dead-band supervision (figure 4). To disable the periodic reporting, set the reporting time interval to 0 s .



(*)Set value for t: RepInt

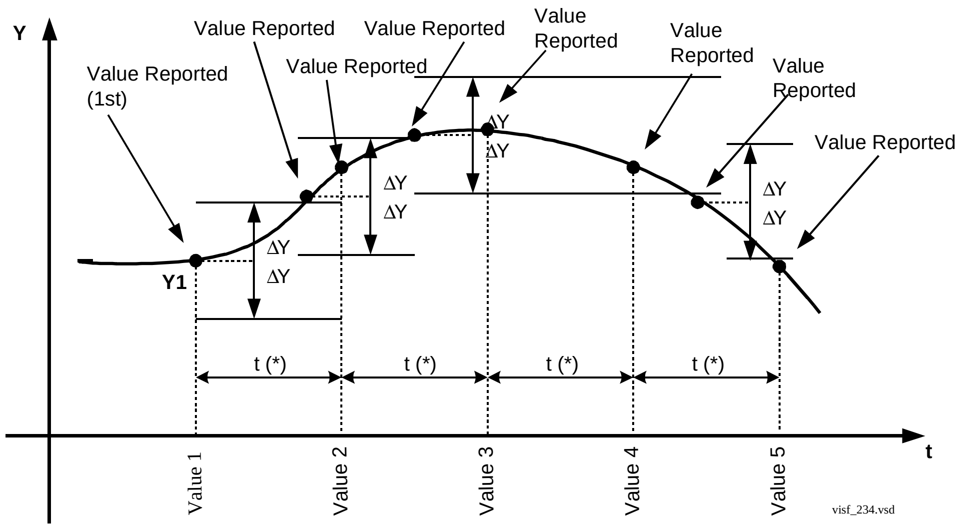
Figure 4: Periodic reporting

1.3.4 Periodic reporting with parallel dead-band supervision

The newly measured value is reported:

- After each time interval for the periodic reporting expired, **OR**
- When the new value is detected by the dead-band supervision function

Both amplitude and integrating dead-bands can be selected. The periodic reporting can be set in time intervals between 1 and 3600 seconds.

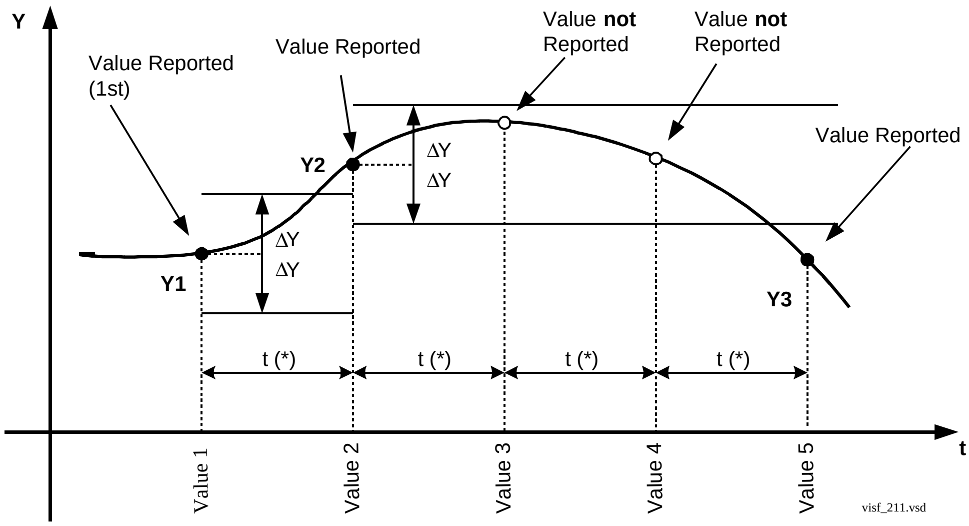


(*)Set value for t: RepInt

Figure 5: Periodic reporting with amplitude dead-band supervision in parallel

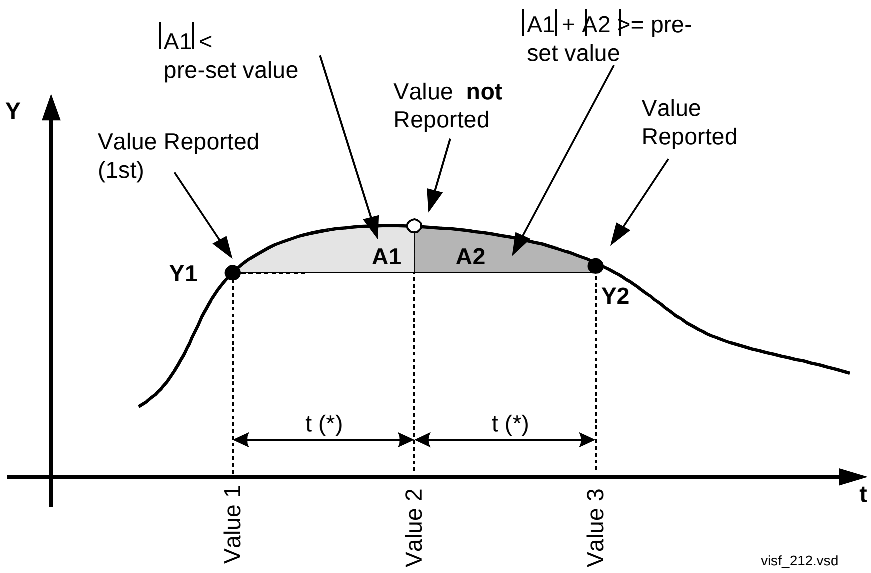
1.3.5 Periodic reporting with serial dead-band supervision

Periodic reporting can operate serially with the dead-band supervision. This means that the new value is reported only if the set time period expired **AND** if the dead-band limit was exceeded during the observed time (figures 6 and 7). The amplitude dead-band and the integrating dead-band can be selected. The periodic reporting can be set in time intervals between 1 and 3600 seconds.



