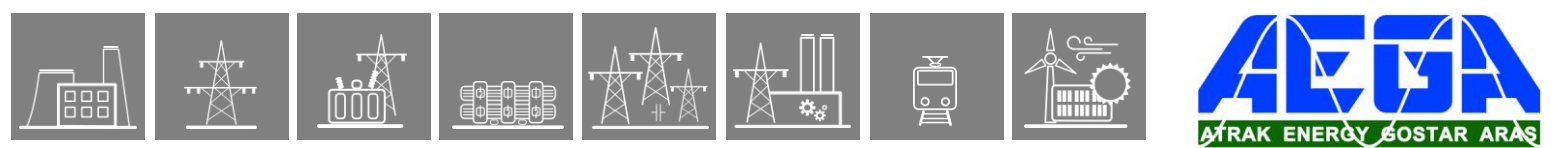


Manual

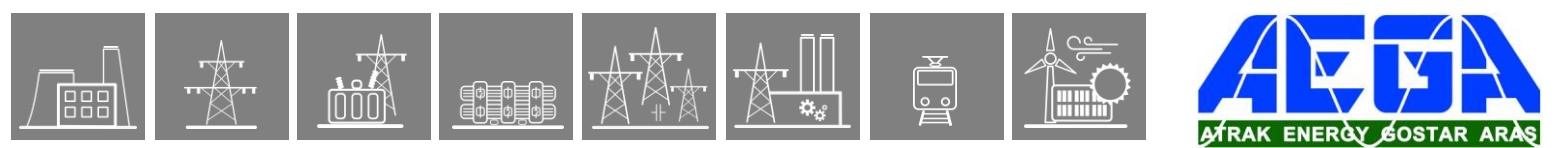
Transformer Protection & control
EuroProt+/DTRV

E5-TR



VERSION INFORMATION

| NAME | DOCUMENT ID | VERSION | DATE |
|-----------------------------------------------------------------------------------------|--------------|---------|------------|
| EuroProt+ DTRV type | PP-13-21886 | 1.0 | 2019-04-04 |
| EuroProt+ Hardware description | PP-13-19958 | 2.0 | 2023-02-10 |
| Overexcitation protection function | PP-13-22350 | 2.0 | 2021-05-21 |
| Definite time undervoltage protection function | PP-13-21403 | 1.1 | 2017-01-11 |
| Negative sequence overcurrent protection | PP-13-20319 | 1.3 | 2022-08-09 |
| Negative sequence definite time overvoltage protection function | PP-13-20580 | 1.0 | 2014-08-26 |
| Line thermal protection | VERSION 1.0 | 1.0 | 2011-10-25 |
| Three-phase Instantaneous Overcurrent Protection | PP-13-22489 | 2.0 | 2022-03-04 |
| Residual Instantaneous Overcurrent Protection | PP-13-22488 | 2.1 | 2022-11-28 |
| Breaker failure protection | PP-13- 22253 | 2.1 | 2022-10-03 |
| Three-phase overcurrent protection | PP-13-21408 | 2.4 | 2022-08-22 |
| Residual overcurrent protection | PP-13-20320 | 1.3 | 2022-08-22 |
| Definite time overvoltage protection function | PP-13-21400 | 1.2 | 2017-01-11 |
| Residual definite time overvoltage protection function | VERSION 1.0 | 1.0 | 2011-06-27 |
| Overfrequency protection function | PP-13-21379 | 2.2 | 2021-07-30 |
| Underfrequency protection function | PP-13-21379 | 2.2 | 2021-07-30 |
| Rate of change of frequency function | PP-13-21385 | 2.1 | 2020-02-11 |
| Current unbalance protection | PP-13-22163 | 2.0 | 2020-06-25 |
| Directional residual time overcurrent protection function | PP-13-20322 | 1.3 | 2022-08-22 |
| Restricted earth-fault protection | VERSION 1.0 | 1.0 | 2011-06-27 |
| Differential protection | PP-13-21650 | 3.4 | 2023-03-14 |
| Inrush current detection function | PP-13-22394 | 2.0 | 2021-08-10 |
| Phase-Selective Trip Logic | PP-13-21531 | 2.0 | 2019-03-12 |
| Circuit breaker wear monitoring | PP-13-21310 | 1.1 | 2016-09-06 |
| Circuit Breaker control | PP-13-21877 | 2.0 | 2019-04-01 |
| Disconnecter control | PP-13-20396 | 2.0 | 2019-04-01 |
| Ethernet Links function | PP-13-21870 | 1.0 | 2019-02-19 |
| Trip Circuit Supervision (TCS) | PP-13-21875 | 1.2 | 2019-08-09 |
| Application of high-speed TRIP contacts | PP-13-21592 | 1.1 | 2017-10-02 |
| Dead Line Detection Function | PP-13-22522 | 2.0 | 2022-03-04 |
| Voltage transformer supervision and dead line detection | VERSION 1.1 | 1.1 | 2011-10-25 |
| Current input function block setting guide | VERSION 1.1 | 1.0 | 2015-01-29 |
| Voltage input function block setting guide | VERSION 1.0 | 1.0 | 2015-01-29 |
| Line measurement Frequency measurement Voltage measurement Current measurement | PP-13-21168 | 2.3 | 2021-09-02 |
| Disturbance recorder | PP-13-20368 | 3.0 | 2017-06-02 |
| Average and maximum measurement function | PP-11-20109 | 1.0 | 2013-09-27 |
| Metering function | PP-13-22238 | 2.1 | 2022-10-19 |



| | | | |
|------------------------------------------------------------------------------------------------------------------------------|---------------------|------------|-------------------|
| Trip value recorder function | PP-13-20947 | 2.1 | 2020-12-10 |
| Voltage measurement selection function | VERSION 1.0 | 1.0 | 2013-02-06 |
| Earth-fault phase selection function | VERSION 1.0 | 1.0 | 2015-06-05 |
| Application guide to the differential protection and restricted earth-fault protection functions for autotransformers | - | 1.1 | 2016-05-19 |
| Differential protection function setting guide | - | 1.0 | 2015-11-19 |
| Setting guide to the directional overcurrent protection | - | 1.0 | 2014-10-21 |
| AIC current input function | PP-13-21392 | 1.0 | 2017-01-03 |
| Remote I/O (RIO) server description | PP-13-22346 | 1.0 | 2021-06-02 |
| Technical notes on EOB interoperability | - | 1.0 | 2011-06-27 |
| Maintenance guide | PP-13-226045 | 2.0 | 2022-11-18 |
| RTD temperature input function | PP-13-21394 | 1.0 | 2017-01-03 |
| EP+ Installation manual | PP-06-22516 | 1.0 | 2022-03-09 |

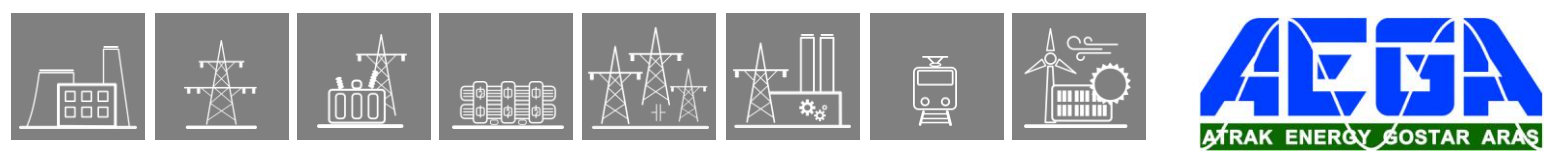
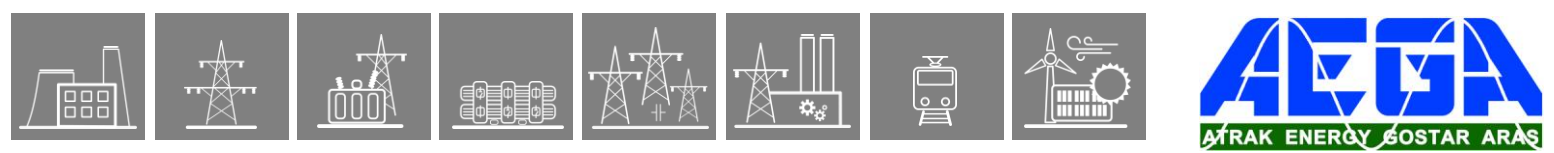
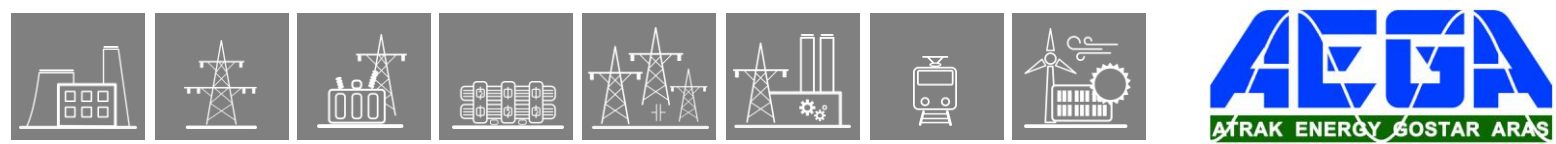


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1. Introduction

The **DTRV** product type is a member of the **EuroProt+** product line, made by Protecta Co. Ltd. The **EuroProt+** complex protection in respect of hardware and software is a modular device. The modules are assembled and configured according to the requirements, and then the software determines the functions. This manual describes the **DTRV** product type.

1.1. Application

The **DTRV** products are designed for protection and control applications of power transformers and generators including generator-transformer blocks (these generator applications are handled independently).

The main application field of the **DTRV** type here is power transformers of any type with any vector group, whether it be two- or three-winding transformers, autotransformers at MV and/or HV voltage level.

The relays of this type support double breaker terminals such as breaker and a half or ring bus topology.

The main protection functions of the **DTRV** type include differential protection, overcurrent protections for both (or all three) sides, and voltage and frequency-based protections.

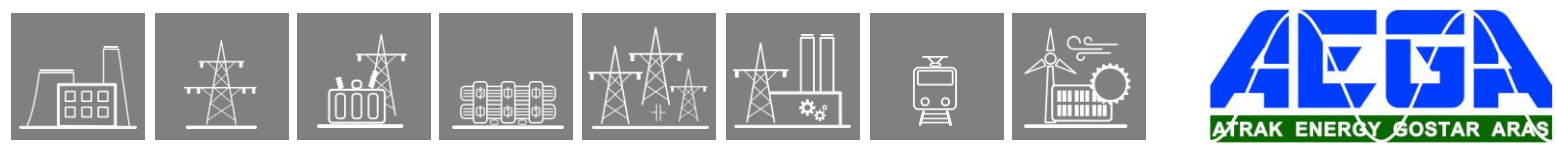
Additionally, the **DTRV** product type incorporates the control of tap changers / automatic voltage regulators by dedicated configuration variants.

Because of the implemented control, measuring and monitoring function, the IEDs can also be used as a bay control unit.

The **EuroCAP configuration tool**, which is available free of charge, offers a user-friendly and flexible application for protection, control and measurement functions to ensure that the IED-EP+ devices are fully customizable.

1.1.1. General features

- Native IEC 61850 IED with Edition 2 compatibility
- Scalable hardware to adapt to different applications
- 84 HP or 42HP wide rack size (height: 3U)
- The pre-defined factory configuration can be customized to the user's specification with the powerful EuroCAP tool
- Flexible protection and control functionality to meet special customer requirements
- Advanced HMI functionality via color touchscreen and embedded WEB server, extended measuring, control and monitoring functions
- User configurable LCD user screens, which can display SLDs (Single Line Diagrams) with switchgear position indication and control as well as measuring values and several types of controllable objects.
- Various protection setting groups available
- Enhanced breaker monitoring and control
- High capacity disturbance recorder (DRE) and event logging (data is stored in non-volatile memory):
 - DRE for up to 32 analogue and 64 digital signal channels.
 - Event recorder can store more than 10,000 events.
- Several mounting methods: Rack; Flush mounting; Semi-flush mounting; Wall mounting; Wall-mounting with terminals; Flush mounting with IP54 rated cover.
- Wide range of communication protocols:
 - Ethernet-based communication: IEC61850; IEC60870-5-104; DNP3.0 TCP; Modbus TCP
 - Serial communication: DNP3.0; IEC60870-5-101/103; MODBUS, SPA



- The EuroProt+ family can handle several communication protocols simultaneously.
- Built-in self-monitoring to detect internal hardware or software errors
- Different time sources available: NTP server; Minute pulse; Legacy protocol master; IRIG-B000 or IRIG-B12X

1.2. Pre-defined configuration variants

The number and the functionality of the members of each product type is put together according to the application philosophy, keeping in mind the possible main usages. The available configurations of the DTRV type for transformers are listed in the table below.

| VARIANT | MAIN APPLICATION |
|--------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| E0-Tr | Simplified protection for small transformers |
| E1-Tr | Two-winding transformer differential protection and control |
| E2-Tr | Two-winding transformer differential protection and control with voltage-based functions |
| E3-Tr | Two-winding transformer differential protection and control with voltage-based functions and automatic voltage regulator / tap changer controller |
| E4-Tr | Three-winding transformer differential protection and control |
| E5-Tr | Three-winding transformer differential protection and control with voltage-based functions |
| E6-Tr | Three-winding transformer differential protection and control with voltage-based functions and automatic voltage regulator / tap changer controller |
| E7-Tr | Automatic voltage regulator / tap changer controller |

Table 1-1 The members of the DTRV type

Note that there are further members of the DTRV type, such as the E9, E10, E11 and E12 which are *generator protections* with several special functions, therefore they are handled separately from the ones listed here.

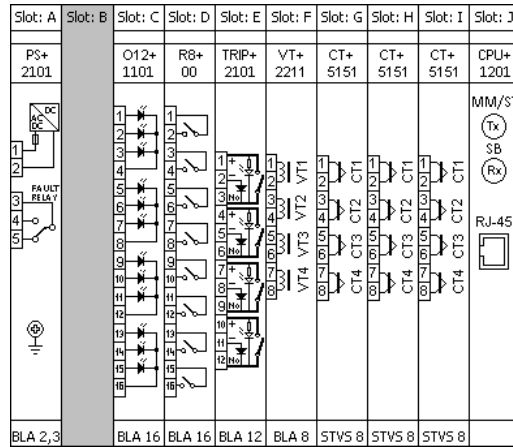


Figure 2 Basic module arrangement of the E5-TR configuration (42TE, rear view)

1.3.1. The applied hardware modules

The applied modules are listed in Table 4.

The technical specification of the device and that of the modules are described in the document “**Hardware description**”.

| Module identifier | Explanation |
|-------------------|-------------------------------------|
| PS+ 1301 | Power supply unit (in 84TE) |
| PS+ 2101 | Power supply unit (in 42TE) |
| O12+ 1101 | Binary input module |
| R8+ 00 | Signal relay output module |
| TRIP+ 2101 | Trip relay output module |
| VT+ 2211 | Analog voltage input module |
| CT + 5151 | Analog current input module |
| CPU+ 1201 | Processing and communication module |

Table 4 The applied modules of the E5-TR configuration

1.3.2. Meeting the device

The basic information for working with the **EuroProt+** devices are described in the document “**Quick start guide to the devices of the EuroProt+ product line**”.



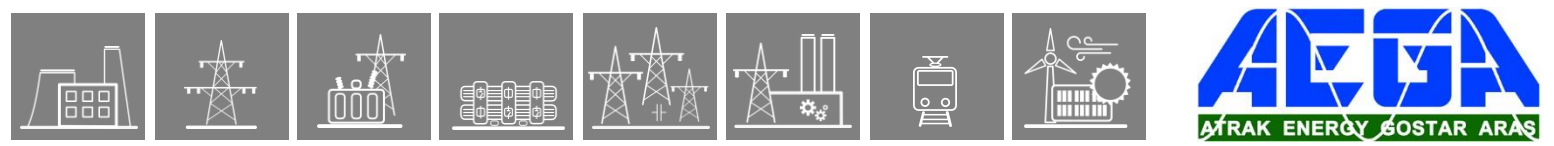
*Figure 3 The 84 inch rack of **EuroProt+** family*



*Figure 4 The 42 inch rack of **EuroProt+** family*



*Figure 5 The double 42 inch rack of **EuroProt+** family*



1.3.4. CPU and COM module

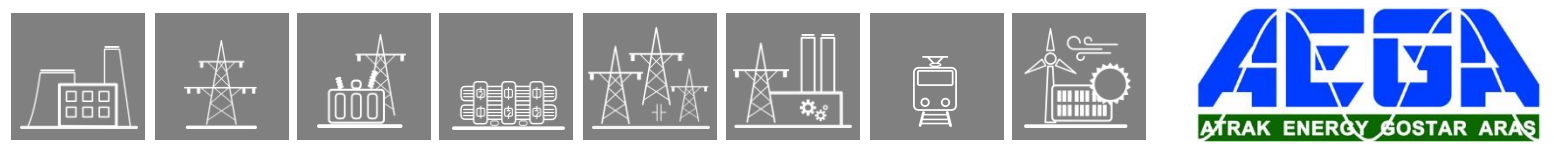
1.3.4.1. CPU+ module

The CPU module contains all the protection, control and communication functions of the EuroProt+ device. Dual 500 MHz high-performance Analog Devices Blackfin processors separate relay functions (RDSP) from communication and HMI functions (CDSP). Reliable communication between processors is performed via high-speed synchronous serial internal bus (SPORT).

Each processor has its own operative memory such as SDRAM and flash memories for configuration, parameter and firmware storage. Both firmwares are stored in a dedicated flash memory independent from the disturbance recorder and event storage.

The CDSP's operating system (uClinux) utilizes a robust JFFS flash file system, which enables fail-safe operation and the storage of disturbance record files, configuration and parameters.

The RDSP core runs at 500 MHz and its external bus speed is 125 MHz. The backplane data speed is limited to approx. 20 MHz, which is more than enough for module data throughput. An additional logic element (CPLD and SRAM) is used as a bridge between the RDSP and the backplane. The CPLD collects analogue samples from CT/VT modules and also controls signaling outputs and inputs.



| CPU VERSION | PRIMARY STATION BUS SBW | SECONDARY (REDUNDANT) STATION BUS SBR | LEGACY PORT/PROTOCOL | PROCESS BUS (FIBER) PB | SERVICE PORT ON FRONT PANEL EOB/ RJ45 |
|-------------|-------------------------|---------------------------------------|----------------------|------------------------|---------------------------------------|
| CPU+/0007 | - | - | - | - | + |
| CPU+/0091 | - | - | - | + SM SH | + |
| CPU+/0201* | - | + RJ45 | - | - | + |
| CPU+/0211* | - | + RJ45 | - | + MM | + |
| CPU+/0281* | - | + RJ45 | - | + SM LH | + |
| CPU+/0291* | - | + RJ45 | - | + SM SH | + |
| CPU+/0301 | - | - | + POF | - | + |
| CPU+/0401 | - | - | + GS | - | + |
| CPU+/0501* | - | - | + Galv. RS485/422 | - | + |
| CPU+/1001 | + MM | - | - | - | + |
| CPU+/1004 | + MM | - | - | - | + |
| CPU+/1011 | + MM | - | - | + MM | + |
| CPU+/1091 | + MM | - | - | + SM SH | + |
| CPU+/1101* | + MM | + MM | - | - | + |
| CPU+/1111 | + MM | + MM | - | + MM | + |
| CPU+/1181 | + MM | + MM | - | + SM LH | + |
| CPU+/1191 | + MM | + MM | - | + SM SH | + |
| CPU+/1201* | + MM | + RJ45 | - | - | + |
| CPU+/1202 | + MM | + RJ45 | - | - | + |
| CPU+/1211 | + MM | + RJ45 | - | + MM | + |
| CPU+/1281 | + MM | + RJ45 | - | + SM LH | + |
| CPU+/1291* | + MM | + RJ45 | - | + SM SH | + |
| CPU+/1292 | + MM | + RJ45 | - | + SM SH | + |
| CPU+/1301 | + MM | - | + POF | - | + |
| CPU+/1311 | + MM | - | + POF | + MM | + |
| CPU+/1331 | + MM | - | + double POF | - | + |
| CPU+/1381 | + MM | - | + POF | + SM LH | + |
| CPU+/1391 | + MM | - | + POF | + SM SH | + |
| CPU+/1401 | + MM | - | + GS | - | + |
| CPU+/1411 | + MM | - | + GS | + MM | + |
| CPU+/1481 | + MM | - | + GS | + SM LH | + |
| CPU+/1491 | + MM | - | + GS | + SM SH | + |
| CPU+/1501 | + MM | - | + Galv. RS485/422 | - | + |
| CPU+/1511 | + MM | - | + Galv. RS485/422 | + MM | + |

| CPU VERSION | PRIMARY STATION BUS (FIBER) SBW | SECONDARY (REDUNDANT) STATION BUS SBR | LEGACY PORT/PROTOCOL | PROCESS BUS (FIBER) PB | SERVICE PORT ON FRONT PANEL EOB/ RJ45 |
|-------------|---------------------------------|---------------------------------------|----------------------|------------------------|---------------------------------------|
| CPU+/1581 | + MM | - | + Galv. RS485/422 | + SM LH | + |
| CPU+/1611 | + MM | - | + Galvanic sync | + MM | + |
| CPU+/1681 | + MM | - | + Galvanic sync | + SM LH | + |
| CPU+/6001 | + MM/LC | - | - | - | + |
| CPU+/6004 | + MM/LC | - | - | - | + |
| CPU+/6093 | + MM/LC | - | - | + SM SH | + |
| CPU+/6094 | + MM/LC | - | - | + SM SH | + |
| CPU+/6601* | + MM/LC | + MM/LC | - | - | + |
| CPU+/9201 | + SM SH | + RJ45 | - | - | + |
| CPU+/9291 | + SM SH | + RJ45 | - | + SM SH | + |
| CPU+/9501 | + SM SH | - | + Galv. RS485/422 | - | + |
| CPU+/9901 | + SM SH | + SM SH | - | - | + |
| CPU+/A001* | + MM/LC PRP/HSR | - | - | - | + |
| CPU+/A004 | + MM/LC PRP/HSR | - | - | - | + |
| CPU+/A011 | + MM/LC PRP/HSR | - | - | + MM | + |
| CPU+/A081 | + MM/LC PRP/HSR | - | - | + SM LH | + |
| CPU+/A091 | + MM/LC PRP/HSR | - | - | + SM SH | + |
| CPU+/A094 | + MM/LC PRP/HSR | - | - | + SM SH | + |

*Note: the modules can be equipped with a different handle (narrower and made of aluminum, instead of the standard plastic), if the other modules of the device are equipped with top-screw terminals (see Chapter 20.2). In these cases, a "T" letter appears on the label of the module (e.g. CPU+/1201T), but all other properties remain the same.

For legacy CPU cards (e.g. CPU+0001, ...) see [Product availability](#) chapter.

PRP/HSR option: A and F types can be ordered with PRP/HSR communication as sw option **Legend for CPU version table:**

| | |
|-------------------------------------------------------------|---------------------------------------------------|
| MM: Multimode with ST connector | GS: Glass with ST connector |
| MM/LC: Multimode with LC connector | SFP: Small Form-factor Pluggable connector |
| SM: Single mode with FC/PC connector | SB: Station Bus |
| LH: Long Haul with FC/PC connector | SBW: Station Bus Working |
| SH: Short Haul with FC/PC connector | SBR: Station Bus Redundant |
| POF: Plastic Optical Fiber with 1 mm fiber connector | PB: Proprietary Process Bus |

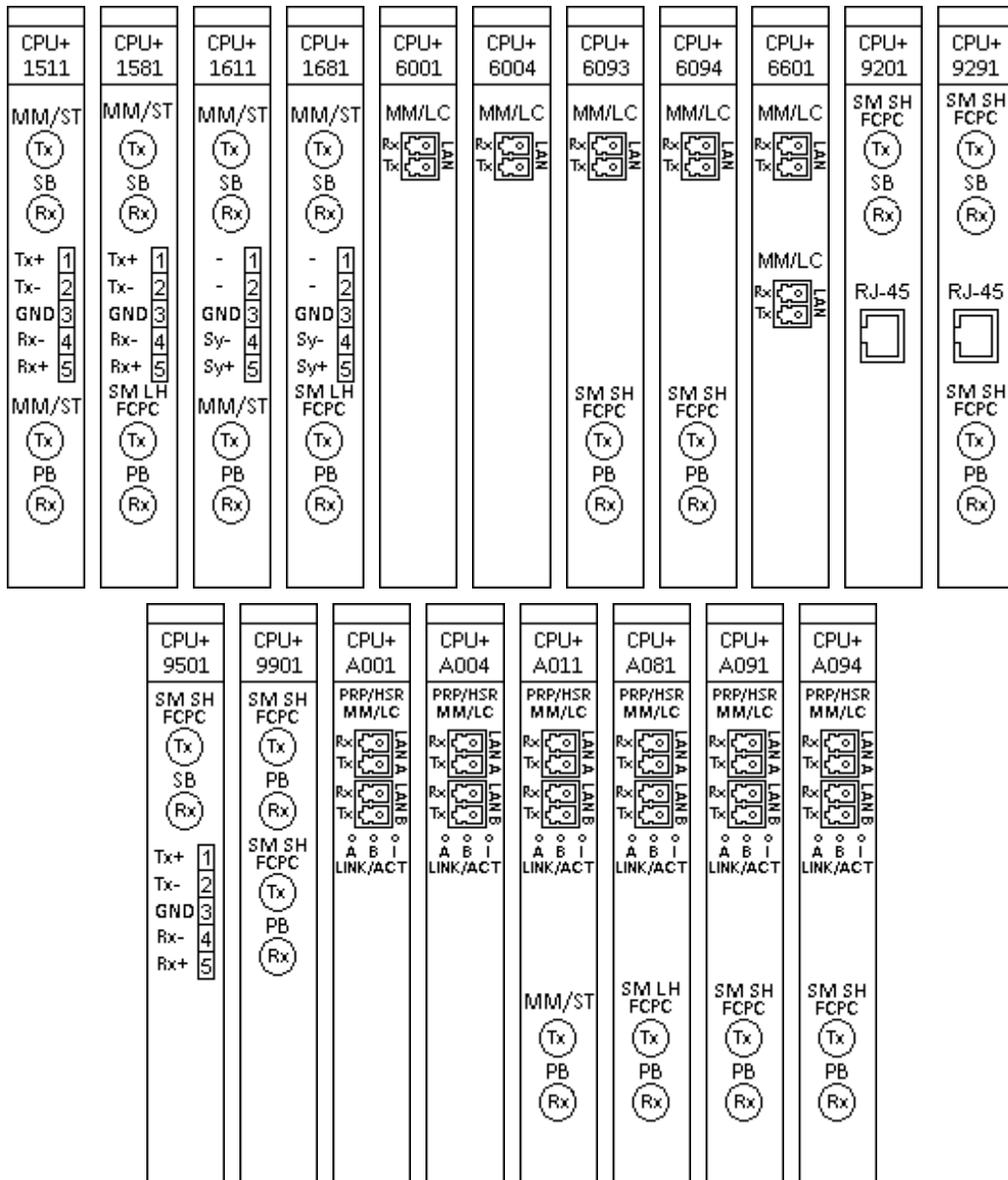
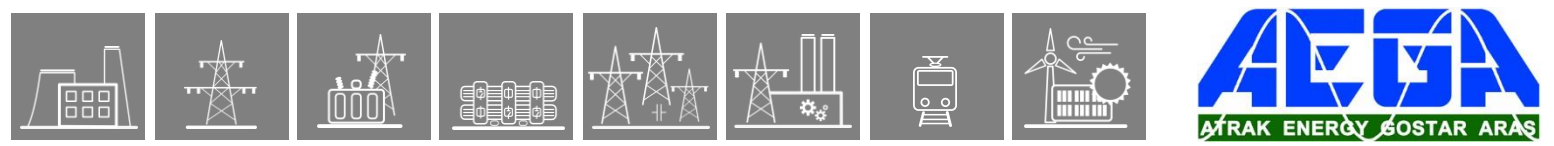


Figure 2-1 CPU versions

Interface types:

- 100Base-FX Ethernet:
 - MM/ST 1300 nm, 50/62.5/125 μm connector, (up to 2 km) fiber
 - SM/FC 1550 nm, 9/125 μm connector, (LH: long haul, up to 120 km)
 - SM/FC 1550 nm, 9/125 μm connector, (SH: short haul, up to 50 km)
 - MM/LC 1300 nm, 50/62.5/125 μm connector, (up to 2 km) fiber
- 10/100 Base-TX Ethernet: RJ-45-8/8
- Service port on HMI:
 - 10/100 Base-T Ethernet: RJ-45-8/8
 - EOB2 interface: attachable to the front panel by a proprietary magnetic connector; the connector box ends in a RJ-45 8/8 plug. It is 10Base-T full duplex interface, and it enables 10/100Base TX communication with service computers.
- ASIF: Asynchronous Serial Interface
 - plastic optical fiber (ASIF-POF)
 - glass with ST connector (ASIF-GS)
 - galvanic RS485/422 (ASIF-G)



1.3.4.2. COM modules

The COM+ modules are responsible for special communication tasks, these are the following:

- binary signal transmission
- line differential protection communication via Ethernet or telecommunication networks
- busbar differential protection communication
- multi-port Ethernet switch using MODBUS/TCP protocol for Remote I/O (RIO) servers

1.3.4.2.1. COM modules for binary signal transmission

| MODULE TYPE | INTERFACE TYPE | NUMBER OF INTERFACES | UNIT WIDTH | APPLICATION |
|-------------------|---------------------------------------------------------------------------------------------------------|----------------------|------------|-----------------------------------------------------------------------------------------------|
| COM+/1801* | MM/ST 1300 nm, 50/62.5/125 µm and SM/FC 1550 nm, 9/125 µm connector, 100Base-FX Ethernet | 2 | 4 HP | Line differential protection, binary signal transmission up to 2 km and up to 120 km |
| COM+/1901* | MM/ST 1300 nm, 50/62.5/125 µm and SM/FC 1550 nm, 9/125 µm connector, 100Base-FX Ethernet | 2 | 4 HP | Line differential protection, binary signal transmission up to 2 km and up to 50 km |
| COM+/8882 | SM/FC 1550 nm, 9/125 µm connector, 100Base-FX Ethernet | 3 | 4 HP | 3 direction binary signal transmission up to 120 km |
| COM+/9902 | SM/FC 1550 nm, 9/125 µm connector, 100Base-FX Ethernet | 2 | 4 HP | 2 direction binary signal transmission up to 50 km |
| COM+/9992 | SM/FC 1550 nm, 9/125 µm connector, 100Base-FX Ethernet | 3 | 4 HP | 3 direction binary signal transmission up to 50 km |

*Note: the modules can be equipped with a different handle (narrower and made of aluminum, instead of the standard plastic), if the other modules of the device are equipped with top-screw terminals (see Chapter 20.2). In these cases, a "T" letter appears on the label of the module (e.g. **COM+/1801T**), but all other properties remain the same

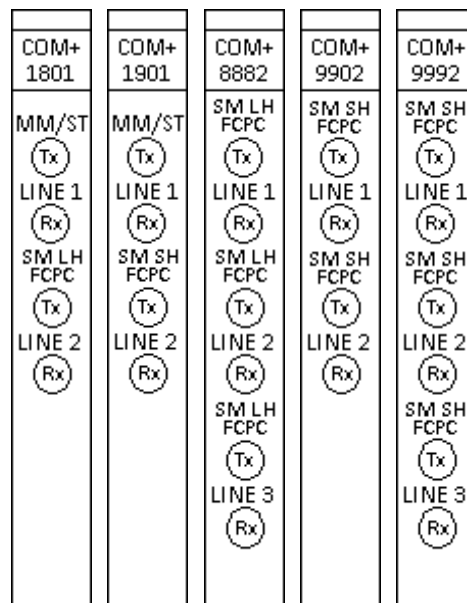


Figure 2-2 COM modules for binary signal transmission

1.3.4.2.3. COM modules for busbar differential protection communication

| MODULE TYPE | INTERFACE TYPE | NUMBER OF INTERFACES | UNIT WIDTH | APPLICATION |
|-------------------|--------------------------------------------------------------|----------------------|------------|-------------------------------------------------------|
| COM+/1111 | MM/ST 1300 nm, 50/62.5/125 μm connector, 100Base-FX Ethernet | 3 | 4 HP | Busbar protection for 3 bay units up to 2 km |
| COM+/1111D | MM/ST 1300 nm, 50/62.5/125 μm connector, 100Base-FX Ethernet | 3 | 4 HP | Busbar protection for 3x2 bay units (dual) up to 2 km |

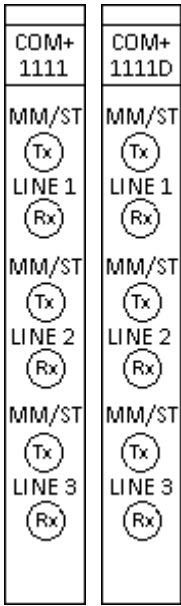


Figure 2-4 COM modules for busbar differential protections

1.3.4.2.4. COM modules for Remote I/O (RIO) servers

| MODULE TYPE | INTERFACE TYPE | NUMBER OF INTERFACES | UNIT WIDTH | APPLICATION |
|-------------|--------------------------------------------------------------|----------------------|------------|-------------------------------------------|
| COM+/1202* | MM/LC 1300 nm, 50/62.5/125 µm connector, 100Base-FX Ethernet | 2 | 8 HP | 2-port Ethernet switch for MODBUS via RIO |
| COM+/1324* | MM/LC 1300 nm, 50/62.5/125 µm connector, 100Base-FX Ethernet | 4 | 8 HP | 4-port Ethernet switch for MODBUS via RIO |
| COM+/1335 | MM/LC 1300 nm, 50/62.5/125 µm connector, 100Base-FX Ethernet | 5 | 8 HP | 5-port Ethernet switch for MODBUS via RIO |
| COM+/6603 | MM/LC 1300 nm, 50/62.5/125 µm connector, 100Base-FX Ethernet | 2 | 4 HP | 2-port Ethernet switch for MODBUS via RIO |
| COM+/6663 | MM/LC 1300 nm, 50/62.5/125 µm connector, 100Base-FX Ethernet | 3 | 4 HP | 3-port Ethernet switch for MODBUS via RIO |

*Obsolete module. These modules are not recommended for new designs!

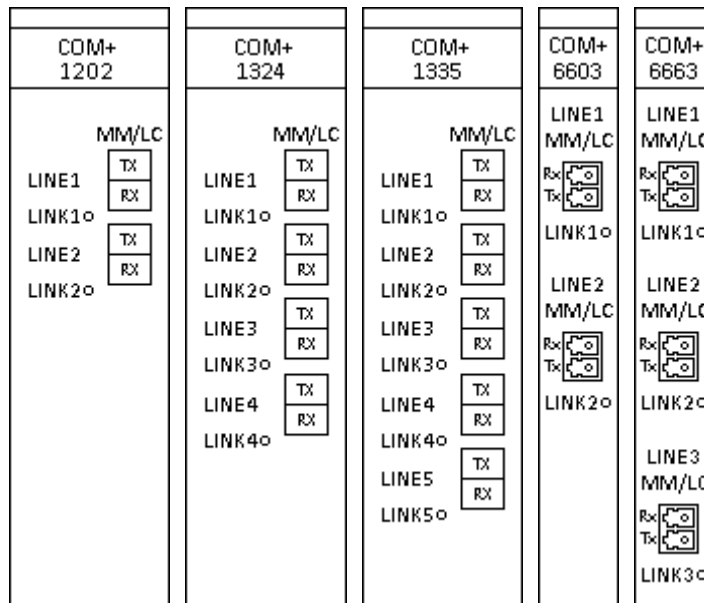


Figure 2-5 COM modules for RIO servers

1.3.4.3. Communication interface characteristics

1.3.4.3.1. Ethernet multi-mode transmitter and receiver

1.3.4.3.1.1. MM/ST connector

Up to approximately 2 km.

Transmitter

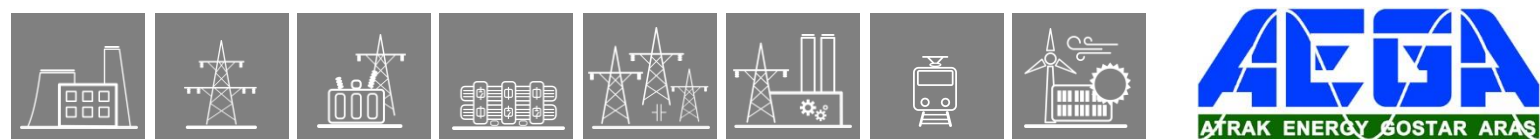
| PARAMETER | SYMBOL | MIN. | TYP. | MAX. | UNIT |
|-------------------------------------------------------------------|-------------|----------------------------|------|-----------|----------|
| OPTICAL OUTPUT POWER 62.5/125 μm , NA = 0.275 FIBER | P_O | BOL*: -19 EOL*: -20 | - | -14 | dBm avg. |
| OUTPUT OPTICAL POWER 50/125 μm , NA = 0.20 FIBER | P_O | BOL*: -22.5 EOL*: -23.5 | - | -14 | dBm avg. |
| OPTICAL EXTINCTION RATIO | ER | - | - | 10 -10 | % dB |
| CENTER WAVELENGTH | λ_C | 1270 | 1308 | 1380 | nm |

* BOL: Beginning of life, EOL: End of life

Note: according to field experiences, the 62.5/125 μm cabling is recommended for applications where the center wavelength is 1300/1310 nm.

Receiver sensitivity is measured with $2^{23} - 1$ PRBS pattern within BER = 2.5×10^{-10}

| PARAMETER | SYMBOL | MIN. | TYP. | MAX. | UNIT |
|--------------------------------------------|-------------|----------------|------|------|---------------|
| SIGNAL DETECT - ASSERTED | P_A | $P_D + 1.5$ dB | - | -33 | dBm avg. |
| SIGNAL DETECT - DEASSERTED | P_D | -45 | - | - | dBm avg. |
| SIGNAL DETECT - HYSTERESIS | $P_A - P_D$ | 1.5 | - | - | dB |
| SIGNAL DETECT ASSERT TIME (OFF TO ON) | AS_Max | 0 | 2 | 100 | μs |
| SIGNAL DETECT DEASSERT TIME (ON TO OFF) | ANS_Max | 0 | 8 | 350 | μs |



1.3.4.3.1.2. MM/LC connector

Up to approximately 2 km.

Transmitter

| PARAMETER | SYMBOL | MIN. | TYP. | MAX. | UNIT |
|---------------------------------------------------------------------|-------------|----------------------------|--------------|------------|----------|
| OPTICAL OUTPUT POWER** 62.5/125 μm , NA = 0.275 FIBER | P_O | BOL*: -19 EOL*: -20 | -15.7 | -14 | dBm avg. |
| OUTPUT OPTICAL POWER 50/125 μm , NA = 0.20 FIBER | P_O | BOL*: -22.5 EOL*: -23.5 | - | -14 | dBm avg. |
| OPTICAL EXTINCTION RATIO | ER | - | 0.002 -47 | 0.2 -27 | % dB |
| CENTER WAVELENGTH | λ_C | 1270 | 1308 | 1380 | nm |

* BOL: Beginning of life, EOL: End of life

Note: according to field experiences, the 62.5/125 μm cabling is recommended for applications where the center wavelength is 1300/1310 nm.

Receiver sensitivity is measured with $2^{23} - 1$ PRBS pattern within $\text{BER} = 2.5 \times 10^{-10}$

| PARAMETER | SYMBOL | MIN. | TYP. | MAX. | UNIT |
|--------------------------------------------|-------------|------------------------|------|------|---------------|
| SIGNAL DETECT - ASSERTED | P_A | $P_D + 1.5 \text{ dB}$ | - | -33 | dBm avg. |
| SIGNAL DETECT - DEASSERTED | P_D | -45 | - | - | dBm avg. |
| SIGNAL DETECT - HYSTERESIS | $P_A - P_D$ | 1.5 | - | - | dB |
| SIGNAL DETECT ASSERT TIME (OFF TO ON) | AS_Max | 0 | 2 | 100 | μs |
| SIGNAL DETECT DEASSERT TIME (ON TO OFF) | ANS_Max | 0 | 5 | 100 | μs |

1.3.4.3.2. Ethernet single mode transmitter and receiver

1.3.4.3.2.1. Long haul single mode transceiver

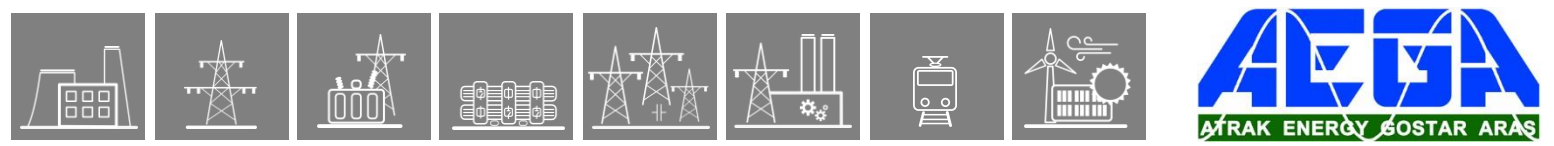
Up to approximately 120 km, with max. 32 dB link attenuation.

Transmitter

| PARAMETER | SYMBOL | MIN. | TYP. | MAX. | UNIT |
|--------------------------|-------------|------|------|------|----------|
| OPTICAL OUTPUT POWER | P_O | -6 | - | 0 | dBm avg. |
| OPTICAL EXTINCTION RATIO | ER | 8.3 | - | - | dB |
| CENTER WAVELENGTH | λ_C | 1490 | 1550 | 1610 | nm |

Receiver sensitivity is measured with $2^{23} - 1$ PRBS pattern within $BER = 2.5 \times 10^{-10}$

| PARAMETER | SYMBOL | MIN. | TYP. | MAX. | UNIT |
|----------------------------|-------------|------|------|------|----------|
| OPTICAL INPUT SENSITIVITY | P_{IN} | - | -38 | -35 | dBm avg. |
| SATURATION | P_{SAT} | -3 | 0 | - | dBm |
| CENTER WAVELENGTH | λ_C | 1100 | - | 1600 | nm |
| SIGNAL DETECT - ASSERTED | P_A | - | - | -35 | dBm avg. |
| SIGNAL DETECT - DEASSERTED | P_D | -45 | - | - | dBm avg. |
| HYSTERESIS | P_{HYS} | - | 3 | - | dB |



1.3.4.3.2.2. Short haul single mode transceiver

Up to approximately 50 km, with max. 27 dB link attenuation.

Transmitter

| PARAMETER | SYMBOL | MIN. | TYP. | MAX. | UNIT |
|--------------------------|-------------|------|------|------|----------|
| OPTICAL OUTPUT POWER | P_O | -12 | - | -6 | dBm avg. |
| OPTICAL EXTINCTION RATIO | ER | 8.3 | - | - | dB |
| CENTER WAVELENGTH | λ_C | 1490 | 1550 | 1610 | nm |

Receiver sensitivity is measured with $2^{23} - 1$ PRBS pattern within $BER = 2.5 \times 10^{-10}$

| PARAMETER | SYMBOL | MIN. | TYP. | MAX. | UNIT |
|----------------------------|-----------|------|------|------|----------|
| OPTICAL INPUT SENSITIVITY | P_{IN} | - | -38 | -35 | dBm avg. |
| SATURATION | P_{SAT} | -3 | 0 | - | dBm |
| CENTER WAVELENGTH | λ | 1100 | - | 1600 | nm |
| SIGNAL DETECT - ASSERTED | P_A | - | - | -35 | dBm avg. |
| SIGNAL DETECT - DEASSERTED | P_D | -45 | - | - | dBm avg. |
| HYSTERESIS | P_{HYS} | - | 3 | - | dB |

1.3.4.3.3. ASIF-O transmitter and receiver

1.3.4.3.3.1. ASIF-O POF

Transmitter

| PARAMETER | SYMBOL | MIN. | TYP. | MAX. | UNIT | JUMPER SETTINGS |
|----------------------------------|----------------|-------|------|------|------|-----------------|
| TRANSMITTER OUTPUT OPTICAL POWER | P_T | -15.3 | - | -9 | dBm | JP1 2-3 |
| | | -23.3 | - | -17 | | JP1 1-2 |
| PEAK EMISSION WAVELENGTH | λ_{PK} | - | 660 | - | nm | |
| EFFECTIVE DIAMETER | D | - | 1 | - | mm | |
| NUMERICAL APERTURE | NA | - | 0.5 | - | | |

Receiver

| PARAMETER | SYMBOL | MIN. | TYP. | MAX. | UNIT |
|-----------------------------------|------------|------|------|-------|------|
| INPUT OPTICAL POWER LEVEL LOGIC 0 | $P_{R(L)}$ | -39 | - | -13.7 | dBm |
| INPUT OPTICAL POWER LEVEL LOGIC 1 | $P_{R(H)}$ | - | - | -53 | dBm |
| EFFECTIVE DIAMETER | D | - | 1 | - | mm |
| NUMERICAL APERTURE | NA | - | 0.5 | - | |

These characteristics are valid for both POF interfaces in CPU+1331 module.