(*)Set value for t: RepInt

Figure 6: Periodic reporting with amplitude dead-band supervision in series



(*)Set value for t: RepInt

Figure 7: Periodic reporting with integrating dead-band supervision in series

1.3.6 Combination of periodic reportings

The reporting of the new value depends on setting parameters for the dead-band and for the periodic reporting. Table 1 presents the dependence between different settings and the type of reporting for the new value of a measured quantity.

Table 1: Dependence of reporting on different setting parameters:

EnDeadB*	EnIDeadB*	EnDeadBP*	RepInt*	**Reporting of the new value**
Off	Off	Off	0	No measured values is reported
Off	On	On	t>0	The new measured value is reported only if the time t period expired and if, during this time, the integrating dead-band limits were exceeded (periodic reporting with integrating dead-band supervision in series)
On	Off	On	t>0	The new measured value is reported only if the time t period has expired and if, during this time, the amplitude dead-band limits were exceeded (periodic reporting with amplitude dead-band supervision in series)
On	On	On	t>0	The new measured value is reported only if the time t period expired and if at least one of the dead-band limits were exceeded (periodic reporting with dead-band supervision in series)
Off	On	Off	0	The new measured value is reported only when the integrated dead-band limits are exceeded
On	Off	Off	0	The new measured value is reported only when the amplitude dead-band limits were exceeded
On	On	Off	0	The new measured value is reported only if one of the dead-band limits was exceeded
x	x	Off	t>0	The new measured value is updated at least after the time t period expired. If the dead-band supervision is additionally selected, the updating also occurs when the corresponding dead-band limit was exceeded (periodic reporting with parallel dead-band supervision)

* please, refer to the setting table for the explanation

2 Theory of operation and Design

The design of the mA input modules follows the design of all REx 5xx-series protection, control, and monitoring terminals that have distributed functionality, where the decision levels are placed as closely as possible to the process.

Each independent measuring module contains all necessary circuitry and functionality for measurement of six independent measuring quantities related to the corresponding measured direct currents.

On the accurate input shunt resistor (R), the direct input current (from the measuring converter) is converted into a proportional voltage signal (the voltage drop across the shunt resistor is in proportion to the measured current). Later, the voltage signal is processed within one differential type of measuring channel (figure 8).

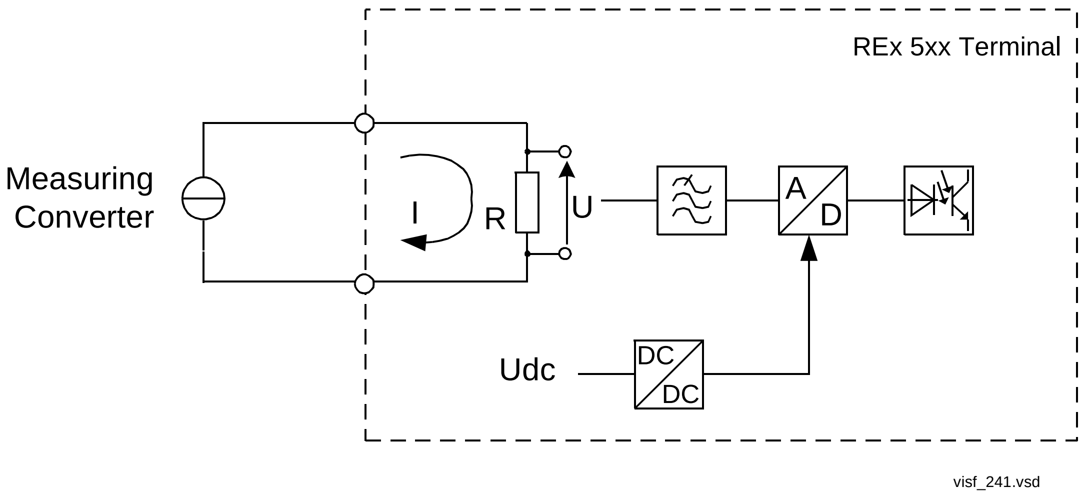


Figure 8: Simplified diagram for the function

The measured voltage is filtered by the low-pass analogue filter before entering the analogue to digital converter (A/D). Users can set the sampling frequency of the A/D converter between 5 Hz and 255 Hz to adapt to different application requirements as best as possible.

The digital information is filtered by the digital low-pass filter with the $(\sin x/x)^3$ response. The filter notch frequency automatically follows the selected sampling frequency. The relation between the frequency corresponding to the suppression of -3 dB and the filter notch frequency corresponds to the equation:

$$f_{-3dB} = 0,262 \cdot f_{notch}$$

Using optocouplers and DC/DC conversion elements that are used separately for each measuring channel, the input circuitry of each measuring channel is galvanically separated from:

- The internal measuring circuits
- The control microprocessor on the board

A microprocessor collects the digitized information from each measuring channel. The microprocessor serves as a communication interface to the main processing module (MPM).

All processing of the measured signal is performed on the module so that only the minimum amount of information is necessary to be transmitted to and from the MPM. The measuring module receives information from the MPM on setting and the command parameters; it reports the measured values and additional information—according to needs and values of different parameters.

Each measuring channel is calibrated very accurately during the production process. The continuous internal zero offset and full-scale calibration during the normal operation is performed by the A/D converter. The calibration covers almost all analogue parts of the A/D conversion, but neglects the shunt resistance.

Each measuring channel has built in a zero-value supervision, which greatly rejects the noise generated by the measuring transducers and other external equipment. The value of the measured input current is reported equal to zero (0) if the measured primary quantity does not exceed ±0.5% of the maximum measuring range.

The complete measuring module is equipped with advanced self-supervision. Only the outermost analogue circuits cannot be monitored. The A/D converter, optocouplers, digital circuitry, and DC/DC converters, are all supervised on the module. Over the CAN bus, the measuring module sends a message to the MPM for any detected errors on the supervised circuitry.

3 Setting instructions

SMS and the CAP 531 configuration tool have to be used in order to set all the parameters that are related to different DC analogue quantities.

Users can set the 13 character name for each measuring channel.

All the monitoring operating values and the hysteresis can be set directly in the mA of the measured input currents from the measuring transducers.

The measured quantities can be displayed locally and/or remotely according to the corresponding modules that are separately set for each measuring channel by the users (five characters).

The relation between the measured quantity in the power system and the setting range of the direct current measuring channel corresponds to this equation:

$$Value = ValueMin + (I - IMin) \cdot \frac{ValueMax - ValueMin}{IMax - IMin} \qquad \text{(Equation 1)}$$

Where:

$IMin$ is the set value for the minimum operating current of a channel in mA

$IMax$ is the set value for the maximum operating current of a channel in mA

$ValueMin$ is the value of the primary measuring quantity corresponding to the set value of minimum operating current of a channel, $IMin$

$ValueMax$ is the value of the primary measuring quantity corresponding to the set value of maximum operating current of a channel, $IMax$

$Value$ is the actual value of the primary measured quantity

Figure 9 shows the relationship between the direct mA current I and the actual value of the primary measured quantity, $Value$.

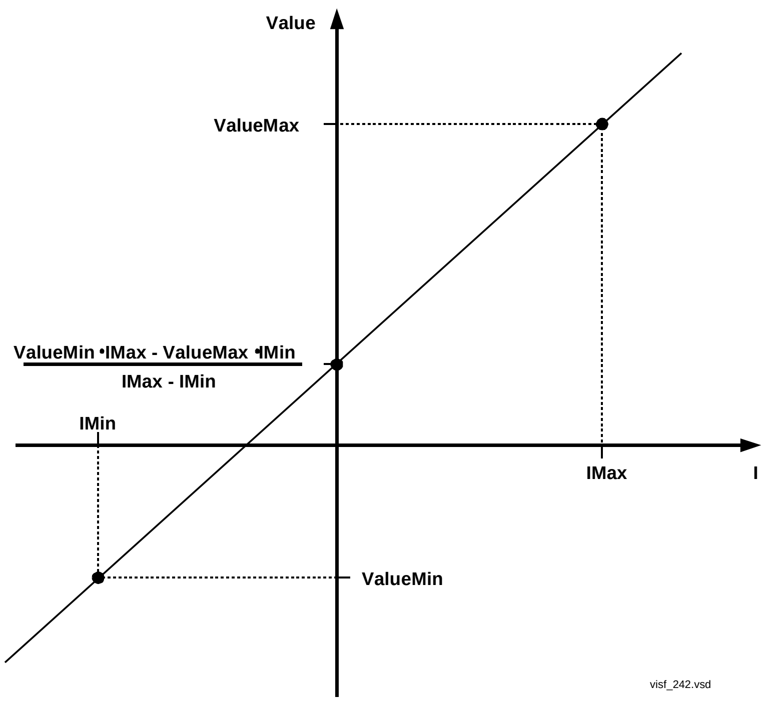


Figure 9: Relationship between the direct current (I) and the measured quantity primary value (Value)

The dead-band limits can be set directly in the mA of the input direct current for:

- Amplitude dead-band supervision ADBS
- Integrating dead-band supervision IDBS

The $IDBS$ area [mAs] is defined by the following equation:

$$IDBS = \frac{IDeadB}{SampRate} = IDeadB \cdot ts \qquad \text{(Equation 2)}$$

where:

$IDeadB$ is the set value of the current level for IDBS in mA

$SampRate$ is the sampling rate (frequency) set value, in Hz

$ts = \frac{1}{SampRate}$ is the time between two samples in s.

If a 0.1 mA variation in the monitored quantity for 10 minutes (600 s) is the event that should cause the trigger of the IDBS monitoring (reporting of the value because of IDBS threshold operation) and the sampling frequency (SampRate) of the monitored quantity is 5 Hz, than the set value for IDBS (IDeadB) will be 300 mA:

$$IDBS = 0.1 \cdot 600 = 60[mA\ s] \qquad \text{(Equation 3)}$$

$$IDeadB = IDBS \cdot SampRate = 60 \cdot 5 = 300[mA] \qquad \text{(Equation 4)}$$

The polarity of connected direct current input signal can be changed by setting the ChSign to On or Off. This way it is possible to compensate by setting the eventually wrong connection of the direct current leeds between the measuring converter and the input terminals of the REx 5xx series unit.

The setting table lists all setting parameters with additional explanation.

Note: It is important to set the time for periodic reporting and deadband in an optimised way to minimise the load on the station bus.

4 Testing

A stabilized direct current generator and mA meter with very high accuracy for measurement of direct current is needed in order to test the dc measuring module. The generator operating range and the measuring range of the mA meter must be at least between -25 and 25 mA.

Connect the current generator and mA meter to the corresponding direct current input terminals. Check that the values presented on the HMI module corresponds to the magnitude of input direct current within the limits of declared accuracy. The service value is available under the submenu:

Service Report
- **I/O**
  - **Slotnm-MIMx**
    - **MIxy-Value**

where:

nm represents the serial number of a slot with tested mA input module

x represents the serial number of a mA input module in a terminal

y represents the serial number of a measuring channel on module x.

The operation of ADBS or IDBS function can be checked separately with the setting of RepInt = 0. The value on the HMI must change only when the changes in input current (compared to the present value) are higher than the set value for the selected dead band.