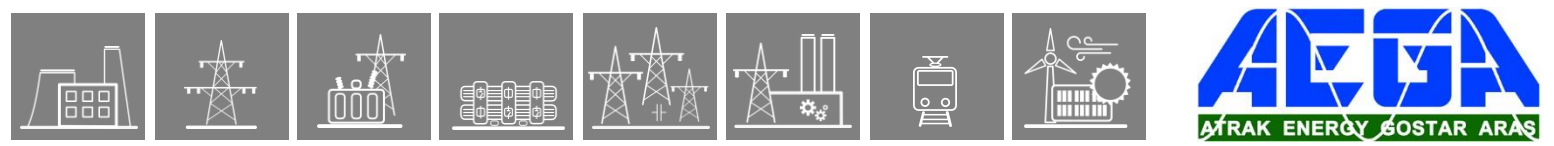
1.3.4.3.3.2. ASIF-O GLASS

Transmitter (Output measured out of 1 meter of cable)

| PARAMETER | SYMBOL | MIN. | TYP. | MAX. | UNIT | JUMPER SETTINGS |
|-----------------------------------------------|--------|-------|-------|-------|----------|-----------------|
| 50/125 μm FIBER CABLE NA = 0.2 | P_o | -19.4 | -16.4 | -14.4 | dBm peak | JP1 2-3 |
| | | -28.9 | -25.9 | -23.9 | | JP1 1-2 |
| 62.5/125 μm FIBER CABLE NA = 0.275 | P_o | -15.6 | -12.6 | -10.6 | dBm peak | JP1 2-3 |
| | | -22.9 | -19.9 | -17.9 | | JP1 1-2 |

Receiver

| PARAMETER | SYMBOL | MIN. | TYP. | MAX. | UNIT |
|----------------------------------------------------------------------------|----------|-------|------|------|----------|
| PEAK OPTICAL INPUT POWER LOGIC LEVEL HIGH ($\lambda_P = 820 \text{ nm}$) | P_{RH} | -25.4 | - | -9.2 | dBm peak |
| PEAK OPTICAL INPUT POWER LOGIC LEVEL LOW | P_{RL} | - | - | -40 | dBm peak |



1.3.4.3.4. ASIF-G transmitter and receiver

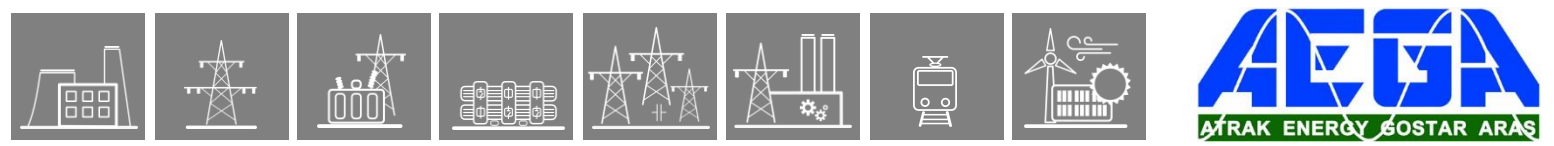
The RS422/RS485 interfaces of our CPU+1501, CPU+1511, CPU+1581, CPU+9501 modules provide galvanic interface to support legacy or other serial protocols. For more details see our RS485/422 application note, available on our homepage.

Transmitter

| PARAMETER | SYMBOL | MIN. | TYP. | MAX. | UNIT |
|------------------------------------------------------------------|-----------|------|------|------|------|
| DIFFERENTIAL OUTPUT VOLTAGE (LOADED, $R_L = 100 \Omega$, RS422) | V_{OD2} | 2 | - | 3.6 | V |
| DIFFERENTIAL OUTPUT VOLTAGE (LOADED, $R_L = 54 \Omega$, RS485) | V_{OD2} | 1.5 | - | 3.6 | V |

Receiver

| PARAMETER | SYMBOL | MIN. | TYP. | MAX. | UNIT |
|--------------------------------------|-----------|------|------|------|------------|
| DIFFERENTIAL INPUT THRESHOLD VOLTAGE | V_{TH} | -200 | -125 | -30 | mV |
| INPUT VOLTAGE HYSTERESIS | V_{HYS} | - | 15 | - | mV |
| LINE INPUT RESISTANCE | R_{IN} | 96 | - | - | k Ω |



1.3.4.3.5. G.703 64 kbit/s co-directional interface (E0)

The EuroProt+ device also supports line differential communication via telecom networks using

- 64 kbit/s co-directional interface type through COM+0091. This type of communication is performed via 2 x 2 wire isolated galvanic type interface. The protection device is connected to a multiplexer or gateway which is responsible for protocol/speed conversion.

- Connector type: Weidmüller: Receptacle: S2L 3.50/12/90 F
Plug: B2L 3.50/12/180 F
- Impedance: 120 Ω
- Cable length: 50 m
- Interface type: G.703.1 64 kbit/s (E0) co-directional, selectable grounding, with optional external clock input

For further information about the cable assembly of this type of interface please see our G.703 E0 cable assembly guide.

Receiver

| PARAMETER | VALUE |
|----------------------------|----------------------------------------------------|
| LOSS OF SIGNAL ALARM LEVEL | ± 1.5 dB difference between alarm-on and alarm-off |
| DYNAMIC RANGE | 10 dB maximum cable loss range |

Transmitter

| PARAMETER | VALUE |
|-----------------------------------------------------|----------------------------------------------------|
| PAIR FOR EACH DIRECTION | ± 1.5 dB difference between alarm-on and alarm-off |
| TEST LOAD IMPEDANCE | 10 dB maximum cable loss range |
| NOMINAL PEAK VOLTAGE OF A “MARK” (PULSE) | One symmetric pair |
| PEAK VOLTAGE OF A “SPACE” (NO PULSE) | 120 Ω resistive |
| NOMINAL PULSE WIDTH | 1.0 V |
| RATIO OF THE AMPLITUDES OF POSITIVE AND NEGATIVE | 0 V ± 0.10 V |
| PULSES AT THE CENTRE OF THE PULSES INTERVAL | 3.9 ms |
| RATIO OF THE WIDTHS OF POSITIVE AND NEGATIVE PULSES | 0.95 to 1.05 |
| AT THE NOMINAL HALF AMPLITUDE | 0.95 to 1.05 |
| MAXIMUM PEAK-TO-PEAK JITTER AT THE OUTPUT PORT | Refer to clause 2/G.823 |

1.3.4.3.5.1. PRP/HSR redundant Ethernet communication interface

The PRP/HSR redundant Ethernet communication interface supports the two new IEC 62439-3 protocols which provide seamless redundancy for Ethernet networking in substations with zero-time recovery in case of a single failure without frame loss:

- PRP – Parallel Redundancy Protocol (IEC 62439-3 Clause 4)
- HSR – High-availability Seamless Redundancy (IEC 62439-3 Clause 5)

This interface uses two MM/LC connectors for double connection to networks as these protocols are based on the duplication of the sent frames.

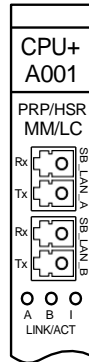


Figure 2-6 PRP/HSR connectors on a CPU+A001 module

1.3.4.3.5.2. Parallel Redundancy Protocol (PRP)

This redundancy protocol implements redundancy in the nodes as they are connected to two independent networks (LAN_A and LAN_B) sending a copy of each frame to both directions. The destination node receives and processes the first copy and discards the other copy of the sent frame.

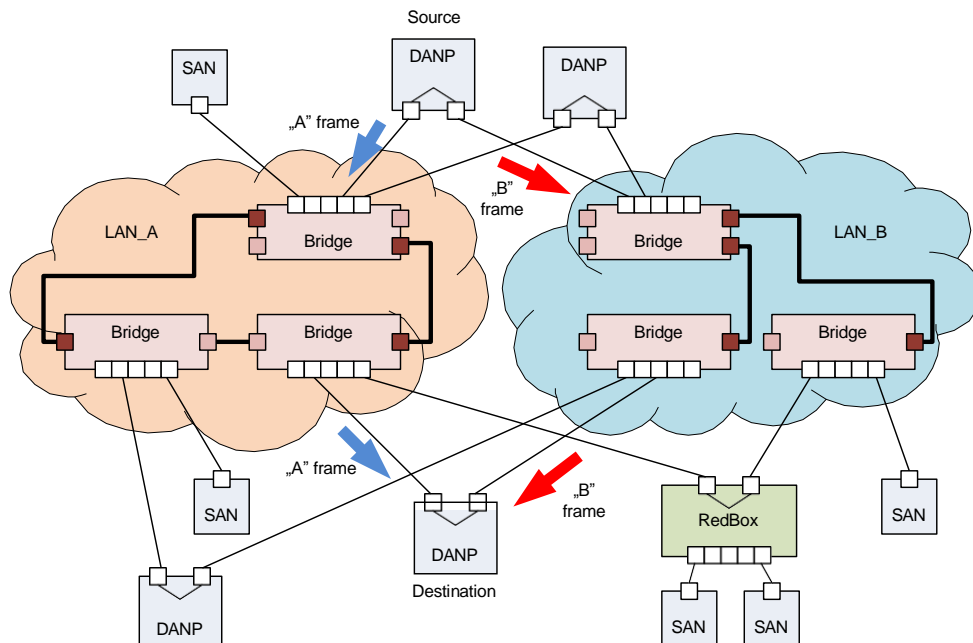


Figure 2-7 Example of a PRP redundant network

Single attached node (SAN): Network device that connects to a network with only one port.

Double attached node implementing PRP (DANP): Network device which connects to a network with two ports implementing PRP redundancy.

1.3.4.3.5.3. High-availability Seamless Redundancy (HSR)

An HSR network provides redundancy with the same safety as PRP does with a lower cost. The principle of this protocol is also based on the duplication of the sent frames but in this solution the nodes are connected to a closed ring. A source node sends two copy of a frame to both direction and the destination node accepts the first received copy and discards the other one. If a frame returns to its source the node does not let it through itself prevent the possibility of an overload of the ring.

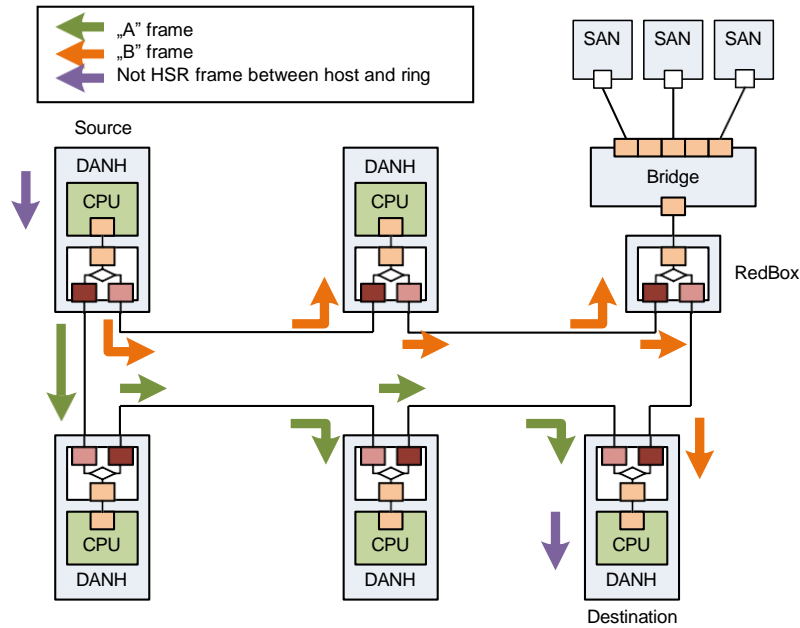
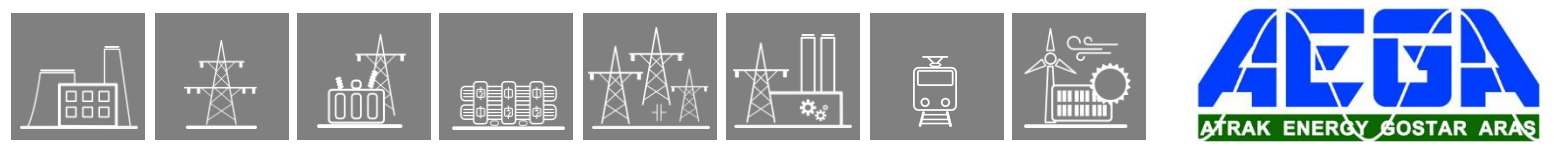


Figure 2-8 Example of an HSR redundant network

Single attached node (SAN): Network device that connects to a network with only one port.
Double attached node implementing HSR (DANH): Network device which connects to a network with two ports implementing HSR redundancy.



1.3.5. Device housings

Three+one versions are available: one is 84 HP wide with 21 module slots, the 42 HP wide, which supports 10 module slots, the double 42 HP wide with 20 module slots, and finally the 24 HP, which supports 6 module slots.

Depending on the installed modules of the configuration, the top and bottom panels of the 84 HP and 42 HP racks can be either solid (default) or perforated by 2 mm holes to prevent overheating. 24 HP housings do not have this feature, as the S24 system is less flexible, their range of the optional modules are narrower.

| RACK CONFIGURATION | FREE MODULE SLOTS* | BOTTOM AND TOP PANELS | DISPLAY OPTIONS |
|------------------------------|--------------------|-----------------------|---------------------------|
| 84 HP, SINGLE RACK (3 U) | 20 | Solid, Perforated | 3.5" TFT, 5.7" TFT |
| 42 HP, SINGLE RACK (3 U) | 9 | Solid, Perforated | 3.5" TFT, 5.7" TFT |
| 42 HP, DOUBLE RACK (6 U) | 19 | Solid, Perforated | 3.5" TFT |
| 24 HP, PANEL INSTRUMENT CASE | 5 | Solid | B/W alphanumeric 3.5" TFT |

**CPU module is mandatory, it uses up one fixed position*

Previously, a new rack type has been introduced to the 42HP devices. As of April 2021. this type is introduced to the 84HP devices as well. The depth of the box has been reduced from 242 mm to 223 mm. By default, this reduced-depth housing shall be used for newly manufactured devices. For more information about the previous and new size, see Chapter 22.1.

The following images showcase examples of the different types of available device housings with different kinds of front panel HMI. The available front panels are listed in Chapter 4.

| | |
|------------------------------------------------------------------------------------------------|--|
| <p>84 HP single rack (3 U) with 3.5" TFT display and solid housing</p> | |
| <p>84 HP single rack (3 U) with 5.7" TFT display and perforated housing</p> | |
| <p>42 HP single rack (3 U) with 3.5" TFT display and solid housing</p> | |
| <p>42 HP double rack (6 U) with 3.5" TFT display and solid housing</p> | |
| <p>24 HP panel instrument case with B/W display (left) TFT display (right)</p> | |









Figure 3-1 Rack configuration illustrations

1.3.6. Human-Machine Interface (HMI) module

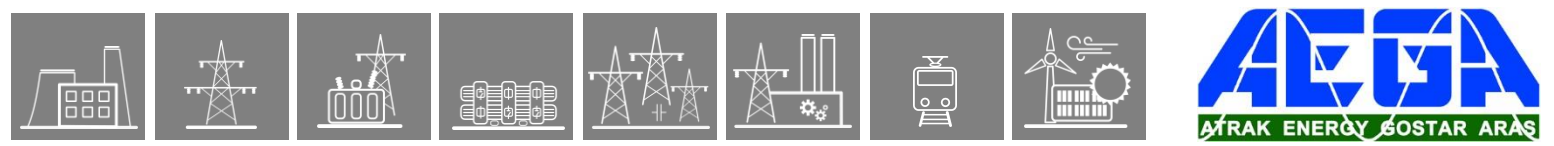
The EuroProt+ device HMI consists of the following two main parts:

- Hardware: the HMI module, which is the front panel of the device, this is described here
- Software: the embedded web server and the menu system that is accessible through the HMI module. The web server is accessible via station bus, EOB interface or RJ-45 Ethernet connector. This is described in detail in the [Operating Manual](#) (external document).

1.3.6.1. Local HMI modules

| MODULE TYPE | DISPLAY | SERVICE PORT | RACK SIZE | RACK DEPTH | ILLUSTRATION |
|---------------------------------------|----------|--------------|--------------|------------|--------------------------------------------------------------------------------------|
| HMI+/3505 HMI+/3405* | 3,5" TFT | EOB | 42 HP | Reduced |  |
| | | | 84 HP | |  |
| HMI+/3506 HMI+/3406* HMI+/3404* | 3,5" TFT | RJ-45 | 42 HP | Reduced |  |
| | | | Double 42HP | |  |
| | | | 84 HP | |  |
| HMI+/5005 | 5,7" TFT | EOB | 42 HP | Reduced |  |
| HMI+/5006 HMI+/5004* | 5,7" TFT | RJ-45 | 42 HP | Reduced |  |
| | | | Double 42 HP | | n/a |
| HMI+/5706 HMI+/5704* | 5,7" TFT | RJ-45 | 84 HP | Reduced |  |

*new display hardware requires CDSP firmware version 1560-H5 or higher!



The following modules were made for the previous (now obsolete) racks (see Chapter 22.1), so they can be found in numerous devices. These became obsolete as well, **they are not recommended for new designs!**

| MODULE TYPE | DISPLAY | SERVICE PORT | RACK SIZE | RACK DEPTH | ILLUSTRATION |
|-------------|----------|--------------|-----------|------------|--------------|
| HMI+/3501 | 3,5" TFT | EOB | 42 HP | Normal | |
| | | | 84 HP | | |
| HMI+/3502 | 3,5" TFT | RJ-45 | 42 HP | Normal | |
| | | | 84 HP | | |
| HMI+/5001 | 5,7" TFT | EOB | 42 HP | Normal | |
| HMI+/5002 | 5,7" TFT | RJ-45 | 42 HP | Normal | |
| HMI+/5701 | 5,7" TFT | EOB | 84 HP | Normal | |
| HMI+/5702 | 5,7" TFT | RJ-45 | 84 HP | Normal | |

1.3.6.2. Remote HMI

Protecta provides an alternative solution in that case if the IED can be only mounted in a non-practical way for managing the device via usual Human-Machine Interface.

By using a remote HMI (*terminal HMI device*), customers can place the HMI up to 3 meters far from the IED itself (*host device*) and mount the IED in any possible way that is applicable. The connection between the remote HMI and the IED is provided by a custom galvanic interface with DA-15 connector on the remote side.





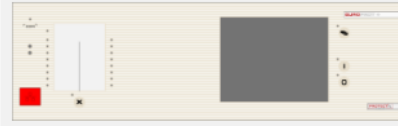


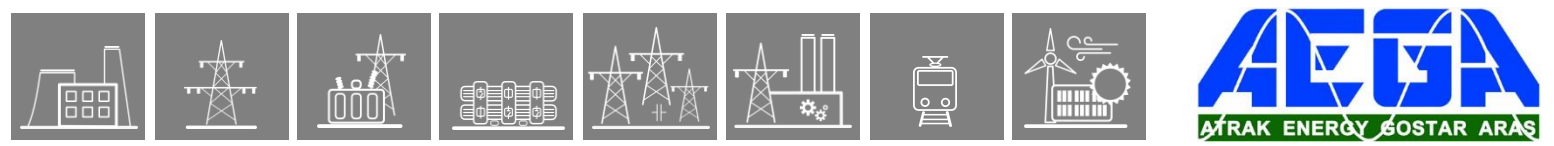
Figure 4-1 42 HP Remote HMI

Depending on the size of the HMI module you can use any applicable mounting methods that described in the [Mounting methods](#) chapter (Flush mounting, Semi-flush mounting, Rack mounting).



Figure 4-2 Remote HMI module with its host device

| MODULE TYPE | DISPLAY | SERVICE PORT | RACK SIZE | RACK DEPTH | ILLUSTRATION |
|-------------|----------|--------------|-----------|------------|--------------------------------------------------------------------------------------|
| HMIT+/3505 | 3,5" TFT | EOB | 42 HP | Reduced |  |
| | | | 84 HP | |  |
| HMIT+/3506 | 3,5" TFT | RJ-45 | 42 HP | Reduced |  |
| | | | 84 HP | |  |
| HMIT+/5706 | 5,7" TFT | RJ-45 | 84 HP | Reduced |  |



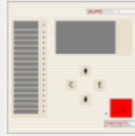



The following modules were made for the previous (now obsolete) racks (see Chapter 22.1), so they can be found in numerous devices. These became obsolete as well, **they are not recommended for new designs!**

| MODULE TYPE | DISPLAY | SERVICE PORT | RACK SIZE | RACK DEPTH | ILLUSTRATION |
|-------------|----------|--------------|-----------|------------|--------------|
| HMIT+/3501 | 3,5" TFT | EOB | 42 HP | Normal | |
| | | | 84 HP | | |
| HMIT+/3502 | 3,5" TFT | RJ-45 | 42 HP | Normal | |
| | | | 84 HP | | |
| HMIT+/5702 | 5,7" TFT | RJ-45 | 84 HP | Normal | |

1.3.6.3. S24 HMI


The S24 Smart Line devices have a different HMI family:

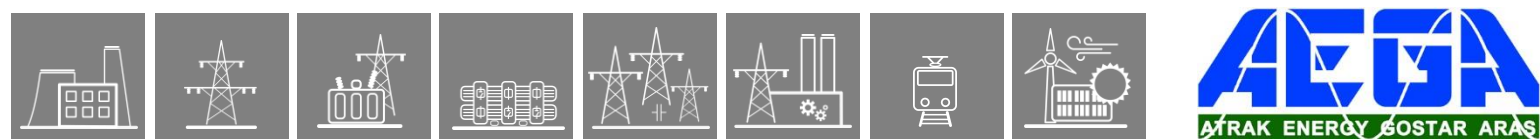
| MODULE TYPE | DISPLAY | SERVICE PORT | RACK SIZE | MOUNTING | ILLUSTRATION |
|----------------------------------------|----------|--------------|-----------|----------|-------------------------------------------------------------------------------------|
| HMI+/2604* HMI+/2404 HMI+/2304** | 3,5" TFT | RJ-45 | 24 HP | Normal |  |
| HMI+/2606* HMI+/2406 HMI+/2306** | 3,5" TFT | RJ-45 | 24 HP | DIN-rail |  |
| HMI+/2704* HMI+/2504 | B&W LCD | RJ-45 | 24 HP | Normal |  |
| HMI+/2706* HMI+/2506 | B&W LCD | RJ-45 | 24 HP | DIN-rail |  |

**for newer, modular-type S24 devices*

***new display hardware requires CDSP firmware version 1560-H5 or higher!*

The following module is **obsolete, it is not recommended for new designs!**

| MODULE TYPE | DISPLAY | SERVICE PORT | RACK SIZE | MOUNTING | ILLUSTRATION |
|-------------|----------|--------------|-----------|----------|---------------------------------------------------------------------------------------|
| HMI+/2401* | 3,5" TFT | EOB | 24 HP | Normal |  |



1.3.6.4. Parts of the HMI modules

The EuroProt+ device HMI on the front panel contains the following elements:

| Function | Description |
|--------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 16 PIECES USER LEDs | Three-color, 3 mm circular LEDs |
| COM LED | Yellow, 3 mm circular LED indicating EOB/RJ-45 (on the front panel) communication link and activity |
| CAPACITIVE TOUCH KEY LEDs | 4 pcs yellow, 3 mm circular LEDs indicating touch key actions |
| DEVICE STATUS LED | 1 piece three-color, 3 mm circular LED Green: normal device operation Yellow: device is in warning state Red: device is in error state |
| DEVICE KEYS (I, O, X, PAGE) | Capacitive touch keys |
| | Tactile push buttons |
| BUZZER | Audible touch key pressure feedback |
| CHANGEABLE LED DESCRIPTION LABEL | Describes user LED functionality |
| DISPLAY | 320 × 240 pixel TFT color display with resistive touchscreen interface (3.5" or optional 5.7") |
| | 128 × 64 LCD black & white display |
| OPTICAL INTERFACE FOR FACTORY USAGE | For debugging and software development purposes <i>Only for 42 HP and 84 HP devices.</i> |
| EOB CONNECTOR | <p>Ethernet Over Board: communication interface accomplishes isolated, non-galvanic Ethernet connection with the help of a magnetically attached EOB device. The EOB device has an RJ-45 type connector supporting Ethernet connection to the user computer. This is a proprietary and patented solution from Protecta Ltd.</p> <p>EOB1: Supporting 10Base-T Ethernet connection. Passive device with one RJ45 type connector. Obsolete module.</p> <p>EOB2: Supporting 10/100Base-Tx Ethernet connection. An active device that has a USB port in addition to the RJ45 connector for powering up.</p> |
| ETHERNET SERVICE PORT | IP56 rated Ethernet 10/100-Base-T interface with RJ-45 type connector (IP56 only valid if the cap of the service port is closed.) |

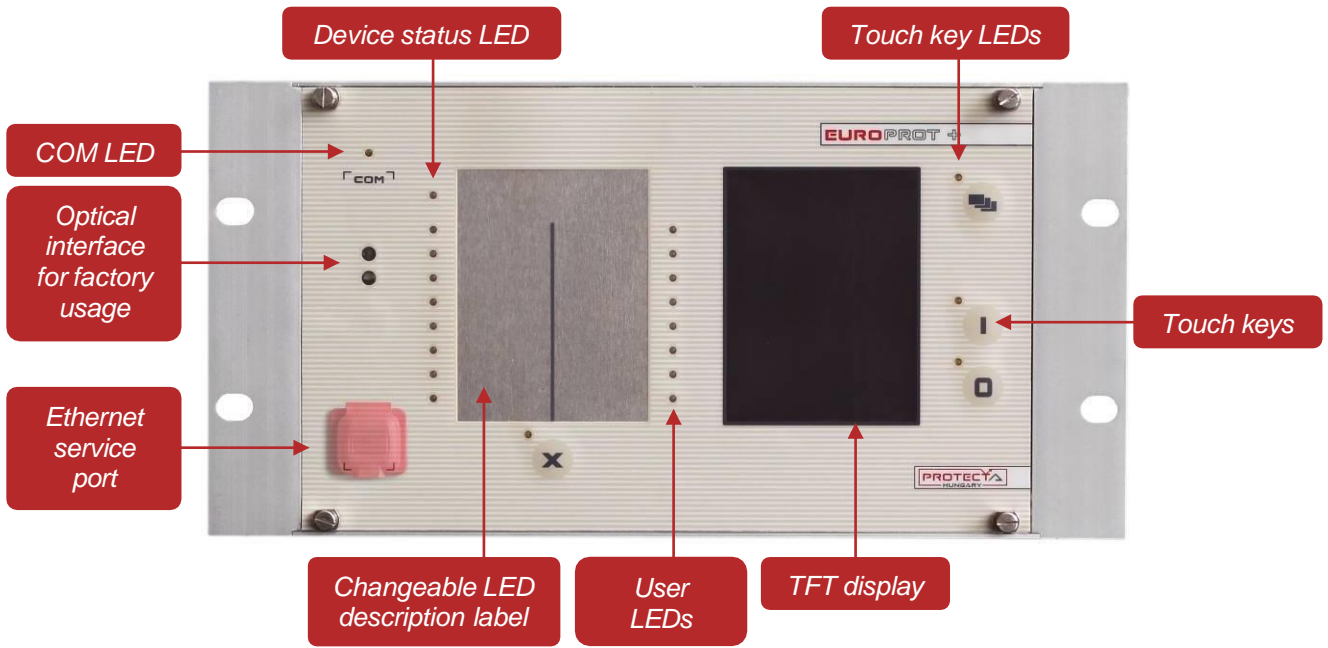


Figure 4–3 HMI signals and controls

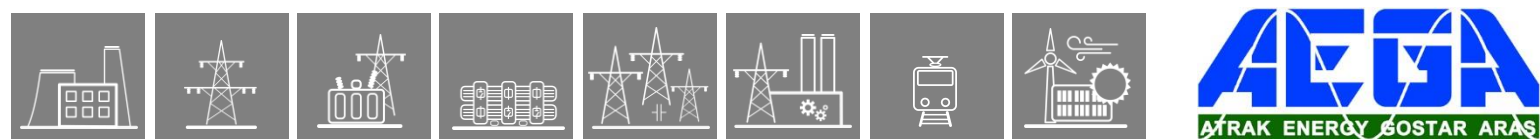
LCD dot-defect handling policy

The definitions of dot-defect are as below:

- The defect area of the dot must be bigger than half of a dot.
- For bright dot-defect (sparkle mode), showing black pattern, the dot's brightness must be over 30 % brighter than others at black raster.
- For dark dot-defect (black mode), showing white pattern, the dot's brightness must be under 70 % darker than others at R.G.B. raster.

| DOT-DEFECT TYPE | | MAXIMUM NUMBER ACCEPTABLE | |
|-----------------------------|----------|---------------------------|------|
| | | 3.5" | 5.7" |
| SPARKLE MODE | 1 dot | 4 | 4 |
| | 2 dots | 2 (sets) | 1 |
| | IN TOTAL | 4 | 5 |
| BLACK MODE | 1 dot | 4 | 5 |
| | 2 dots | 2 (sets) | 2 |
| | IN TOTAL | 4 | 5 |
| SPARKLE MODE AND BLACK MODE | 2 dots | 2 (sets) | n/a |
| IN TOTAL | | 6 | 10 |

For further information please contact our Application Team. (application@protecta.hu)



1.3.7. Current input module

This is an input module with intermediate current transformers to input the phase currents and the zero-sequence current. The rated current for the phase current and for the zero-sequence current can be selectable by parameter.

Main features:

- Rated frequency: 50 Hz, 60 Hz
- *Electronic* iron-core flux compensation

Connector types:

- *The default and optionally available connector types are indicated for each module in the tables below. See Chapter 20.2 for details about each type.*

| MODULE TYPE | CT+/0101 | | CT+/1111* | | CT+/1155 | | CT+/1500 | |
|-----------------------------------------|-------------------------------------------|-----|-------------------------------------------------------------------|------|---------------------------------------------------------------------------------------------------------------|------|-------------------------------------------|------|
| CHANNEL NUMBER | 1 – 4 | | 1 – 4 | | 1 – 4 | | 1 – 3 | |
| SELECTABLE RATED CURRENT, I_N [A] | 0.04 | 0.2 | 1 | 5 | 1 | 5 | 1 | 5 |
| MAX. MEASURED CURRENT ($\pm 10\%$) | $8 \times I_N$ | | $50 \times I_N$ | | $12.5 \times I_N$ | | $2 \times I_N$ | |
| POWER CONSUMPTION AT RATED CURRENT [VA] | 0.005 | 0.1 | 0.01 | 0.25 | 0.02 | 0.45 | 0.1 | 1.55 |
| THERMAL WITHSTAND [A] | | | | | | | | |
| CONTINUOUSLY | 7 | | 20 | | 20 | | 7 | |
| 10 s | 50 | | 175 | | 120 | | 50 | |
| 1 s | 150 | | 500 | | 380 | | 150 | |
| 10 ms | 330 | | 1200 | | 850 | | 330 | |
| CONNECTOR TYPE | <u>Default:</u> STVS <u>Options:</u> - | | <u>Default:</u> STVS <u>Options:</u> - | | <u>Default:</u> STVS <u>Options:</u> - | | <u>Default:</u> STVS <u>Options:</u> R | |
| RECOMMENDED APPLICATION | DEFL earth fault protection | | Special disturbance recorder application in wider frequency range | | Special protection applications where the overcurrent in the secondary circuit can not exceed $10 \times I_N$ | | General three-phase measurement | |

***Obsolete module. These modules are not recommended for new designs!**

| MODULE TYPE | CT+/1515* | | CT+/2500* | | CT+/5101 | | | |
|-----------------------------------------|-------------------------------------------|------|-------------------------------------------|------|----------------------------------------------|------|-------------------|-----|
| CHANNEL NUMBER | 1 – 4 | | 1 – 3 | | 1 – 3 | | 4 | |
| SELECTABLE RATED CURRENT, I_N [A] | 1 | 5 | 1 | 5 | 1 | 5 | 0.2 | 1 |
| MAX. MEASURED CURRENT ($\pm 10\%$) | $2 \times I_N$ | | $2 \times I_N$ | | $50 \times I_N$ | | $12.5 \times I_N$ | |
| POWER CONSUMPTION AT RATED CURRENT [VA] | 0.1 | 1.55 | 0.1 | 1.55 | 0.01 | 0.25 | 0.005 | 0.1 |
| THERMAL WITHSTAND [A] | | | | | | | | |
| CONTINUOUSLY | 7 | | 7 | | 20 | | 7 | |
| 10 s | 50 | | 50 | | 175 | | 50 | |
| 1 s | 150 | | 150 | | 500 | | 150 | |
| 10 ms | 330 | | 330 | | 1200 | | 330 | |
| CONNECTOR TYPE | <u>Default:</u> STVS <u>Options:</u> - | | <u>Default:</u> STVS <u>Options:</u> - | | <u>Default:</u> STVS <u>Options:</u> - | | | |
| RECOMMENDED APPLICATION | Special disturbance recorder application | | Generator protections | | Extremely sensitive earth-fault applications | | | |

***Obsolete module. These modules are not recommended for new designs!**

| MODULE TYPE | CT+/5102 | | | | CT+/5111* | | | |
|-----------------------------------------|-------------------------------------------|------|-----------------|------|-------------------------------------------|------|-----------------|-------|
| CHANNEL NUMBER | 1 – 3 | | 4 | | 1 – 3 | | 4 | |
| SELECTABLE RATED CURRENT, I_N [A] | 1 | 5 | 0.2 | 1 | 1 | 5 | 0.001 | 0.005 |
| MAX. MEASURED CURRENT ($\pm 10\%$) | $50 \times I_N$ | | $50 \times I_N$ | | $50 \times I_N$ | | $50 \times I_N$ | |
| POWER CONSUMPTION AT RATED CURRENT [VA] | 0.01 | 0.25 | 0.001 | 0.01 | 0.01 | 0.25 | 0.005 | 0.1 |
| THERMAL WITHSTAND [A] | | | | | | | | |
| CONTINUOUSLY | 20 | | 20 | | 20 | | 7 | |
| 10 s | 175 | | 120 | | 175 | | 50 | |
| 1 s | 500 | | 380 | | 500 | | 150 | |
| 10 ms | 1200 | | 850 | | 1200 | | 330 | |
| CONNECTOR TYPE | <u>Default:</u> STVS <u>Options:</u> - | | | | <u>Default:</u> STVS <u>Options:</u> R | | | |
| RECOMMENDED APPLICATION | Sensitive earth-fault applications | | | | Sensitive earth-fault applications | | | |

***Obsolete module. These modules are not recommended for new designs!**

| MODULE TYPE | CT+5115 | | CT+5116 | | CT+/5151 | | CT+/5152 | |
|-----------------------------------------|----------------------------------------------------------------------------------------------------------------------|------|-------------------------------------------|------|-------------------------------------------|------|-------------------------------------------|------|
| CHANNEL NUMBER | 1 – 4 | | 1 – 3 | | 1 – 4 | | 1 – 4 | |
| SELECTABLE RATED CURRENT, I_N [A] | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 5 |
| MAX. MEASURED CURRENT ($\pm 10\%$) | $50 \times I_N$ | | $50 \times I_N$ | | $50 I_N$ | | $50 I_N$ | |
| POWER CONSUMPTION AT RATED CURRENT [VA] | 0.01 | 0.25 | 0.01 | 0.25 | 0.01 | 0.25 | 0.01 | 0.25 |
| THERMAL WITHSTAND [A] | | | | | | | | |
| CONTINUOUSLY | 20 | | 20 | | 20 | | 20 | |
| 10 s | 175 | | 175 | | 175 | | 175 | |
| 1 s | 500 | | 500 | | 500 | | 500 | |
| 10 ms | 1200 | | 1200 | | 1200 | | 1200 | |
| CONNECTOR TYPE | <u>Default:</u> STVS <u>Options:</u> R | | <u>Default:</u> STVS <u>Options:</u> - | | <u>Default:</u> STVS <u>Options:</u> R | | <u>Default:</u> STVS <u>Options:</u> R | |
| RECOMMENDED APPLICATION | <ul style="list-style-type: none"> General protection applications* Three-phase measurement* | | High-impedance differential protection | | General protection applications | | Busbar protection bay units | |

*The CT+/5115 module handles both applications: it can be connected to the protection and measurement core of the primary CT as well

| MODULE TYPE | CT+/5153 | | | | | CT+/5154* | | | | |
|-----------------------------------------|---------------------------------------------------------------------------------------|-----|-----|-----------------|-----------|-----------------------------------------------------------------------------|-----|-----|-----------------|-------|
| CHANNEL NUMBER | 1 – 3 | | 4 | | | 1 – 3 | | 4 | | |
| SELECTABLE RATED CURRENT, I_N [A] | 1 | 5 | 1 | 0.2 | 0.2 sens. | 1 | 5 | 5 | 1 | 0.2 |
| MAX. MEASURED CURRENT ($\pm 10\%$) | $50 \times I_N$ | | | $10 \times I_N$ | | $50 \times I_N$ | | | $10 \times I_N$ | |
| POWER CONSUMPTION AT RATED CURRENT [VA] | 0.06 | 1.3 | 0.6 | 0.004 | 0.0004 | 0.06 | 1.3 | 1.3 | 0.06 | 0.004 |
| THERMAL WITHSTAND [A] | | | | | | | | | | |
| CONTINUOUSLY | 20 | | 7 | | | 20 | | | | |
| 10 s | 175 | | 50 | | | 175 | | | | |
| 1 s | 500 | | 150 | | | 500 | | | | |
| 10 ms | 1200 | | 330 | | | 1200 | | | | |
| CONNECTOR TYPE | <u>Default:</u> STVS <u>Options:</u> R, T** | | | | | <u>Default:</u> STVS <u>Options:</u> R | | | | |
| RECOMMENDED APPLICATION | General protection application, extremely sensitive transient earth-fault protections | | | | | General protection application, sensitive transient earth-fault protections | | | | |

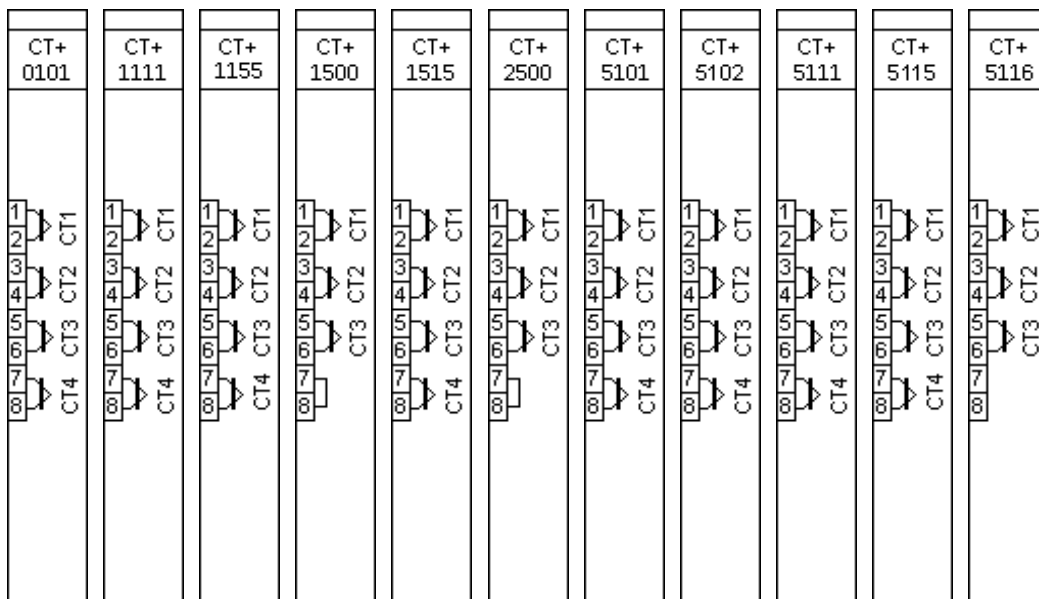
***Obsolete module. These modules are not recommended for new designs!**

**The connector remains the same STVS, only the handle of the module becomes narrower and will be made of aluminum

| MODULE TYPE | CT+/5155* | | | | | CT+/5253** | | | | |
|-----------------------------------------|-------------------------------------------------|-----|------|-----------------|------------|-----------------------------|-----|------|-------|------------|
| CHANNEL NUMBER | 1 – 3 | | 4 | | | 1 – 3 | | 4 | | |
| SELECTABLE RATED CURRENT, I_N [A] | 1 | 5 | 0.25 | 0.05 | 0.05 sens. | 5 | 1 | 0.25 | 0.05 | 0.05 sens. |
| MAX. MEASURED CURRENT ($\pm 10\%$) | $50 \times I_N$ | | | $10 \times I_N$ | | $25 \times I_N$ | | | | |
| POWER CONSUMPTION AT RATED CURRENT [VA] | 0.06 | 1.3 | 0.6 | 0.004 | 0.0004 | 0.06 | 1.3 | 0.6 | 0.004 | 0.0004 |
| THERMAL WITHSTAND [A] | | | | | | | | | | |
| CONTINUOUSLY | 20 | | 7 | | | 20 | | 7 | | |
| 10 s | 175 | | 50 | | | 175 | | 50 | | |
| 1 s | 500 | | 150 | | | 500 | | 150 | | |
| 10 ms | 1200 | | 330 | | | 1200 | | 330 | | |
| CONNECTOR TYPE | Default: STVS Options: - | | | | | Default: STVS Options: - | | | | |
| RECOMMENDED APPLICATION | DMD Special sensitive earth fault protection | | | | | Circuit breaker diagnostics | | | | |

***Obsolete module. These modules are not recommended for new designs!**

****Special module**



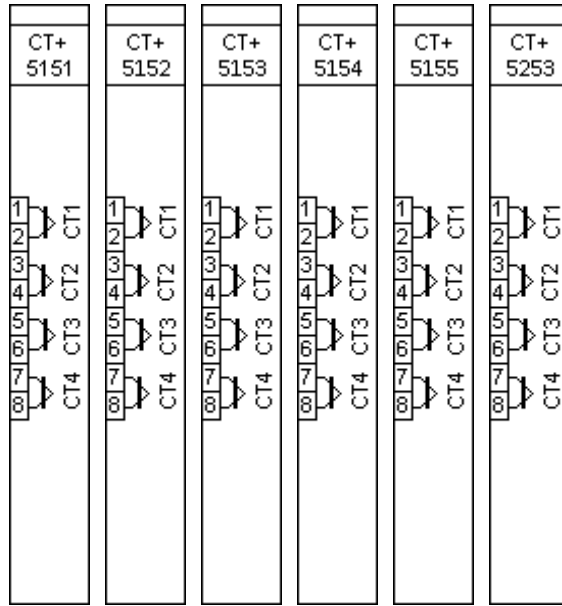
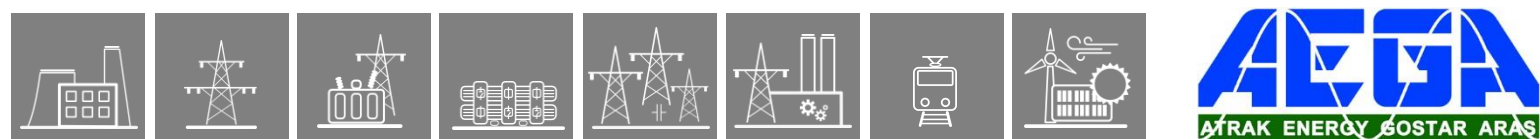


Figure 5-1 CT modules



1.3.8. Voltage input module

If the device performs voltage and/or frequency related functions and measurements (voltage protections, directional protections, frequency protections etc.), then this module is needed.

Connector types:

- The default and optionally available connector types are indicated for each module in the tables below. See Chapter 20.2 for details about each type.

| MODULE TYPE | VT+/2211 | VT+/2212* | VT+/2215** |
|----------------------------------------|----------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|
| CHANNEL NUMBER | 4 | 4 | 4 |
| SELECTABLE VOLTAGE RANGE | <u>Type 100:</u> $\frac{100}{\sqrt{3}}$, 100 V <u>Type 200:</u> $\frac{200}{\sqrt{3}}$, 200 V | <u>Type 100:</u> $\frac{100}{\sqrt{3}}$, 100 V <u>Type 200:</u> $\frac{200}{\sqrt{3}}$, 200 V | <u>Type 100:</u> $\frac{100}{\sqrt{3}}$, 100 V <u>Type 200:</u> $\frac{200}{\sqrt{3}}$, 200 V |
| CONTINUOUS VOLTAGE WITHSTAND | 200 V | 200 V | 200 V |
| SHORT TIME OVERLOAD (1 s) | 275 V (10s) | 275 V | 275 V |
| VOLTAGE MEASURING RANGE ($\pm 10\%$) | $0.05 U_N - 1.3 U_N$ | $0.05 U_N - 1.3 U_N$ | $0.05 U_N - 1.3 U_N$ |
| POWER CONSUMPTION OF VOLTAGE INPUT | 0.61 VA at 200 V 0.2 VA at 100 V | 0.61 VA at 200 V 0.2 VA at 100 V | <u>ch. 1-3:</u> 0.61 VA at 200 V 0.2 VA at 100 V <u>ch. 4:</u> 50 mVA at 100 V |
| CONNECTOR TYPE | <u>Default:</u> BLA <u>Options:</u> F, T, R | <u>Default:</u> BLA <u>Options:</u> - | <u>Default:</u> BLA <u>Options:</u> - |
| RECOMMENDED APPLICATION | General protection applications. | Special disturbance recorder application in wider frequency range | Special protection applications with voltage transformers that require low power consumption on the 4 th channel. |

***Obsolete module. These modules are not recommended for new designs!**

**Special module

| MODULE TYPE | VT+/2245 | VT+/2246* |
|----------------------------------------|--------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|
| CHANNEL NUMBER | 4 | 3 |
| SELECTABLE VOLTAGE RANGE | Type 200: $\frac{200}{\sqrt{3}}$, 200 V Type 400: $\frac{400}{\sqrt{3}}$ | |
| CONTINUOUS VOLTAGE WITHSTAND | 400 V | |
| SHORT TIME OVERLOAD (1 s) | 420 V | 420 V (10 s) |
| VOLTAGE MEASURING RANGE ($\pm 10\%$) | 0.05 U _N – 1.3 U _N | |
| POWER CONSUMPTION OF VOLTAGE INPUT | 0.21 VA at 200 V 0.28 VA at 230 V | |
| CONNECTOR TYPE | <u>Default:</u> BLA <u>Options:</u> T | <u>Default:</u> BLA <u>Options:</u> - |
| RECOMMENDED APPLICATION | Protection applications for 400 V AC secondary voltage | Special protection applications for 400 V AC secondary voltage and increased isolation to 6 kV |

*Special module

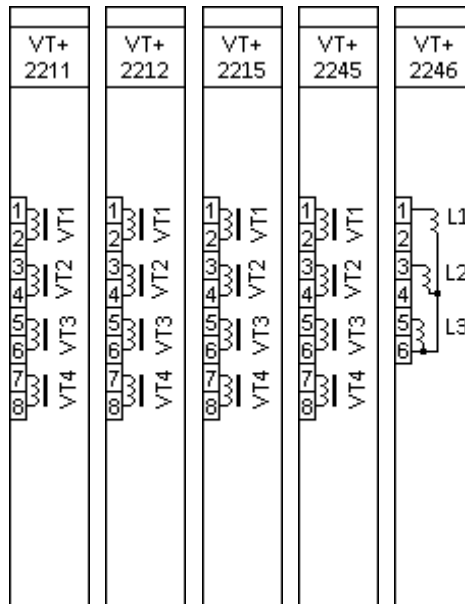
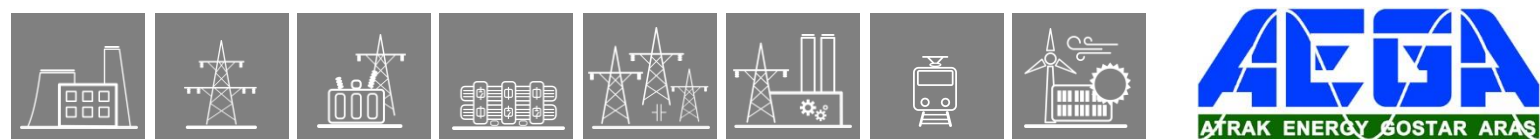


Figure 6-1 VT modules



1.3.9. Binary input module

The inputs are galvanic isolated, and the module converts high-voltage signals to the voltage level and format of the internal circuits. The inputs of this module can be also programmed to serve as a PPM input for time synchronization.

Connector types:

- The default and optionally available connector types are indicated for each module in the tables below. See Chapter 20.2 for details about each type.

Notes for the following tables:

- **Thermal withstand voltage:** continuous with 60 % of the input channels are energized.
- **Clamp voltage:** these are the guaranteed values; the actual ones might differ from those provided here (falling and rising around $0.66 U_N$ and $0.77 U_N$, respectively)

| MODULE TYPE | O8+/2401 | O8+/4801 | O8+/1101 | O8+/2201 |
|---------------------------|------------------------------------------|------------------------------------------|------------------------------------------|------------------------------------------|
| CHANNEL NUMBER | 8 | 8 | 8 | 8 |
| TIME SYNCHRONIZATION | configured by EuroCAP | configured by EuroCAP | configured by EuroCAP | configured by EuroCAP |
| RATED VOLTAGE | 24 V | 48 V | 110 V | 220 V |
| THERMAL WITHSTAND VOLTAGE | 72 V | 100 V | 250 V | 320 V |
| CLAMP VOLTAGE | falling $0.64 U_N$ rising $0.8 U_N$ | falling $0.64 U_N$ rising $0.8 U_N$ | falling $0.64 U_N$ rising $0.8 U_N$ | falling $0.64 U_N$ rising $0.8 U_N$ |
| COMMON GROUPS | independent | independent | independent | independent |
| CONNECTOR TYPE | <u>Default:</u> BLA <u>Options:</u> T | <u>Default:</u> BLA <u>Options:</u> T | <u>Default:</u> BLA <u>Options:</u> T | <u>Default:</u> BLA <u>Options:</u> T |

| MODULE TYPE | O12+/2401 | O12+/4801 | O12+/1101 | O12+/2201 |
|---------------------------|------------------------------------------|---------------------------------------------|---------------------------------------------|------------------------------------------|
| CHANNEL NUMBER | 12 | 12 | 12 | 12 |
| TIME SYNCHRONIZATION | configured by EuroCAP | configured by EuroCAP | configured by EuroCAP | configured by EuroCAP |
| RATED VOLTAGE | 24 V | 48 V | 110 V | 220 V |
| THERMAL WITHSTAND VOLTAGE | 72 V | 72 V | 250 V | 320 V |
| CLAMP VOLTAGE | falling $0.64 U_N$ rising $0.8 U_N$ | falling $0.64 U_N$ rising $0.8 U_N$ | falling $0.64 U_N$ rising $0.8 U_N$ | falling $0.64 U_N$ rising $0.8 U_N$ |
| COMMON GROUPS | 4 × 3 common | 4 × 3 common | 4 × 3 common | 4 × 3 common |
| CONNECTOR TYPE | <u>Default:</u> BLA <u>Options:</u> T | <u>Default:</u> BLA <u>Options:</u> F, T | <u>Default:</u> BLA <u>Options:</u> F, T | <u>Default:</u> BLA <u>Options:</u> T |

| MODULE TYPE | O12+/4201* | O12+/2101* | O15+/4801T | O15+/1101T |
|---------------------------|---------------------------------------------------------------|-----------------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|
| CHANNEL NUMBER | 12 | 12 | 15 | 15 |
| TIME SYNCHRONIZATION | configured by EuroCAP | configured by EuroCAP | configured by EuroCAP | configured by EuroCAP |
| RATED VOLTAGE | 24 V DC / 48 V DC user selectable on channel basis by jumpers | 110 V DC / 220 V DC user selectable on channel basis by jumpers | 48 V | 110 V |
| THERMAL WITHSTAND VOLTAGE | 72 V | 320 V | 100 V | 250 V |
| CLAMP VOLTAGE | falling 0.64 U _N rising 0.8 U _N | falling 0.64 U _N rising 0.8 U _N | falling 0.64 U _N rising 0.8 U _N | falling 0.64 U _N rising 0.8 U _N |
| COMMON GROUPS | 4 × 3 common | 4 × 3 common | 1 × 15 common | 1 × 15 common |
| CONNECTOR TYPE | <u>Default:</u> BLA <u>Options:</u> - | <u>Default:</u> BLA <u>Options:</u> T | BLT | BLT |

• O12+2101 and O12+4201 modules can be used only in demonstration applications! For further information see our [Product availability](#) chapter.

| MODULE TYPE | O16+/2401* | O16+/4801* | O16+/1101* | O16+/2201* |
|---------------------------|----------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|
| CHANNEL NUMBER | 16 | 16 | 16 | 16 |
| TIME SYNCHRONIZATION | - | - | - | - |
| RATED VOLTAGE | 24 V | 48 V | 110 V | 220 V |
| THERMAL WITHSTAND VOLTAGE | 72 V | 100 V | 250 V | 320 V |
| CLAMP VOLTAGE | falling 0.64 U _N rising 0.8 U _N | falling 0.64 U _N rising 0.8 U _N | falling 0.64 U _N rising 0.8 U _N | falling 0.64 U _N rising 0.8 U _N |
| COMMON GROUPS | 2 × 8 common | 2 × 8 common | 2 × 8 common | 2 × 8 common |
| CONNECTOR TYPE | <u>Default:</u> BL 3.5 <u>Options:</u> - | <u>Default:</u> BL 3.5 <u>Options:</u> - | <u>Default:</u> BL 3.5 <u>Options:</u> - | <u>Default:</u> BL 3.5 <u>Options:</u> - |

*Obsolete module. These modules are not recommended for new designs! O15+ modules are recommended instead (see above).

Main features:

- Digitally filtered per channel
- Current drain:
 - max. 1.6 mA per channel at 220 V DC
 - max. 1.8 mA per channel at 110 V DC
 - max. 2 mA per channel at 48 V DC
 - max. 3 mA per channel at 24 V DC
- In such applications where the input voltage is 60 V the modules with 48 V rated voltage can be used.
- Input voltage type can be either DC or AC voltage. If AC voltage is used make sure that the type and the parameters of the binary inputs are configured properly in EuroCAP tool.

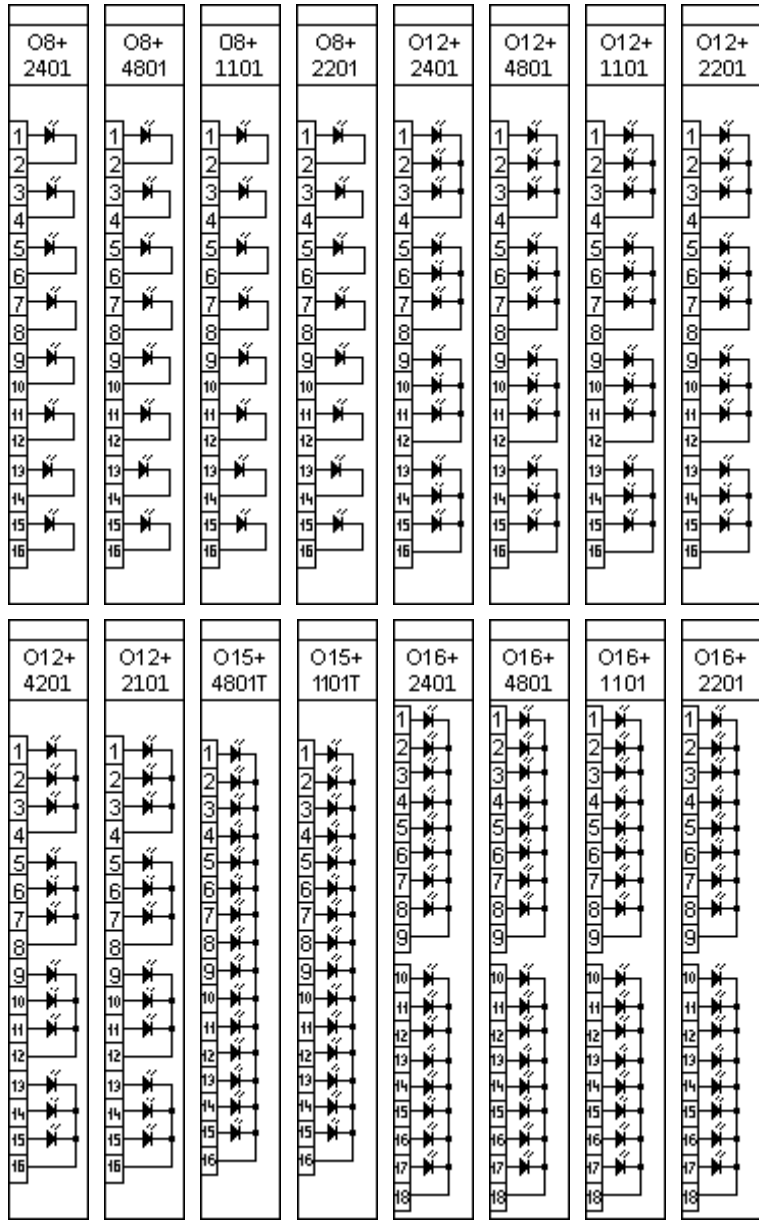
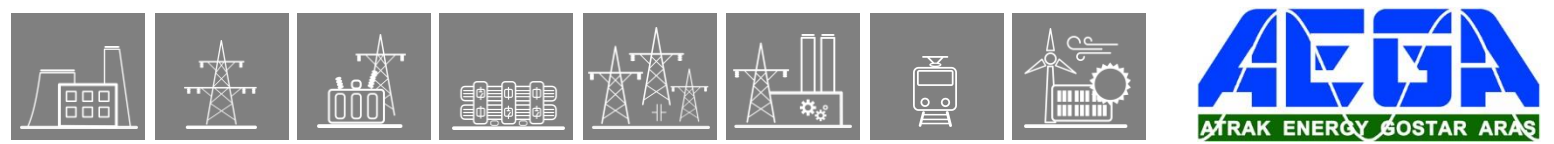


Figure 7-1 Binary input modules



1.3.10. Signaling module

The signaling module has 4, 8, 12 or 16 relay outputs with dry contacts.

Connector types:

- The default and optionally available connector types are indicated for each module in the tables below. See Chapter 20.2 for details about each type.

| MODULE TYPE | R4+/01 | R8+/00 | R8+/80 | R8+/C0 |
|------------------|------------------------------------------|---------------------------------------------|------------------------------------------|------------------------------------------|
| RATED VOLTAGE | 250 V AC/DC | 250 V AC/DC | 250 V AC/DC | 250 V AC/DC |
| CONTINUOUS CARRY | 8 A | 8 A | 8 A | 8 A |
| CONTACT VERSIONS | 4 CO | 8 NO | CH8 NC others NO | CH7 and CH8 NC others NO |
| GROUP ISOLATION | 4 independent | 8 independent | 8 independent | 8 independent |
| CONNECTOR TYPE | <u>Default:</u> BLA <u>Options:</u> F | <u>Default:</u> BLA <u>Options:</u> F, T | <u>Default:</u> BLA <u>Options:</u> T | <u>Default:</u> BLA <u>Options:</u> T |

| MODULE TYPE | R8+/FF | R12+/0000 | R12+/4000 |
|------------------|------------------------------------------|---------------------------------------------|---------------------------------------------|
| RATED VOLTAGE | 250 V AC/DC | 250 V AC/DC | 250 V AC/DC |
| CONTINUOUS CARRY | 8 A | 8 A | 8 A |
| CONTACT VERSIONS | 8 NC | 12 NO | CH12 NC others NO |
| GROUP ISOLATION | 8 independent | 4 x 3 common | 4 x 3 common |
| CONNECTOR TYPE | <u>Default:</u> BLA <u>Options:</u> - | <u>Default:</u> BLA <u>Options:</u> F, T | <u>Default:</u> BLA <u>Options:</u> F, T |

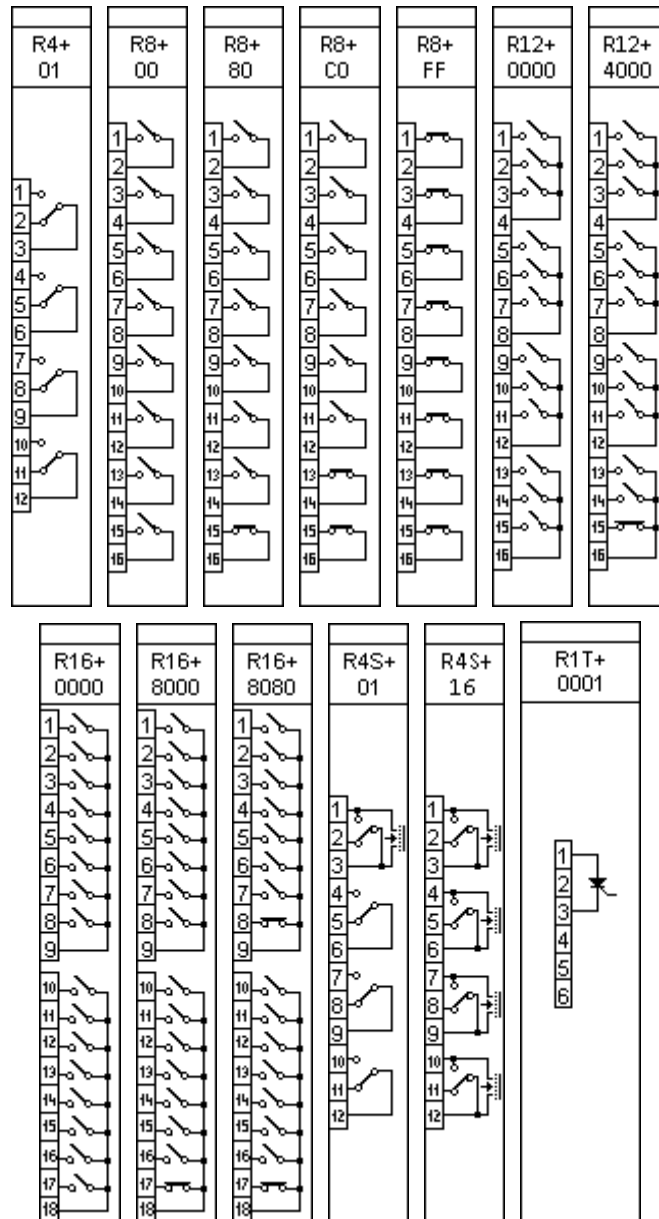


Figure 8-1 Signaling modules

1.3.11. Tripping module

The tripping module is a proprietary and patented solution that facilitates direct control of a circuit breaker.

Connector types:

- The default and optionally available connector types are indicated for each module in the table below. See Chapter 20.2 for details about each type.

| MODULE TYPE | TRIP+/4201 | TRIP+1101* | TRIP+/2101 | TRIP+/21F1** | TRIP+/2201 |
|---------------------------|---------------------------------------------|------------------------------------------|---------------------------------------------|------------------------------------------|------------------------------------------|
| CHANNEL NUMBER | 4 | 4 | 4 | 4 | 4 |
| RATED VOLTAGE | 24 V DC and 48 V DC | 110 V DC | 110 V DC | 110 V DC | 220 V DC |
| THERMAL WITHSTAND VOLTAGE | 72 V DC | 242 V DC | 150 V DC | 150 V DC | 242 V DC |
| CONTINUOUS CARRY | 8 A | 8 A | 8 A | 8 A | 8 A |
| MAKING CAPACITY | 0.5 s, 30 A | 0.5 s, 30 A | 0.5 s, 30 A | 0.5 s, 30 A | 0.5 s, 30 A |
| BREAKING CAPACITY | L/R = 40 ms: 4 A DC | L/R = 40 ms: 4 A DC | L/R = 40 ms: 4 A DC | L/R = 40 ms: 4 A DC | L/R = 40 ms: 4 A DC |
| CONNECTOR TYPE | <u>Default:</u> BLA <u>Options:</u> F, T | <u>Default:</u> BLA <u>Options:</u> - | <u>Default:</u> BLA <u>Options:</u> F, T | <u>Default:</u> BLA <u>Options:</u> T | <u>Default:</u> BLA <u>Options:</u> T |

***Obsolete module. These modules are not recommended for new designs!**

****Without trip circuit supervision.**

Main features:

- High-speed operation: with pre-trip 0.5 ms, without pre-trip typically 10 ms, maximally 22 ms.
- Trip circuit supervision for each trip contact, except TRIP+21F1
- With 2-wire wiring, the tripping output can be *dry* contact type, too

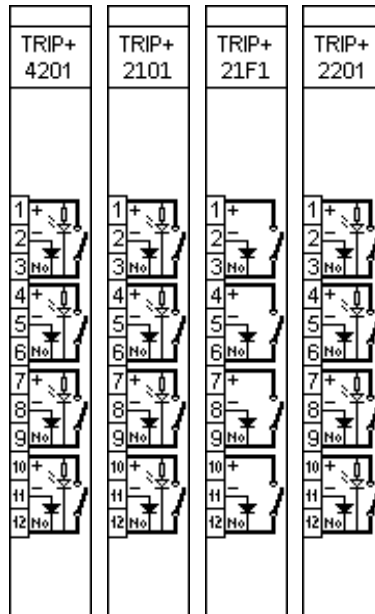


Figure 9-1 Tripping modules

1.3.11.1. TRIP+ module wiring

The tripping module provides tripping circuit supervision function (TCS). The wiring of these modules can be 2-wire or 3-wire. (TCS function is active for all wiring methods.)

The voltage of the "No" contact is maximized at 15 V by a Zener-diode. Make sure that the voltage caused by the resistance of the circuit breaker and the injected current from the TRIP+ module does not reach 10 V.

Our TRIP+ modules are improved to switch DC circuits. **Using reversed polarity or AC voltage can cause the damage of the internal circuits. Improper wiring might cause improper operation!**

1.3.11.1.1. 3-wire TRIP+ wiring methods

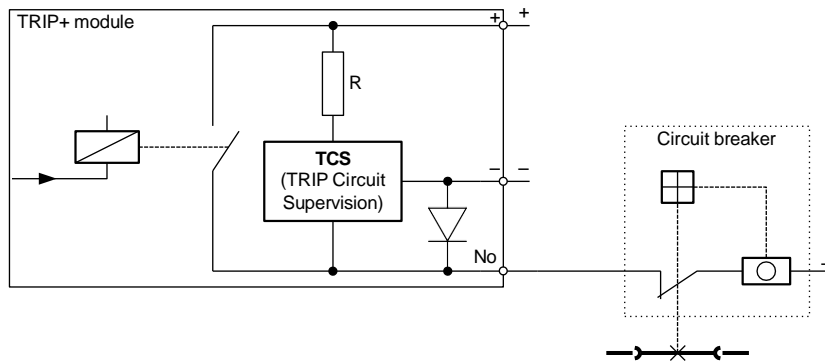


Figure 9-2 3-wire TRIP+ wiring

It is possible to use parallel connected TRIP+ modules. In this case the negative terminals must be common.

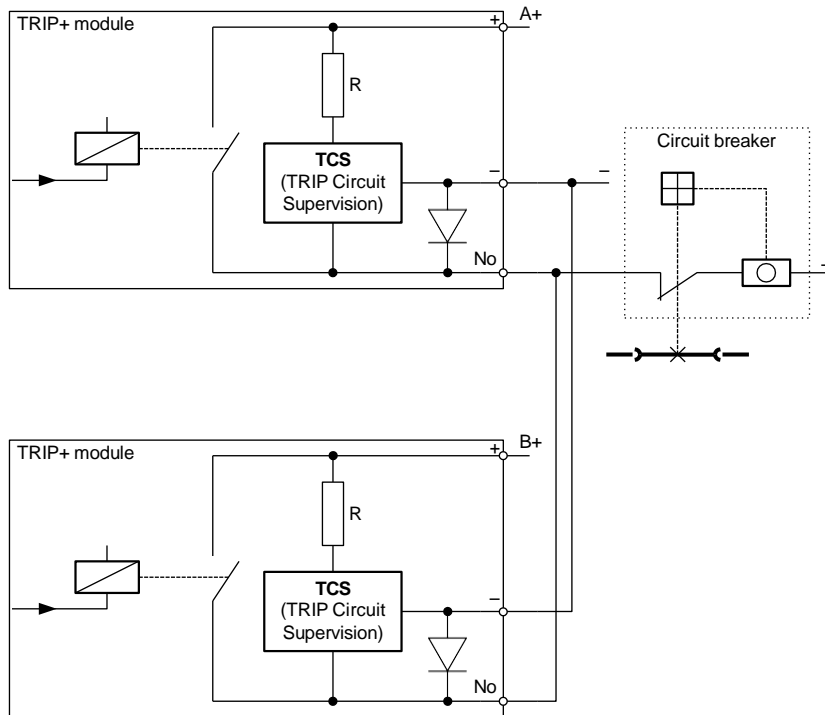


Figure 9-3 3-wire TRIP+ wiring using parallel connected TRIP+ modules

1.3.11.1.2. 2-wire TRIP+ wiring methods

If necessary, the TRIP+ modules can be wired using only the “+” and the “No” contacts.

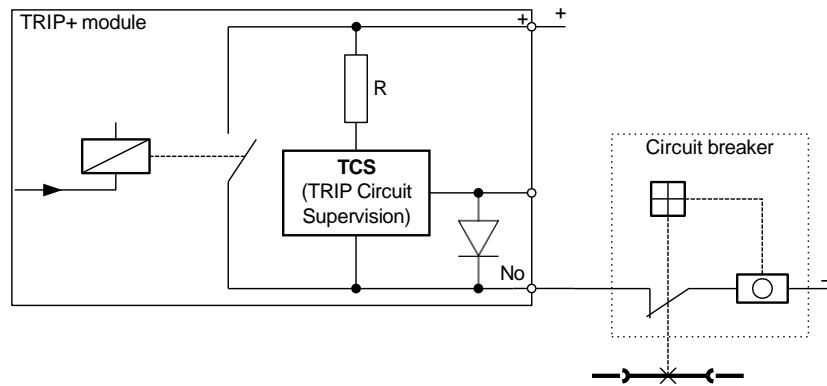


Figure 9-4 2-wire TRIP+ wiring

It is possible to use parallel connected TRIP+ modules.

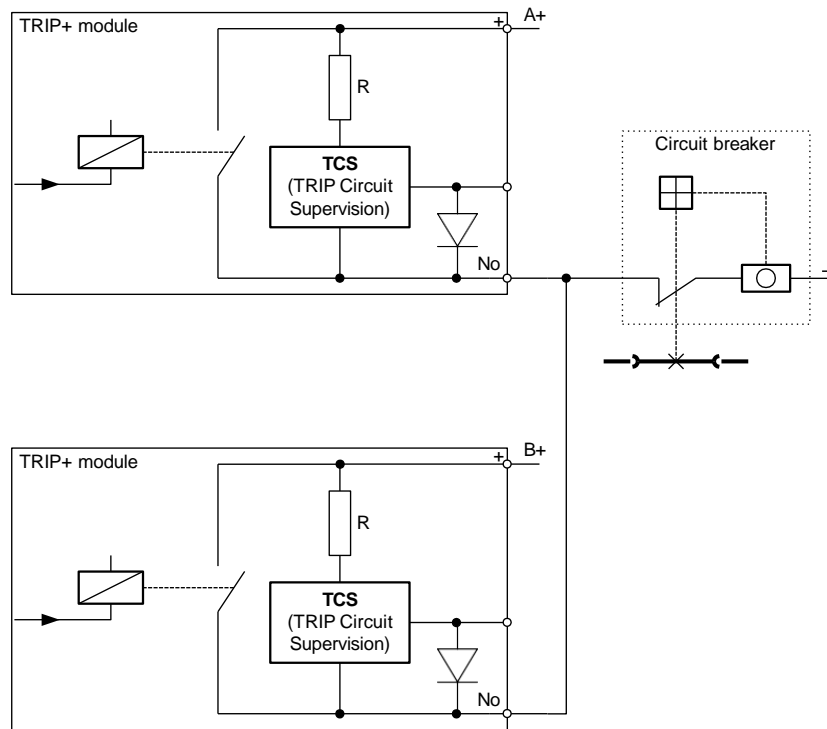


Figure 9-5 2-wire TRIP+ wiring using parallel connected TRIP+ modules

If the circuit breaker needs two-pole switching TRIP+ modules can be connected series as you can see in Figure 9–6.

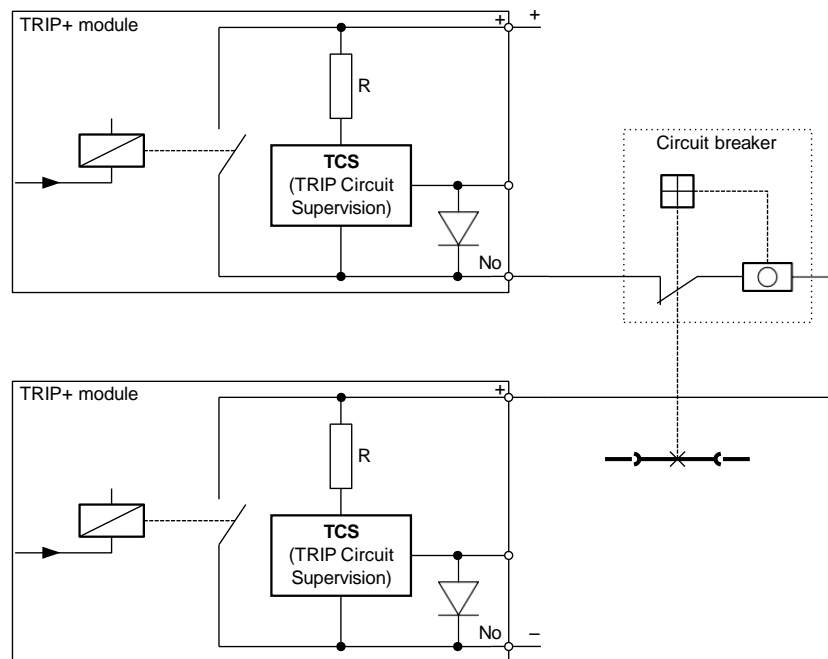


Figure 9-6 2-wire TRIP+ wiring using series connected TRIP+ modules

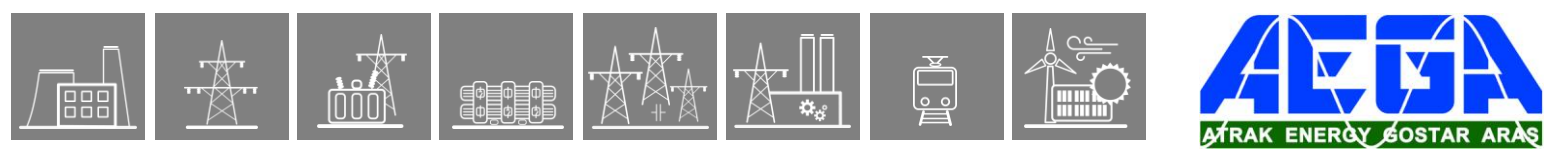
1.3.11.2. Trip Circuit Supervision (TCS)

Apart from the TRIP+/21F1, all TRIP modules have TCS. The feature is described in detail (tech. data, instructions, etc.) in a separate document:

https://www.protecta.hu/downloads/tcs_en

The technical data of the TCS is shown here as well:

| MODULE TYPE | TRIP+/4201 | TRIP+/2101 | TRIP+/2201 |
|--------------------------------------------|---------------------------------------------------|-----------------------------------------------------|------------------------------------------------------|
| VALUE OF R RESISTOR (± 10 %) | 10 kΩ | 73 kΩ | 130 kΩ |
| INJECTED CURRENT AT "NO" CONTACT | 2.4 mA @ 24 V DC 4.8 mA @ 48 V DC | 1.5 mA @ 110 V DC | 1.7 mA @ 220 V DC |
| MAXIMUM RESISTANCE OF THE TRIP COIL | 3-WIRE WIRING (MAX. 10 V) | 11.8 kΩ @ 24 V DC 3.7 kΩ @ 48 V DC | 9.7 kΩ @ 110 V DC 8.4 kΩ @ 125 V DC |
| | 3-WIRE WIRING WITH IN PARALLEL (MAX. 10 V) | 5.9 kΩ @ 24 V DC 1.8 kΩ @ 48 V DC | 4.8 kΩ @ 110 V DC 4.2 kΩ @ 125 V DC |
| | 2-WIRE METHOD (1 mA MIN. CURRENT) | 14 kΩ @ 24 V DC 38 kΩ @ 48 V DC | 37 kΩ @ 110 V DC 52 kΩ @ 125 V DC |
| | | 8.1 kΩ @ 220 V DC | 4 kΩ @ 220 V DC |
| | | 90 kΩ @ 220 V DC | |



1.3.11.3. Relay output modules of the EuroProt+ system

1.3.11.3.1. Types of the relay output modules of the EuroProt+ system

Basically there are two different types of relay output modules in the EuroProt+ devices: TRIP relay output module for high-speed operation of the circuit breakers Signal relay output module

1.3.11.3.2. Operating modes of the relay contacts

For operation of the relay output modules there are four different modes:

Application of TRIP relays for commands of fast protection functions

User application of the TRIP relays Fast operation of any relay contacts (TRIP relays or signal relays) Control of signal relay outputs.

The procedures of command processing are shown in. This document describes the details using the TRIP relay contacts as an example.

The left side of the Figure shows the available sources of the trip commands:

The functionblocks, configured in the device,

The communication channels to the SCADA system,

Commands generated using the front panel LCD of the device,

Any other binary signals, e.g. signals from the binary inputs of the device.

The right side of the Figure shows one of the TRIP relays symbolically.

The Figure provides a survey of the configured trip command processing methods. In the middle of the Figure, the locations indicated by "User" shows the possibilities for the user to modify the procedures. All other parts are factory programmed.

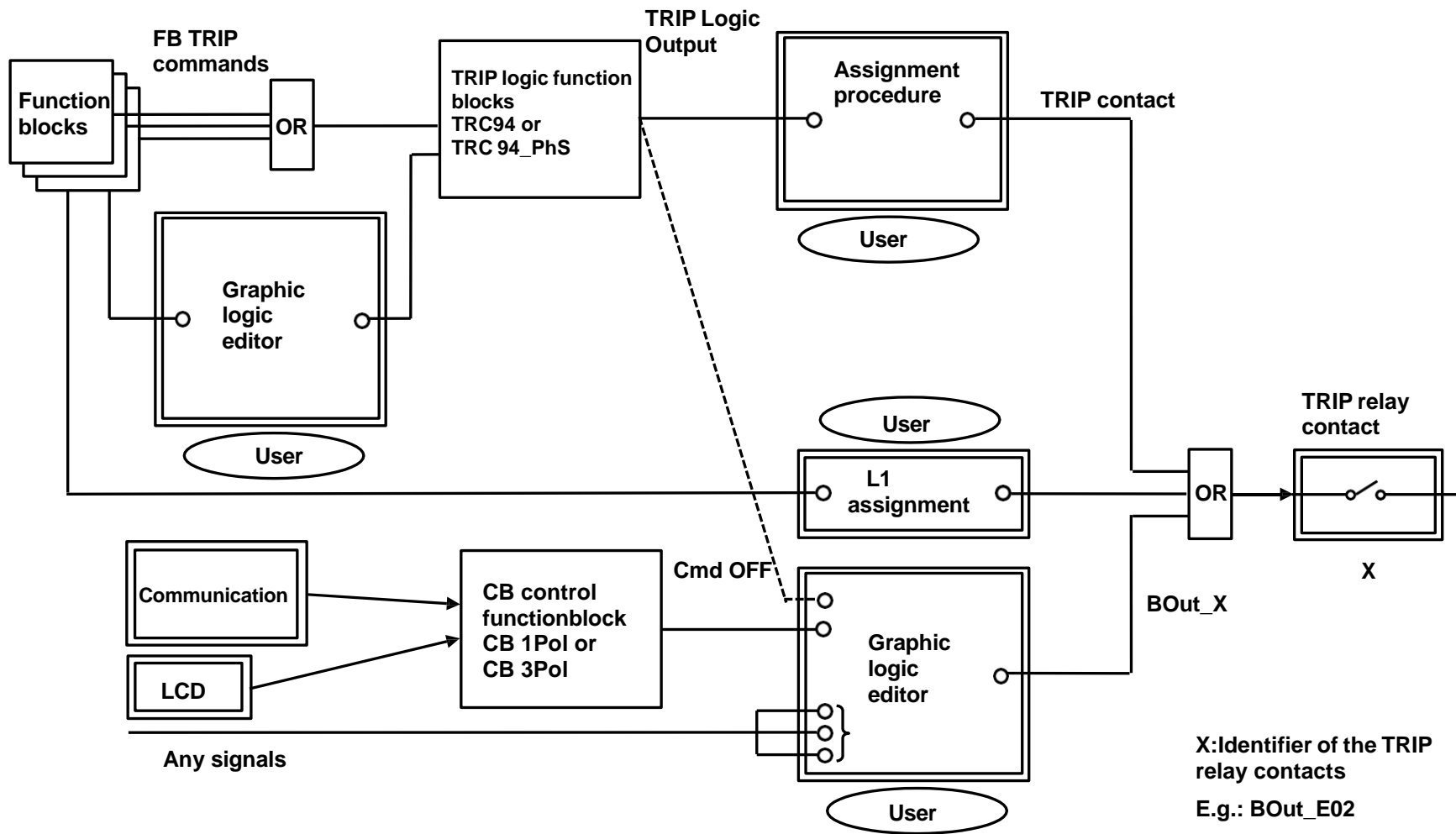
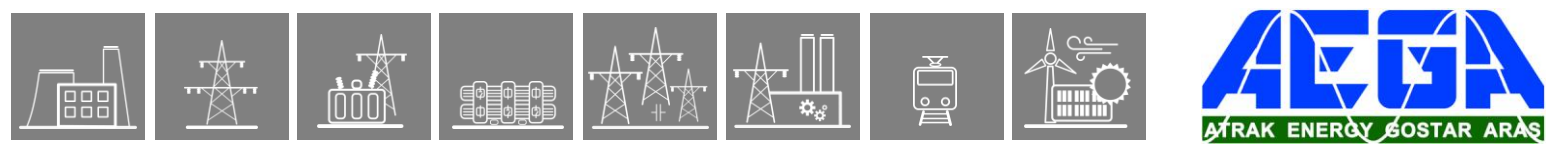


Figure 1-1 Principle of TRIP command processing



1.3.11.3.3. Application of TRIP relays for commands of fast protection functions

1.3.11.3.3.1. Aim of application of TRIP relays

The main aim of application of TRIP relays is to bypass the time delay of the mechanical contacts. For this aim there is a „slow” mechanical contact and a „fast” electronic switch in serial connection.

1.3.11.3.3.2. Control of the TRIP relays

The operation of the TRIP relays is performed in two steps:
Preparation of the circuit for the trip command
Trip command generation

1.3.11.3.3.2.1. Preparation of the circuit for the trip command

At the time when a protection function detects violation of the setting value of the characteristic quantity, the preparation process closes the „slow” mechanical contact, preparing the circuit for command generation.

1.3.11.3.3.2.2. The trip command generation

At the moment when the fast protection function – after some repeated checks, i.e. the timeout of the internal time counter – decides to generate the trip command then the „fast” electronic switch performs the operation, generating the trip command to the circuit breaker. This command is generated via the „TRC94_ PhS” or via the simplified „TRC94” trip logic functionblocks.

NOTE: If the TRIP command is not received within the expected time delay, then the command preparation resets after 50 ms. When the device is tested in the laboratory e.g. for measuring the limits of the distance protection characteristic, this can result a cyclic closing and opening of the mechanical contact and rattling can be heard. This does not mean faulty operation of the device!

1.3.11.3.3.3. The factory programming for relay control

For the trip command of protection functions, where the requirement is the fast operation (distance protection first zone, line differential protection, transformer differential protection, fast overcurrent stage, synchronous switching, etc.) the process of preparation and command generation is programmed in the form of „Fast logic”.

The alignment of the TRIP command is the task of the “TRIP logic functionblock”. All devices operating with TRIP binary output module, has a configured TRC 94 simplified, or a TRC 94_PhS TRIP logic functionblock. This converts e.g. the trip command due to phase-to-phase fault to a three-phase trip command, or extends the duration of the command according to the parameter setting. All these are described in the dedicated document.

The fast TRIP commands are assigned to the TRIP relay output contacts according to the factory configuration, but the user has a possibility to modify or extend this assignment using the EuroCAP configuration software. The factory assignment is described in the user manual of the given device configuration.

To ensure fast operation, this „Fast logic” is performed in each sampling cycle (1ms).

1.3.11.3.3.4. Changing the TRIP command assignment

The user has a possibility to modify or extend the TRIP command assignment using the EuroCAP configuration software. The menu item to be started is shown in *Figure 2-1*.

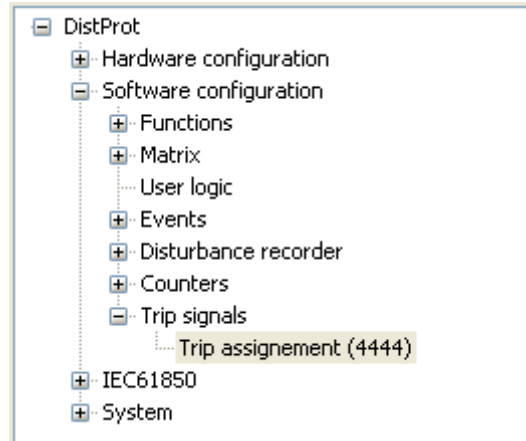


Figure 2-1 Menu item for TRIP command assignment

As *Figure 2-2* shows, the signal of type „TripLogic Output” (this is the command generated by the „TRIP logic functionblock”) can be assigned to a „Trip Contact” type relay output. The dialog window of the EuroCAP software selects these types of signals only; the available signals however can be assigned freely.

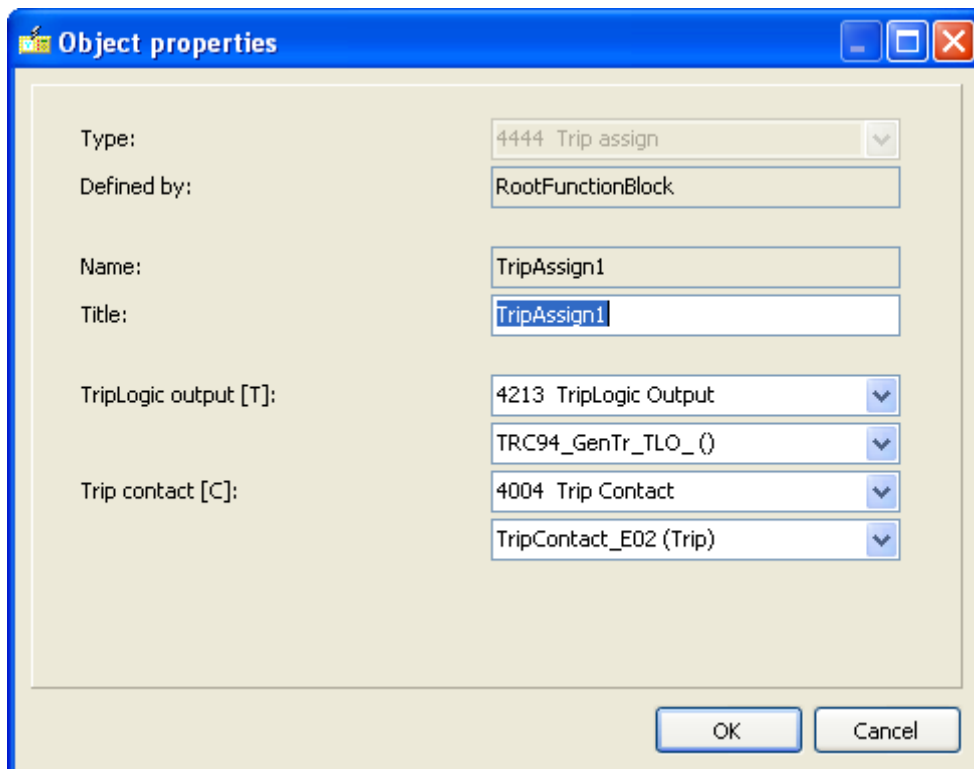
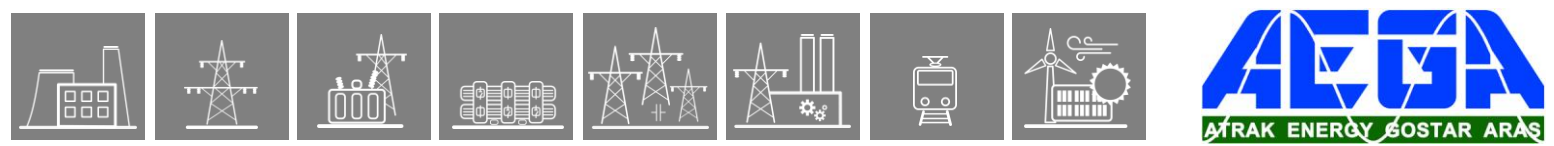


Figure 2-2 Changing the TRIP command assignment



The assigned signal is the input of an OR gate. As it is described below, several other signals can be directed to this OR gate. Using this method, also other TRIP modules extended by the user can be applied to operate the TRIP coil of the circuit breaker.

1.3.11.3.3.5. Fast operation of the relays

If the aim is to operate the contacts by a signal in each sampling cycle (1 ms), then the “Fast L1 contact option is to be applied. This option is provided by the EuroCAP configuration software in the menu „Hardware configuration/ IO signals/ Binary outputs/ Relay contacts/ Fast_L1 contacts”.

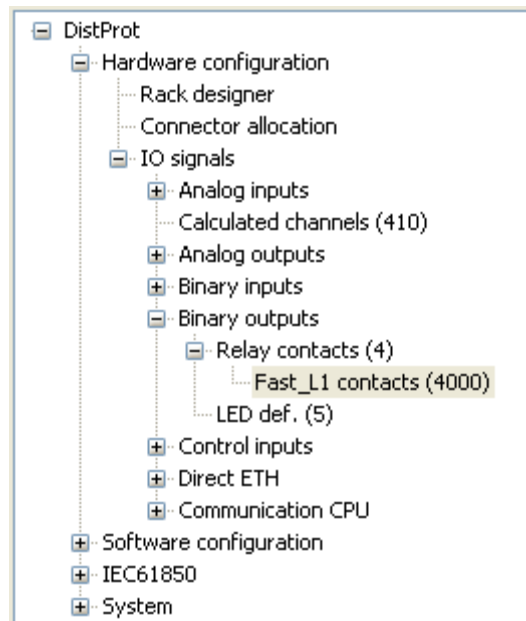


Figure 2-3 Configuring Fast L1 contacts

This menu offers the assignment of the appropriate binary signals to the relay contacts. As *Figure 2-4* shows, the signal can be of several types.

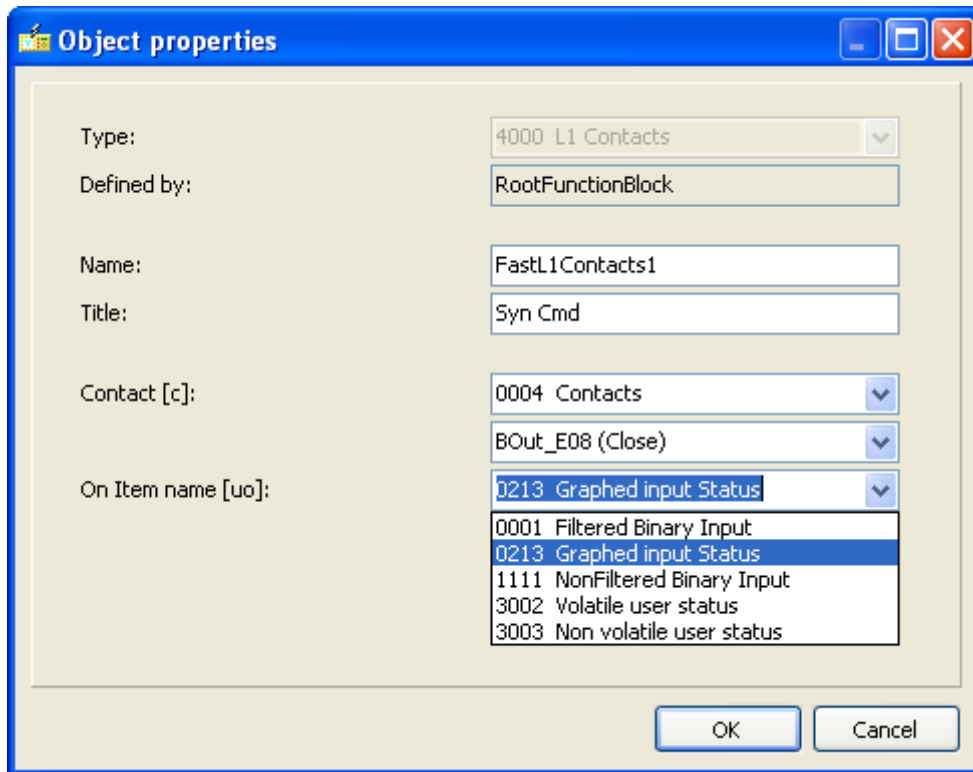


Figure 2-4 Fast L1 contact assignment

The processing of these fast signals is performed in a single step, the possibility for command preparation in the first step and additionally the TRIP command generation in the second step is not offered for the user. To perform this assignment, the application of the EuroCap configuration program in “Master” level is needed.