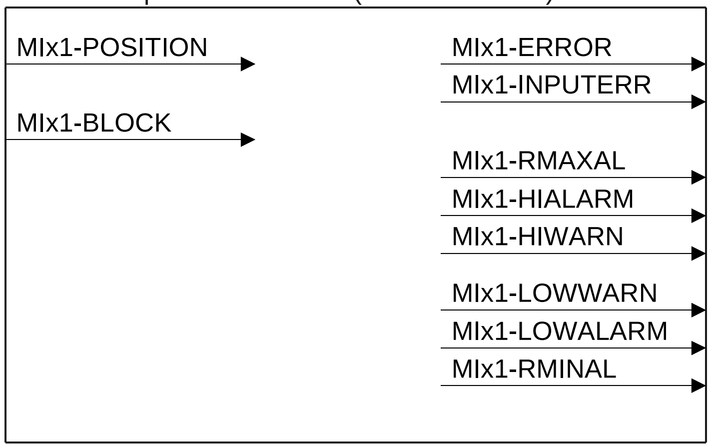
Configure the monitoring output signals (see the signal list) to the corresponding output relays. Check the operating monitoring levels by changing the magnitude of input current and observing the operation of the corresponding output relays.

The output contact changes its state when the changes in the input measuring quantity are higher than the set values RMAXAL, HIWARN, HIALARM, or lower than the set values LOWWARN, LOWALARM, RMINAL.

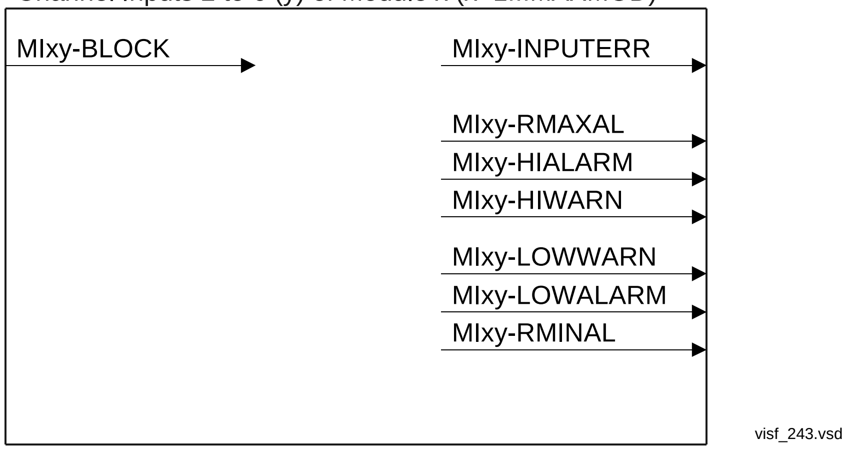
5 Appendix

5.1 Function blocks

Monitoring of DC analogue measurements
Channel Input 1 of Module x (x=1...MAXMOD)



Monitoring of DC analogue measurements
Channel Inputs 2 to 6 (y) of Module x (x=1...MAXMOD)



MAXMOD: REx 5xx terminals can accept from one up to six independent mA input modules, depending on the case size. Refer to the technical data and ordering particulars for the particular terminal.

5.2 Signal list

Table 2:

Block	Signal	Type	Description
			Module signals and input 1
MIx1-	POSITION	IN	Position of module number x
MIx1-	BLOCK	IN	Block updating of values input 1
MIx1-	ERROR	OUT	Board Error on module number x. It signalises also the wrong module on the specified position.
MIx1-	INPUTERR	OUT	Error on input 1
MIx1-	RMAXAL	OUT	Rangemax Alarm input 1
MIx1-	HIALARM	OUT	High Alarm input 1
MIx1-	HIWARN	OUT	High Warning input 1
MIx1-	LOWWARN	OUT	Low Warning input 1
MIx1-	LOWALARM	OUT	Low Alarm input 1
MIx1-	RMINAL	OUT	Rangemin Alarm input 1
			Input 2
MIx2	BLOCK	IN	Block updating of values input 2
MIx2-	INPUTERR	OUT	Error on input 2
MIx2-	RMAXAL	OUT	Rangemax Alarm input 2
MIx2-	HIALARM	OUT	High Alarm input 2
MIx2-	HIWARN	OUT	High Warning input 2
MIx2-	LOWWARN	OUT	Low Warning input 2
MIx2-	LOWALARM	OUT	Low Alarm input 2
MIx2-	RMINAL	OUT	Rangemin Alarm input 2
			Input 3
MIx3	BLOCK	IN	Block updating of values input 3
MIx3-	INPUTERR	OUT	Error on input 3
MIx3-	RMAXAL	OUT	Rangemax Alarm input 3
MIx3-	HIALARM	OUT	High Alarm input 3
MIx3-	HIWARN	OUT	High Warning input 3
MIx3-	LOWWARN	OUT	Low Warning input 3
MIx3-	LOWALARM	OUT	Low Alarm input 3
MIx3-	RMINAL	OUT	Rangemin Alarm input 3
			Input 4
MIx4	BLOCK	IN	Block updating of values input 4
MIx4-	INPUTERR	OUT	Error on input 4
MIx4-	RMAXAL	OUT	Rangemax Alarm input 4
MIx4-	HIALARM	OUT	High Alarm input 4
MIx4-	HIWARN	OUT	High Warning input 4
MIx4-	LOWWARN	OUT	Low Warning input 4
MIx4-	LOWALARM	OUT	Low Alarm input 4

Table 2:

Block	Signal	Type	Description
MIx4-	RMINAL	OUT	Rangemin Alarm input 4
			Input 5
MIx5	BLOCK	IN	Block updating of values input 5
MIx5-	INPUTERR	OUT	Error on input 5
MIx5-	RMAXAL	OUT	Rangemax Alarm input 5
MIx5-	HIALARM	OUT	High Alarm input 5
MIx5-	HIWARN	OUT	High Warning input 5
MIx5-	LOWWARN	OUT	Low Warning input 5
MIx5-	LOWALARM	OUT	Low Alarm input 5
MIx5-	RMINAL	OUT	Rangemin Alarm input 5
			Input 6
MIx6	BLOCK	IN	Block updating of values input 6
MIx6-	INPUTERR	OUT	Error on input 6
MIx6-	RMAXAL	OUT	Rangemax Alarm input 6
MIx6-	HIALARM	OUT	High Alarm input 6
MIx6-	HIWARN	OUT	High Warning input 6
MIx6-	LOWWARN	OUT	Low Warning input 6
MIx6-	LOWALARM	OUT	Low Alarm input 6
MIx6-	RMINAL	OUT	Rangemin Alarm input 6

The x within the block name corresponds to the module number.

5.3 Setting table

Table 3: Setting table for a generic input module

Parameter	Range	Unit	Default	Parameter description
				Module Parameter
SampRate	5-255	Hz	5	Sampling Rate for mA Input Module x
				Input 1
Name	Usr def. string	String	MI61-Value	Use defined name for input 1. String length up to 13 characters, all characters available on the HMI can be used
Operation	Off, On		Off	Input 1 On/Off
Calib	Off, On		On	Set to ’On’ to use production calibration for Input 1
ChSign	Off, On		Off	Set to ’On’ if sign of Input 1 shall be changed
Unit	0-5		Unit1	State a 5 character unit name for Input 1
Hysteres	0.0-20.0	mA	1.0	Alarm hysteresis for Input 1 in mA
EnAlRem	Off, On		Off	Immediate event when an alarm is removed for Input 1
I_Max	-25.00-25.00	mA	20.00	Max current of transducer to Input 1 in mA
I_Min	-25.00-25.00	mA	4.00	Min current of transducer to Input 1 in mA

Table 3: Setting table for a generic input module

Parameter	Range	Unit	Default	Parameter description
EnAlarm	Off, On		Off	Set to 'On' to activate alarm supervision for Input 1
HiAlarm	-25.00-25.00	mA	19.00	High Alarm level for Input 1 in mA
HiWarn	-25.00-25.00	mA	18.00	High Warning level for Input 1 in mA
LowWarn	-25.00-25.00	mA	6.00	Low warning level for Input 1 in mA
LowAlarm	-25.00-25.00	mA	5.00	Low Alarm level for Input 1 in mA
RepInt	0-3600	s	0	Time between reports for Input 1 in seconds
EnDeadB	Off, On		Off	Enable amplitude dead band supervision for Input 1
DeadBand	0.00-20.00	mA	1.00	Amplitude dead band for Input 1 in mA
EnIDeadB	Off, On		Off	Enable integrating dead band supervision for Input 1
IDeadB	0.00-1000.00	mA	2.00	Integrating dead band for Input 1 in mA
EnDeadBP	Off, On		Off	Enable periodic dead band reporting Input 1
MaxValue	-1000.00-1000.00	(*)	20.00	Max primary value corr. to I_Max, Input 1. It determines the maximum value of the measuring transducer primary measuring quantity, which corresponds to the maximum permitted input current I_Max
MinValue	-1000.00-1000.00	(*)	4.00	Min primary value corr. to I_Min, Input 1. It determines the minimum value of the measuring transducer primary measuring quantity, which corresponds to the minimum permitted input current I_Min
				Input 2
Name	Usr def. string	String	MI62-Value	Use defined name for input 2. String length up to 13 characters, all characters available on the HMI can be used
Operation	Off, On		Off	Input 2 On/Off
Calib	Off, On		On	Set to 'On' to use production calibration for Input 2
ChSign	Off, On		Off	Set to 'On' if sign of Input 2 shall be changed
Unit	0-5		Unit2	State a 5 character unit name for Input 2
Hysteres	0.0-20.0	mA	1.0	Alarm hysteresis for Input 2 in mA
EnAlRem	Off, On		Off	Immediate event when an alarm is removed for Input 2
I_Max	-25.00-25.00	mA	20.00	Max current of transducer to Input 2 in mA
I_Min	-25.00-25.00	mA	4.00	Min current of transducer to Input 2 in mA
EnAlarm	Off, On		Off	Set to 'On' to activate alarm supervision for Input 2
HiAlarm	-25.00-25.00	mA	19.00	High Alarm level for Input 2 in mA
HiWarn	-25.00-25.00	mA	18.00	High Warning level for Input 2 in mA
LowWarn	-25.00-25.00	mA	6.00	Low warning level for Input 2 in mA
LowAlarm	-25.00-25.00	mA	5.00	Low Alarm level for Input 2 in mA
RepInt	0-3600	s	0	Time between reports for Input 2 in seconds
EnDeadB	Off, On		Off	Enable amplitude dead band supervision for Input 2
DeadBand	0.00-20.00	mA	1.00	Amplitude dead band for Input 2 in mA
EnIDeadB	Off, On		Off	Enable integrating dead band supervision for Input 2
IDeadB	0.00-1000.00	mA	2.00	Integrating dead band for Input 2 in mA
EnDeadBP	Off, On		Off	Enable periodic dead band reporting Input 2