The selected signal is the input of an OR gate. To this gate additional other signals are connected, as it is described in the previous chapter, or in the description below.

IMPORTANT NOTE: The contacts of a TRIP hardware module are configured in the factory as “Fast L1 contacts”, the user does not need to define them additionally!

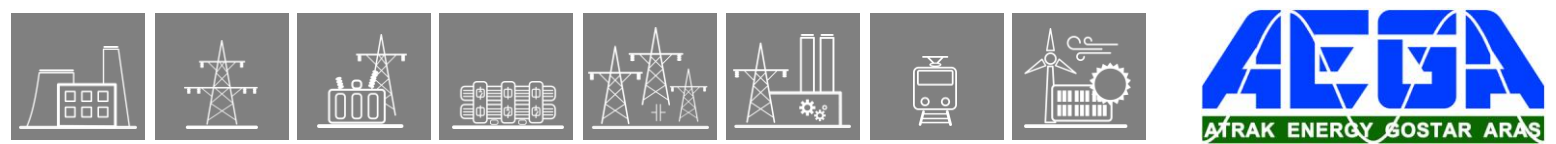
1.3.11.3.4. User application of the TRIP relays

The contacts controlling the circuit breaker operation can be programmed also by the user. Additionally to the command of the factory configured protection functions the user can assign signals to the channels of the TRIP hardware module. The two steps for the command generation however, as it is described in the paragraph above, cannot be applied by the user.

In this case, the source of the signals can be:

- Pre-configured TRIP commands
 - Received from the SCADA system via communication channels,
 - Generated by the user, applying the front panel LCD of the device,
- Any additional binary signals, e.g. an external command received by the binary input module of the device.

The pre-configured TRIP commands are aligned by the “CB control functionblock”, the output of which is the “CmdOff” TRIP command. This one and several other



signals can be programmed by the user to the output TRIP contact of the device, using the graphic logic editor of the EuroCAP configuration software.

Additionally the output signals of the „TRC94_PhS” trip logic or those of the „TRC94” simplified trip logic block can be programmed here. (These function-blocks are described in separate documents.) The output signal of the graphic logic editor is the „BOut_X” logic variable, where X is the identifier of the relay module and the contact, e.g. BOut_E02.

1.3.11.3.4.1. Graphic editor for the signal logic

For the protection functions, the operation of which are not required being extreme fast (in the range of one network period), the trip command must be assigned to the trip contacts usually by the user. These logic assignments can be programmed also in the factory, but the user can modify or extend them according to the requirements. To do this, the graphic editor of the EuroCap configuration tool must be applied with „Master” access rights.

1.3.11.3.4.2. The process of command generation

If a “simple” protection function generates a trip command then this logic signal is present on the dedicated output of the functionblock (see the description of the functionblocks).

The operation of the logic connections edited in the graphic editor is performed outside the sampling cycle, consequently, depending on the actual load of the processor a random time delay of additional 2-4 ms can be measured.

The contacts of the TRIP hardware modules are operated by several sources parallel:

The high-speed factory configured fast protection functions,
The defined Fast L1 signals,
The graphically edited logic connections (programmed in the factory and editable also by the user).

1.3.11.3.5. Control of signal relay outputs

If there is no special requirement to generate the signal with high speed, i.e. a time delay of 2-4 ms can be tolerated between the intent to generate the signal and the closing of the output contact then it is sufficient to apply normal signal relay contacts. To perform this programming the graphic editor of the EuroCap configuration tool is to be applied. To perform the programming the „Master” access level is needed.

1.3.11.4. Examples

1.3.11.4.1. Application of the TRIP logic

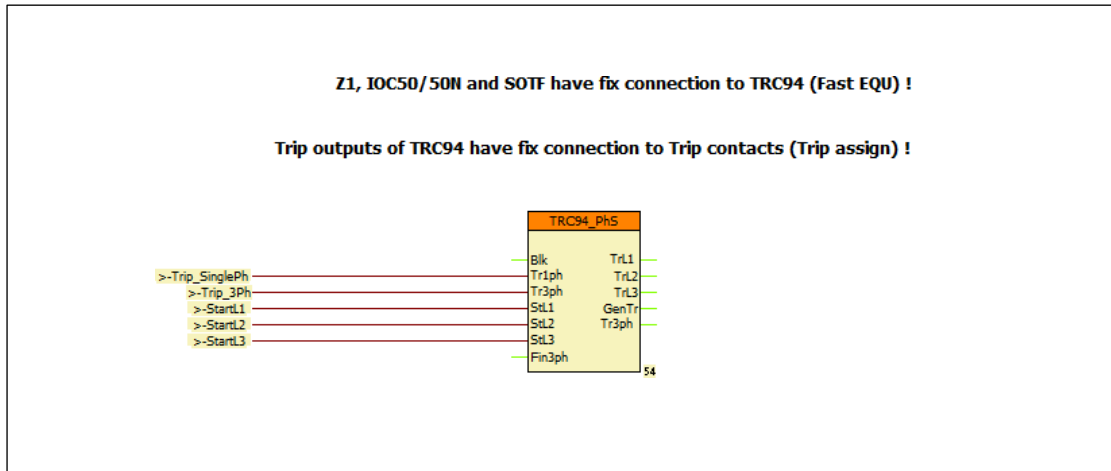


Figure 5-1 Example: A simple configuration to trip the circuit breaker

Figure 5-1 shows a simple configuration to trip the circuit breaker. In this Figure it is supposed that the fast protection functions operate according to the factory configuration and they control the TRIP contacts applying two steps of the preparation and command generation phases. This part of the program is not visible. (The description of the fast operating protection functions are listed in the configuration description of the devices.)

The outputs of the TRC94_PhS trip logic block are assigned to the channels of the TRIP hardware module. This assignment, which can be modified also by the user, is made not here but in the “TRIP assignment” menu of the EuroCAP configuration software. Consequently the Figure is complete; related to the outputs, the user needs additional graphic programming only if e.g. the operation is to be visualized also by signal relays.

If the configuration includes protection functions blocks the trip command of which does not need fast contact operation then these commands must be additionally directed to the TRIP relay outputs. To do this, the user collects these commands (with OR connection) and connects them to the dedicated inputs of the TRC94_PhS functionblock.

This Figure shows the collected signals (E.g. “Trip_SinglePh”, “Trip_3Ph”, etc.) only. As an example the „Trip_3Ph” signal collects the commands of all (not fast operating) protection functions which can generate three-phase trip command. The detailed description of the inputs and operation of the “TRC94_PhS” trip logic functionblock can be found in another document.

1.3.11.4.2. Application of circuit breaker control block

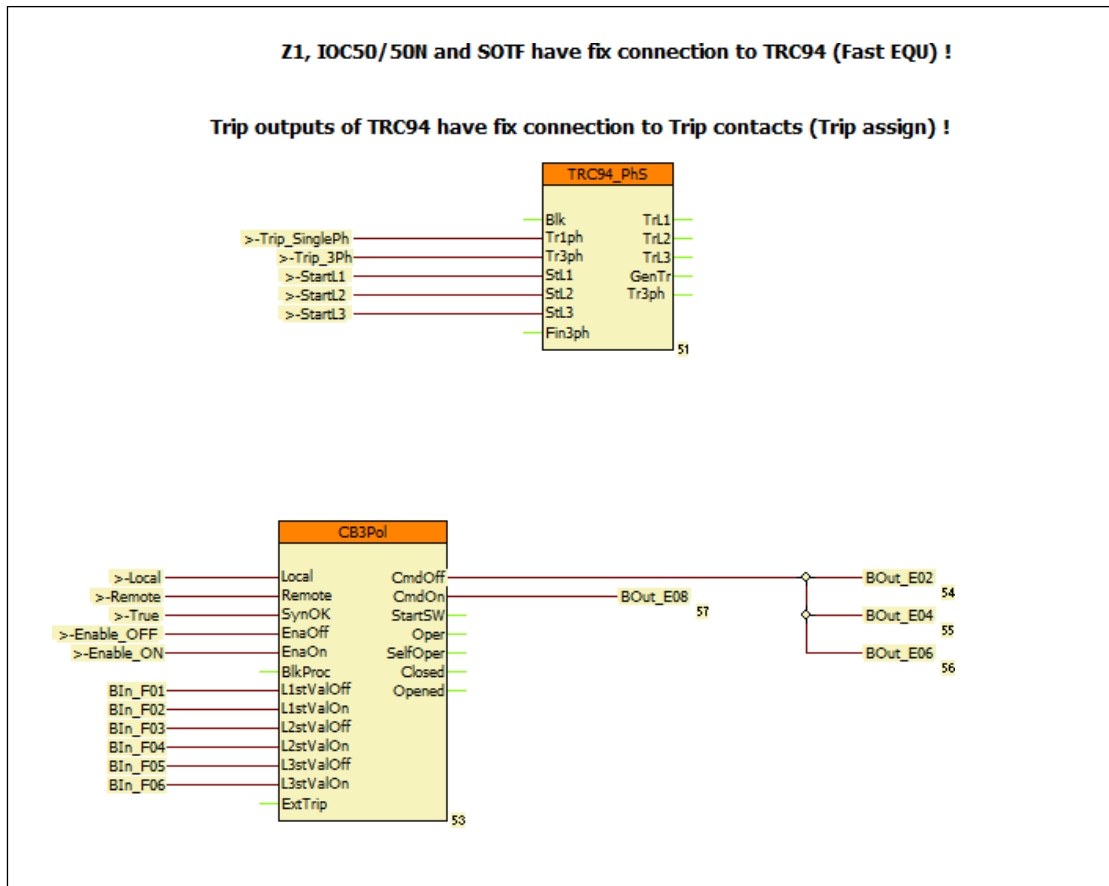


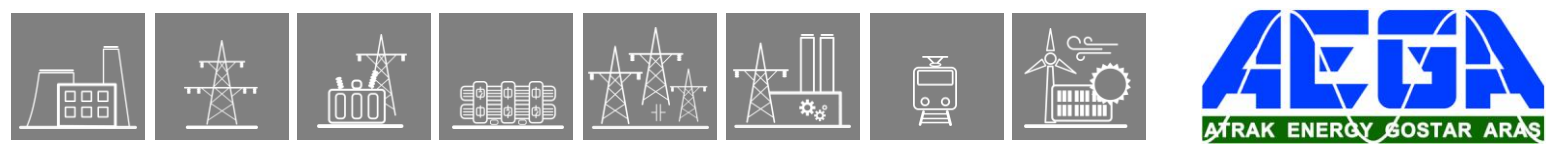
Figure 5-2 Example: Application of circuit breaker control block

Figure 5-2 shows an example for the application of the circuit breaker control block “CB3Pol”. In this Figure it is supposed that the fast protection functions operate according to the factory configuration and they control the TRIP contacts applying two steps of the preparation and command generation phases. This part of the program is not visible. (The description of the fast operating protection functions are listed in the configuration description of the devices.)

The outputs of the TRC94_PhS trip logic block are assigned to the channels of the TRIP hardware module. This assignment, which can be modified also by the user, is made not here but in the “TRIP assignment” menu of the EuroCAP configuration software. Consequently the Figure is complete; related to the outputs, the user needs additional graphic programming only if e.g. the operation is to be visualized also by signal relays.

If the configuration includes protection functions blocks the trip command of which does not need fast contact operation then these commands must be additionally connected to the TRIP relay outputs. To do this, the user collects these commands (with OR connection) and assigns them to the dedicated inputs of the TRC94_PhS functionblock.

This Figure shows the collected signals (E.g. “Trip_SinglePh”, “Trip_3Ph”, etc.) only. As an example the „Trip_3ph” signal collects the commands of all (not fast operating) protection functions which can generate three-phase trip command. The detailed description of the inputs and operation of the “TRC94_PhS” trip logic functionblock can be found in another document.



An extension to the example in *Figure 5-2* is that in this configuration also the „CB3pol” (circuit breaker control block) is applied. This block is needed if e.g. the front panel LCD of the device can display an active control scheme. For this purpose the signals „BIn_F...” in the Figure are the status signals of the circuit breaker poles, connected to the dedicated binary inputs of the device. The signals „Local”/”Remote” enable the local or remote control of the primary equipment. In the standard factory configurations these signals are programmed in the factory, but they can be modified also by the user.

If there is no synchro-check function activated in the device, connect the input „SynOK” of the “CB3Pol” to logic TRUE state. *Figure 5-2*, the local command issued via LCD of the device or the remote command received from the remote SCADA system is processed by the „CB3pol” functionblock (Output „CmdOff”). This control is programmed in the factory to “BOut_xx” variables. The user can perform any modification in the graphic programming.

The close command is connected directly to a dedicated “BOut_xx” variable. (This directs usually the fourth contact of the TRIP hardware module.)

The programming of the interlocking function must be performed by the user.

1.3.11.4.3. Automatic reclosing and circuit breaker control

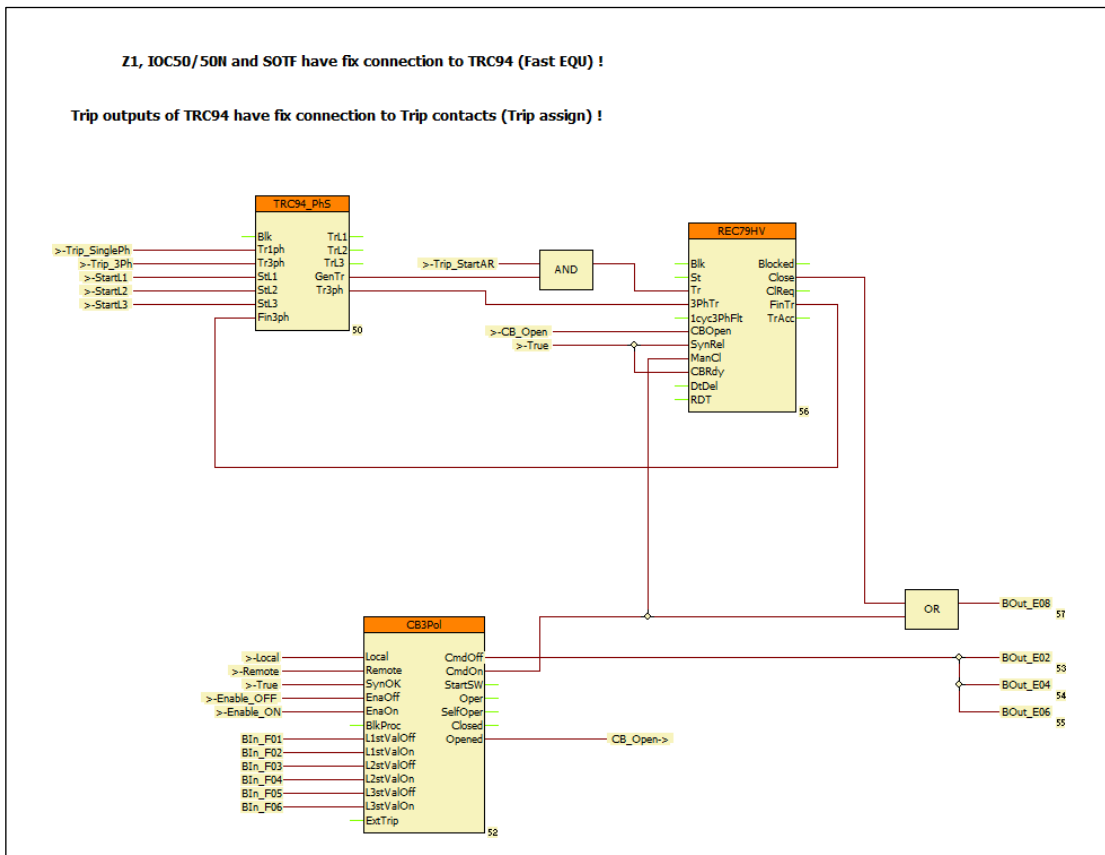


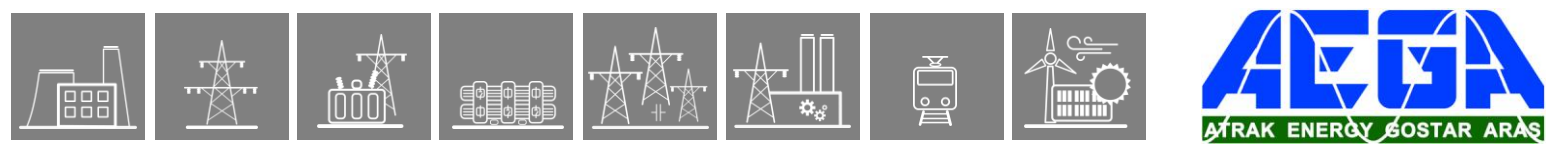
Figure 5-3 Example: Automatic reclosing and circuit breaker control

Figure 5-3 shows an example for the application of the automatic reclosing control block. In this Figure it is supposed that the fast protection functions operate according to the factory configuration and they control the TRIP contacts applying two steps of the preparation and command generation phases. This part of the program is not visible in “Master” level. (The description of the fast operating protection functions are listed in the configuration description of the devices.)

The outputs of the TRC94_PhS trip logic block are assigned to the output channels of the TRIP hardware module. This assignment, which can be modified also by the user, is made not here but in the “TRIP assignment” menu of the EuroCAP configuration software. Consequently the Figure is complete; related to the outputs, the user needs additional graphic programming only if e.g. the operation is to be visualized also by signal relays.

If the configuration includes protection functions blocks the trip command of which does not need fast contact operation then these commands must be additionally assigned to the TRIP relay outputs. To do this, the user collects these commands (with OR connection) and assigns them to the dedicated inputs of the TRC94_PhS functionblock.

This Figure shows the collected signals (E.g. “Trip_SinglePh”, “Trip_3Ph”, etc.) only. As an example the „Trip_3ph” signal collects the commands of all (not fast operating) protection functions which can generate three-phase trip command. The detailed description of the inputs and operation of the “TRC94_PhS” trip logic functionblock can be found in another document.



In this configuration also the „CB3pol” (circuit breaker control block) is applied. This block is needed if e.g. the front panel LCD of the device can display an active control scheme. For this purpose the signals „BIn_F...” in the Figure are the status signals of the circuit breaker poles, connected to the dedicated binary inputs of the device. The signals „Local”/”Remote” enable the local or remote control of the primary equipment. In the standard factory configurations these signals are programmed in the factory, but they can be modified also by the user.

If there is no synchro-check function activated in the device, connects the input „SynOK” of the “CB3Pol” to logic TRUE state.

According to *Figure 5-3*, the local command issued via LCD of the device or the remote command received from the remote SCADA system is processed by the „CB3pol” functionblock (Output „CmdOff”). This control is programmed in the factory to “BOut_xx” variables. The user can perform any modification in the graphic programming.

The close command is connected directly to a dedicated “BOut_xx” variable. (This directs usually the fourth contact of the TRIP hardware module.)

In *Figure 5-3* the close command is connected directly to a dedicated output. (This is usually the fourth contact of the TRIP hardware module.)

The programming of the interlocking function must be performed by the user.

An extension to the example in *Figure 5-2* is the application of the „REC79_HV” automatic reclosing function. The start signal „Trip_StartAR” can be programmed by the user. The automatic reclosing function is started only if the preceding trip command was performed by the circuit breaker, i.e. for example that the function is not disabled. The AND gate on this Figure performs this checking.

The „REC79_HV” automatic reclosing function needs the status signal indicating three-phase open state of the circuit breaker, connected to the „3PhTr” input of the „REC79_HV” functionblock. This signal is generated by the „TRC94_PhS” functionblock on the output „Tr3Ph”.

If the automatic reclosing is to be disabled after a fault caused by a manual close command, then the „CmdOn” output of the „CB3Pol” module must be connected to the „ManCl” input of the „REC79_HV” automatic reclosing function.

If there is no synchro-check function configured in the device, connect the „SynRel” input of the „REC79_HV” automatic reclosing function to logic TRUE state.

The evaluation of the status signals indicating the open state of the circuit breaker poles in OR gate is needed for the operation of the automatic reclosing function. According to the scheme of *Figure 5-3* the open state is indicated by at least one pole open state of the circuit breaker. (For simplicity, this Figure shows a realization without checking the FALSE signal of the closed states.)

Figure 5-3 supposes that the CB ready signal is not connected to the device; accordingly the steady TRUE state signal is connected to the „CBRdy” input of the „REC79_HV” automatic reclosing function. If the real signal is available, the signal must be connected similarly.

The close command of the „REC79_HV” automatic reclosing function is connected via OR gate to the dedicated close contact.

1.3.11.4.4. Closing the circuit breaker with synchro-check

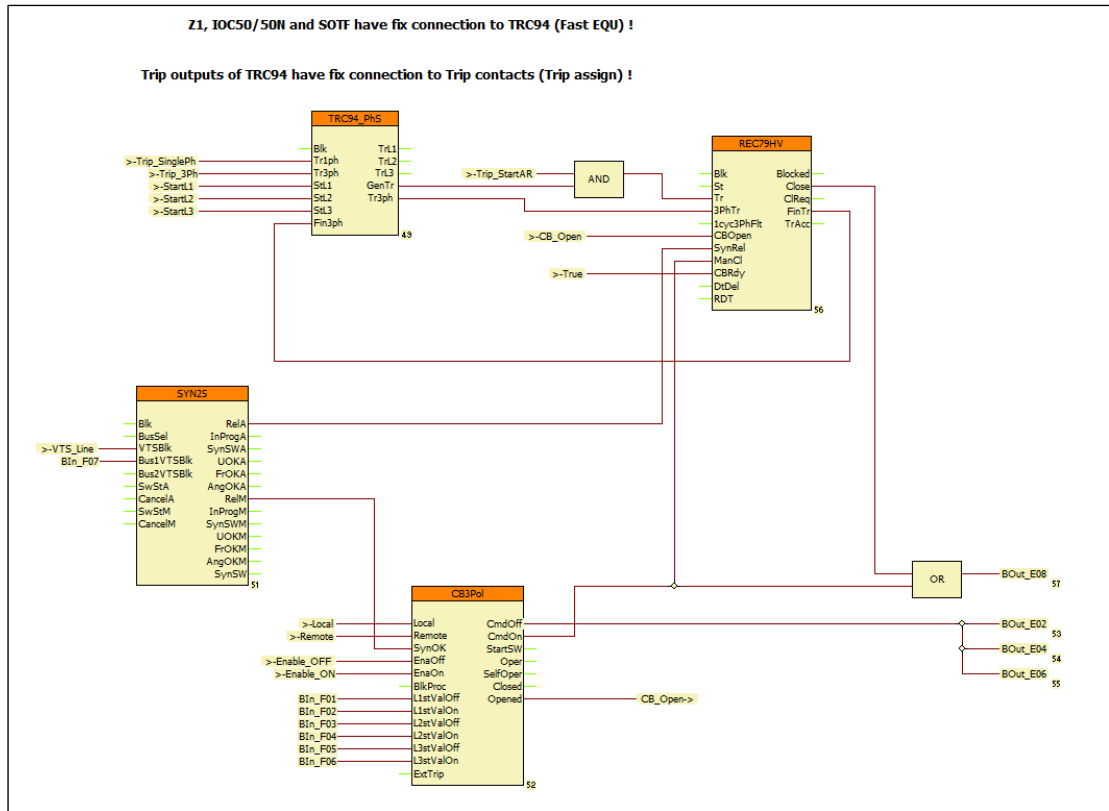


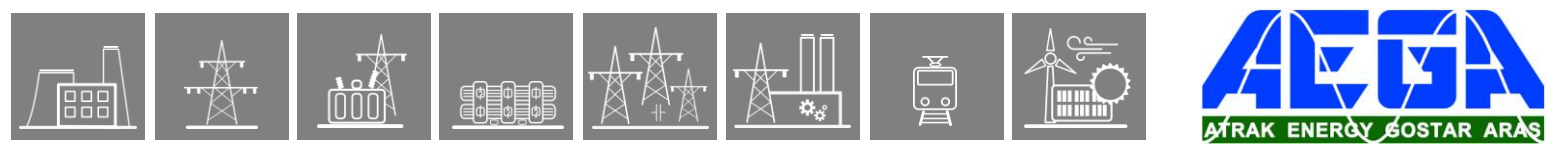
Figure 5-4 Example: closing the circuit breaker with synchro-check

Figure 5-4 shows an example for the application of “SYN25” cynchro-check functionblock. In this Figure it is supposed that the fast protection functions operate according to the factory configuration and they control the TRIP contacts applying two steps of the preparation and command generation phases. This part of the program is not visible in “Master” level. (The description of the fast operating protection functions are listed in the configuration description of the devices.)

The outputs of the TRC94_PhS trip logic block are assigned to the output channels of the TRIP hardware module. This assignment, which can be modified also by the user, is made not here but in the “TRIP assignment” menu of the EuroCAP configuration software. Consequently the Figure is complete; related to the outputs, the user needs additional graphic programming only if e.g. the operation is to be visualized also by signal relays.

If the configuration includes protection functions blocks the trip command of which does not need fast contact operation then these commands must be additionally assigned to the TRIP relay outputs. To do this, the user collects these commands (with OR connection) and assigns them to the dedicated inputs of the TRC94_PhS functionblock.

This Figure shows the collected signals (E.g. “Trip_SinglePh”, “Trip_3Ph”, etc.) only. As an example the „Trip_3ph” signal collects the commands of all (not fast operating) protection functions which can generate three-phase trip command. The detailed description of the inputs and operation of the “TRC94_PhS” trip logic functionblock can be found in another document.



In this configuration also the „CB3pol” (circuit breaker control block) is applied. This block is needed if e.g. the front panel LCD of the device can display an active control scheme. For this purpose the signals „BIn_F...” in the Figure are the status signals of the circuit breaker poles, connected to the dedicated binary inputs of the device. The signals „Local”/„Remote” enable the local or remote control of the primary equipment. In the standard factory configurations these signals are programmed in the factory, but they can be modified also by the user.

According to *Figure 5-4*, the local command issued via LCD of the device or the remote command received from the remote SCADA system is processed by the „CB3pol” functionblock (Output „CmdOff”). This control is programmed in the factory to “BOut_xx” variables. The user can perform any modification in the graphic programming.

The close command is connected directly to a dedicated “BOut_xx” variable. (This directs usually the fourth contact of the TRIP hardware module.)

In *Figure 5-4* the close command is connected directly to a dedicated output. (This is usually the fourth contact of the TRIP hardware module.)

The programming of the interlocking function must be performed by the user.

Figure 5-4 includes the application of the „REC79_HV” automatic reclosing function. The start signal „Trip_StartAR” can be programmed by the user. The automatic reclosing function is started only if the preceding trip command was performed by the circuit breaker, i.e. for example that the function is not disabled. The AND gate on this Figure performs this checking.

The „REC79_HV” automatic reclosing function needs the status signal indicating three-phase open state of the circuit breaker, connected to the „3PhTr” input of the „REC79_HV” functionblock. This signal is generated by the „TRC94_PhS” functionblock on the output „Tr3Ph”.

If the automatic reclosing is to be disabled after a fault caused by a manual close command, then the „CmdOn” output of the „CB3Pol” module must be connected to the „ManCl” input of the „REC79_HV” automatic reclosing function.

The evaluation of the status signals indicating the open state of the circuit breaker poles in OR gate is needed for the operation of the automatic reclosing function. According to the scheme of *Figure 5-4* the open state is indicated by at least one pole open state of the circuit breaker. (For simplicity, this Figure shows a realization without checking the FALSE signal of the closed states.)

Figure 5-4 supposes that the CB ready signal is not connected to the device; accordingly the steady TRUE state signal is connected to the „CBRdy” input of the „REC79_HV” automatic reclosing function. If the real signal is available, the signal must be connected similarly.

The close command of the „REC79_HV” automatic reclosing function is connected via OR gate to the dedicated close contact.

An extension to the example in *Figure 5-3* is the close command to the circuit breaker is generated by synchro-check. The enabling signal for the close command is generated by the „SYN25” software module. This module is described in details in a separate document. The needed input signals indicating the state of the voltage transformers („VTSBik” and „Bus1VTSBik”), must be programmed graphically.

The output signal „RelA” of the „SYN25” software module enables the closing operation of the „REC79_HV” automatic reclosing function via its „SynRel” input.

For manual close commands the output signal „ReIM” of the „SYN25” software module enables the closing operation of the „CB3pol” via its „SynOK” input.

1.3.11.4.5. Closing the circuit breaker with synchro-check and synchro-switch

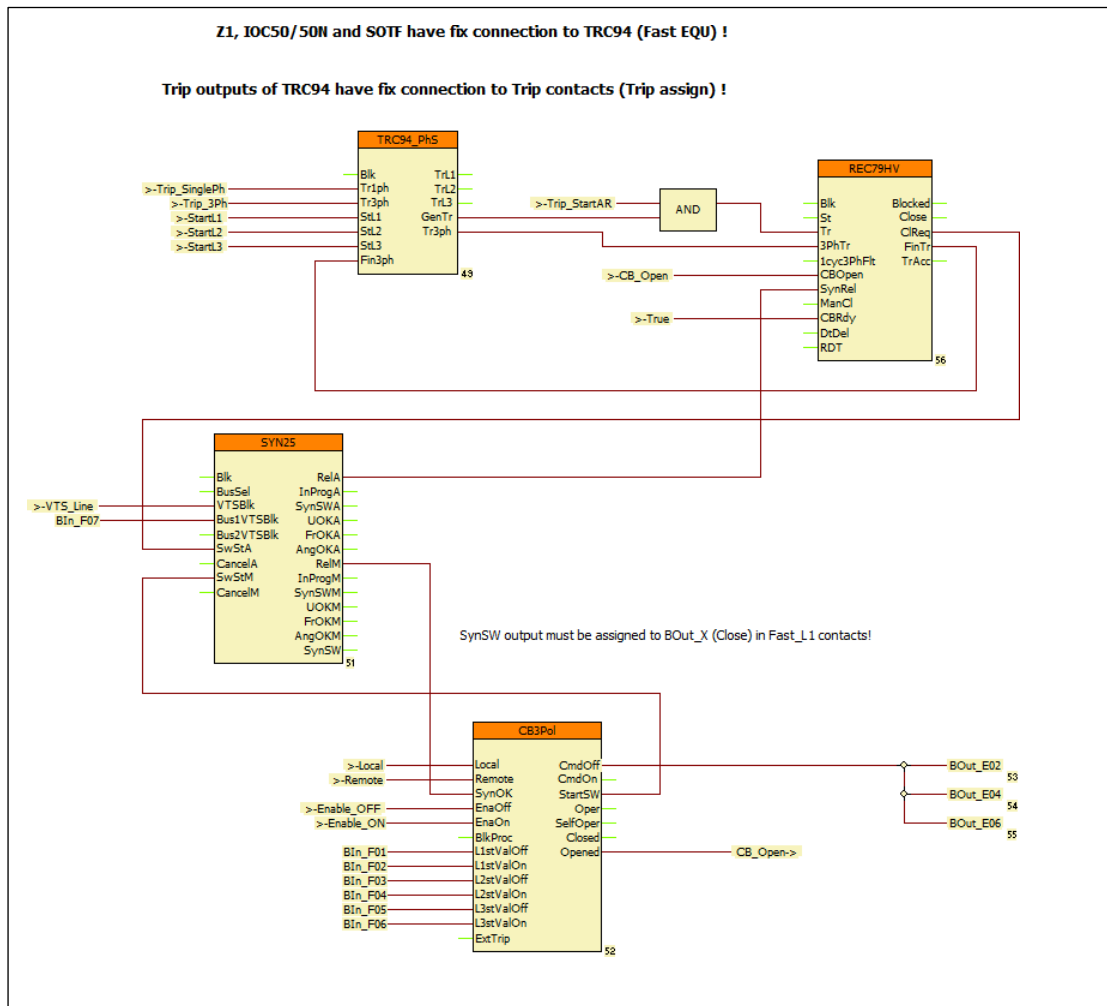


Figure 5-5 Example: closing the circuit breaker with synchro-check and synchro- switch

Figure 5-5 shows an example for the application of “SYN25” cynchro-check functionblock with synchro switch extension. In this Figure it is supposed that the fast protection functions operate according to the factory configuration and they control the TRIP contacts applying two steps of the preparation and command generation phases. This part of the program is not visible in “Master” level. (The description of the fast operating protection functions are listed in the configuration description of the devices.)

The outputs of the TRC94_PhS trip logic block are assigned to the output channels of the TRIP hardware module. This assignment, which can be modified also by the user, is made not here but in the “TRIP assignment” menu of the EuroCAP configuration software. Consequently the Figure is complete; related to the outputs, the user needs additional graphic programming only if e.g. the operation is to be visualized also by signal relays.

If the configuration includes protection functions blocks the trip command of which does not need fast contact operation then these commands must be additionally assigned to the TRIP relay outputs. To do this, the user collects these commands



(with OR connection) and assigns them to the dedicated inputs of the TRC94_PhS functionblock.

This Figure shows the collected signals (E.g. “Trip_SinglePh”, “Trip_3Ph”, etc.) only. As an example the „Trip_3ph” signal collects the commands of all (not fast operating) protection functions which can generate three-phase trip command. The detailed description of the inputs and operation of the “TRC94_PhS” trip logic functionblock can be found in another document.

In this configuration also the „CB3pol” (circuit breaker control block) is applied. This block is needed if e.g. the front panel LCD of the device can display an active control scheme. For this purpose the signals „BIn_F...” in the Figure are the status signals of the circuit breaker poles, connected to the dedicated binary inputs of the device. The signals „Local”/”Remote” enable the local or remote control of the primary equipment. In the standard factory configurations these signals are programmed in the factory, but they can be modified also by the user.

According to *Figure 5-5*, the local command issued via LCD of the device or the remote command received from the remote SCADA system is processed by the „CB3pol” functionblock (Output „CmdOff”). This control is programmed in the factory to “BOut_xx” variables. The user can perform any modification in the graphic programming.

The close command is connected directly to a dedicated “BOut_xx” variable. (This directs usually the fourth contact of the TRIP hardware module.)

In *Figure 5-5* the close command is connected directly to a dedicated output. (This is usually the fourth contact of the TRIP hardware module.)

The programming of the interlocking function must be performed by the user.

Figure 5-5 includes the application of the „REC79_HV” automatic reclosing function. The start signal „Trip_StartAR” can be programmed by the user. The automatic reclosing function is started only if the preceding trip command was performed by the circuit breaker, i.e. for example that the function is not disabled. The AND gate on this Figure performs this checking.

The „REC79_HV” automatic reclosing function needs the status signal indicating three-phase open state of the circuit breaker, connected to the „3PhTr” input of the „REC79_HV” functionblock. This signal is generated by the „TRC94_PhS” functionblock on the output „Tr3Ph”.

If the automatic reclosing is to be disabled after a fault caused by a manual close command, then the „CmdOn” output of the „CB3Pol” module must be connected to the „ManCl” input of the „REC79_HV” automatic reclosing function.

If there is no synchro-check function configured in the device, then connect the „SynRel” input of the „REC79_HV” automatic reclosing function to logic TRUE state.

The evaluation of the status signals indicating the open state of the circuit breaker poles in OR gate is needed for the operation of the automatic reclosing function. According to the scheme of *Figure 5-5* the open state is indicated by at least one pole open state of the circuit breaker. (For simplicity, this Figure shows a realization without checking the FALSE signal of the closed states.)

Figure 5-5 supposes that the CB ready signal is not connected to the device; accordingly the steady TRUE state signal is connected to the „CBRdy” input of the „REC79_HV” automatic reclosing function. If the real signal is available, the signal must be connected similarly.

The close command of the „REC79_HV” automatic reclosing function is connected via OR gate to the dedicated close contact.

In this application the close command to the circuit breaker is generated by synchro-check. The enabling signal for the close command is generated by the „SYN25” software module. This module is described in details in a separate document. The



needed input signals indicating the state of the voltage transformers („VTSBIK” and „Bus1VTSBIK”), must be programmed graphically.

The output signal „RelA” of the „SYN25” software module enables the closing operation of the „REC79_HV” automatic reclosing function via its „SynRel” input.

For manual close commands the output signal „RelM” of the „SYN25” software module enables the closing operation of the „CB3pol” via its „SynOK” input.

An extension to the example in *Figure 5-4* is the following: If there is no continuous synchron state because the frequency at one side of the circuit breaker is different to that of the other side, then the voltage vector of one side rotates continuously as compared to the other one. In this case a synchronous switching is attempted to restore the normal operation of the network.

The manual synchron switching mode is started by the signal on the „StSwM” input of the SYN25 functionblock. To do this the the „StartSW” output of the „CB3Pol” functionblock must be connected here.

For automatic synchron switching mode the „CIReq” output of the „Rec79HV” module must be connected to the „SwStA” input of the „SYN25” software module.

IMPORTANT NOTE: the close command is generated for both manual and automatic

switching at the output „SynSW” of the „SYN25” software module. It is advised not to connect this output using the „slow” graphic programming, but the contact assigned to the close command („BOutClose”) must be handled as fast operating „L1 contact”. The „SynSW” signal must be programmed to this contact. This assignment is performed using the EuroCap configuration tool in the menu „Hardware configuration/Binary outputs/Relay contacts/Fast_L1 contacts”.

1.3.12. RTD input module

The RTD+1100 module is used to measure the temperature through the variation of resistance of temperature detectors. RTD+0200 and RTD+1200 are special modules for Petersen coil controllers (DRL) measuring the resistance of the potentiometer.

Connector types:

- The default and optionally available connector types are indicated for each module in the table below. See Chapter 20.2 for details about each type.

| MODULE TYPE | RTD+/0200* | RTD+/1100 | RTD+/1200* |
|-------------------------|------------------------------------------|----------------------------------------------------------------------------------------------------------|------------------------------------------|
| CHANNEL NUMBER | 1 | 4 | 1 |
| MEASUREMENT METHOD | 3 wire configuration | 2, 3 or 4 wire configuration | 3 wire configuration |
| ACCURACY | ± 0.5 % ± 1 digit | ± 0.5 % ± 1 digit | ± 0.5 % ± 1 digit |
| SENSOR TYPE | Service-Ohm | Pt100/Ni100 Ni120/Ni120US Pt250/Ni250 Pt1000/Ni1000 Cu10 Service-Ohm (60 Ω ... 1.6 kΩ) | Service-Ohm |
| MEASUREMENT RANGES | 2 Ω ... 200 Ω | - 50 °C – +150 °C | 10 Ω ... 1000 Ω |
| CONNECTOR TYPE | <u>Default:</u> BLA <u>Options:</u> - | <u>Default:</u> BLA <u>Options:</u> T | <u>Default:</u> BLA <u>Options:</u> - |
| RECOMMENDED APPLICATION | Arc suppression coil controller | General resistance-based temperature measurement | Arc suppression coil controller |

*Special module

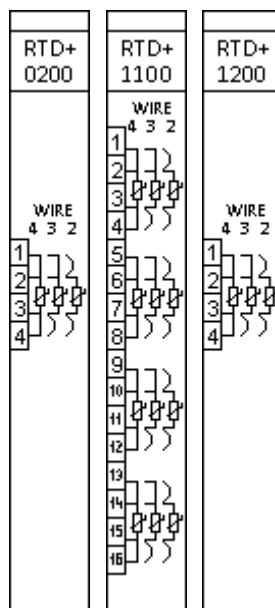


Figure 10-1 RTD input modules

1.3.12.1. RTD module wiring

If 2-wire wiring is used you have to make sure that the value of RA and RD resistors are set correctly in the “parameters” menu of the web server.

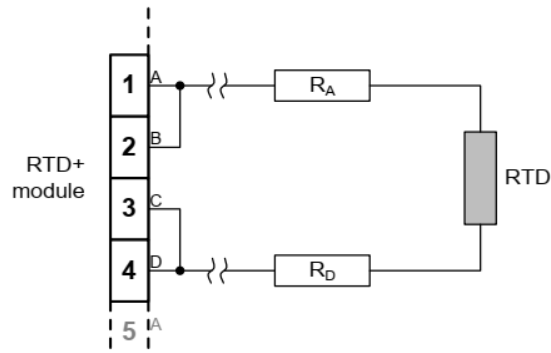


Figure 10-2 2-wire RTD wiring

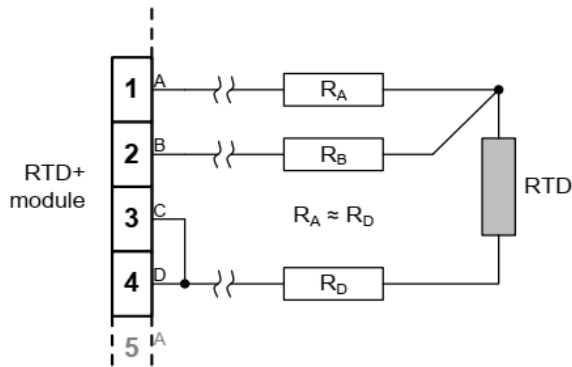


Figure 10-3 3-wire RTD wiring

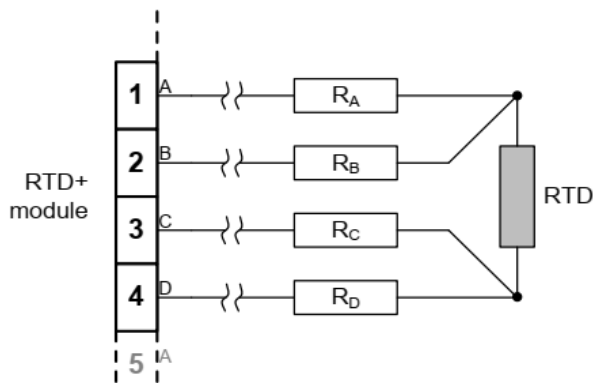


Figure 10-4 4-wire RTD wiring

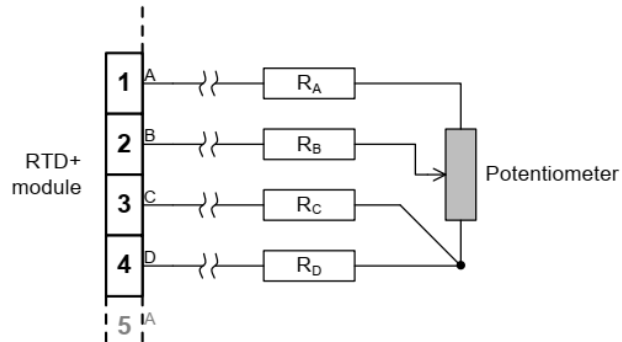


Figure 10-5 4-wire RTD wiring of potentiometer

1.3.13. Analog input module (AI)

The analog input module accepts transducers' current outputs. The AIC module can measure unipolar and bipolar current values in wide ranges.

Connector types:

- The default and optionally available connector types are indicated for each module in the table below. See Chapter 20.2 for details about each type.

| MODULE TYPE | AIC+/0200* | AIC+/0201* | AIC+/0202 |
|--------------------|------------------------------------------------------------------|------------------------------------------------------------------|------------------------------------------------------------------|
| CHANNEL NUMBER | 4 | 4 | 4 |
| MEASUREMENT METHOD | 2 wire inputs | 2 wire inputs with optional 12 V excitation | 2 wire inputs |
| RELATIVE ACCURACY | $\pm 0.5 \% \pm 1$ digit | $\pm 0.5 \% \pm 1$ digit | $\pm 0.5 \% \pm 1$ digit |
| MEASUREMENT RANGES | ± 20 mA (typical 0-20, 4-20 mA) $R_{LOAD} = 56 \Omega$ | ± 20 mA (typical 0-20, 4-20 mA) $R_{LOAD} = 56 \Omega$ | ± 20 mA (typical 0-20, 4-20 mA) $R_{LOAD} = 56 \Omega$ |
| CONNECTOR TYPE | Default: BLA Options: - | Default: BLA Options: - | Default: BLA Options: F, T |

*Obsolete module. These modules are not recommended for new designs!

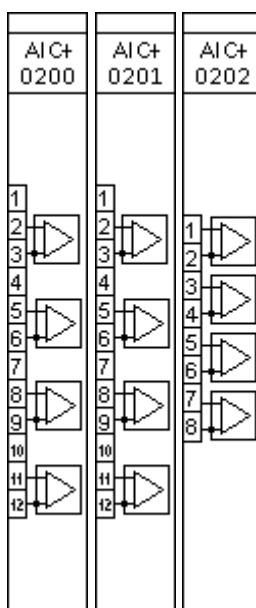


Figure 11-1 Analog input modules

1.3.13.1. AI module wiring

The following wiring method can be applied.

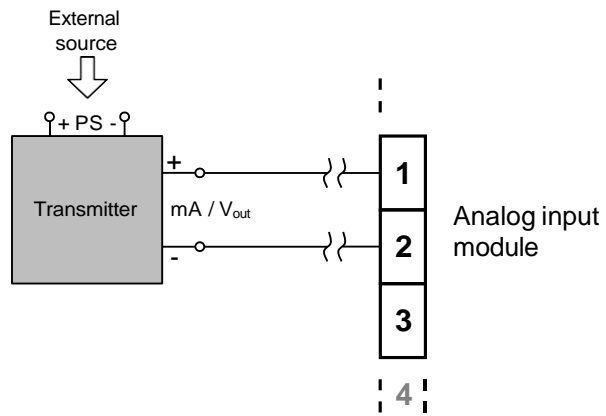


Figure 11-2 AI wiring

1.3.14. Analog output module (ATO)

The analog output module transmits current or voltage signals. The ATO module can be used in wide ranges in unipolar and bipolar mode.

Connector types:

- The default and optionally available connector types are indicated for each module in the table below. See Chapter 20.2 for details about each type.

| MODULE TYPE | ATO+/0002 | ATO+/0004 |
|--------------------------------------------------------------|---------------------------------------|---------------------------------------|
| CHANNEL NUMBER | 2 | 4 |
| OUTPUT MODE | 2 wire output | 2 wire output |
| MAXIMUM LOAD ($R_{\text{CABLE}} + R_{\text{RECEIVER}}$) | 500 Ω | 500 Ω |
| OUTPUT RANGES | ± 20 mA 0 - 20 mA 4 - 20 mA | ± 20 mA 0 - 20 mA 4 - 20 mA |
| CONNECTOR TYPE | Default: BLA Options: T | Default: BLA Options: - |

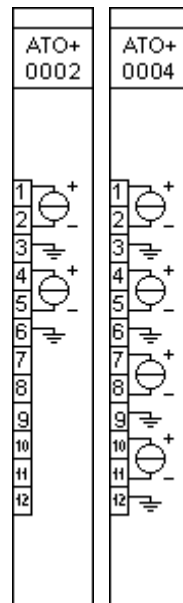


Figure 12-1 Analog output modules

1.3.14.1. ATO module wiring

The analog output module should be connected according to the following wiring diagram.

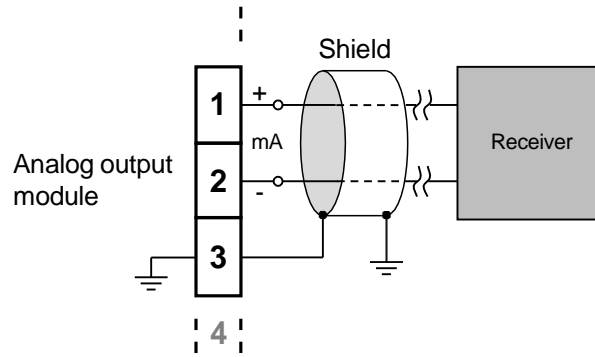


Figure 12-2 Analog output module wiring diagram

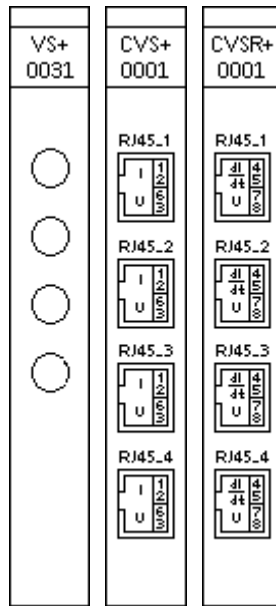
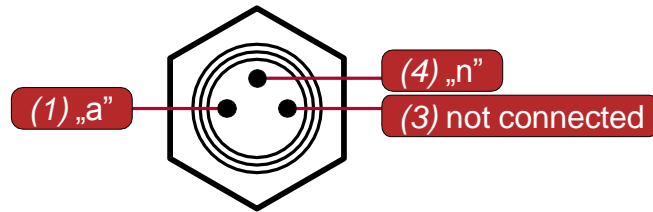


Figure 13-1 Voltage sensor modules



(FRONT VIEW)

Figure 13-2 M8 connector pinout



- 1.: S1
- 2.: S2
- 3.: "a"
- 6.: "n"

Figure 13-3 CVS module connector pinout



- 4.: S1
- 5.: S2
- 8.: "n"
- 7.: "a"

Figure 13-4 CVSR module connector pinout

1.3.16. INJ module

Complex module for controlling the Petersen coil, which contains an injector function for the measurements, an enabling and a blocking input, and a fault relay indicating if there is any fault in the injection circuit.

Connector types:

- The default and optionally available connector types are indicated for each module in the table below. See Chapter 20.2 for details about each type.

| MODULE TYPE | INJ+/0005 | INJ+/0015* |
|-----------------------------------------|-------------------------------------|----------------------------------------------------------------------|
| INJECTED CURRENT | 2 A | 4 A |
| ENABLING INPUT CLAMP VOLTAGE | 85 V AC | Not available function |
| BLOCKING INPUT CLAMP VOLTAGE | 200 V AC | 200 V AC |
| ADDITIONAL RESISTANCE FOR VOLTAGE INPUT | Not available function | 265 kΩ ± 1% |
| CONNECTOR TYPE | Default: STVS6, BLA10 Options: - | |
| RECOMMENDED APPLICATION | Arc suppression coil controller | Network compensation level measurement on resonant grounded networks |

*Special module

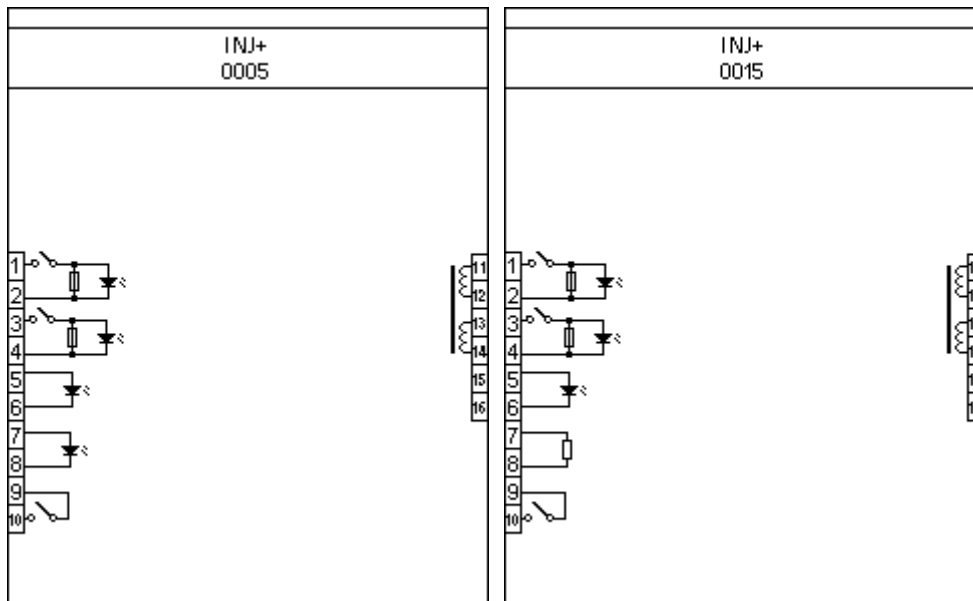


Figure 14-1 INJ modules

1.3.17. Generator protection modules

Special generator protection modules whose system measures and produces the necessary analog signals.

Connector types:

- The default and optionally available connector types are indicated for each module in the tables below. See Chapter 20.2 for details about each type.

| MODULE TYPE | RAI+/01 | RAI+/11 | RINJ+/21 |
|---------------------------------------------|--------------------------------------------------------|--------------------------------------------------------------|--------------------------------------------------------------|
| NOMINAL VOLTAGE | - | - | 110 V / 220 V |
| INPUT VOLTAGE RANGE | - | - | 88 - 264 V DC 80 - 250 V AC |
| OUTPUT VOLTAGE | - | - | 100V DC \pm 2 % |
| MEASUREMENT RANGE | \pm 20 mA | \pm 20 mA | - |
| THERMAL WITHSTAND CONTINUOUS: 30 SEC: | 15 mA 20 mA | 10 mA 20 mA | 20 mA |
| CONNECTOR TYPE | <u>Default:</u> STVS8 <u>Options:</u> - | <u>Default:</u> STVS8 <u>Options:</u> T* | <u>Default:</u> STVS8 <u>Options:</u> T* |
| RECOMMENDED APPLICATION | Rotor earth-fault protection of middle-grounded rotors | Rotor earth-fault protection of ungrounded (isolated) rotors | Rotor earth-fault protection of ungrounded (isolated) rotors |

*By choosing this option, the connector remains the same, only the handle is changed

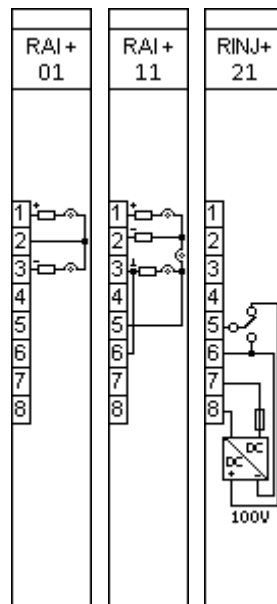


Figure 15-1 Generator protection modules

1.3.17.1. Auxiliary boxes for rotor earth fault protection

These DIN-rail mounted external boxes serve as couplings between the rotor (exciter circuit) of the generator and the corresponding RAI module of the protection device.

Note: the data about the resistances and capacitors provided here does not tell the actual time constants of the measured values, as those can be determined on-site only, when the rotor earth fault protection is being tested on the actual generator itself.

| MODULE TYPE | RAI+01 BOX | RAI+11 BOX BASE | RAI+11 BOX EXTENSION* |
|----------------------------|------------------------------|------------------------------|------------------------------|
| MAXIMUM INPUT VOLTAGE | 200 V, 300 V, 400 V, 500 V** | 600 V | 1200 V |
| SERIES RESISTANCE ON SIDES | 10 kΩ, 15 kΩ, 20 kΩ, 25 kΩ** | 35 kΩ | 30 kΩ |
| FILTER CAPACITORS | 4x10 μF | 2x1 μF | - |
| CONNECTOR TYPE | Default: STVS6 Options: - | Default: STVS6 Options: - | Default: STVS6 Options: - |
| RECOMMENDED APPLICATION | Middle-grounded rotors | Ungrounded (isolated) rotors | Ungrounded (isolated) rotors |

*This extension module can only be used together with RAI+11 BOX BASE module

**According to the chosen wiring

1.3.17.1.1. Use of auxiliary boxes

A) Ungrounded (isolated) rotors:

If the excitation voltage is lower than 600 V, then it is enough to use the RAI+11 BOX BASE auxiliary box. If the excitation voltage is higher than 600 V, the RAI+11 BOX EXTENSION auxiliary box shall be used *additionally*, so the protection can connect to up to 1200 V excitation voltage.

B) Middle-grounded rotors

Front drawings near the connectors on the box itself indicate the available maximum voltages. The choice from these shall be made according to the excitation voltage. Wiring shall be done according to the chosen voltage.

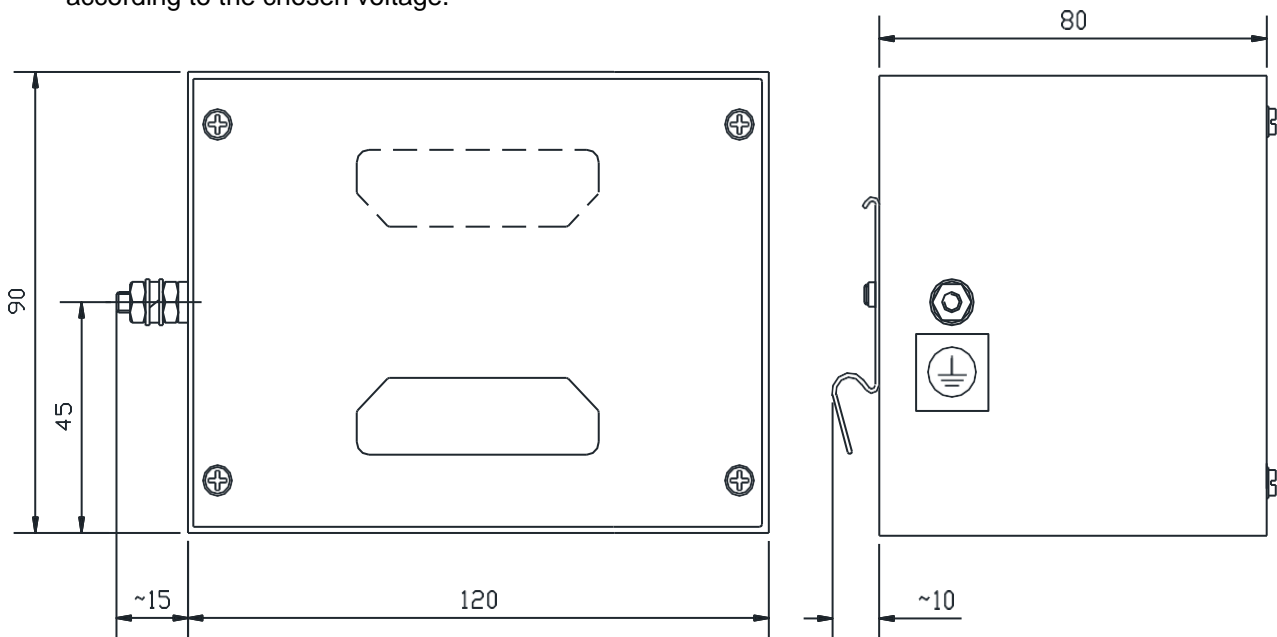


Figure 15-2 Size of the auxiliary boxes

1.3.17.2. Wiring of the rotor earth fault protection modules

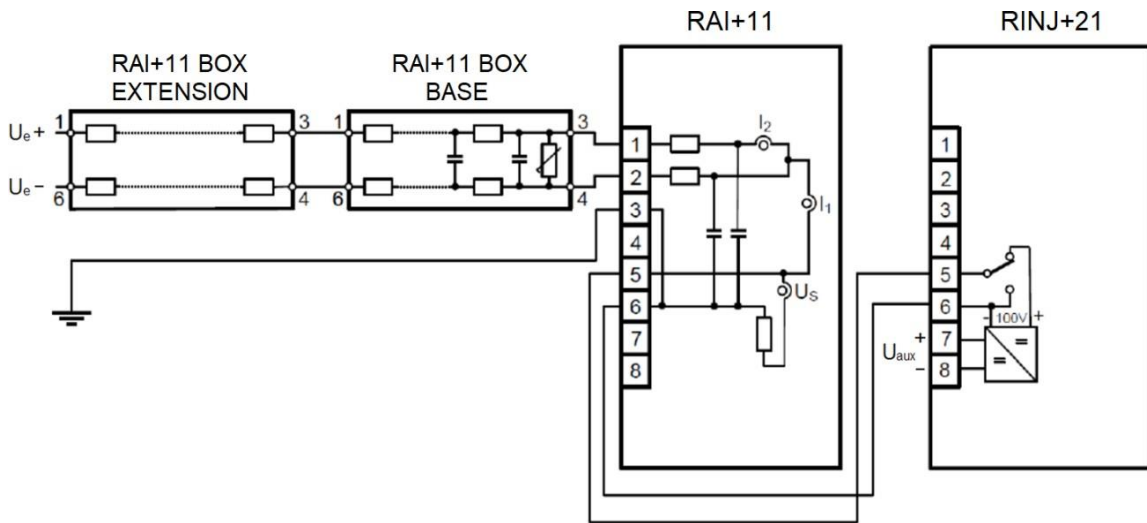


Figure 15-3 Wiring for ungrounded (isolated) rotors

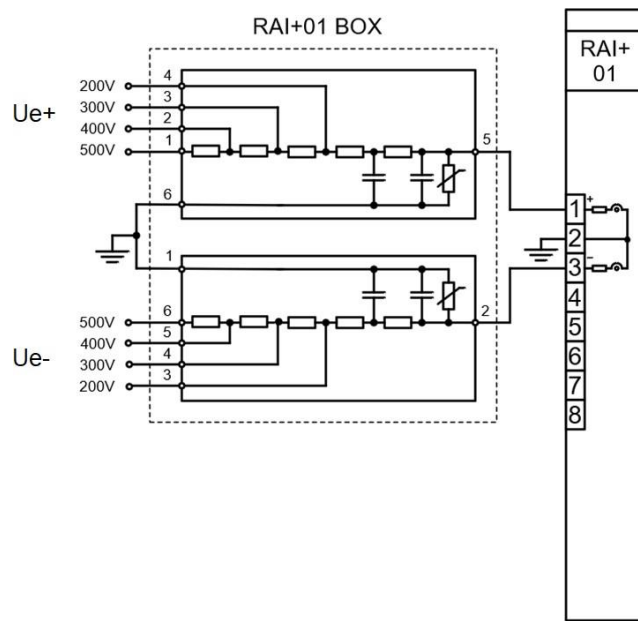
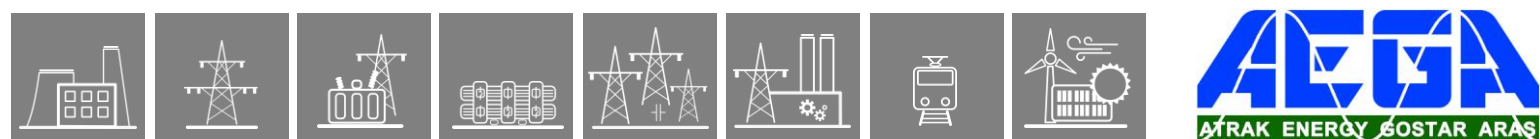


Figure 15-4 Wiring for middle-grounded rotors



1.3.18. Power supply module

The power supply module converts primary AC and/or DC voltage to required system voltages. In most applications, one power supply module is sufficient to provide the required power to the system. Redundant power supply modules extend system availability in case of the outage of any power source.

IMPORTANT

Depending on the hardware configuration, the power consumption of the devices can be different. We reserve the right to make the decision about which PS+ module must be used.

For most applications where the power consumption does not reach 20 W, a 4 HP wide PS+ module shall be installed.

Connector types:

- The default and optionally available connector types are indicated for each module in the tables below. See Chapter 20.2 for details about each type.

| MODULE TYPE | PS+/4201 (4 HP wide) | PS+/2101 (4 HP wide) |
|--------------------------------------------------------------------------------------|------------------------------------------|---------------------------------------------|
| RATED VOLTAGE | 24 V DC / 48 V DC / 60 V DC | 110 V DC / 220 V DC |
| INPUT VOLTAGE OPERATIVE RANGE | 19.2 - 72 V DC | 88 - 264 V DC 80 - 250 V AC |
| NOMINAL POWER | 20 W | 20 W |
| VOLTAGE DIP WITHSTAND AT 80% UN → 0% INPUT VOLTAGE CHANGE (IEC 60255-26) | 50 ms | 100 ms |
| INTERNAL FUSE | 3.15A/250V | 3.15A/250V |
| CONNECTOR TYPE | <u>Default:</u> BLA <u>Options:</u> T | <u>Default:</u> BLA <u>Options:</u> F, T |

- Early power failure indication signals to the CPU for the possibility of power outage, thus the CPU has enough time to save the necessary data to non-volatile memory
- Inrush current (until 0.1 s): < 10 A for all types excluding PS+4401 which has < 21 A inrush current.
- Common features for internal fuses:
 - 5 mm x 20 mm (0.20" x 0.79")
 - TT characteristics (very inverse time-lag)
 - 35 A @ 250 V AC rated breaking capacity
- Recommended external protection: miniature circuit breaker, 6 A (C char.)

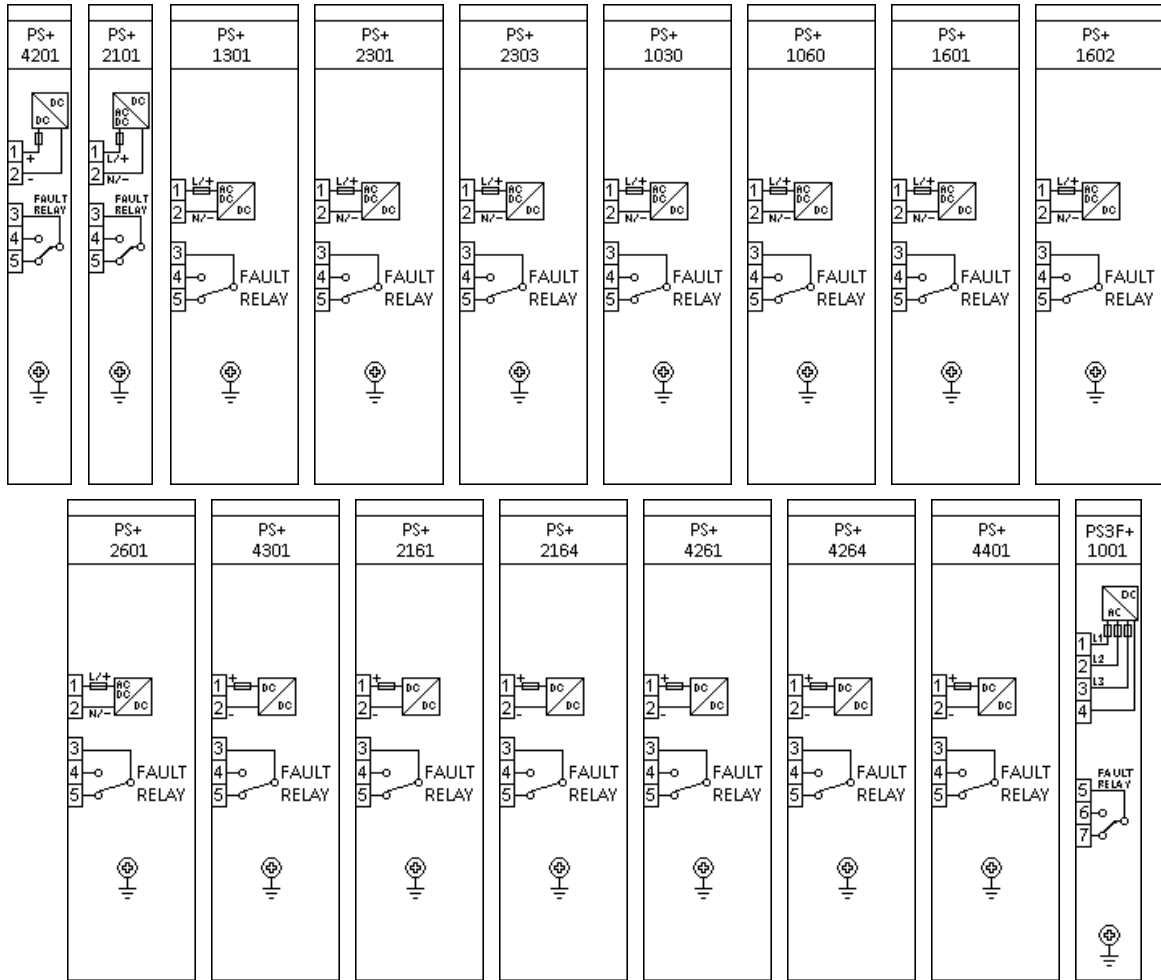


Figure 16-1 Power supply modules

1.3.19. Sampling synchronization module

The IED sampling system is synchronized via this module to an external source (IRIG-B) in PMU (Phasor Measurement Unit) applications. The PLL of the module handles the setting of the phase and frequency if valid IRIG-B signal is received. Note that the sampling signal is generated even if the IRIG-B signal is not present, however in that case, it runs independently.

| MODULE TYPE | TSYNC+/0071 |
|------------------------------------------|-----------------------------------|
| IRIG-B TYPE | B000 (unmodulated) |
| INPUT TYPE | BNC (coaxial) |
| SIGNAL THRESHOLD | 5 VDC CMOS max. 5.5 VDC |
| MAX. CABLE LENGTH | 50 m |
| CLAMP VOLTAGES | falling 1.7 VDC rising 3.1 VDC |
| SAMPLING ACCURACY* | < 100 ns |
| IRIG SYNCH. TIME | max. 1 minute |
| HOLDOVER TIME** | 30 s |
| SAMPLING FREQUENCY | 2 kHz @ 50 Hz 2.4 kHz @ 60 Hz |
| SAMPLING ACCURACY IN INDEPENDENT MODE*** | < 1 ppm |

*max. time difference between synchronized systems connecting to different GNSS (e.g. GPS)
 **the sampling accuracy stays below the given value during this time if the IRIG-B signal is lost
 ***the accuracy of the 2/2.4 kHz sampling signal if an IRIG-B signal is not present

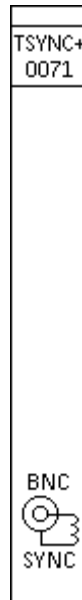


Figure 17-1 Sampling synchronization module

1.3.20. Mixed function modules

1.3.20.1. PSTP+ module

IMPORTANT

PSTP+ modules can be used only if the power consumption of the device does not reach 20 W and maximum 2 TRIP contacts are needed. If the application does not meet any of these two requirements, it is not allowed to use these cards. In this case separate PS+ (Chapter 16) and TRIP+ (Chapter 9) modules must be used.

Connector types:

- The default and optionally available connector types are indicated for each module in the tables below. See Chapter 20.2 for details about each type.

Note for the following tables:

- Thermal withstand voltage:** continuous with 60 % of the input channels are energized.

| MODULE TYPE | PSTP+/2101 | PSTP+/2102* | PSTP+/2131** |
|------------------------------------------------------------|--------------------------------------------------|--------------------------------------------------|--------------------------------------------------|
| | POWER SUPPLY CHARACTERISTICS | | |
| RATED VOLTAGE | 110 V / 220 V | 110 V / 220 V | 110 V / 220 V |
| INPUT VOLTAGE OPERATIVE RANGE | 88 - 264 V DC 80 - 250 V AC | 88 - 264 V DC 80 - 250 V AC | 88 - 264 V DC 80 - 250 V AC |
| MAXIMUM CONTINUOUS POWER OUTPUT | 20 W | 20 W | 20 W |
| VOLTAGE DIP DURATION AT 0% RESIDUAL VOLTAGE (IEC 60255-26) | min. 100 ms in the specified input voltage range | min. 100 ms in the specified input voltage range | min. 100 ms in the specified input voltage range |
| INTERNAL FUSE | 3.15A/250V | 3.15A/250V | 3.15A/250V |
| CONNECTOR TYPE | Default: BLA Options: F, T | Default: BLA Options: F, T | Default: BLA Options: T |
| | TRIPPING CHARACTERISTICS | | |
| CHANNEL NUMBER | 2 | 2 | 2 |
| RATED VOLTAGE | 110 V DC and 220 V DC or dry contacts | 110 V DC and 220 V DC or dry contacts | 110 V DC and 220 V DC or dry contacts |
| THERMAL WITHSTAND VOLTAGE | 242 V DC | 242 V DC | 242 V DC |
| CONTINUOUS CARRY | 8 A | 8 A | 8 A |
| MAKING CAPACITY | 0.5 s, 30 A | 0.5 s, 30 A | 0.5 s, 30 A |
| BREAKING CAPACITY | L/R = 40 ms: 4 A DC | L/R = 40 ms: 4 A DC | L/R = 40 ms: 4 A DC |
| CONNECTOR TYPE | Default: BLA Options: F, T | Default: BLA Options: F, T | Default: BLA Options: T |

*Special module that supports **auxiliary voltage measurement**. The module is calibrated to DC voltage measurement.

**Without trip circuit supervision

| MODULE TYPE | PSTP+/4201 | PSTP+/4202* |
|-------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| POWER SUPPLY CHARACTERISTICS | | |
| RATED VOLTAGE | 24 V / 48 V / 60 V | 24 V / 48 V / 60 V |
| INPUT VOLTAGE OPERATIVE RANGE | 19.2 - 72 V DC | 19.2 - 72 V DC |
| MAXIMUM CONTINUOUS POWER OUTPUT | 20 W | 20 W |
| VOLTAGE DIP DURATION AT 0% RESIDUAL VOLTAGE (IEC 60255-26) | 50 ms at nominal input voltages min. 40 ms in the specified input voltage range | 50 ms at nominal input voltages min. 40 ms in the specified input voltage range |
| INTERNAL FUSE | 3.15A/250V | 3.15A/250V |
| CONNECTOR TYPE | <u>Default:</u> BLA <u>Options:</u> T | <u>Default:</u> BLA <u>Options:</u> T |
| TRIPPING CHARACTERISTICS | | |
| CHANNEL NUMBER | 2 | 2 |
| RATED VOLTAGE | 24 V DC and 48 V DC or dry contacts | 24 V DC and 48 V DC or dry contacts |
| THERMAL WITHSTAND VOLTAGE | 72 V DC | 72 V DC |
| CONTINUOUS CARRY | 8 A | 8 A |
| MAKING CAPACITY | 0.5 s, 30 A | 0.5 s, 30 A |
| BREAKING CAPACITY | L/R = 40 ms: 4 A DC | L/R = 40 ms: 4 A DC |
| CONNECTOR TYPE | <u>Default:</u> BLA <u>Options:</u> T | <u>Default:</u> BLA <u>Options:</u> T |

***Special module** that supports **auxiliary voltage measurement**. The module is calibrated to DC voltage measurement.

Main features:

- High-speed operation: with pre-trip 0.5 ms, without pre-trip typically 10 ms, maximally 22 ms.
- Trip circuit supervision for each trip contact
- 1 unit wide (4 HP) modules
- Inrush current (until 0.1 s): < 10 A
- Common features for internal fuses:
 - 5 mm x 20 mm (0.20" x 0.79")
 - TT characteristics (very inverse time-lag)
 - 35 A @ 250 V AC rated breaking capacity
- Recommended external protection: miniature circuit breaker, 6 A (C char.)

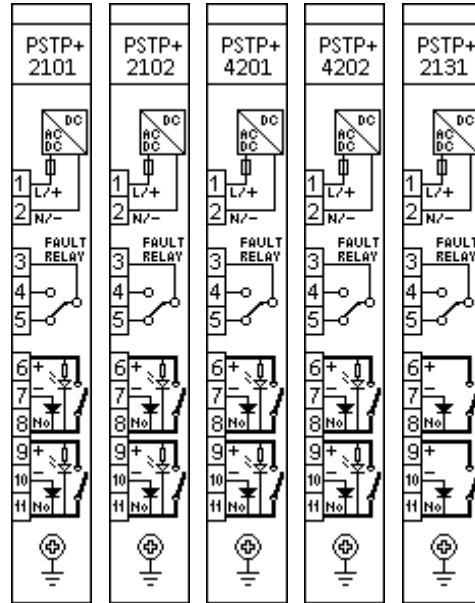


Figure 18-1 Power supply with 2 Ch. TRIP modules

1.3.20.1.1. Trip Circuit Supervision (TCS) in PSTP modules

Apart from the PSTP+/2131, all PSTP modules have TCS.

The technical data of the TCS in PSTP modules:

| | MODULE TYPE | PSTP+/4201 PSTP+/4202 | PSTP+/2101 PSTP+/2102 |
|-------------------------------------|-----------------------------------|-------------------------------------------------------|----------------------------------------|
| | INJECTED CURRENT AT "NO" CONTACT | 1.5 mA | 1.5 mA |
| MAXIMUM RESISTANCE OF THE TRIP COIL | 3-WIRE WIRING (1 mA CURRENT) | 8 kΩ (max. 8 V) | 13 kΩ (max. 13 V) |
| | 3-WIRE WIRING IN PARALLEL | 4 kΩ (max. 8 V) | 6.5 kΩ (max. 13 V) |
| | 2-WIRE METHOD (1 mA MIN. CURRENT) | 24 kΩ @ 24 V DC 48 kΩ @ 48 V DC 60 kΩ @ 60 V DC | 110 kΩ @ 110 V DC 220 kΩ @ 220 V DC |

Main features (according to IEC 60255-26):

- Maximum switching voltage: 400 V AC
- Breaking capacity: (L/R=40 ms) at 220 V DC: 0.2 A, at 110 V DC: 0.3 A
- Breaking capacity max.: 2000 VA
- Short time carrying capacity: 1 s, 35 A
- Limiting making current, max. 4 s: 15 A (df = 10 %)
- Dielectric strength between open contacts, 1 min: 1000 V_{RMS}
- Mechanical endurance: 10 × 10⁶ cycles
- Circuit closing capability: typically 10 ms, maximally 22 ms.
- Bounce time: typically 6,5 ms, maximally 10 ms.
- Minimal switching requirement: 5 V

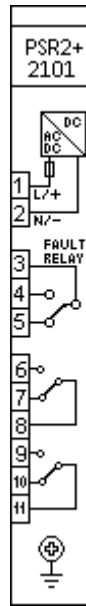
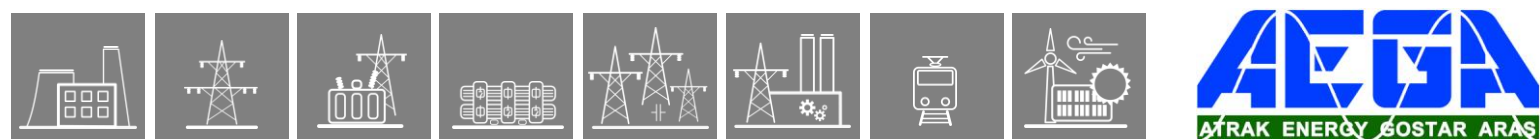


Figure 18-2 Power supply with 2 Ch. signaling modules



1.3.20.3. O6R5+ module

The O6R5+ module contains 6 binary input channels in one grounding group, and 5 relay outputs with 2 × 2 NO contacts and one CO contact.

Connector types:

- The default and optionally available connector types are indicated for each module in the tables below. See Chapter 20.2 for details about each type.

Notes for the following table:

- **Thermal withstand voltage:** continuous with 60 % of the input channels are energized.
- **Clamp voltage:** these are the guaranteed values; the actual ones might differ from those provided here (falling and rising around 0.66 U_N and 0.77 U_N , respectively)

| MODULE TYPE | O6R5+/2101 | O6R5+/4201 |
|-------------------------------------------------------|--------------------------------------------------------------|------------------------------------------------------------|
| BINARY INPUT CHARACTERISTICS | | |
| CHANNEL NUMBER | 6 | 6 |
| RATED VOLTAGE | 110 V / 220 V user selectable on channel basis by jumpers | 24 V / 48 V user selectable on channel basis by jumpers |
| TIME SYNCHRONIZATION | configured by EuroCAP | configured by EuroCAP |
| THERMAL WITHSTAND VOLTAGE | 320 V | 72 V |
| CLAMP VOLTAGE | falling 0.64 U_N rising 0.8 U_N | falling 0.64 U_N rising 0.8 U_N |
| COMMON GROUPS | 1 × 6 common | 1 × 6 common |
| RELAY OUTPUT CHARACTERISTICS | | |
| RATED VOLTAGE | 250 V AC/DC | 250 V AC/DC |
| CONTINUOUS CARRY | 8 A | 8 A |
| CONTACT VERSIONS | 4 NO, 1 CO | 4 NO, 1 CO |
| GROUP ISOLATION | 2 × 2 common, 1 independent | 2 × 2 common, 1 independent |
| CONNECTOR TYPE FOR BOTH BINARY INPUT AND RELAY OUTPUT | <u>Default:</u> BLA <u>Options:</u> T | <u>Default:</u> BLA <u>Options:</u> T |

Main features for binary inputs:

- Digitally filtered per channel
- Current drain:
 - max. 1.6 mA per channel at 220 V DC
 - max. 1.8 mA per channel at 110 V DC
 - max. 2 mA per channel at 48 V DC
 - max. 3 mA per channel at 24 V DC
- In such applications where the input voltage is 60 V the modules with 48 V rated voltage can be used.
- Input voltage type can be either DC or AC voltage. If AC voltage is used make sure that the type and the parameters of the binary inputs are configured properly in EuroCap tool.

Main features for signaling outputs:

- Maximum switching voltage: 400 V AC
- Breaking capacity, (L/R=40 ms) at 220 V DC: 0.1 A, at 110 V DC: 0.2 A
- Breaking capacity max.: 2000 VA
- Short time carrying capacity: 1 s, 35 A
- Limiting making current, max. 4 s: 15 A (df = 10 %)
- Initial dielectric strength between open contacts, 1 min: 1000 V_{RMS}
- Circuit closing capability: typically 10 ms, maximally 22 ms.
- Bounce time: typically 6,5 ms, maximally 10 ms.
- Mechanical endurance: 10 × 10⁶ cycles
- Circuit closing capability

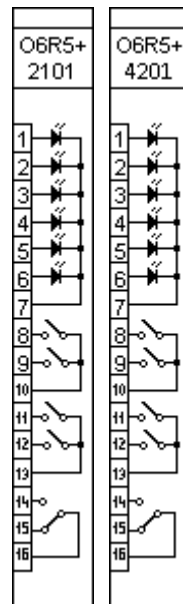
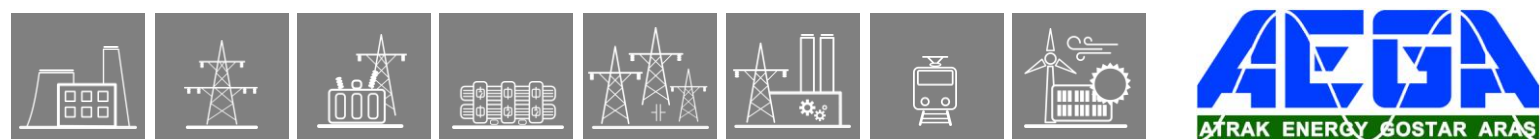


Figure 18-3 Binary input/output modules



1.3.20.4. Binary input module with time synchronization

The inputs are galvanically isolated and the module converts high-voltage signals to the voltage level and format of the internal circuits. This module is also used as an external IRIG-B synchronization (**IRIG-B000, unmodulated**), PPM or PPS input. Dedicated synchronization input is used for this purpose.

Connector types:

- The default and optionally available connector types are indicated for each module in the tables below. See Chapter 20.2 for details about each type.

Notes for the following table:

- **Thermal withstand voltage:** continuous with 60 % of the input channels are energized.
- **Clamp voltage:** these are the guaranteed values; the actual ones might differ from those provided here (falling and rising around $0.66 U_N$ and $0.77 U_N$, respectively)

| MODULE TYPE | O9S+/2111 | O9S+/2121 | O9S+/4221 |
|-----------------------------------|------------------------------------------------|------------------------------------------------|----------------------------------------------|
| CHANNEL NUMBER | 9 | 9 | 9 |
| SYNCHRON CHANNEL TYPE AND NUMBER | 1 isolated BNC connector | 1 850 nm multimode fiber with ST connector | 1 850 nm multimode fiber with ST connector |
| RATED VOLTAGE | 110 V DC / 220 V DC user selectable by jumpers | 110 V DC / 220 V DC user selectable by jumpers | 24 V DC / 48 V DC user selectable by jumpers |
| THERMAL WITHSTAND VOLTAGE | 320 V | 320 V | 72 V |
| WITHSTAND VOLTAGE FOR SYNC. INPUT | 35 V _{PEAK} | - | - |
| CLAMP VOLTAGE | falling $0.64 U_N$ rising $0.8 U_N$ | falling $0.64 U_N$ rising $0.8 U_N$ | falling $0.64 U_N$ rising $0.8 U_N$ |
| COMMON GROUPS | 9 (3 × 3 common) | 9 (3 × 3 common) | 9 (3 × 3 common) |
| CONNECTOR TYPE | <u>Default:</u> BLA <u>Options:</u> T | <u>Default:</u> BLA <u>Options:</u> F, T | <u>Default:</u> - <u>Options:</u> F, T |

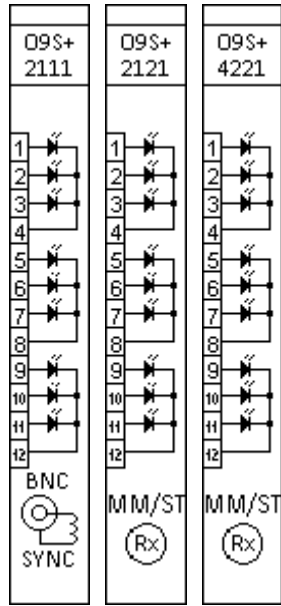


Figure 18-4 Binary input modules with time synchronization

1.3.20.5. Externally driven trip module

The R4MC+01 is a special TRIP module, which can be operated from the connector side. It also has two diode inputs with cathodes which are connected and led to the connector side.

Connector types:

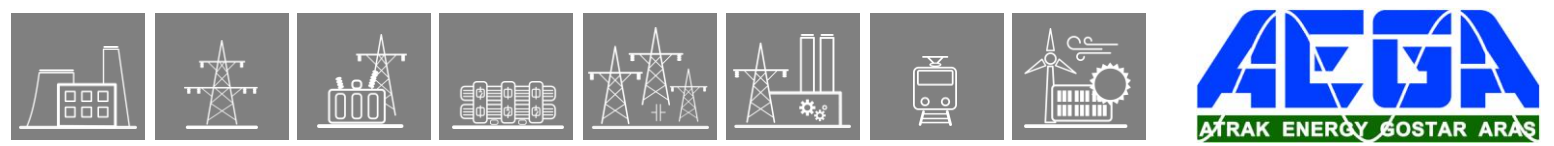
- The default and optionally available connector types are indicated for each module in the tables below. See Chapter 20.2 for details about each type.

| Module type | R4MC+/01* |
|---------------------------|------------------------------------------|
| CHANNEL NUMBER | 2 |
| RATED VOLTAGE | 110 V DC |
| THERMAL WITHSTAND VOLTAGE | 132 V DC |
| CONTINUOUS CARRY | 8 A |
| MAKING CAPACITY | 0.5 s, 30 A |
| BREAKING CAPACITY | L/R = 40 ms: 4 A DC |
| DIODE PROPERTIES | 1 A, 1000 V DC |
| CONNECTOR TYPE | <u>Default:</u> BLA <u>Options:</u> F |

*Special module

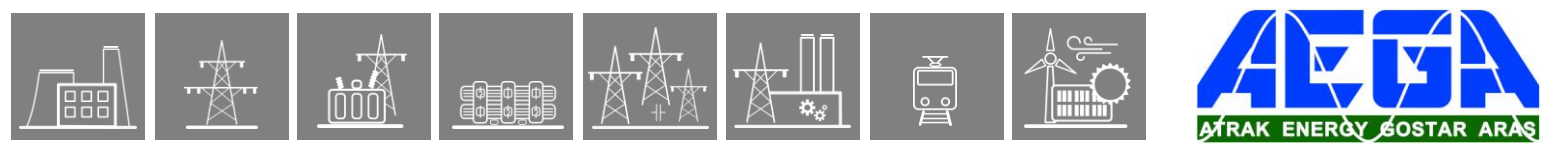


Figure 18-5 Externally driven TRIP module



1.3.21. General data

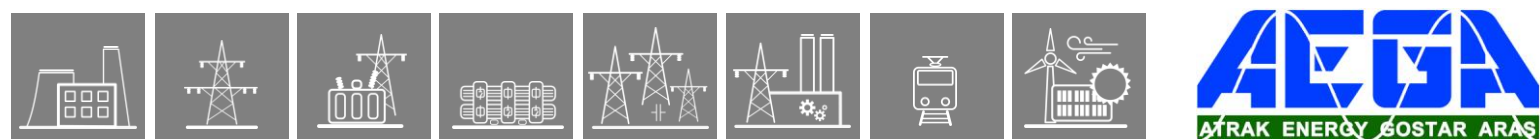
- Storage temperature: - 40 °C ... + 70 °C
- Operation temperature: - 20 °C ... + 55 °C
- Humidity: 10 % ... 93 %
- Altitude: up to 2000 m
- Atmospheric pressure: 86 ... 106 kPa



1.3.22. Mechanical data

1.3.22.1. General mechanical data

- Construction: chromate aluminum surface with built-in EMC accessories
 - If the power consumption of a 84 HP or 42 HP device does not exceed 30 W (84 HP) or 14 W (42 HP), the construction will be built with solid top and bottom cover panels.
 - If the power consumption exceeds 30 W (84 HP) or 14 W (42 HP), the construction will be built with (honeycomb) perforated top and bottom cover panels.
- EMC rack protects against electromagnetic environmental influences and protects the environment from radiation from the interior
- IP protection:
 - 24 HP panel instrument case: IP4x; optionally IP54 (front)
 - 84 HP and 42 HP (including double) rack: IP4x from front side, IP2x from rear side; optionally IP54 (front)
- Size:
 - 19" (84 HP), 3 U, single rack
 - ½ 19" (42 HP), 3 U, single rack
 - ½ 19" (42 HP), 6 U, double rack
 - 24 HP, panel instrument case
- Weight:
 - 84 HP: max. 8 kg
 - 42 HP, 3 U: max. 4.5 kg
 - 42 HP, 6 U: max. 8 kg
 - 24 HP: max. 3 kg



1.3.22.2. Connectors

Optionally, certain modules can be equipped with different terminals for different connectors. The available choices are listed among each module's technical data with their *short ID* (see the first column of the table below).

The type of the used terminal is indicated on the module's label with its *short ID* (see the following example). The actual type of the connector is chosen according to the number of the available pins of the module.

Example: the *VT+/2211* module may have four types of connectors. In its description (Chapter 6), these are indicated with their ID:

- The default terminal is indicated with nothing attached (*VT+/2211*), only its name (BLA) is mentioned. Since it has 8 pins, the type is BLA 8/180
- The flanged terminal's *short ID* is **F**, so the module's label will be "*VT+/2211F*", if it is equipped with this terminal (BLA 8B/180)
- Top-screw terminal: **T**, the label becomes "*VT+/2211T*" (BLT 5.08HC/08/180F)
- Ring-lug terminal: **R**, so the module's label shall be "*VT+/2211R*"

| CONNECTOR NAME (SHORT ID) | CONNECTOR TYPES | STRIP LENGTH [MM] | CONDUCTOR AREA [MM ²] | CONDUCTOR DIAMETER [MM] | TIGHTENING TORQUE [Nm] | MINIMUM BEND RADIUS* |
|---------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|-------------------|-----------------------------------|-------------------------------|------------------------|----------------------|
| BLA (-) | Weidmüller BLA 2/180, BLA 3/180, BLA 4/180, BLA 6/180, BLA 8/180, BLA 10/180, BLA 12/180, BLA 13/180, BLA 16/180 | 7 | 0.2 – 1.5 solid: 0.2 – 2.5 | 0.5 – 1.4 solid: 0.5 – 1.8 | 0.4 – 0.5 | 3 × OD** |
| BL 3.5 (-) | Weidmüller BL 3.5/05/180 BL 3.5/09/180 | 6 | 0.2 – 1.5 | 0.5 – 1.4 | 0.2 – 0.25 | 3 × OD** |
| FLANGED (F) | Weidmüller BLA 2B/180, BLA 3B/180, BLA 4B/180, BLA 6B/180, BLA 8B/180, BLA 10B/180, BLA 12B/180, BLA 16B/180 | 7 | 0.2 – 1.5 solid: 0.2 – 2.5 | 0.5 – 1.4 solid: 0.5 – 1.8 | 0.4 – 0.5 | 3 × OD** |
| TOP-SCREW (T) | Weidmüller BLT 5.08HC/06/180F, BLT 5.08HC/08/180F, BLT 5.08HC/12/180F, BLT 5.08HC/16/180F | 13 | 0.2 – 1.5 solid: 0.2 – 2.5 | 0.5 – 1.4 solid: 0.5 – 1.8 | 0.4 – 0.5 | 3 × OD** |
| RING-LUG (R) | TE Connectivity BC6-Q308-08 | - | 0.33 – 3.31 | 0.65 – 2.05 | 0.79 | 3 × OD** |

- Bend radius is measured along the inside curve of the wire or wire bundles.
- ** OD is the outer diameter of the wire or cable, including insulation.