Table 3: Setting table for a generic input module

Parameter	Range	Unit	Default	Parameter description
MaxValue	-1000.00-1000.00	(*)	20.00	Max primary value corr. to I_Max, Input 2. It determines the maximum value of the measuring transducer primary measuring quantity, which corresponds to the maximum permitted input current I_Max
MinValue	-1000.00-1000.00	(*)	4.00	Min primary value corr. to I_Min, Input 2. It determines the minimum value of the measuring transducer primary measuring quantity, which corresponds to the minimum permitted input current I_Min
				Input 3
Name	Usr def. string	String	MI63-Value	Use defined name for input 3. String length up to 13 characters, all characters available on the HMI can be used
Operation	Off, On		Off	Input 3 On/Off
Calib	Off, On		On	Set to 'On' to use production calibration for Input 3
ChSign	Off, On		Off	Set to 'On' if sign of Input 3 shall be changed
Unit	0-5		Unit3	State a 5 character unit name for Input 3
Hysteres	0.0-20.0	mA	1.0	Alarm hysteresis for Input 3 in mA
EnAlRem	Off, On		Off	Immediate event when an alarm is removed for Input 3
I_Max	-25.00-25.00	mA	20.00	Max current of transducer to Input 3 in mA
I_Min	-25.00-25.00	mA	4.00	Min current of transducer to Input 3 in mA
EnAlarm	Off, On		Off	Set to 'On' to activate alarm supervision for Input 3
HiAlarm	-25.00-25.00	mA	19.00	High Alarm level for Input 3 in mA
HiWarn	-25.00-25.00	mA	18.00	High Warning level for Input 3 in mA
LowWarn	-25.00-25.00	mA	6.00	Low warning level for Input 3 in mA
LowAlarm	-25.00-25.00	mA	5.00	Low Alarm level for Input 3 in mA
RepInt	0-3600	s	0	Time between reports for Input 3 in seconds
EnDeadB	Off, On		Off	Enable amplitude dead band supervision for Input 3
DeadBand	0.00-20.00	mA	1.00	Amplitude dead band for Input 3 in mA
EnIDeadB	Off, On		Off	Enable integrating dead band supervision for Input 3
IDeadB	0.00-1000.00	mA	2.00	Integrating dead band for Input 3 in mA
EnDeadBP	Off, On		Off	Enable periodic dead band reporting Input 3
MaxValue	-1000.00-1000.00	(*)	20.00	Max primary value corr. to I_Max, Input 3. It determines the maximum value of the measuring transducer primary measuring quantity, which corresponds to the maximum permitted input current I_Max
MinValue	-1000.00-1000.00	(*)	4.00	Min primary value corr. to I_Min, Input 3. It determines the minimum value of the measuring transducer primary measuring quantity, which corresponds to the minimum permitted input current I_Min
				Input 4
Name	Usr def. string	String	MI64-Value	Use defined name for input 4. String length up to 13 characters, all characters available on the HMI can be used
Operation	Off, On		Off	Input 4 On/Off
Calib	Off, On		On	Set to 'On' to use production calibration for Input 4

Table 3: Setting table for a generic input module

Parameter	Range	Unit	Default	Parameter description
ChSign	Off, On		Off	Set to ’On’ if sign of Input 4 shall be changed
Unit	0-5		Unit4	State a 5 character unit name for Input 4
Hysteres	0.0-20.0	mA	1.0	Alarm hysteresis for Input 4 in mA
EnAlRem	Off, On		Off	Immediate event when an alarm is removed for Input 4
I_Max	-25.00-25.00	mA	20.00	Max current of transducer to Input 4 in mA
I_Min	-25.00-25.00	mA	4.00	Min current of transducer to Input 4 in mA
EnAlarm	Off, On		Off	Set to ’On’ to activate alarm supervision for Input 4
HiAlarm	-25.00-25.00	mA	19.00	High Alarm level for Input 4 in mA
HiWarn	-25.00-25.00	mA	18.00	High Warning level for Input 4 in mA
LowWarn	-25.00-25.00	mA	6.00	Low warning level for Input 4 in mA
LowAlarm	-25.00-25.00	mA	5.00	Low Alarm level for Input 4 in mA
RepInt	0-3600	s	0	Time between reports for Input 4 in seconds
EnDeadB	Off, On		Off	Enable amplitude dead band supervision for Input 4
DeadBand	0.00-20.00	mA	1.00	Amplitude dead band for Input 4 in mA
EnIDeadB	Off, On		Off	Enable integrating dead band supervision for Input 4
IDeadB	0.00-1000.00	mA	2.00	Integrating dead band for Input 4 in mA
EnDeadBP	Off, On		Off	Enable periodic dead band reporting Input 4
MaxValue	-1000.00-1000.00	(*)	20.00	Max primary value corr. to I_Max, Input 4. It determines the maximum value of the measuring transducer primary measuring quantity, which corresponds to the maximum permitted input current I_Max
MinValue	-1000.00-1000.00	(*)	4.00	Min primary value corr. to I_Min, Input 4. It determines the minimum value of the measuring transducer primary measuring quantity, which corresponds to the minimum permitted input current I_Min
				Input 5
Name	Usr def. string	String	MI65-Value	Use defined name for input 5. String length up to 13 characters, all characters available on the HMI can be used
Operation	Off, On		Off	Input 5 On/Off
Calib	Off, On		On	Set to ’On’ to use production calibration for Input 5
ChSign	Off, On		Off	Set to ’On’ if sign of Input 5 shall be changed
Unit	0-5		Unit5	State a 5 character unit name for Input 5
Hysteres	0.0-20.0	mA	1.0	Alarm hysteresis for Input 5 in mA
EnAlRem	Off, On		Off	Immediate event when an alarm is removed for Input 5
I_Max	-25.00-25.00	mA	20.00	Max current of transducer to Input 5 in mA
I_Min	-25.00-25.00	mA	4.00	Min current of transducer to Input 5 in mA
EnAlarm	Off, On		Off	Set to ’On’ to activate alarm supervision for Input 5
HiAlarm	-25.00-25.00	mA	19.00	High Alarm level for Input 5 in mA
HiWarn	-25.00-25.00	mA	18.00	High Warning level for Input 5 in mA
LowWarn	-25.00-25.00	mA	6.00	Low warning level for Input 5 in mA
LowAlarm	-25.00-25.00	mA	5.00	Low Alarm level for Input 5 in mA
RepInt	0-3600	s	0	Time between reports for Input 5 in seconds