1.3.23. Mounting methods

- Flush mounting
 - 84 HP single rack
 - 42 HP single rack
 - 42 HP double rack
 - 24 HP panel instrument case
 - Remote HMI
- Rack mounting
 - 84 HP single rack
 - 42 HP single rack
 - Remote HMI
- Semi-flush mounting
 - 84 HP single rack
 - 42 HP single rack
 - 24 HP panel instrument case
 - Remote HMI
- Wall mounting (with terminals)
 - 84 HP single rack
 - 42 HP single rack
- Din rail mounting
 - 24 HP panel instrument case
- IP54 rated mounting
 - 84 HP single rack
 - 42 HP single rack
 - 24 HP panel instrument case (original frame with additional gasket)
- Fold-down mounting (with optional terminals)
 - 84 HP single rack
 - 42 HP single rack
- No mounting
 - 84 HP single rack
 - 42 HP single rack

| MOUNTING METHOD | 84 HP SINGLE RACK | 42 HP SINGLE RACK | 42 HP DOUBLE RACK | 24 HP PANEL INSTRUMENT CASE | REMOTE HMI |
|--------------------------------|-------------------|-------------------|-------------------|-----------------------------|------------|
| FLUSH MOUNTING | X | X | X | X | X |
| RACK MOUNTING | X | X | | | X |
| SEMI-FLUSH MOUNTING | X | X | | X | X |
| WALL MOUNTING (WITH TERMINALS) | X | X | | | |
| DIN RAIL MOUNTING | | | | X | |
| IP54 RATED MOUNTING | X | X | | X* | |
| FOLD-DOWN MOUNTING | X | X | | | |

*additional gasket inserted into the original front panel frame



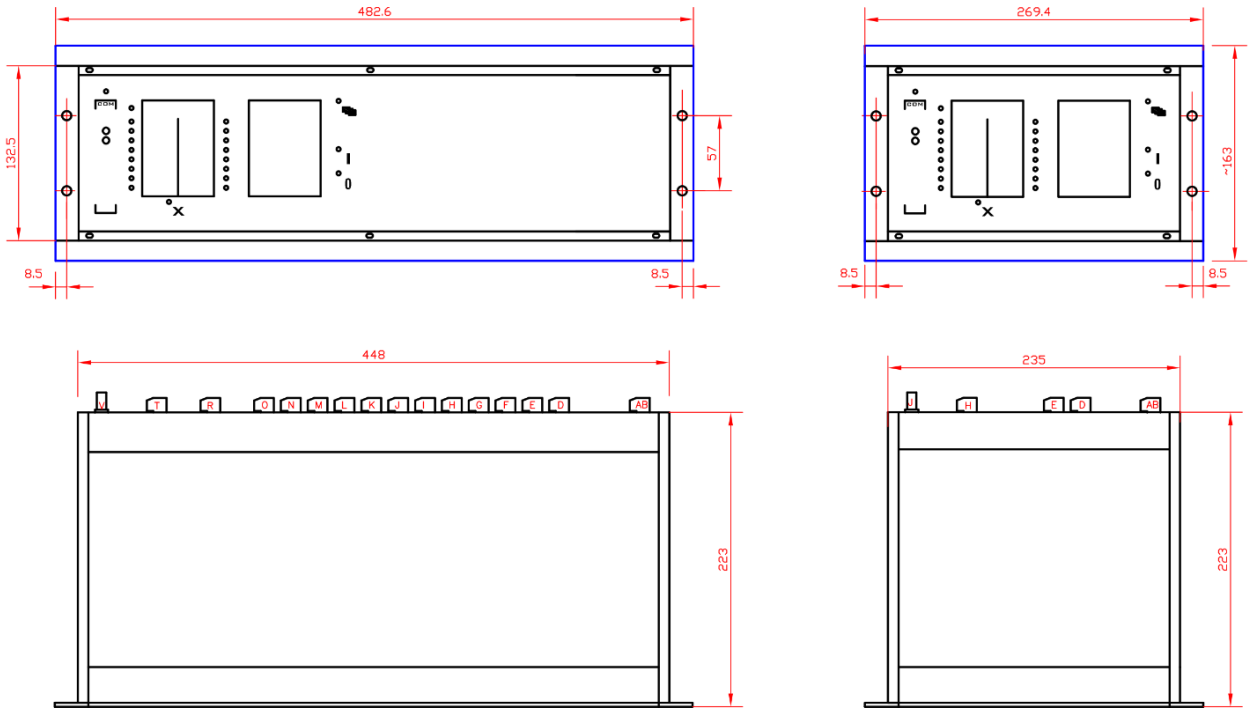
It is recommended to leave at least 80 mm free space for the wiring at the back of the IED in case of Flush mounting, Rack mounting, and Semi-flush mounting.

1.3.23.1. Flush mounting

Flush mounting can be used for all size of racks (84 HP, 42 HP, double 42 HP) including the 24 HP panel instrument case and the remote HMI devices. When this type of mounting alternative is used the 84 HP, 42 HP, double 42 HP and remote HMI devices have got a cover profile fit on and the 24 HP devices have got a mounting frame fit on.

The dimensions of the cut-outs for the 84 HP and 42 HP devices are also applicable for the same sized remote HMI devices.

1.3.23.1.1. Flush mounting of 84 HP and 42 HP single rack



PANEL CUT-OUT

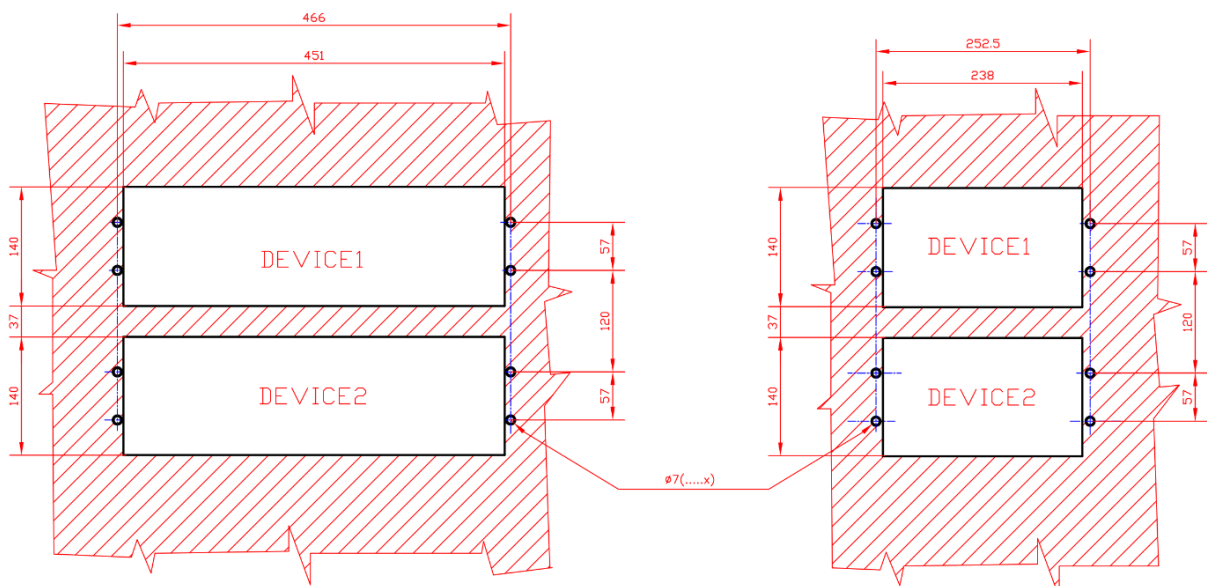


Figure 21-1 Dimensions for flush mounting of 84 HP and 42 HP single rack

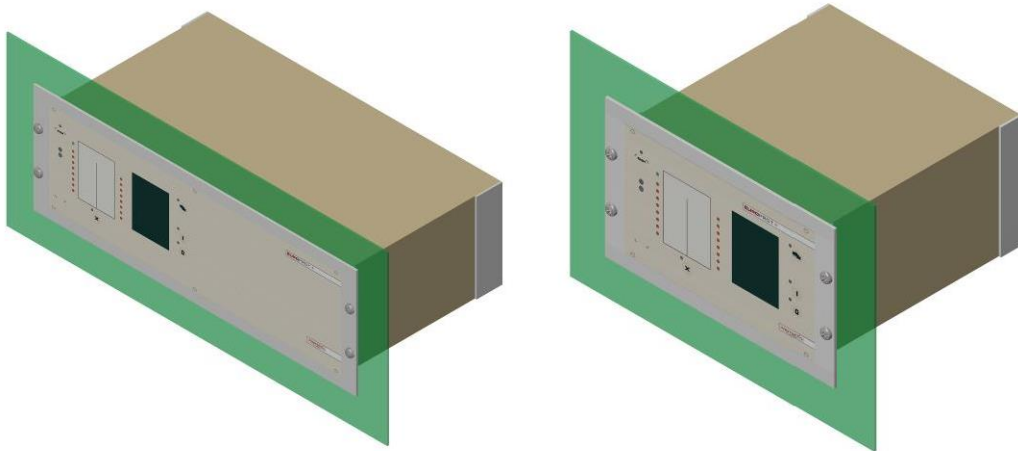


Figure 21-2 3D illustration for flush mounting of 84 HP and 42 HP devices

1.3.23.1.2. Flush mounting of 42 HP double rack

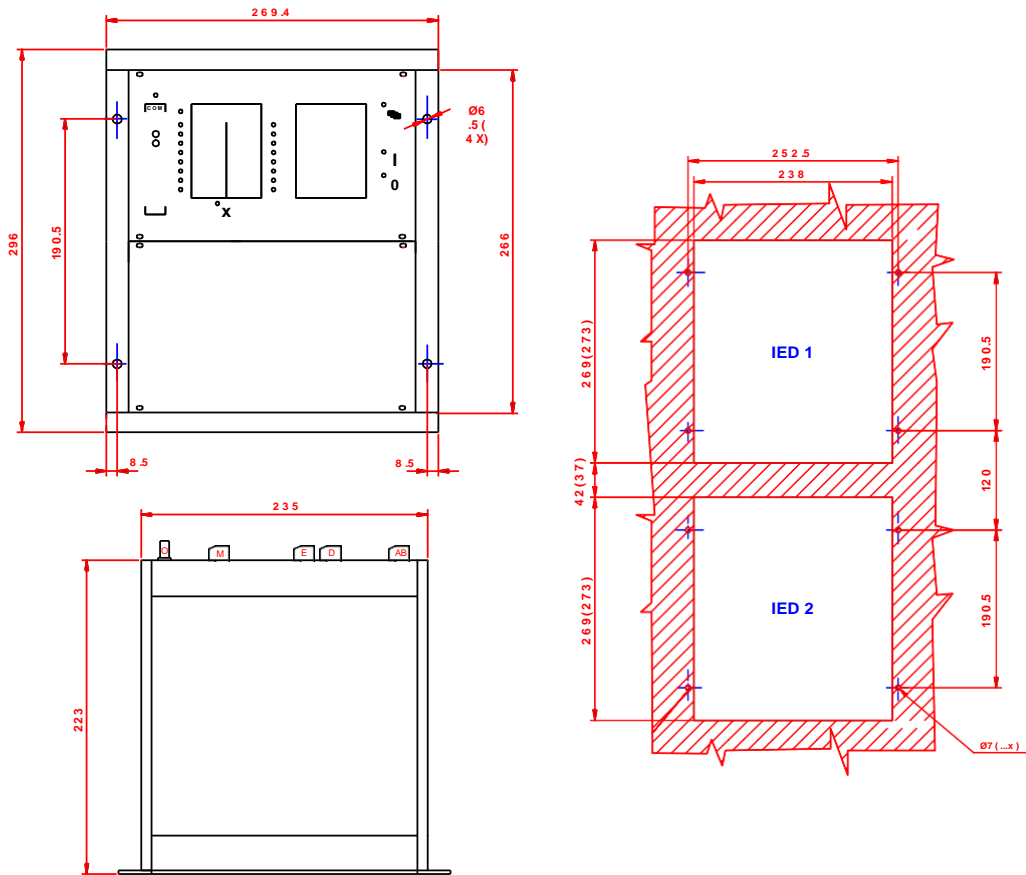


Figure 21-3 Dimensions for flush mounting of 42 HP double rack

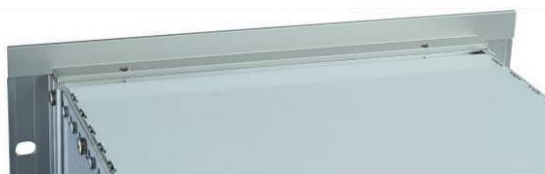


Figure 21-4 42 HP wide cover profile

1.3.23.1.3. Flush mounting of 24 HP panel instrument case

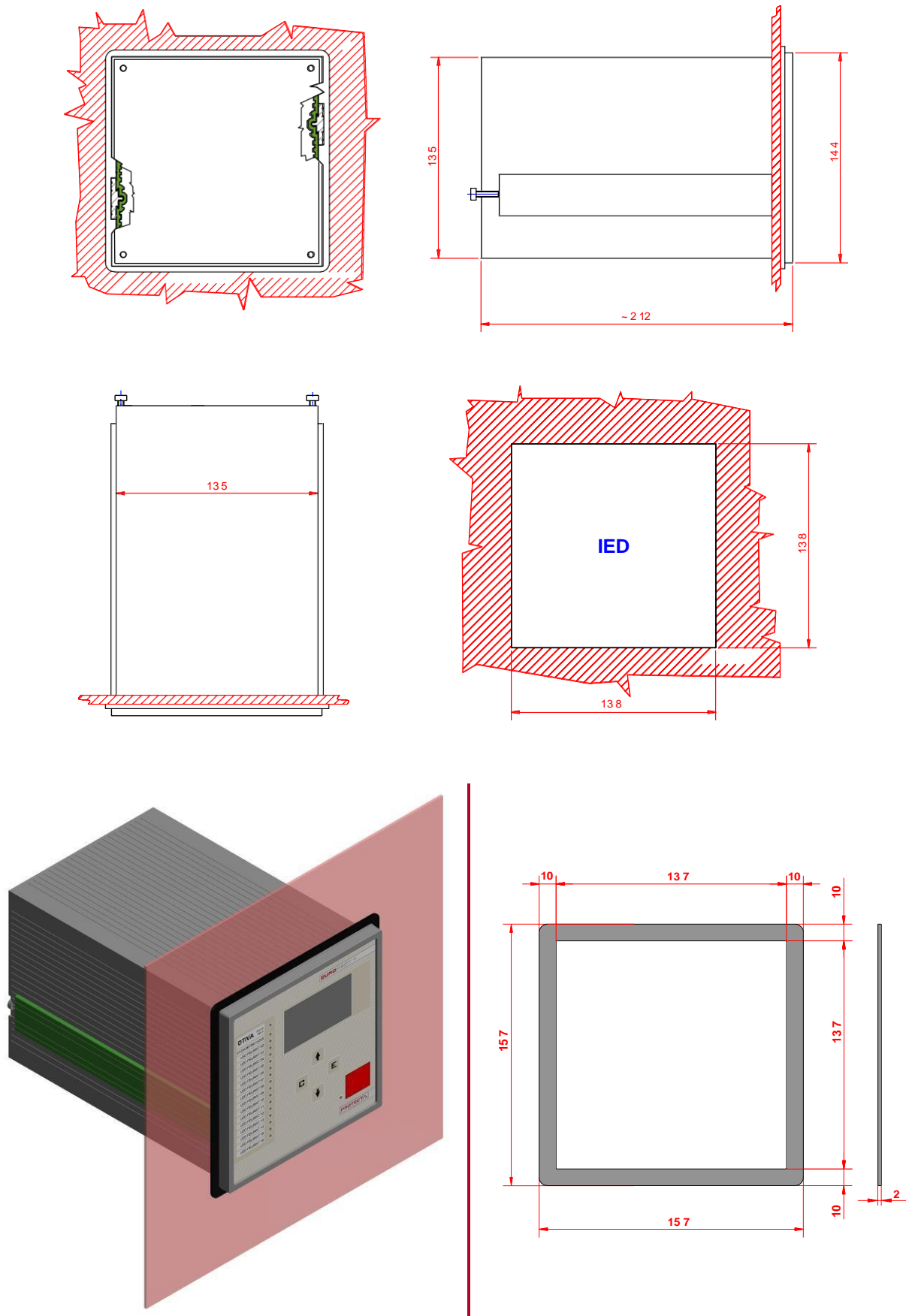


Figure 21-5 Dimensions for flush mounting of 24 HP panel instrument case with 3D illustration

1.3.23.2. Rack mounting

When rack mounting is used, the devices do not have a cover profile fit on, so it is possible to mount them in a 19" rack.

1.3.23.2.1. Rack mounting of 84 HP and 42 HP single rack

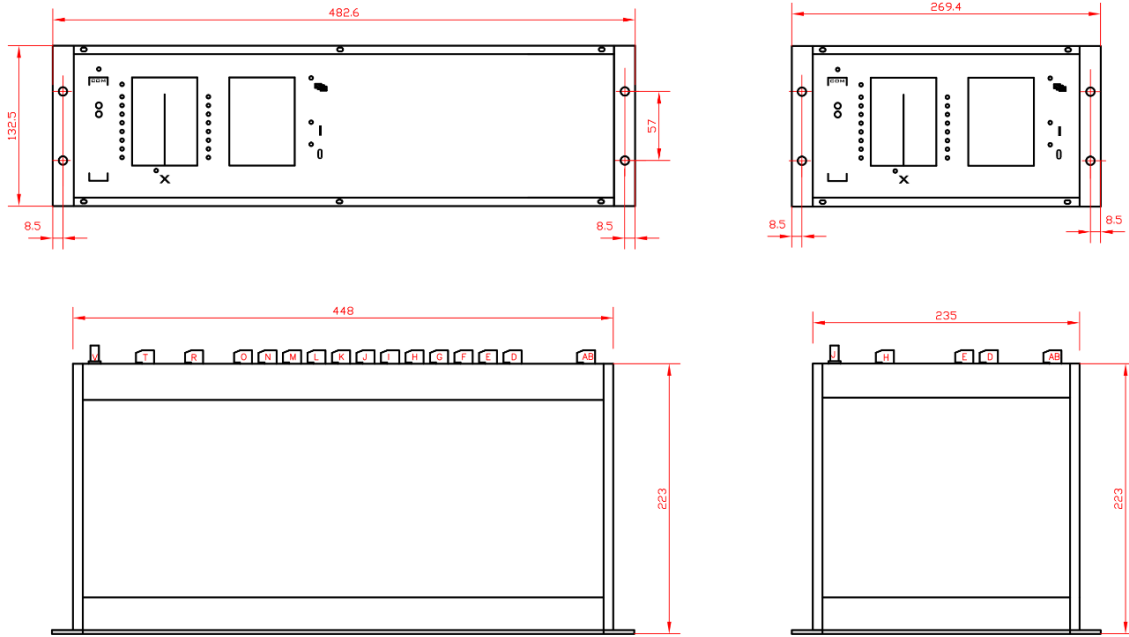


Figure 21-6 Dimensions for rack mounting of 84 HP and 42 HP single rack

Note that rack mounting type devices can also be mounted in a cut-out (e.g. on a switchgear door). It is possible to mount them from the front or from the back of the cut-out. The dimensions for rack mounting cut-outs are in the figure below. Dimensions in brackets are applicable in case of mounting from the back.

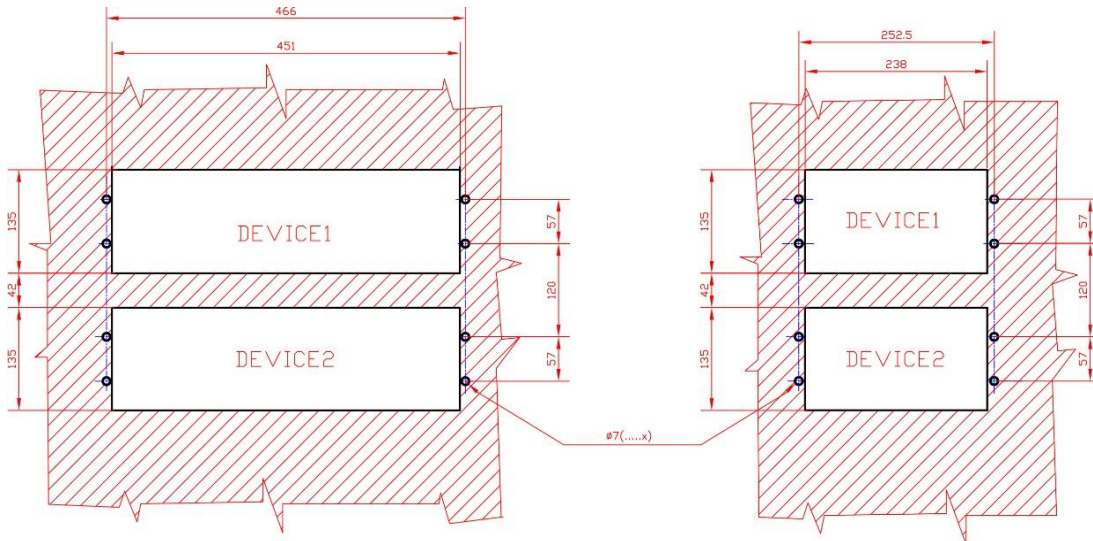
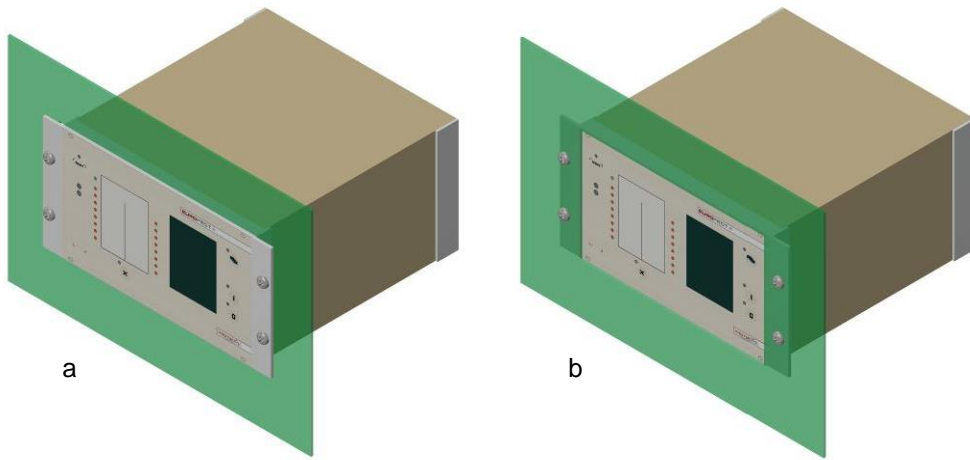
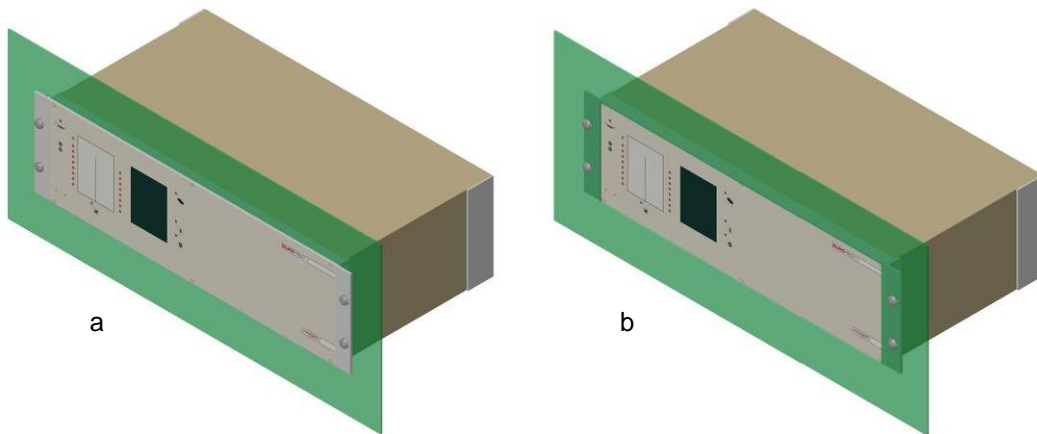


Figure 21-7 Dimensions of rack mounting cut-outs



*Figure 21-8 3D illustration for rack mounting of 42 HP device
(a - from the front; b - from the back)*



*Figure 21-9 3D illustration for rack mounting of 84 HP device
(a - from the front; b - from the back)*

1.3.23.2.2. Rack mounting of 42 HP double rack

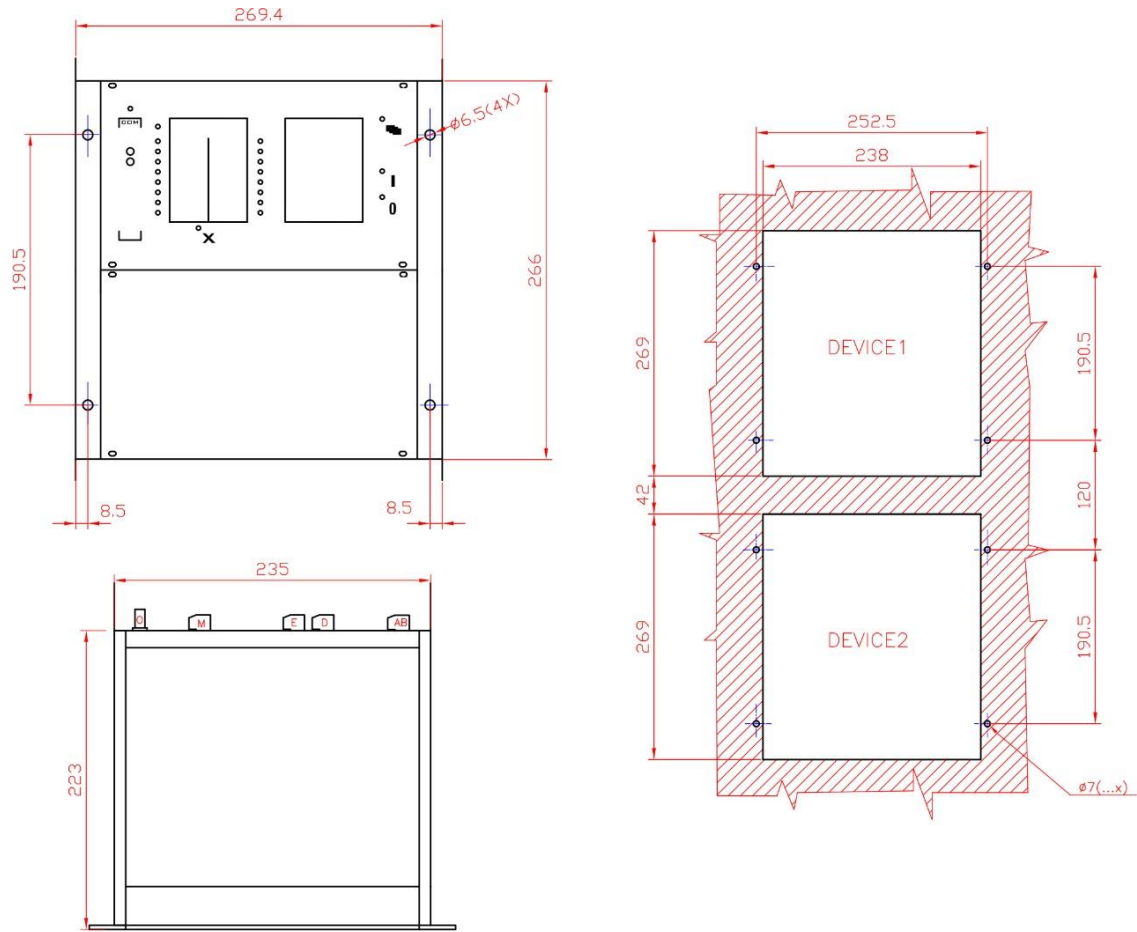


Figure 21-10 Dimensions for rack mounting of 42 HP double rack

1.3.23.3. Semi-flush mounting

Semi-flush mounting can be used for 84 HP and 42 HP single racks, for 24 HP panel instrument cases and for remote HMI devices. The purpose of this type of mounting alternative is to reduce the depth of the devices in the switchgear/rack if there is not enough space in that direction. To achieve this, a special mounting collar must be fit on the rack type devices. The default color of the mounting collar is grey (RAL 7035).

The dimensions of the special mounting collars and the cut-outs for the 84 HP and 42 HP devices are also applicable for the same sized remote HMI devices.

1.3.23.3.1. Semi-flush mounting of 84 HP single rack

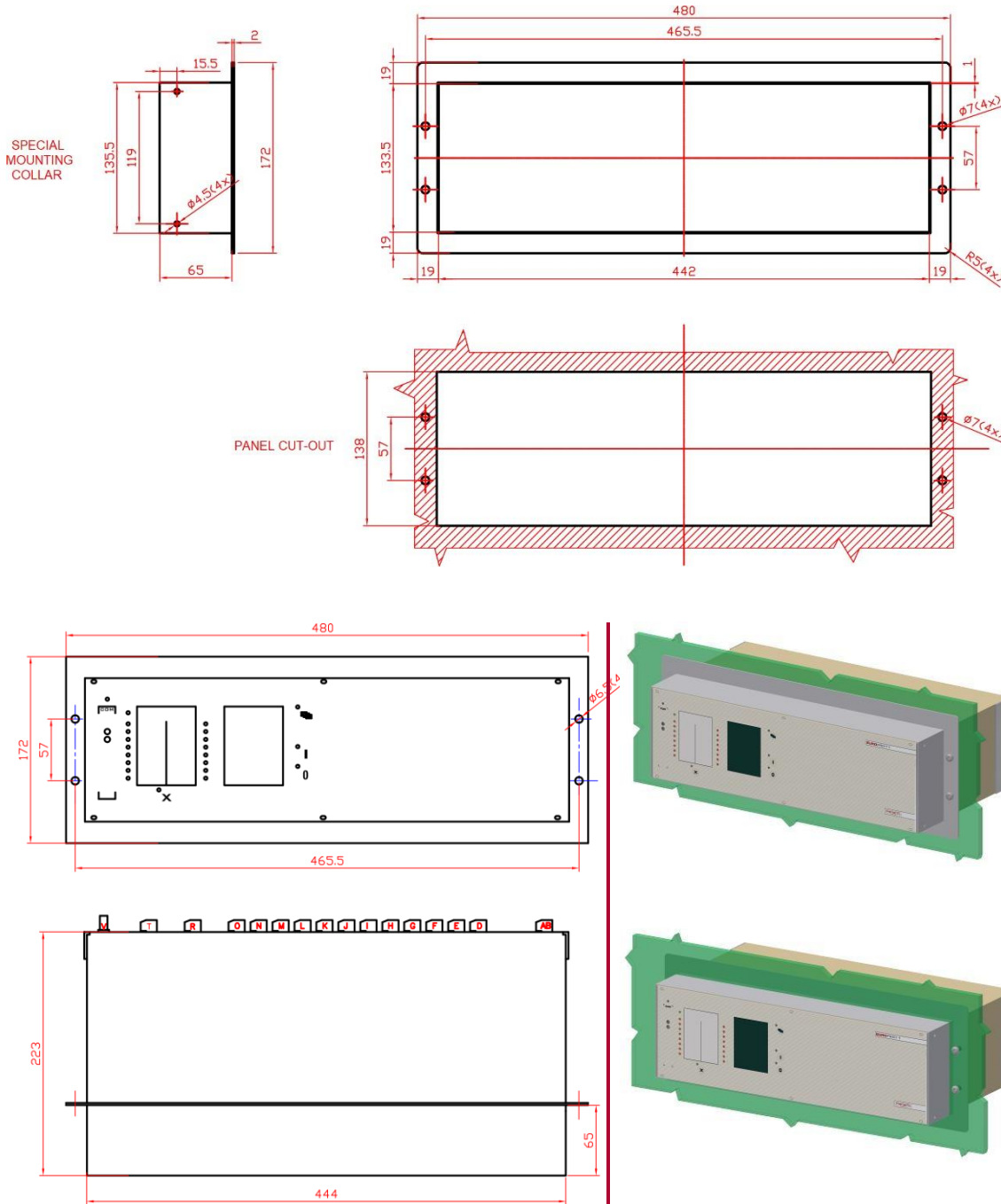


Figure 21-11 Dimensions for semi-flush mounting of 84 HP single rack with 3D illustration

1.3.23.3.2. Semi-flush mounting of 42 HP single rack

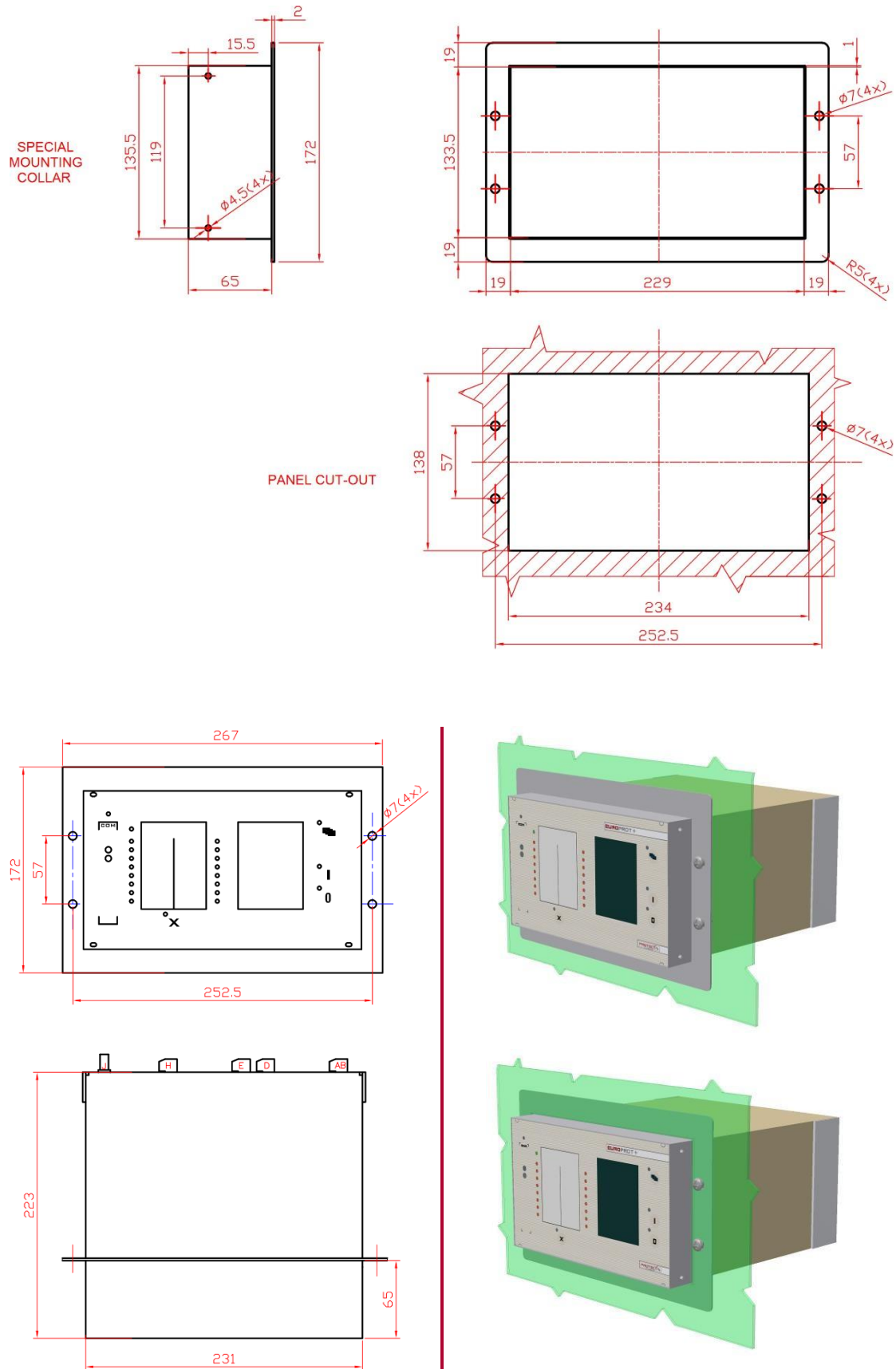
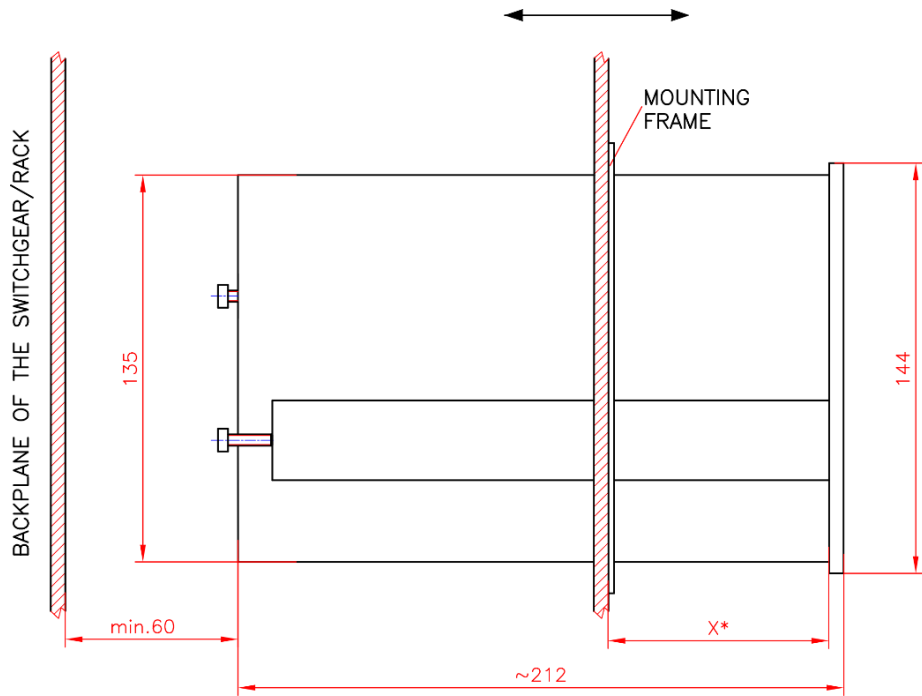


Figure 21-12 Dimensions for semi-flush mounting of 42 HP single rack with 3D illustration

1.3.23.3.3. Semi-flush mounting of 24 HP panel instrument case

The dimensions of the panel cut-out for this type of mounting method are the same as in case of flush mounting (138 mm x 138 mm). For semi flush mounting, it is enough to cut in two the fixing elements (with green colour in the 3D illustration below) and to make the assembly as shown in the pictures below.

Note that the IP54 front panel option cannot be utilized with this type of mounting.



*X: depending on the position of the cutting, the frame can be placed freely

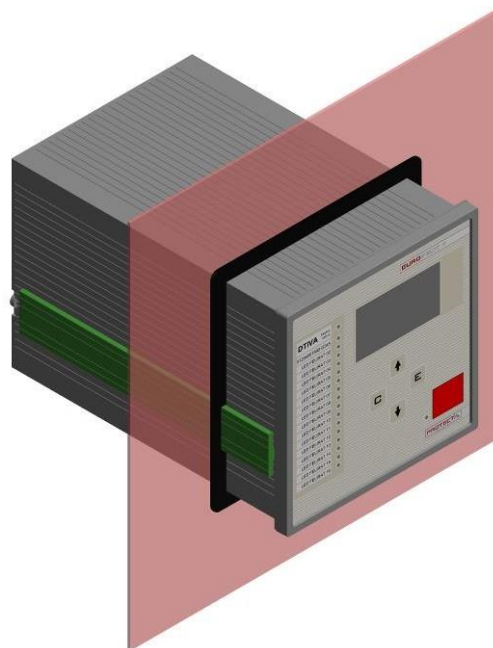


Figure 21-13 Dimensions for semi-flush mounting of 24 HP panel instrument case with 3D illustration

1.3.23.4. Wall mounting of 42 HP and 84 HP devices

Depending on the amount of the terminal contacts, it is possible to use both upper and lower terminals.