Table 3: Setting table for a generic input module

Parameter	**Range**	**Unit**	**Default**	**Parameter description**
EnDeadB	Off, On		Off	Enable amplitude dead band supervision for Input 5
DeadBand	0.00-20.00	mA	1.00	Amplitude dead band for Input 5 in mA
EnIDeadB	Off, On		Off	Enable integrating dead band supervision for Input 5
IDeadB	0.00-1000.00	mA	2.00	Integrating dead band for Input 5 in mA
EnDeadBP	Off, On		Off	Enable periodic dead band reporting Input 5
MaxValue	-1000.00-1000.00	(*)	20.00	Max primary value corr. to I_Max, Input 5. It determines the maximum value of the measuring transducer primary measuring quantity, which corresponds to the maximum permitted input current I_Max
MinValue	-1000.00-1000.00	(*)	4.00	Min primary value corr. to I_Min, Input 5. It determines the minimum value of the measuring transducer primary measuring quantity, which corresponds to the minimum permitted input current I_Min
				Input 6
Name	Usr def. string	String	MI66-Value	Use defined name for input 6. String length up to 13 characters, all characters available on the HMI can be used
Operation	Off, On		Off	Input 6 On/Off
Calib	Off, On		On	Set to 'On' to use production calibration for Input 6
ChSign	Off, On		Off	Set to 'On' if sign of Input 6 shall be changed
Unit	0-5		Unit6	State a 5 character unit name for Input 6
Hysteres	0.0-20.0	mA	1.0	Alarm hysteresis for Input 6 in mA
EnAlRem	Off, On		Off	Immediate event when an alarm is removed for Input 6
I_Max	-25.00 - 25.00	mA	20.00	Max current of transducer to Input 6 in mA
I_Min	-25.00 - 25.00	mA	4.00	Min current of transducer to Input 6 in mA
EnAlarm	Off, On		Off	Set to 'On' to activate alarm supervision for Input 6
HiAlarm	-25.00-25.00	mA	19.00	High Alarm level for Input 6 in mA
HiWarn	-25.00-25.00	mA	18.00	High Warning level for Input 6 in mA
LowWarn	-25.00-25.00	mA	6.00	Low warning level for Input 6 in mA
LowAlarm	-25.00-25.00	mA	5.00	Low Alarm level for Input 6 in mA
RepInt	0-3600	s	0	Time between reports for Input 6 in seconds
EnDeadB	Off, On		Off	Enable amplitude dead band supervision for Input 6
DeadBand	0.00-20.00	mA	1.00	Amplitude dead band for Input 6 in mA
EnIDeadB	Off, On		Off	Enable integrating dead band supervision for Input 6
IDeadB	0.00-1000.00	mA	2.00	Integrating dead band for Input 6 in mA
EnDeadBP	Off, On		Off	Enable periodic dead band reporting Input 6
MaxValue	-1000.00-1000.00	(*)	20.00	Max primary value corr. to I_Max, Input 6. It determines the maximum value of the measuring transducer primary measuring quantity, which corresponds to the maximum permitted input current I_Max
MinValue	-1000.00-1000.00	(*)	4.00	Min primary value corr. to I_Min, Input 6. It determines the minimum value of the measuring transducer primary measuring quantity, which corresponds to the minimum permitted input current I_Min

Note: (*) is referred to the five characters user-defined setting parameter called “Unit” where the user can write the name of the unit of the measuring converter input measuring quantity.

1 Application

The pulse counter function provides the Substation Automation system with the number of pulses, which have been accumulated in the REx 5xx terminal during a defined period of time, for calculation of, for example, energy values. The pulses are captured on the Binary Input Module (BIM) that is read by the pulse counter function. The number of pulses in the counter is then reported via LON to the station HMI or read via SPA as a service value.

The normal use for this function is the counting of energy pulses for kWh and kvarh in both directions from external energy meters. Up to 12 binary inputs in a REx 5xx can be used for this purpose with a frequency of up to 40 Hz.

2 Theory of operation

The registration of pulses is done for positive transitions (0–>1) on one of the 16 binary input channels located on the Binary Input Module (BIM). Pulse counter values are read from the station HMI with predefined cyclicity without reset, and an analogue event is created.

The integration time period can be set in the range from 30 seconds to 60 minutes and is synchronised with absolute system time. That means, a cycle time of one minute will generate a pulse counter reading every full minute. Interrogation of additional pulse counter values can be done with a command (intermediate reading) for a single counter. All active counters can also be read by the LON General Interrogation command (GI).

The pulse counter in REx 5xx supports unidirectional incremental counters. That means only positive values are possible. The counter uses a 32 bit format, that is, the reported value is a 32-bit, signed integer with a range 0...+2147483647. The counter is reset at initialisation of the terminal or by turning the pulse counter operation parameter Off/On.

The reported value to station HMI over the LON bus contains Identity, Value, Time, and Pulse Counter Quality. The Pulse Counter Quality consists of:

- Invalid (board hardware error or configuration error)
- Wrapped around
- Blocked
- Adjusted

The transmission of the counter value by SPA can be done as a service value, that is, the value frozen in the last integration cycle is read by the station HMI from the database. The pulse counter function updates the value in the database when an integration cycle is finished and activates the NEW_VAL signal in the function block. This signal can be connected to an Event function block, be time tagged, and transmitted to the station HMI. This time corresponds to the time when the value was frozen by the function.

3 Design

The function can be regarded as a function block with a few inputs and outputs. The inputs are divided into two groups: settings and connectables (configuration). The outputs are divided into three groups: signals (binary), service value for SPA, and analogue event for LON.

Figure 1: shows the pulse counter function block with connections of the inputs and outputs.