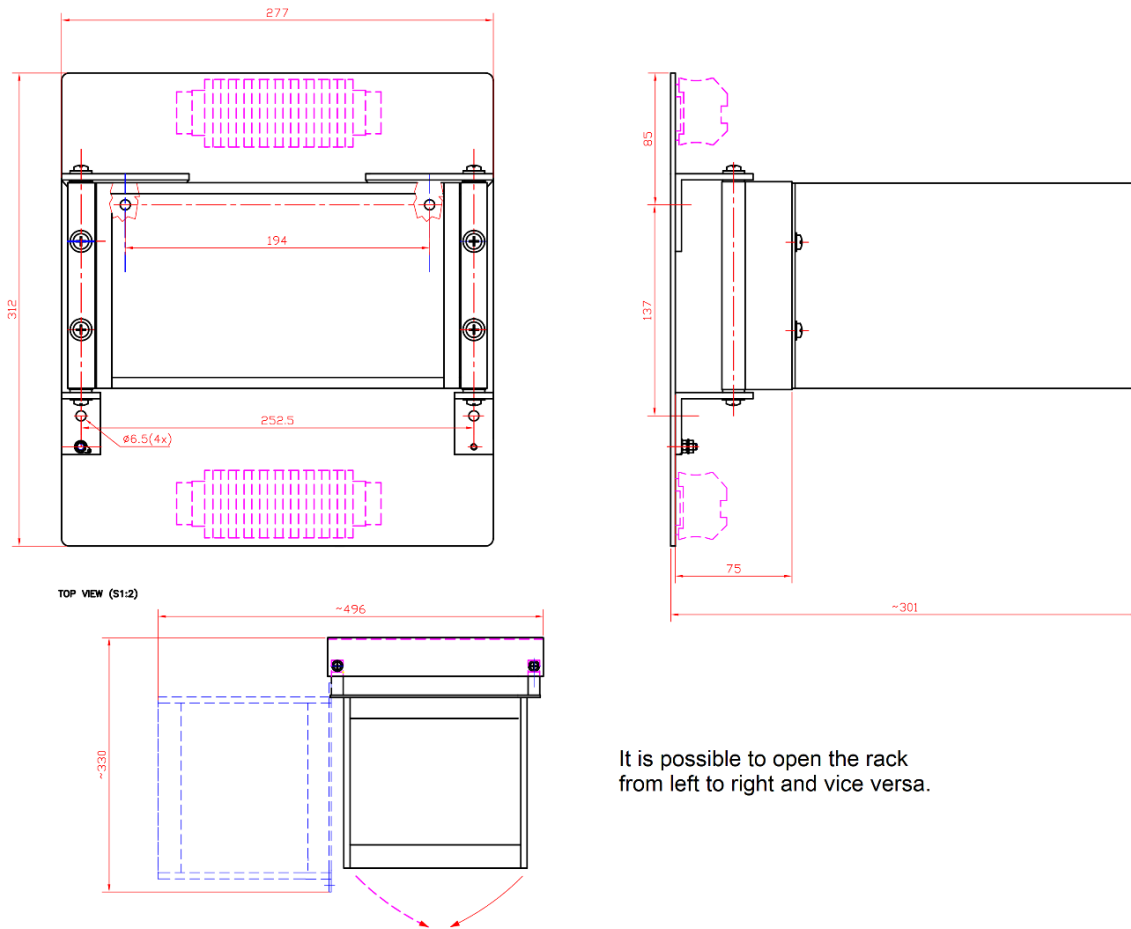


Figure 21-14 Dimensions for wall mounting of 42 HP devices (upper and lower terminals)

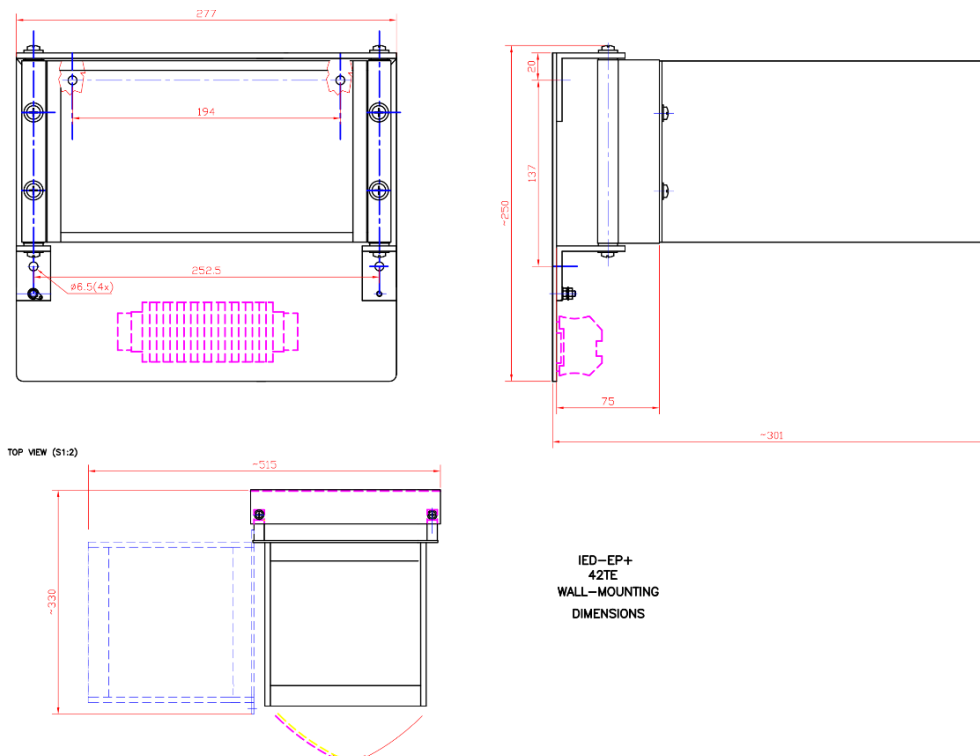


Figure 21-15 Dimensions for wall mounting of 42 HP devices (lower terminal only)

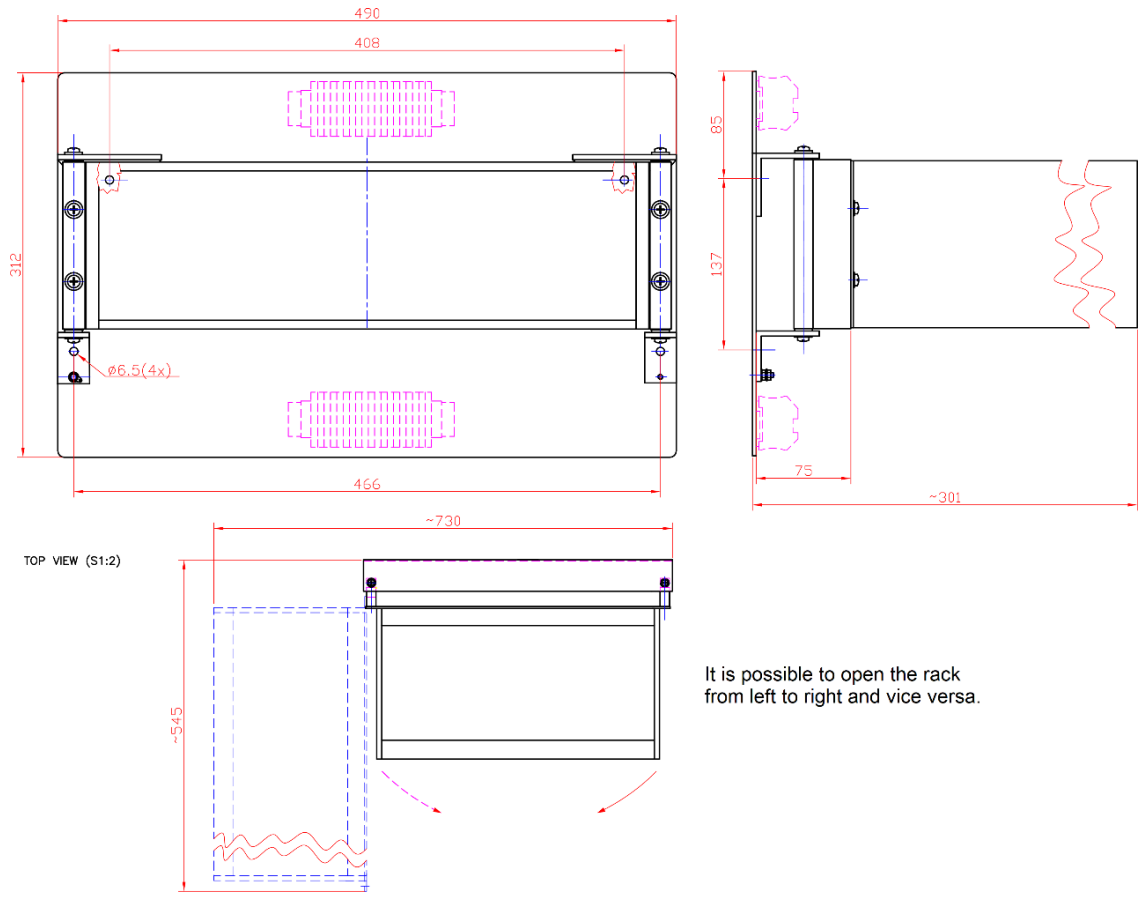


Figure 21-16 Dimensions for wall mounting of 84 HP devices (upper and lower terminals)

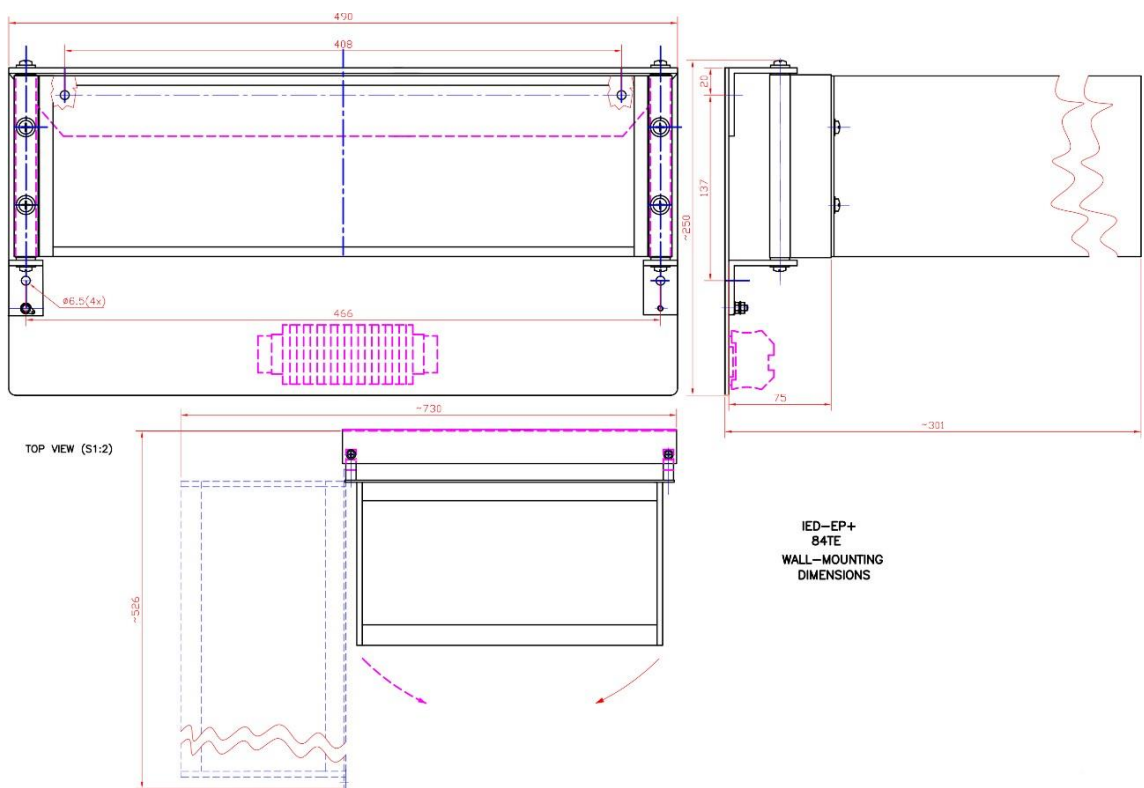


Figure 21-17 Dimensions for wall mounting of 84 HP devices (lower terminals only)

1.3.23.5. Din rail mounting of 24 HP panel instrument case

Note that the IP54 front panel option cannot be utilized with this type of mounting.

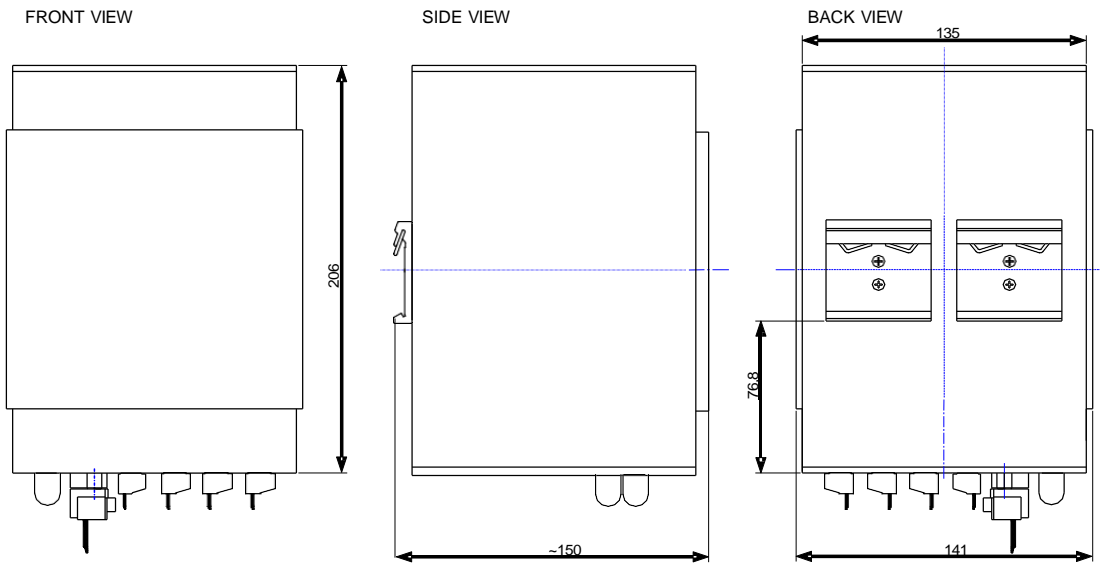


Figure 21-18 Dimensions for din rail mounting of 24 HP panel instrument case

1.3.23.6. IP54 rated mounting kit

The IP frame seen below provides IP54 protection from front side for 84HP and 42HP devices.

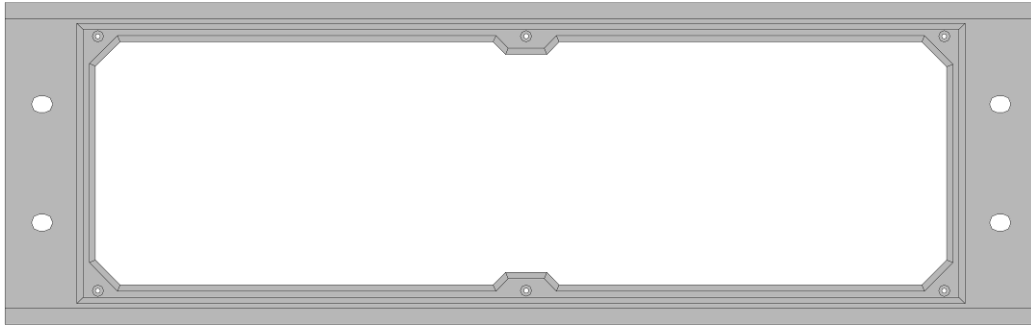


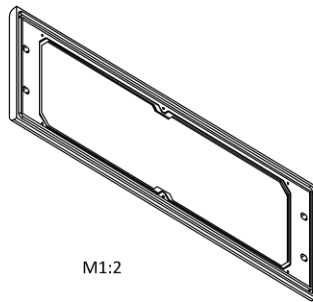
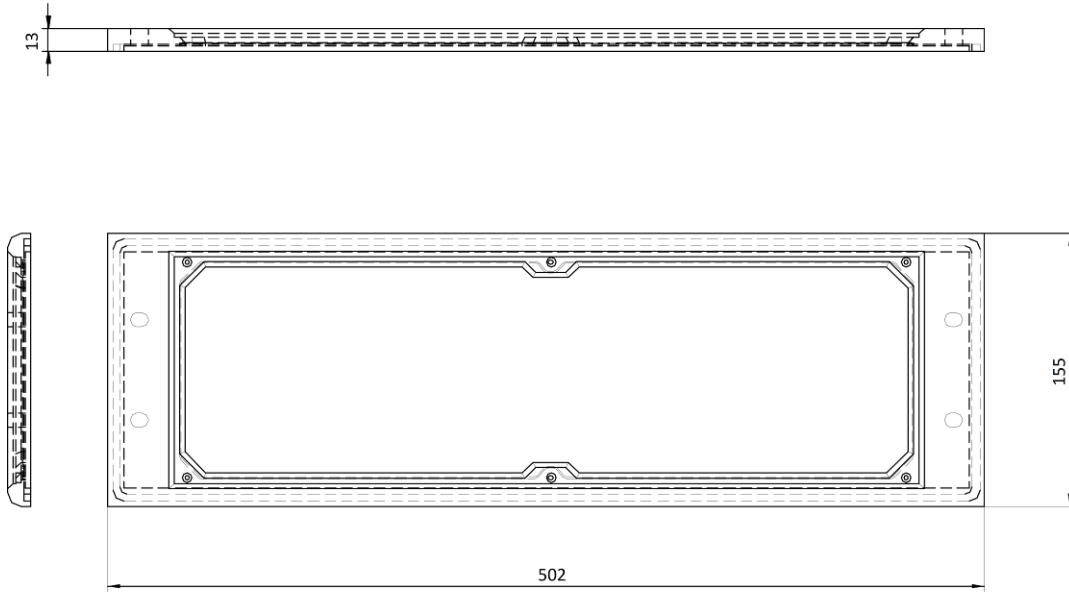
Figure 21-19 84 HP IP frame front view



Figure 21-20 42 HP IP frame front view

S24 devices

The S24 devices' front panel *does not differ from the normal front panel on the outside*, as there is IP54 gasket applied within the frame itself. Devices ordered with this option must be mounted by *flush mounting*; with other types of mountings (e.g. semi-flush), the IP54 protection is not guaranteed!



M1:2

Figure 21-21: 84 HP IP frame dimensions

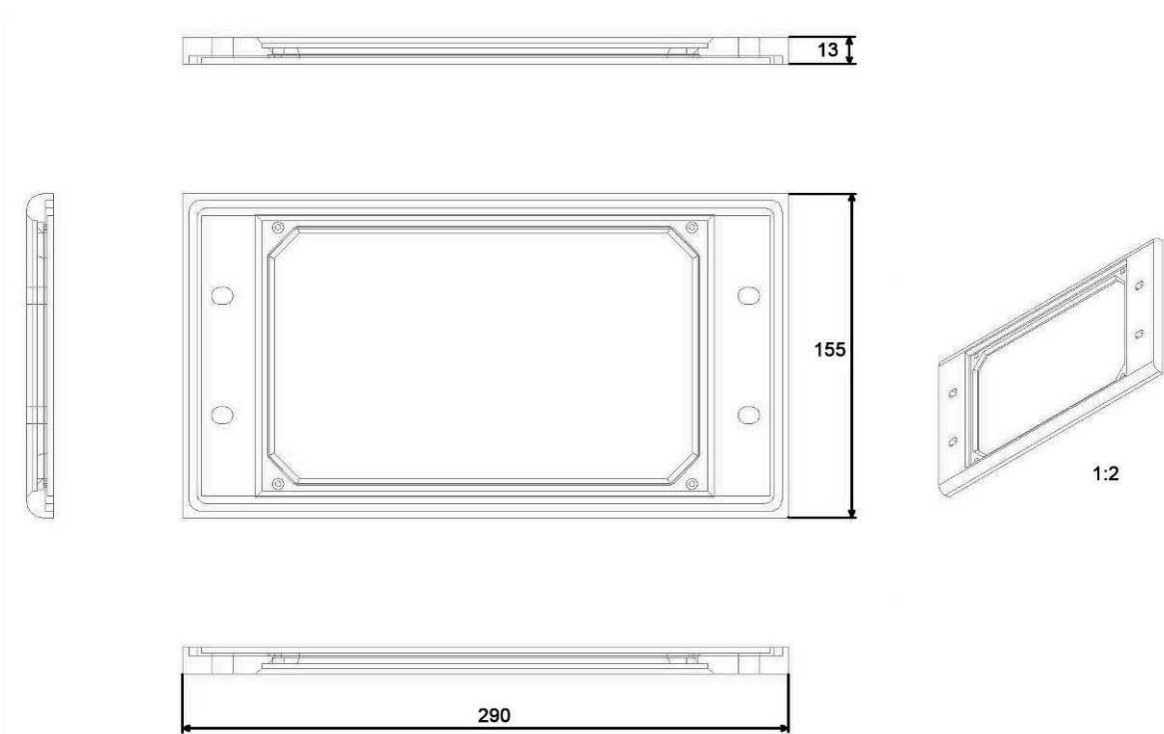


Figure 21-22 42 HP IP frame dimensions

1.3.23.7. Fold-down mounting

1.3.23.7.1. Fold-down mounting without terminals

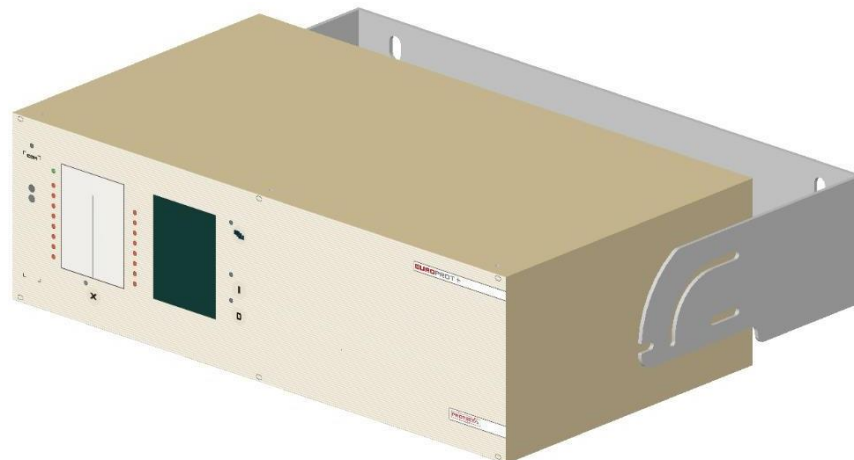
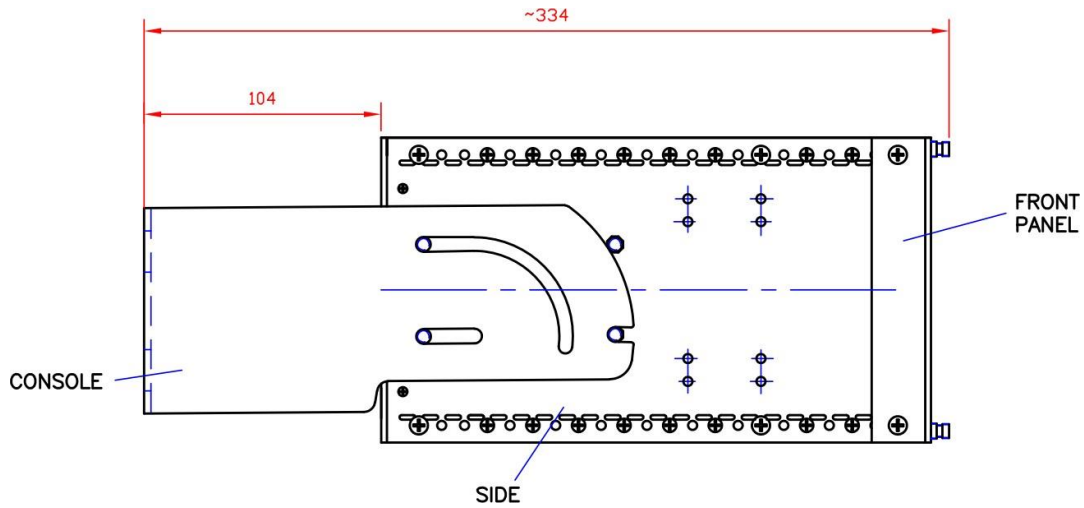
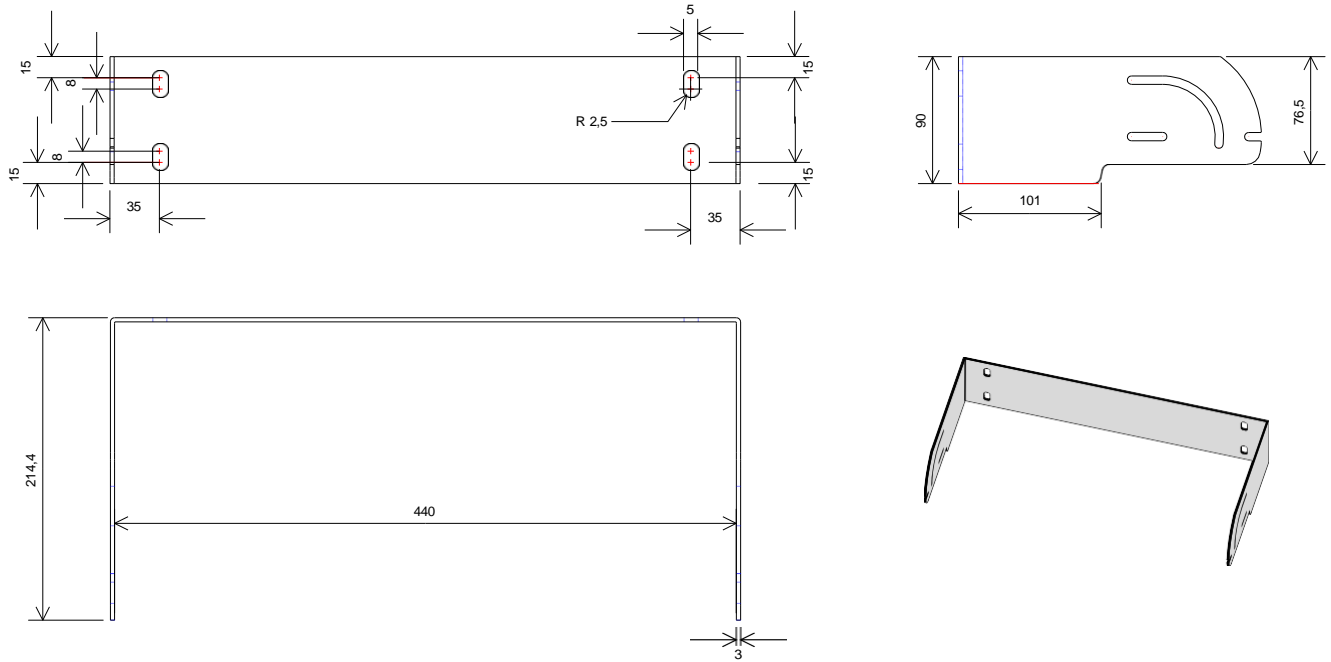


Figure 21-23 84 HP fold-down mounting

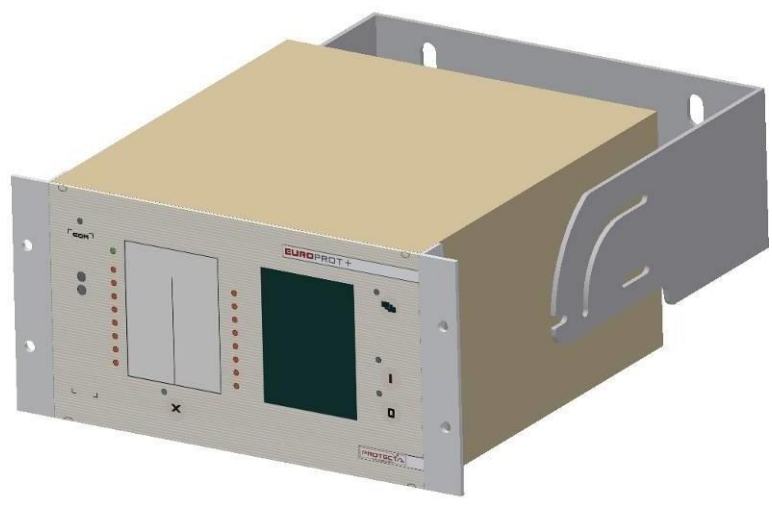
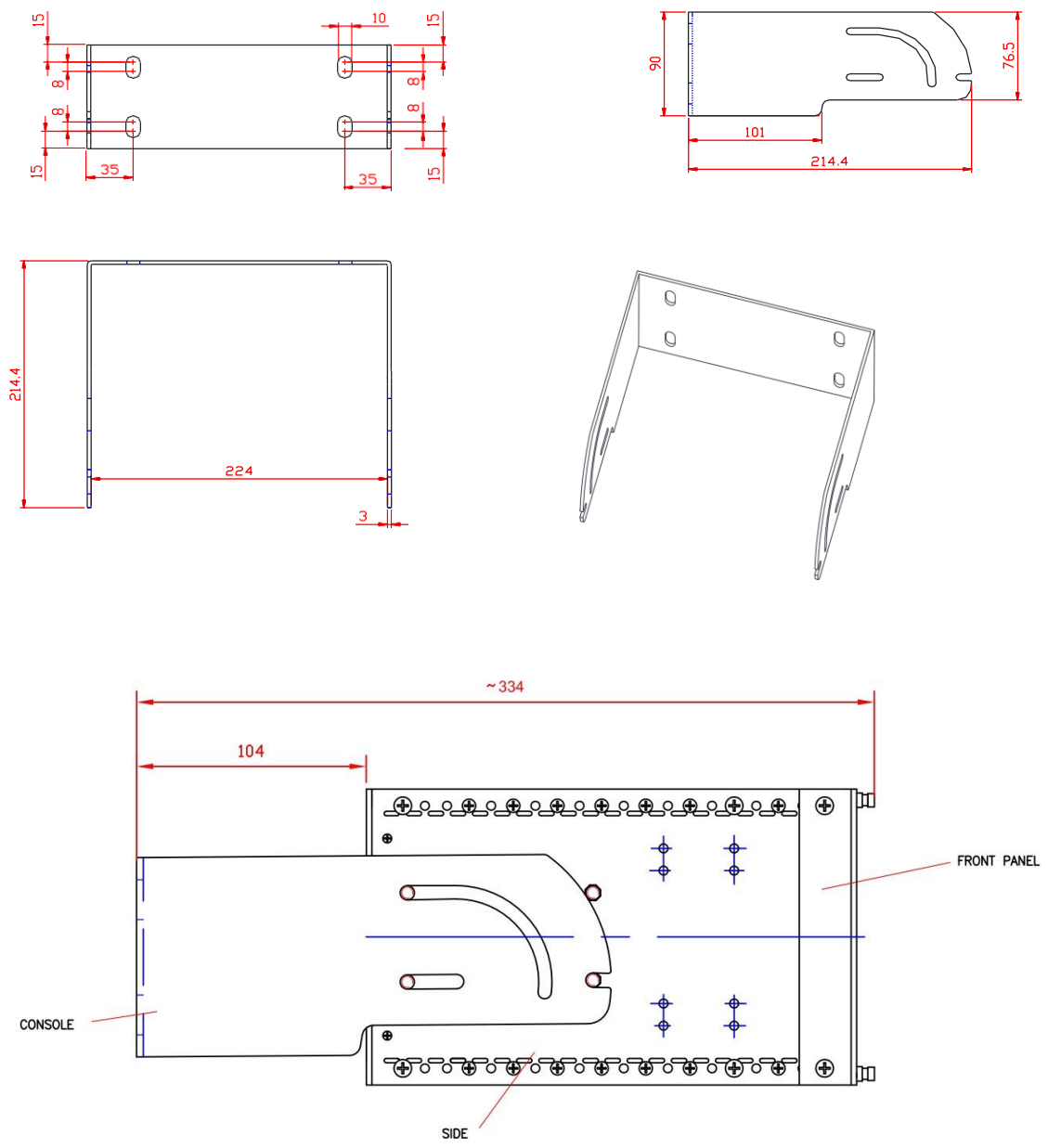


Figure 21-24 42 HP fold-down mounting

1.3.23.7.2. Fold-down mounting with terminals

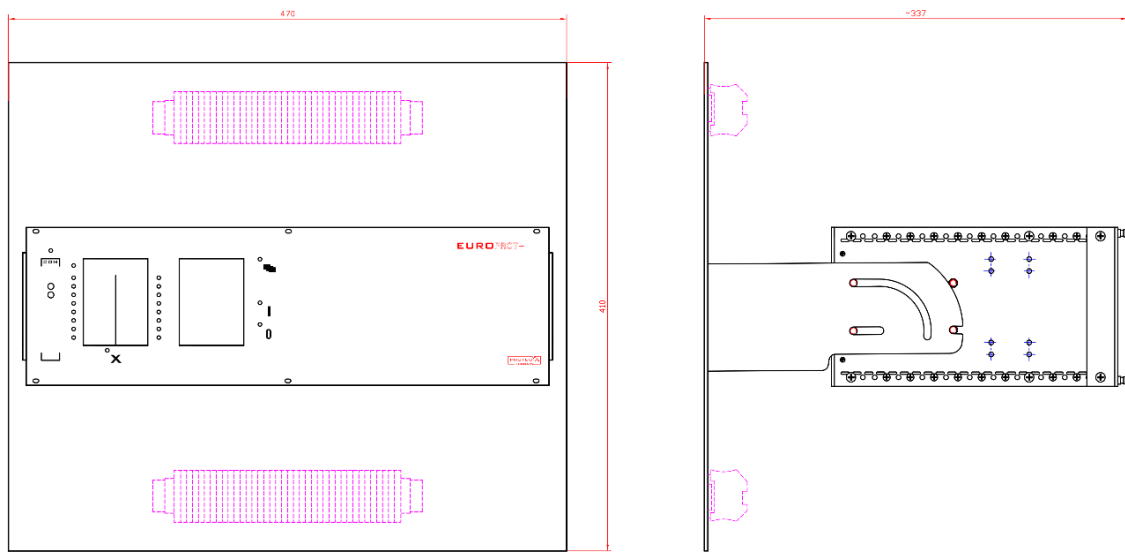


Figure 21-25 Fold-down mounting with terminals for 84HP devices

*fastening points are customized

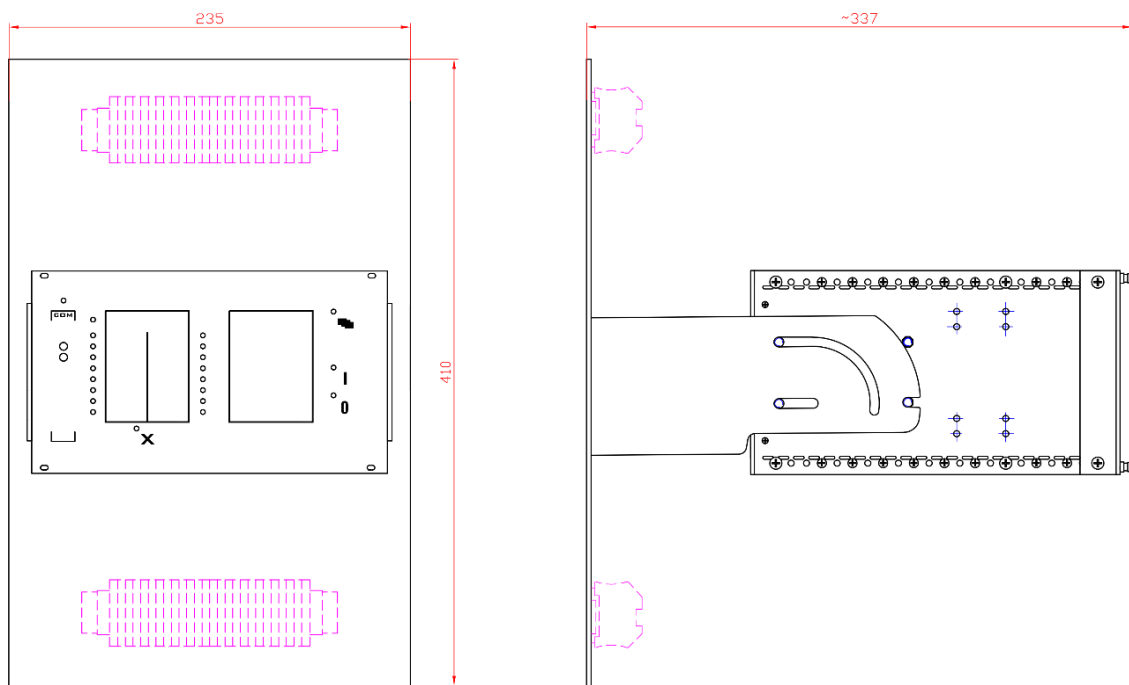
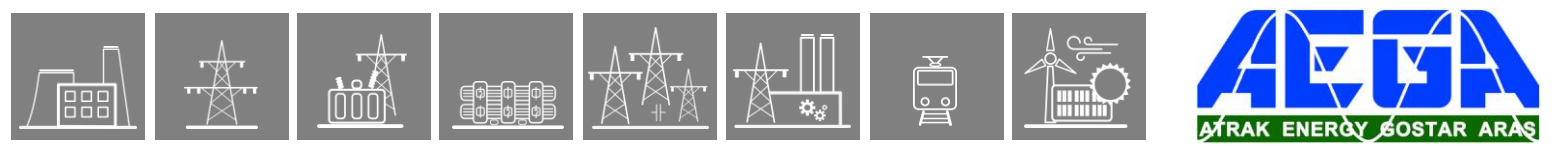


Figure 21-26 Fold-down mounting with terminals for 42HP devices



1.3.23.8. No mounting

“No mounting” means that the 84 HP and 42 HP devices do not have any mounting accessories on them.

This mounting method is only applicable if the device is for demonstration application.

For more information about this topic please contact our Application Team.
(application@protecta.hu)

IMPORTANT

The dimensions of the cut-outs applicable for the remote HMI are depending on which previously mentioned mounting method is used (flush mounting, semi-flush mounting or rack mounting).

1.3.23.9. Remote HMI devices

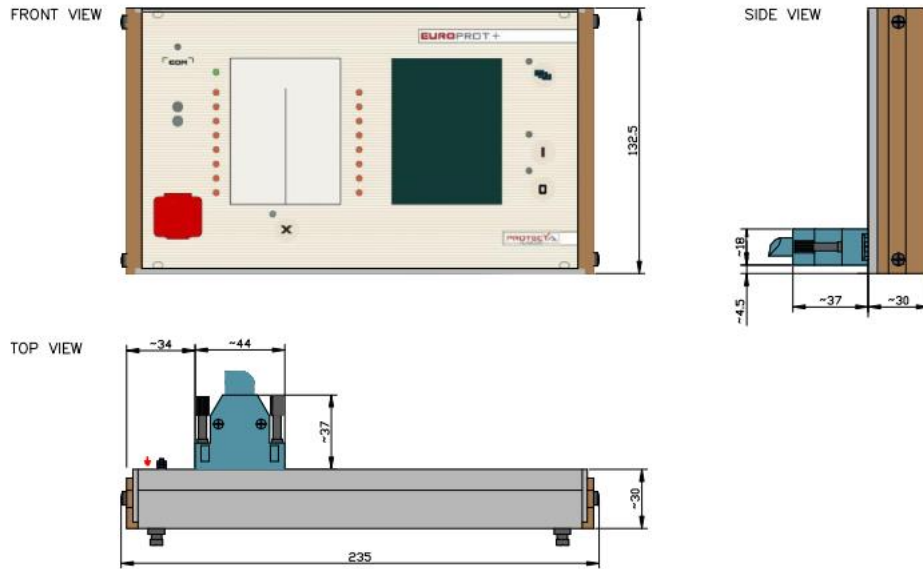
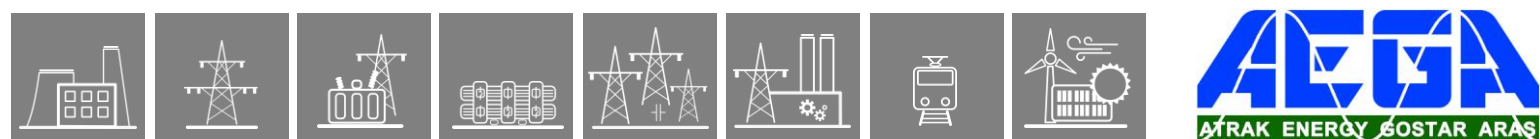


Figure 21-27 Dimensions for 42 HP wide remote HMI



Figure 21-28 Dimensions for 84 HP wide remote HMI



1.3.24. Product availability (special and obsolete modules)

In this chapter you can read a list of the modules that have not regular availability for any reason (being obsolete or being used only in special configurations).

Special modules:

These modules can be ordered in case of special applications which are indicated for each module at its description in the previous chapters.

For more information about these devices please contact our Application Team. (application@protecta.hu)

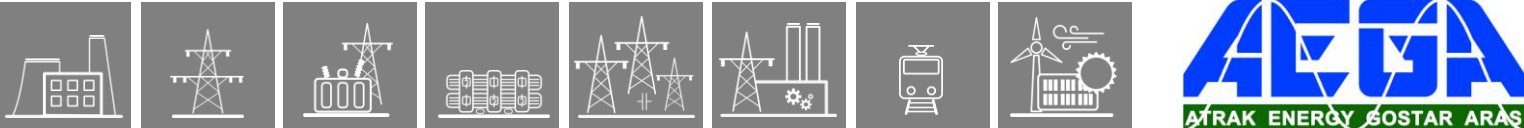
Optional connectors:

The optional connectors are indicated at each module's description in the previous chapters. If a module is to be shipped with an optional connector, the issue must be discussed during ordering.

| MODULE TYPE | COMMENT | DATE |
|-------------|-----------------------------------------------------------------------------------|------------|
| CPU+/0001 | Legacy CPU card, not recommended for new configurations. Replacement: CPU+1211 | 2013-06-12 |
| CPU+/0002 | Legacy CPU card, not recommended for new configurations. Replacement: CPU+1111 | 2013-06-12 |
| CPU+/0003 | Legacy CPU card, not recommended for new configurations. Replacement: CPU+1101 | 2013-06-12 |
| CPU+/0004 | Legacy CPU card, not recommended for new configurations. Replacement: CPU+1201 | 2013-06-12 |
| CPU+/0005 | Legacy CPU card, not recommended for new configurations. Replacement: CPU+1281 | 2013-06-12 |
| CPU+/0006 | Legacy CPU card, not recommended for new configurations. Replacement: CPU+1381 | 2013-06-12 |
| CT+/1155 | Available only for special configurations. | 2013-06-12 |
| CT+/5152 | Available only for OGYD bay unit configurations. | 2013-06-12 |
| VT+/2215 | Available only for special configurations. | 2013-06-12 |
| O12+/2101 | Available only for demonstration applications. | 2013-06-12 |
| O12+/4201 | Available only for demonstration applications. | 2013-06-12 |
| R4S+/01 | Available only for special configurations. | 2013-06-12 |
| R4S+/16 | Available only for special configurations. | 2013-06-12 |
| TRIP+/1101 | Obsolete module. Not recommended for new designs. | 2013-06-12 |
| PS+/1602 | Available only for special configurations. | 2013-06-12 |
| HMI+/2401 | Obsolete module. Not recommended for new designs. | 2014-10-06 |

| | | |
|-------------------|------------------------------------------------------------------------------|------------|
| HMI+/2404 | Smart Line S24 special selection modules. | 2014-10-06 |
| HMI+/2504 | Smart Line S24 special selection modules. | 2014-10-06 |
| COM+/8882 | Available only for special configurations. | 2014-10-06 |
| CT+/1111 | Available only for special configurations. | 2014-10-06 |
| CT+/2500 | Available only for special configurations. | 2014-10-06 |
| CT+/5153 | Available only for special configurations. | 2014-10-06 |
| VT+/2212 | Available only for special configurations. | 2014-10-06 |
| R8+/01 | Available only for special configurations. | 2014-10-06 |
| R8+/A1 | Available only for special configurations. | 2014-10-06 |
| R8+/C0 | Available only for special configurations. | 2014-10-06 |
| R8+/FF | Available only for special configurations. | 2014-10-06 |
| R12+/4400 | Available only for special configurations. | 2014-10-06 |
| R16+/0101 | Available only for special configurations. | 2014-10-06 |
| R16+/0001 | Available only for special configurations. | 2014-10-06 |
| R16+/A001 | Available only for special configurations. | 2014-10-06 |
| PS+/4401 | Available only for special configurations. | 2014-10-06 |
| CT+/2500 | Obsolete module. Not recommended for new designs. Replacement: CT+1500. | 2015-02-13 |
| PSTP+/2102 | Available only for special configurations. | 2015-06-23 |
| PSTP+/4202 | Available only for special configurations. | 2015-06-23 |
| CT+/5111 | Available only for special configurations. | 2015-12-08 |
| CT+/0101 | Available only for special configurations. DEFL earth fault protection only. | 2018-03-19 |
| INJ+/0015 | Available only for special configurations. | 2018-03-19 |
| CT+/5155 | Available only for special configurations. | 2018-03-26 |
| VT+/2246 | Available only for special configurations. | 2018-03-26 |
| AIC+/0201 | Obsolete module. Not recommended for new designs. | 2018-03-26 |
| CT+/5111 | Obsolete module. Not recommended for new designs. | 2018-03-27 |
| VS+/0031 | Obsolete module. Not recommended for new designs. | 2018-05-25 |

| | | |
|-----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| R1T+/0001 | Available only for special configurations. DMD. | 2018-10-05 |
| CT+/5253 | Available only for special configurations. | 2018-10-05 |
| 42 HP housing | The length of the 42 HP box has been reduced from 242 mm to 223 mm. For more information about the previous size of the 42 HP box please see the Figure 22-1. | 2018-12-18 |
| AIC+/0200 | Obsolete module. Not recommended for new designs. | 2019-04-08 |
| PS+/1030 | Available only for special configurations. | 2020-05-07 |
| PS+/1060 | Available only for special configurations. | 2020-05-07 |
| HMI+/5001 | Obsolete module. Not recommended for new designs. | 2020-06-04 |
| HMI+/5002 | Obsolete module. Not recommended for new designs. | 2020-06-04 |
| HMI+/3502 (for 42HP) | Obsolete module. Not recommended for new designs. | 2020-06-04 |
| CT+/1515 | Available only for special configurations. | 2020-06-04 |
| CT+/5115 | Available only for special configurations. | 2020-06-04 |
| CT+/5116 | Available only for special configurations. | 2020-06-04 |
| CT+/5154 | Available only for special configurations. | 2020-06-04 |
| PSF+/1001 | Available only for special configurations. | 2020-06-04 |
| RTD+/0200 | Available only for special configurations. | 2020-06-04 |
| RTD+/1200 | Available only for special configurations. | 2020-06-04 |
| R4MC+/01 | Available only for special configurations. | 2020-06-04 |
| PS+/4301 | Obsolete module. Not recommended for new designs. | 2020-06-04 |
| 84 HP housing | The depth of the 84 HP box has been reduced from 242 mm to 223 mm. For more information about the previous size of the 84 HP box, see the Figure 22-1. | 2021-04-01 |
| HMI+/3501 | Obsolete module. Not recommended for new designs. | 2021-04-20 |
| HMI+/3502 | Obsolete module. Not recommended for new designs. | 2021-04-20 |
| HMI+/5701 | Obsolete module. Not recommended for new designs. | 2021-04-20 |
| HMI+/5702 | Obsolete module. Not recommended for new designs. | 2021-04-20 |
| COM+/1202 | Obsolete module. Not recommended for new designs. | 2021-04-20 |
| COM+/1324 | Obsolete module. Not recommended for new designs. | 2021-04-29 |
| VT+/2212 | Obsolete module. Not recommended for new designs. | 2021-05-06 |
| CT+/5154 | Obsolete module. Not recommended for new designs. | 2021-05-06 |
| O16+/2401 | Obsolete module. Not recommended for new designs. | 2022-03-22 |
| O16+/4801 | Obsolete module. Not recommended for new designs. | 2022-03-22 |



| | | |
|------------------|---------------------------------------------------|------------|
| O16+/1101 | Obsolete module. Not recommended for new designs. | 2022-03-22 |
| O16+/2201 | Obsolete module. Not recommended for new designs. | 2022-03-22 |

1.3.24.1. Previous 42HP and 84HP device housings

As of 2021. Q2, not only the 42HP, but the 84HP devices are shipped with shorter racks as well. Note that this is the only difference between the new and old housings. The new racks are shorter by 19 mm from the front, thus their depth is 223 mm instead of 242 mm.

The mounting methods described in Chapter 21 are valid for the previous racks as well, keeping in mind that the depth of the device is 19 mm bigger than that of the drawings. As an example, see the previous drawing of the flush mounting for 42HP and 84HP devices in Figure 22-1. As a comparison, the new, shorter rack is also drawn in light blue.

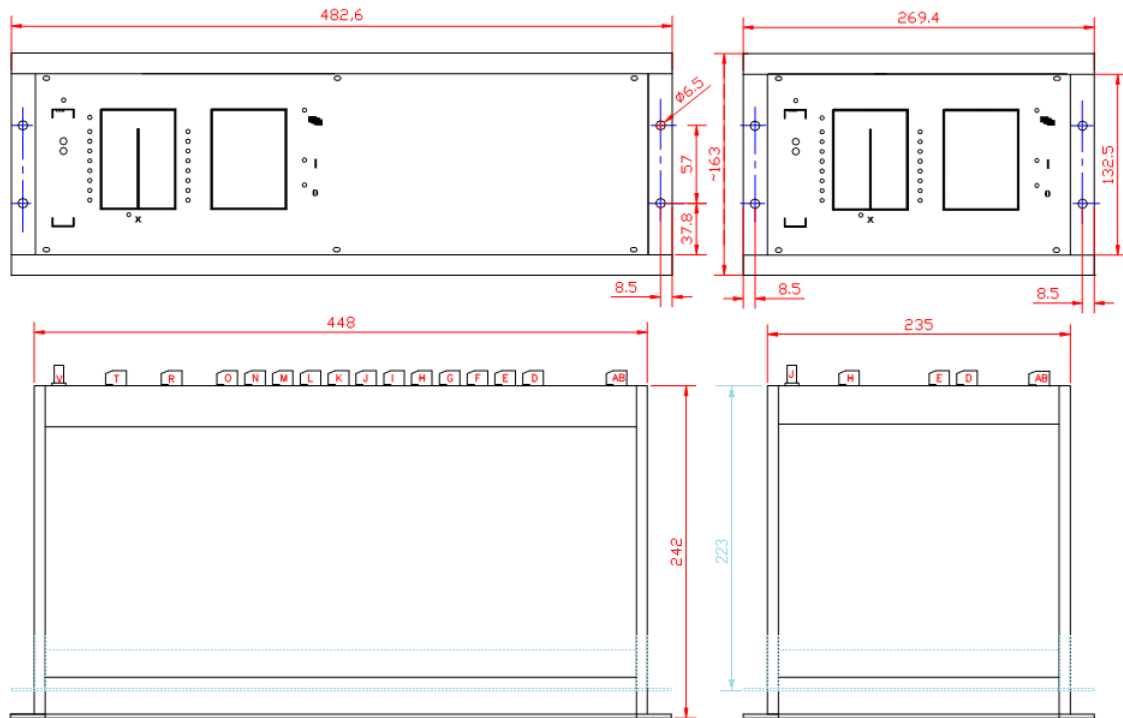


Figure 22-1 Dimensions for flush mounting of the previous 84HP and 42HP single rack, including the new (shorter) rack dimensions as well.