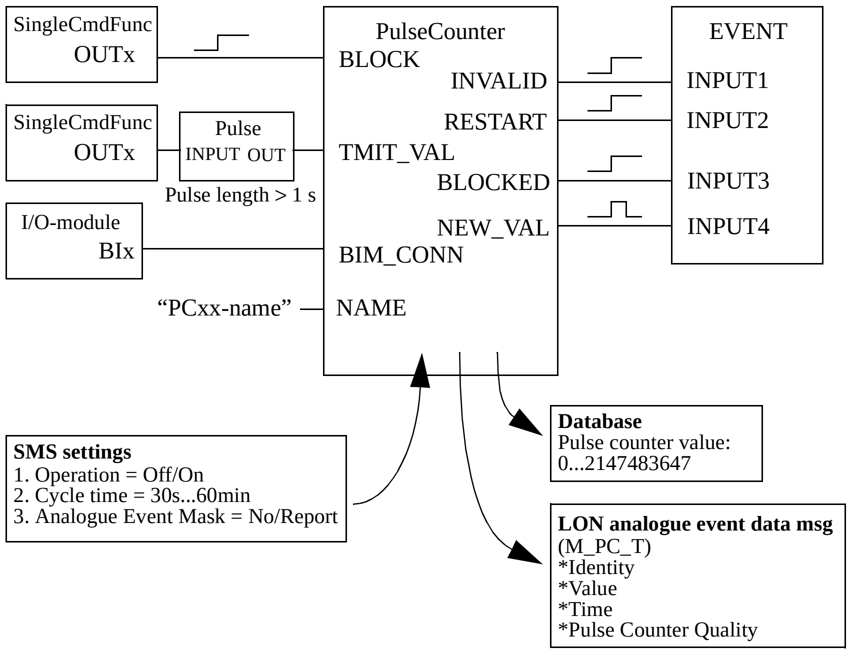


Figure 1: Overview of the pulse counter function

The BLOCK and TMIT_VAL inputs can be connected to Single Command blocks, which are intended to be controlled either from the station HMI or/and the local HMI. As long as the BLOCK signal is set, the pulse counter is blocked. The signal connected to TMIT_VAL performs one additional reading per positive flank. The signal must be a pulse with a length >1 second.

The BIM_CONN input is connected to the used input of the function block for the Binary Input Module (BIM). If BIM_CONN is connected to another function block, the INVALID signal is activated to indicate the configuration error.

The NAME input is used for a user-defined name with up to 19 characters.

Each pulse counter function block has four output signals: INVALID, RESTART, BLOCKED, and NEW_VAL. These signals can be connected to an Event function block for event recording.

The INVALID signal is a steady signal and is set if the Binary Input Module, where the pulse counter input is located, fails or has wrong configuration.

The RESTART signal is a steady signal and is set when the reported value does not comprise a complete integration cycle. That is, in the first message after terminal start-up, in the first message after deblocking, and after the counter has wrapped around during last integration cycle.

The BLOCKED signal is a steady signal and is set when the counter is blocked. There are two reasons why the counter is blocked:

- The BLOCK input is set, or
- The Binary Input Module, where the counter input is situated, is inoperative.

The NEW_VAL signal is a pulse signal. The signal is set if the counter value was updated since last report.

4 Setting

From SMS under the “Set Pulse Counter 1...12” menu, these parameters can be set individually for each pulse counter:

- Operation = Off/On
- Cycle Time = 30s / 1min / 1min30s / 2min / 2min30s / 3min / 4min / 5min / 6min / 7min30s / 10min / 12min / 15min / 20min / 30min / 60min.

Under “Mask - Analogue Events” in SMS, the reporting of the analogue events can be masked:

- Event Mask = No Events/Report Events

The configuration of the inputs and outputs of the pulse counter function block is made by the CAP 531 configuration tool.

The appendix shows the parameters and their setting ranges.

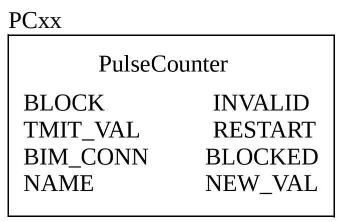
On the Binary Input Module, the debounce filter time is fixed set to 5 ms, that is, the counter suppresses pulses with a pulse length less than 5 ms. The input oscillation blocking frequency is preset to 40 Hz. That means that the counter finds the input oscillating if the input frequency is greater than 40 Hz. The oscillation suppression is released at 30 Hz. From SMS under the “Configure I/O-modules” menu and from the local HMI, the values for blocking/release of the oscillation can be changed. Note that the setting is common for all channels on a Binary Input Module, that is, if changes of the limits are made for inputs not connected to the pulse counter, the setting also influences the inputs on the same board used for pulse counting.

5 Testing

The test of the pulse counter function requires at least a SPA (or LON) connection to a station HMI including corresponding functionality. A known number of pulses are with different frequency connected to the pulse-counter input. The test should be performed for the settings operation = Off/On and for blocked/deblocked function. The pulse counter value is then read by the station HMI.

6 Appendix

6.1 Function block



6.2 Signal list

PC01-	**BIM_CONN**	**IN**	**Binary input module connection used for pulse aquisition**
PC01-	BLOCK	IN	Block aquisition
PC01-	TMIT_VAL	IN	Asyncronous reading. Pulsing of this input makes an additional reading of the pulse input. Value is read at TMIT_VAL positive flank
PC01-	BLOCKED	OUT	Set when BLOCK input is set or when the used BIM is inoperative
PC01-	INVALID	OUT	Set when used BIM fails or has wrong configuration
PC01-	NEW_VAL	OUT	New value exists. Set if counter value has changed since last read report
PC01-	RESTART	OUT	Set if counter value does not comprise a full integration cycle for read report
PC01-	NAME		See settings table

6.3 Setting table

Parameter	Range	Unit	Default	Parameter description
NAME	User def. string	String	PC01-NAME	User defined name String length up to 19 characters. Can only be set using the CAP 531 configuration tool
Operation	Off, On		Off	Pulse counter Off/On. Can only be set from SMS
CycleTime	30s, 1min, 1min30s, 2min, 2min30s, 3min, 4min, 5min, 6min, 7min30s, 10min, 12min, 15min, 20min,30min, 60min		15min	Reporting of counter value cycle time in minutes and seconds. Can only be set from SMS
EventMaskx	No events, Report events		No events	Mask for analogue events from pulse counter x (x=01-12). Can only be set from SMS