1.3.25. Remote I/O (RIO) server description

1.3.25.1. Introduction

Remote I/O (RIO) server is an IED, which provides remote binary inputs and outputs far from an EuroProt+ protection device.



Figure 1-1 Remote I/O device



Figure 1-2 Front view and rear view with fastening for mounting rail

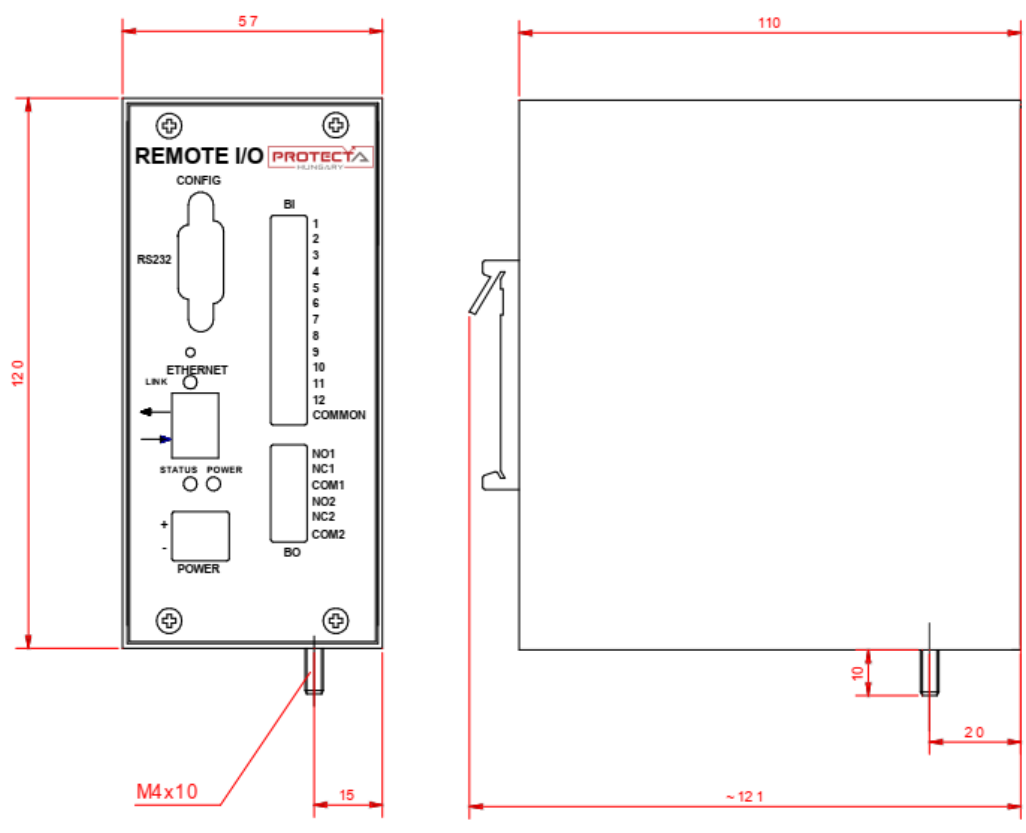


Figure 1-3 Remote I/O dimensions

1.3.25.2. Application

1.3.25.2.1. Connectors, LEDs

The connectors of the device are illustrated in the following figure.

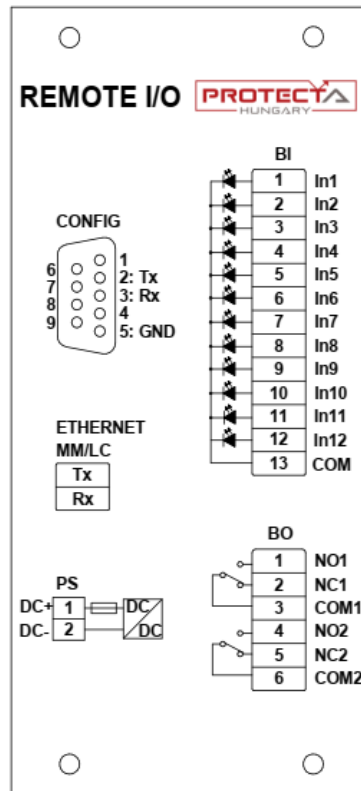


Figure 2-1 Connectors of the device

The RIO server has three LED indicators:

- **LINK:** located at the Ethernet connector; it shows active communication (green color)
- **POWER:** located above the power connector; it lights up if the device is operating (green color)
- **STATUS:** located also above the power connector. The behavior and color of this LED shows different situations:
 - Blinking **red**: there are no clients connected
 - Blinking alternatively **red-green**: the server has one client connected
 - Blinking **green**: two or more clients are connected

1.3.25.2.2. Wiring, usage

The device communicates with the EP+ device using the MODBUS/TCP protocol, via either of the COM+/1202, COM+/1324, COM+/1335, COM+/6603 or COM+/6663 modules.

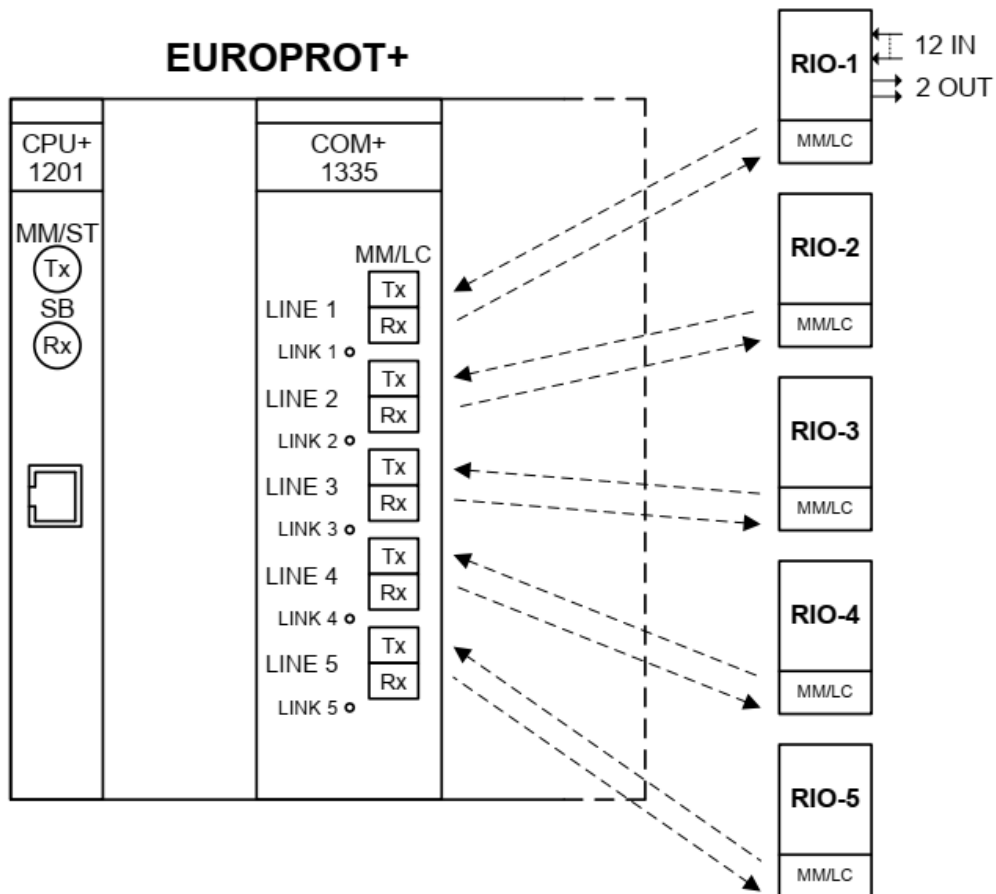


Figure 2-2 Wiring of the Remote I/O-s

The RIO inputs and outputs appear among the other binary inputs and outputs of the EuroProt+ device, and they can be utilized the same way.

1.3.25.3. Sub-modules

The RIO server consists of two mixed function modules:

- SCPU/PS: combination of a CPU and power supply module
- SO12/R2: binary I/O module with 12 inputs and 2 relay outputs

1.3.25.3.1. SCPU/PS sub-module

The SCPU/PS module contains all the control, communication and the power supply functions of the device.

1.3.25.3.1.1. CPU

Table 3-1 Technical data of the RIO CPU

| CPU TYPE | ETHERNET INTERFACE | SERVICE PORT |
|-----------|-----------------------------------------------------------|--------------|
| SCPU+0011 | MM/LC 1300 nm, 50/62,5/125 µm connector, 100Base-FX | RS232* |

*The service port labeled "CONFIG" is only for factory usage

1.3.25.3.1.2. Power supply, external MCB

Table 3-2 Technical data of the RIO power supply

| PS TYPE | INPUT VOLTAGE | NOMINAL POWER | INPUT VOLTAGE INTERRUPTION TIME | INRUSH CURRENT (< 0.1 s) | CONNECTOR TYPE |
|---------|----------------------------------|---------------|-----------------------------------------|--------------------------|----------------------|
| PS+1101 | 65-180 V DC | 9 W | min. 140 ms @ 110 V DC input voltage | < 10 A | Weidmüller BLA 2/180 |
| PS+2301 | 176 – 264 V DC 160 – 250 V AC | 9 W | min. 50 ms @ 230 V AC input voltage | < 10 A | Weidmüller BLA 2/180 |

The power supply must be protected by an **external midget circuit breaker**. Note that it is not part of the RIO device:

- Characteristics: **6A C**

1.3.25.3.2. SO12/R2 sub-module

The SO12/R2 module contains 12 binary inputs in one grounding group, and 2 relay outputs with dry contacts.

1.3.25.3.2.1. Binary inputs

Main features:

- Digitally filtered per channel
- Current drain approx.: 2 mA per channel

Table 3-3 Technical data of the binary inputs

| BI TYPE | CHANNEL NUMBER | TIME SYNC. | RATED VOLTAGE | THERMAL WITHSTAND VOLTAGE | CLAMP VOLTAGE | CONNECTOR TYPE |
|-----------|----------------|------------|---------------|---------------------------|-----------------------------------------|-----------------------------|
| SO12+4801 | 12 | - | 48 V | 72 V | falling $0.71 U_N$ rising $0.76 U_N$ | Weidmüller BL 3.5/13/180 |
| SO12+1101 | 12 | - | 110 V | 250 V | falling $0.7 U_N$ rising $0.73 U_N$ | Weidmüller BL 3.5/13/180 |

Thermal withstand voltage: continuous with 60 % of the input channels energized.

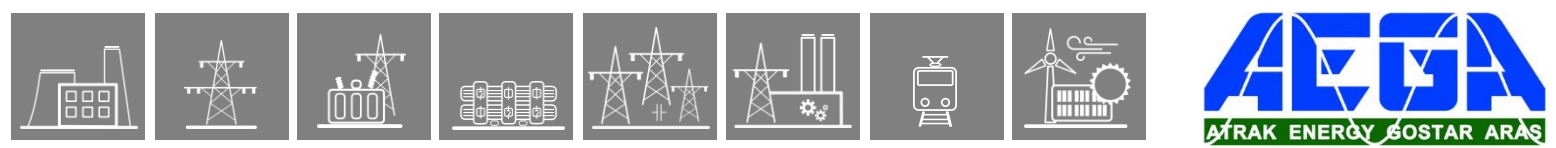
1.3.25.3.2.2. Binary outputs

Main features:

- Breaking capacity, (L/R = 40 ms) at 220 V DC: 0.2 A
- Breaking capacity, (L/R = 40 ms) at 110 V DC: 0.3 A

Table 3-4 Technical data of the relay outputs

| BO TYPE | RATED VOLTAGE | CONTINUOUS CARRY | CONTACT VERSIONS | GROUP ISOLATION | CONNECTOR TYPE |
|---------|----------------|------------------|------------------|-----------------|----------------------------|
| R2+0001 | 250 V AC/DC | 6 A | CO | 2 independent | Weidmüller BL 3.5/6/180 |



1.3.25.4. General data

- Storage temperature: - 40 °C ... + 70 °C
- Operation temperature: - 20 °C ... + 55 °C
- Humidity: 10 % ... 93 %
- Altitude: up to 2000 m
- Atmospheric pressure: 86 ... 106 kPa

1.3.25.4.1. Standard conformance

- Electrostatic discharge immunity (ESD), IEC-EN 60255-26:2013, Level 4
 - Test voltages: 15 kV air discharge, 8 kV contact discharge
- Radiated, radio-frequency, electromagnetic field immunity, IEC-EN 60255-26:2013 Level 3
 - Test field strength: 10 V/m
- Electrical fast transient/burst immunity (EFT/B), IEC-EN 60255-26:2013, Level 4
 - Test voltage: 4 kV
- Surge immunity test, IEC-EN 60255-26:2013
 - Test voltages: 2 kV line-to-earth, 1 kV line-to-line
- Immunity to conducted disturbances, induced by radio-frequency fields, IEC-EN 60255-26:2013, Level 3
 - Test voltage: 10 V
- Damped oscillatory wave immunity test, IEC-EN 60255-26:2013
 - Test frequency: 1 MHz
 - Test voltage: 2.5 kV in common mode, 1 kV in differential mode
- Voltage dips, short interruptions and voltage variations immunity, IEC-EN 60255-26:2013
 - Voltage dips: 40 % (200 ms), 70 % (500 ms), 80 % (5000 ms)
- Ripple on d.c. input power port immunity, IEC-EN 60255-26:2013
 - Level 4, 15 % of rated d.c. value
- Power frequency magnetic field immunity test, IEC-EN 60255-26:2013, Level 5
 - Test field strength: 100 A/m continuous, 1000 A/m for 3 s
- Power frequency immunity test on the binary inputs, IEC-EN 60255-26:2013, Class A
 - Test voltages: 300 V in common mode, 150 V in differential mode
- Insulation tests, IEC-EN 60255-27:2013
 - Impulse voltage test
 - Test levels: 5 kV (1 kV for transducer and temperature measuring inputs)
 - Dielectric test
 - Test levels: 2 kV AC 50 Hz (0.705 kV DC for transducer inputs)
 - Insulation resistance
 - Insulation resistance > 15 GΩ
- Radiated emission, IEC-EN 60255-26:2013
Limits:
 - 30 MHz to 230 MHz: 50 dB(μV/m) quasi peak, 3 m
 - 230 MHz to 1 000 MHz: 57 dB(μV/m) quasi peak, 3 m
 - 1 GHz to 3 GHz: 76 dB(μV/m) peak, 3 m
 - 3 GHz to 6 GHz: 80 dB(μV/m) peak, 3 m
- Conducted emission, IEC-EN 60255-26:2013
Limits:
 - 0,15 MHz to 0,50 MHz: 79 dB(μV) quasi peak, 66 dB(μV) average
 - 0,5 MHz - 30 MHz: 73 dB(μV) quasi peak, 60 dB(μV) average
- Vibration, shock, bump and seismic tests on measuring relays and protection equipment
 - Vibration tests (sinusoidal), Class I, IEC 60255-21-1:1988
 - Shock and bump tests, Class I, IEC 60255-21-2:1988
 - Seismic tests, Class I, IEC 60255-21-3:1993

1.3.25.5. Mechanical data

1.3.25.5.1. General mechanical data

- Construction
 - Painted steel surface
- IP protection:
 - IP2x
- Size:
 - See Figure 1-3 for the device dimensions
- Weight:
 - 0.7 kg

1.3.25.5.2. Connectors

Table 5-1 Connectors on the RIO

| CONNECTOR NAME | CONNECTOR TYPE | STRIP LENGTH [MM] | CONDUCTOR AREA [MM ²] | CONDUCTOR DIAMETER [MM] | TIGHTENING TORQUE [Nm] | MINIMUM BEND RADIUS* |
|---------------------------|---------------------------------------------|-------------------|-----------------------------------|-------------------------------|------------------------|----------------------|
| BLA | Weidmüller BLA 2/180 | 7 | 0.2 – 1.5 solid: 0.2 – 2.5 | 0.5 – 1.4 solid: 0.5 – 1.8 | 0.4 – 0.5 | 3 × OD** |
| BL 3.5 | Weidmüller BL 3.5/6/180 BL 3.5/13/180 | 6 | 0.2 – 1.5 | 0.5 – 1.4 | 0.2 – 0.25 | 3 × OD** |
| PE FASTON TERMINAL | TE Connectivity 6.3x0.8 | 7 | min. 4 | min. 2.3 | - | 3 × OD** |

* Bend radius is measured along the inside curve of the wire or wire bundles.

** OD is the outer diameter of the wire or cable, including insulation.

The tightening torque of the screw for protective earth connection must be approx. 5 Nm.

During the installation, make sure that the shortest possible length for PE (Protective Earth) cable.

The minimum distance between the device and its wire channel must be at least 3 cm.

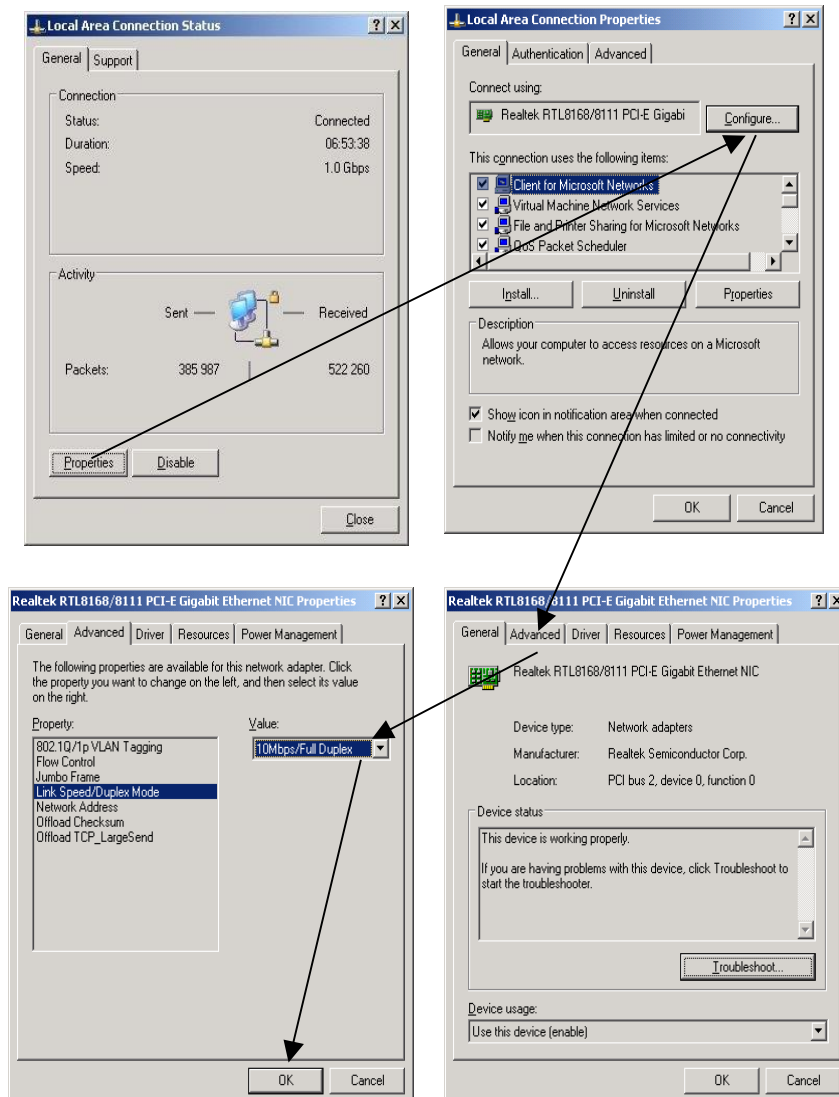
1.3.26. Technical notes on EOB interoperability

1.3.26.1. Description

We experienced some interoperability issues regarding front panel communication with EP+ devices. The link establishment procedure of the ethernet communication become unstable with certain type of NICs (Network Interface Card) of network devices. Network devices with 10/100Base-T speed support has no limitation but devices with 1000Base-T (called gigabit) may cause this link establishment failure. In this case the operating system periodically signals that interface is connected, then disconnected, then connected etc.

1.3.26.2. EOB Troubleshooting

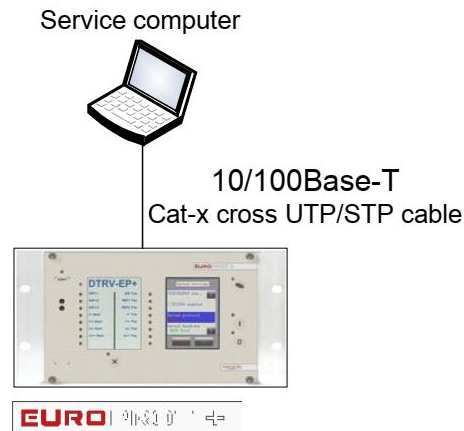
- force NIC speed and mode to 10Base-T Full-duplex (setting method may depend on Your PC hardware configuration) on Your PC. Local Area Network settings can be found at:
 - WindowsXP: Control Panel/Network Connections/Local Area Connection
 - Windows 7: Control Panel\All Control Panel Items\Network and Sharing Center



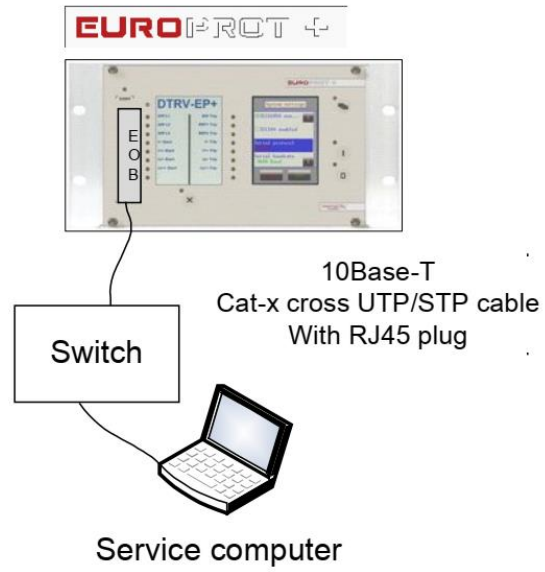
1.3.26.3. Workaround

- using station bus interface connector at the front panel of the CPU card
 - if the device equipped with 100Base-Fx station bus interface then You can connect Your computer via a third-party media converter unit
 - if the device equipped with 10/100Base-Tx station bus interface (RJ45) then connect Your computer directly to the EP+ via a crossed CATx cable

Service computer



- using EOB at the HMI:
 - in case of unstable link with Your PC apply a third-party external 10/100Base-T switch with one port connected via EOB to the EP+ and other port connected to Your PC via a CATx cable.



1.3.26.4. Further details

For getting started guide and IP configuration download: http://www.protecta.hu/epp-prelim/QuickStart/Quick_Start_Guide_V1.0.pdf

1.3.27. EP+ Installation manual

USED SYMBOLS

Symbols on devices:



Test voltage: 2 kV



Protective conductor terminal



Do not dispose of this device

Symbols in this document:



Caution, risk of electric shock



Caution, hot surface



Caution, refer to the documentation



Do not dispose of this device



1.3.27.1. Introduction

This manual is intended to provide instruction for proper device installation, which includes mechanical mounting and electrical wiring. Furthermore, the information provided here will strongly support commissioning, maintenance, and deinstallation work as well. This document's targeted user groups are skilled electrical professionals executing installation works and commissioning with EuroProt+ devices.

Given that the EuroProt+ product family has a modular design, the instructions provided here can cover all configurations. Therefore, this manual shall be used in conjunction with the "EuroProt+ Hardware description" document, which includes essential information about all hardware components of the product.

1.3.27.2. Equipment handling

1.3.27.2.1. Unpacking

Inspect the package for transport damages. Carefully remove the packing material without applying excessive force.

1.3.27.2.2. Visual inspection

Identify the product by reading the order code. This can be found on the device nameplate located mostly on the right side of the device in the top right corner and shall be identical to your order.

Picture 2-2 Device nameplate



The protection device may have loose items packed in a different box based on the configuration. Check, that these items are also included in the shipment.

Visually inspect all unpacked items for damages, water ingress, or any sign of external impact. If you discover any transport damage, please notify Protecta Ltd. first and do not start any further work on the equipment.

1.3.27.2.3. Storage

If temporary storage is required before installation, please store the device in its original packing in a dry and clean place. The required environmental conditions can be found in the “General data” section of the “EuroProt+ Hardware description” document.

1.3.27.3. Mounting

1.3.27.3.1. Tools for mounting

The tools and screws necessary for mounting depend on the method of the mounting, see the “Mounting methods” section of the “EuroProt+ Hardware description” document.

Assuming the panel or cubicle is ready for installation of the device, screwdrivers matching the screws used, pliers, wrenches, etc. are necessary. For safety aspects, mechanical protective gloves shall be used to avoid injuries.

1.3.27.3.2. Environmental conditions

Make sure, that the mounting location fulfils environment requirements stated in the “General data” section of the “EuroProt+ Hardware description” document. The IP protection class of the device shall fit the surrounding environment at the place of installation. It is also important to have space around the device to support conventional cooling (See 3.3).

1.3.27.3.3. Mounting location

Before mounting the device make sure, that suitable space is available in the location of installation. Cutouts shall fit the device rack dimensions and it is recommended to leave 80mm free space behind the IED for the wiring.

The minimum distance between an EP+ device and its wire channel must be at least 3 cm. The minimum distance between two EP+ devices must be at least 10 cm.

1.3.27.3.4. Mounting the device

The EuroProt+ product line utilizes different rack sizes and depending on that different mounting methods. An overview of the rack sizes with dimensions and mounting methods can be found in the “Mounting methods” section of the “EuroProt+ Hardware description” document.

During the installation make sure that the shortest possible length for PE (Protective Earth) cable routing is applied.

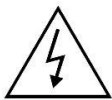
1.3.27.3.5. Safety aspects

1.3.27.3.5.1. Earth connections

1.3.27.3.5.1.1. Protective earth

The device shall be connected to the station earth system with a minimum of 2,5 mm² cross-section solid or stranded wire. A 6,3 mm (1/4 inch) female flat connector (according to IEC 61210) shall be used crimped to the earthing wire. During the installation make sure that the shortest possible length for PE (Protective Earth) cable routing is applied.

The earth connection of the device is situated at all kinds of Power supply modules. In the case of more Power supply modules, all of them shall be earthed.



The protective earth connections should not be removed when the equipment is energized.

Picture 3-5-1-1 Earth connection point of the device at the Power supply module



1.3.27.3.5.1.2. Stranded wires

Soft soldering of stranded wires is not allowed due to the cold flow of the solder material.

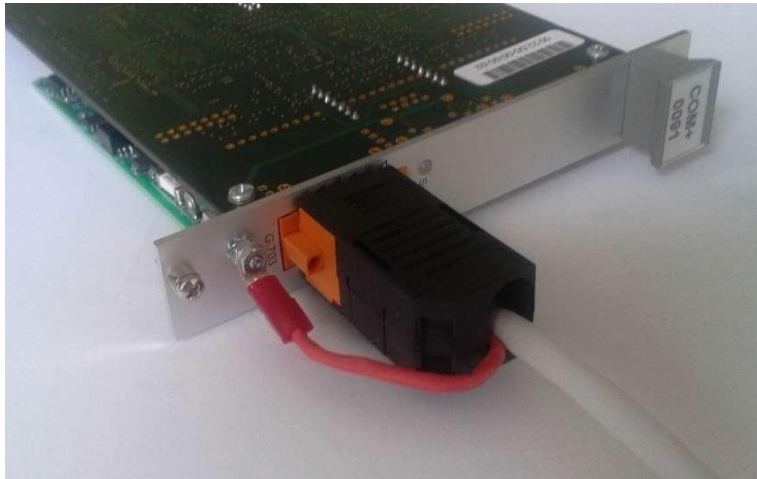


Loose strands of stranded wires can cause fire risk or electric shock. Insulated crimp terminals shall be used.

1.3.27.3.5.1.3. Cable screen connection

The screen of the telecommunication cables connected directly to the device shall be terminated to the earthing connection point of the corresponding module.

Picture 3-5-1-3 An example of the cable screen connection



1.3.27.3.5.1.4. CT and VT circuits



The CT and VT circuits to be connected to the device shall be connected to the station earth system.

1.3.27.3.5.2. Connections of the device

Before connecting the wires, make sure that all voltage levels correspond to the device ratings. It is particularly important by the power supply, trip and binary input, CT and VT module

Use only the connectors provided to the device or identical ones.



The CT connectors shall be fixed with screws provided. During the operation of the device, the CT connectors can be disconnected only after the CT circuits having short-circuited.

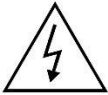
1.3.27.3.5.3. Optical ports



Take adequate measures to protect your eyes and do not view directly into optical ports.

The fiber optics cables are vulnerable. Sharp bending can damage them. The minimum bending radius can be between 15 cm and 25 cm approximately, depending on the type and the material of the cable. For details see the datasheets of the fiber optics cables to be installed. The fiber shall not be twisted or bent. When connecting or disconnecting the cable always hold the connector, not the cable.

1.3.27.3.5.4. Removing and changing modules



Before removing and changing modules first the power supply voltage of the device shall be disconnected. Then all the energizing quantities connected to each module of the device shall be disconnected. Before removing the connectors of the CT modules, the CT circuits shall be short-circuited and disconnected.

The protective earth connection can be disconnected last if it is necessary (e.g. when removing a Power supply module).



The devices contain components that are sensitive to electrostatic discharges. ESD wrist strap shall be worn during any operations with modules.



Some of the modules can operate at high internal temperatures. Remove these modules carefully to avoid any burn injury. Take care of the possible high temperature at each module.



The modules have got sharp edges. Remove them carefully to avoid injury.

After changing a module, it shall be fixed with the screws provided with a torque of 0,5 Nm. Use Philips 2 screwdriver.

1.3.27.4. Wiring

1.3.27.4.1. Tools for connecting

Screwdrivers for the connectors: blade 0,6/3,5 mm, 0,4/2,5 mm.

Cutter, stripper, crimper tools to prepare the connecting end of the wires.

1.3.27.4.2. Connectors

The “Connectors” section of the “EuroProt+ Hardware description” provides information about the required conductor dimensions and connecting methods. The “Connectors” table shall be used together with the other sections describing the different modules.

1.3.27.5. Deinstallation and Repair

1.3.27.5.1. Deinstallation



Before removing the device make sure, that all incoming power supply and control voltages are switched off. The earth connection of the device shall be disconnected last.

1.3.27.5.2. Repair



Thanks to its modular design, many hardware problems can be fixed by replacing single modules. By executing this procedure note, that the printed board’s surface may get hot during normal operation.



In addition, attention shall be paid to the sharp edges of the modules to avoid minor injuries on the hand.

1.3.27.5.3. Disposal



Removed IEDs shall be handed over to a local electronic waste handler for proper disposal and recycling.

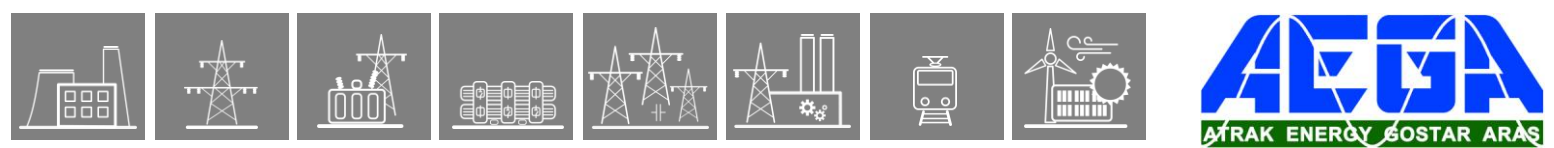


Table 5-3 Disposal of the components and parts

| IED | PARTS | MATERIAL | METHOD OF DISPOSAL |
|--------------------|------------------------------------|--------------------------------------|---------------------------|
| Enclosure | Metal sheets, fastening elements | Aluminum, steel | Separation and recycling |
| Modules | Metallic parts, fastening elements | Aluminum, steel | Separation and recycling |
| | Mounted PC boards | Plastic, various electronic elements | Separation and recycling |
| | Connectors | Plastic, various metals | Separation and recycling |
| | Transformers, coils | Iron, copper, plastic, paper | Separation and recycling |
| | Relays | Iron, copper, plastic, other metals | Separation and recycling |
| Package | Box | Cardboard | Recycling |
| Attachments | Manuals, certificates | Paper | Recycling |

2. Function and I/O listing

The functions listed in Table 2-1 below are the ones that are present most commonly in the configurations, thus they can be considered as factory default arrangements. The hardware information corresponds to the maximum available number of digital I/O, and the default number of analog inputs.

For short descriptions for each function please refer to Chapter 3. Detailed information is available in their respective stand-alone descriptions on the Protecta website after logging in.

*The 'INST.' column contains the numbers of the pre-configured function blocks in the factory configuration. These numbers may be different in order to meet the user's requirements.

| Transformer protection and control Automatic voltage regulator | | | | | | | | | | | | | |
|------------------------------------------------------------------|--------------------------------------------------|--------|---------------------|-----------|--------|-----|-----|-----|-----|-----|----------|-----|----|
| | FAMILY | | | EuroProt+ | | | | | | | | | |
| | TYPE | | | DTRV | | | | | | | | | |
| | CONFIGURATION | | | E0 | E1 | E2 | E3 | E4 | E5 | E6 | E7 | | |
| HARDWARE | CT inputs | | | 4 | 8 | 8 | 8 | 12 | 12 | 12 | 4+4(op.) | | |
| | VT inputs | | | | | 4 | 4 | | 4 | 8 | 4+4(op.) | | |
| | Digital inputs (max) | | | 128 | 112 | 112 | 112 | 100 | 100 | 88 | 128 | | |
| | Signaling relay outputs (max) | | | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | | |
| | Fast Trip outputs (max) | | | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | | |
| FUNCTIONALITY | Function name | | IEC | ANSI | *INST. | E0 | E1 | E2 | E3 | E4 | E5 | E6 | E7 |
| | Protection | | | | | | | | | | | | |
| | Overexcitation | | V/Hz | 24 | 1 | | | ✓ | ✓ | | ✓ | ✓ | |
| | Definite time undervoltage protection | | U <, U << | 27 | 2 | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ |
| | Negative sequence overcurrent protection | | I2 > | 46 | 1 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Negative sequence overvoltage protection | | U2 > | 47 | 1 | ✓ | | ✓ | ✓ | | ✓ | ✓ | |
| | Thermal protection line | | T > | 49 | 1 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Three-phase instantaneous overcurrent protection | | I >>> | 50 | 1 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Residual instantaneous overcurrent protection | | Io >>> | 50N | 1 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Breaker failure protection | | CBFP | 50BF | 1 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Three-phase time overcurrent protection | | I >, I >> | 51 | 2 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Residual time overcurrent protection | | Io >, Io >> | 51N | 2 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Definite time overvoltage protection | | U >, U >> | 59 | 2 | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ |
| | Residual overvoltage protection | | Uo >, Uo >> | 59N | 2 | ✓ | | ✓ | ✓ | | ✓ | ✓ | |
| | Three-phase directional overcurrent protection | | I Dir >, I Dir >> | 67 | 2 | ✓ | | | | | | | |
| | Switch onto fault preparation function | | | | 1 | ✓ | | | | | | | |
| | Residual directional overcurrent protection | | Io Dir >, Io Dir >> | 67N | 2 | ✓ | | ✓ | ✓ | | ✓ | ✓ | |
| | Inrush detection and blocking | | I2h > | 68 | 1 | ✓ | | | | | | | |
| | Overfrequency protection | | f >, f >> | 81O | 2 | ✓ | | ✓ | ✓ | | ✓ | ✓ | |
| | Underfrequency protection | | f <, f << | 81U | 2 | ✓ | | ✓ | ✓ | | ✓ | ✓ | |
| Rate of change of frequency protection | | df/dt | 81R | 1 | ✓ | | ✓ | ✓ | | ✓ | ✓ | | |
| Restricted earth fault | | REF | 87N | 1 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | |
| Transformer differential | | 3IdT > | 87T | 1 | | 2w | 2w | 2w | 3w | 3w | 3w | | |
| Automatic voltage regulator (AVR) / tap change control | | | 90V | 1 | | | | ✓ | | | ✓ | ✓ | |
| Trip Logic | | | 94 | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Lockout trip logic | | | 86 | | Op. | Op. | Op. | Op. | Op. | Op. | Op. | Op. | |
| Bay control | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Circuit breaker wear | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Circuit breaker control | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Disconnecter control | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Ethernet Links | | | | | Op. | Op. | Op. | Op. | Op. | Op. | Op. | Op. | |
| Trip Circuit Supervision | | | 74TC | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Fuse failure (VTS) | | | 60 | 1 | | | ✓ | ✓ | | ✓ | ✓ | ✓ | |
| Current unbalance protection | | | 60 | 1 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Measuring | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Current input | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Voltage input | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Line measurement | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |

Table 2-1 Basic functionality and I/O

3. Software configuration

3.1. Protection functions

The E5-TR configuration measures three phase currents, the zero sequence current component from all three sides of a three winding, three-phase transformer and additionally three phase voltages and the zero sequence voltage component. These measurements allow, in addition to the current- and voltage-based functions, directionality extension of the residual overcurrent function.

The main protection functions are transformer differential protection and restricted earth-fault protection functions.

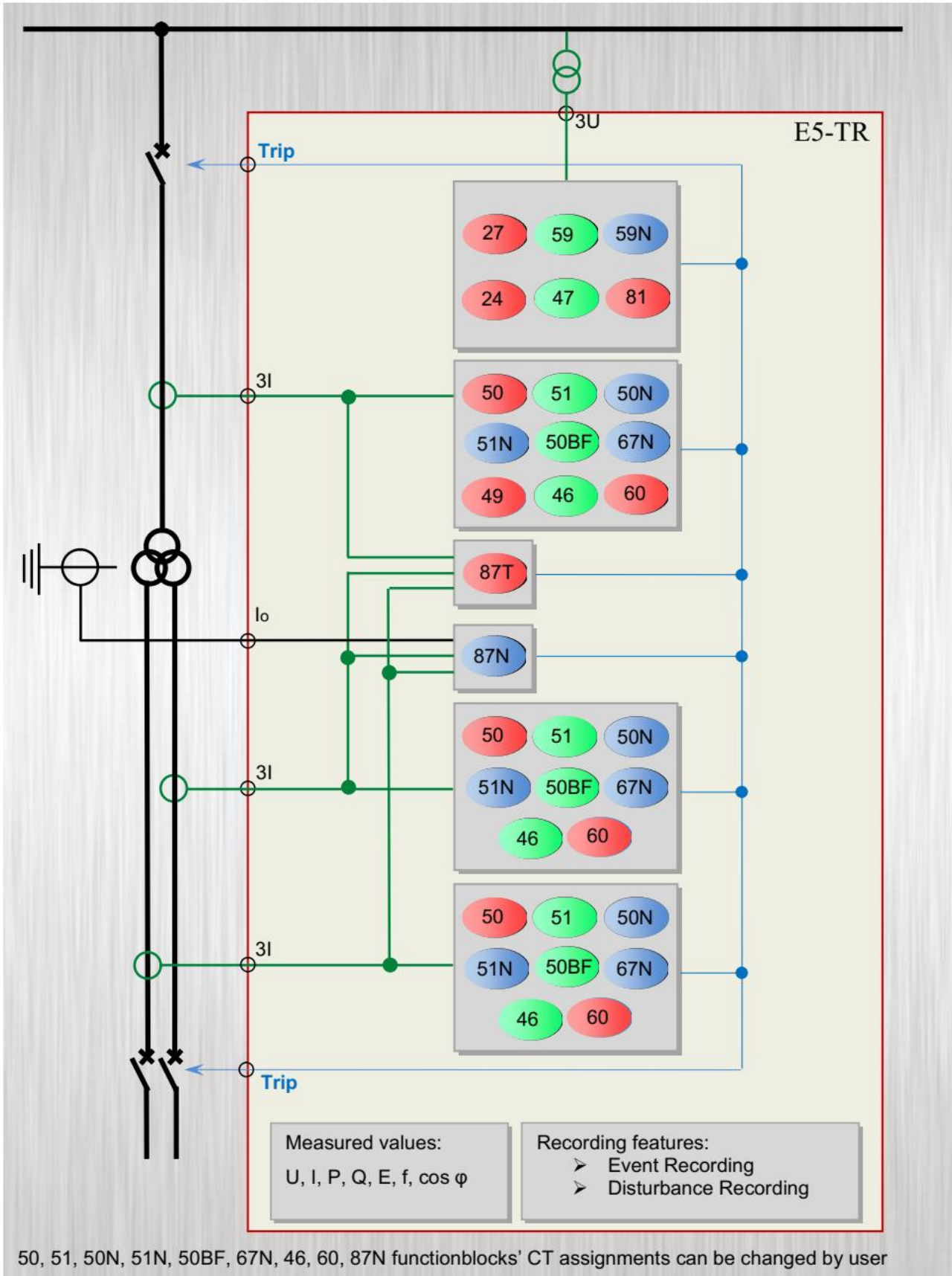
Based on the voltage measurement also the frequency is evaluated to realize frequency- based protection functions.

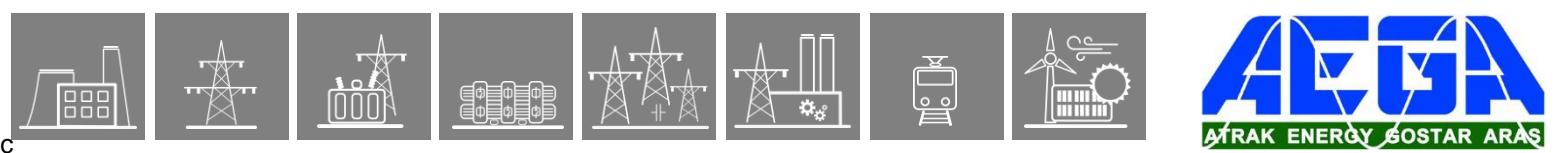
The realized current-based and voltage-based protection functions, including thermal replica protection function, frequency functions and differential functions, are listed in the Table below.

| Protection functions | IEC | ANSI | E5-TR |
|--------------------------------------------------|---------------------------------------------|------|-----------|
| Three-phase instantaneous overcurrent protection | $I >>>$ | 50 | X |
| Three-phase time overcurrent protection | $I >, I >>$ | 51 | X |
| Residual instantaneous overcurrent protection | $I_0 >>>$ | 50N | X |
| Residual time overcurrent protection | $I_0 >, I_0 >>$ | 51N | X |
| Residual directional overcurrent protection | $I_0 \text{ Dir } > >, I_0 \text{ Dir } >>$ | 67N | X |
| Negative sequence overcurrent protection | $I_2 >$ | 46 | X |
| Thermal protection | $T >$ | 49 | X |
| Transformer differential | $3I_d T >$ | 87T | 3w |
| Restricted earth fault | REF | 87N | X |
| Definite time overvoltage protection | $U >, U >>$ | 59 | X |
| Definite time undervoltage protection | $U <, U <<$ | 27 | X |
| Residual overvoltage protection | $U_0 >, U_0 >>$ | 59N | X |
| Negative sequence overvoltage protection | $U_2 >$ | 47 | X |
| Overfrequency protection | $f >, f >>$ | 81O | X |
| Underfrequency protection | $f <, f <<$ | 81U | X |
| Rate of change of frequency protection | df/dt | 81R | X |
| Overexcitation | V/Hz | 24 | X |
| Current unbalance protection | | 60 | X |
| Breaker failure protection | CBFP | 50BF | X |

Table 1 The protection functions of the E5-TR configuration

The configured functions are drawn symbolically in the Figure below.





3.1.1. Overexcitation protection function

3.1.1.1. Application

The overexcitation protection function is applied to protect generators and unit transformers against high flux values causing saturation of the iron cores and consequently high magnetizing currents.

The problem to be solved is as follows. The flux is the integrated value of the voltage:

$$\Phi(t) = \Phi_0 + \int_0^t u(t) dt$$

In steady state, this integral can be high if the area under the sinusoidal voltage-time function is large. Mathematically this means that in steady state the flux, as the integral of the sinusoidal voltage function, can be expressed as

$$\Phi(t) = k \frac{U}{f} \cos \omega t$$

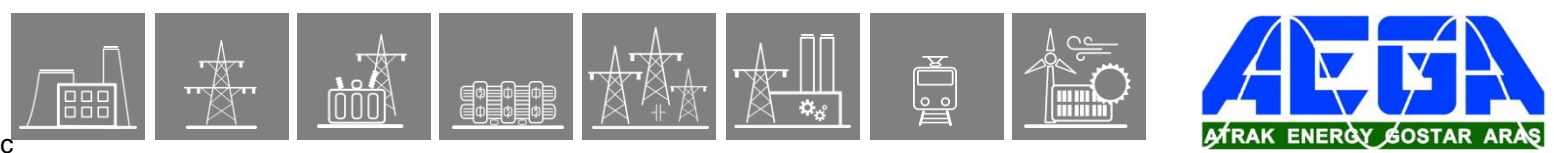
The peak value of the flux increases if the magnitude of the voltage increases, and/or the flux can be high if the duration of a period increases; this means that the frequency of the voltage decreases. That is, the flux is proportional to the peak value (or to the RMS value) of the voltage and inversely proportional to the frequency.

Note: the overexcitation protection function is intended to be applied near the generator, where the voltage is expected to be pure sinusoidal, without any distortion. Therefore, a continuous integration of the voltage and a simple peak detection algorithm can be applied.

The effect of high flux values is the symmetrical saturation of the iron core of the generator or that of the unit transformer. During saturation, the magnetizing current is high and distorted; high current peaks can be detected. The odd harmonic components of the current are of high magnitude and the RMS value of the current also increases. The high peak values of the currents generate high dynamic forces, the high RMS value causes overheating. During saturation, the flux leaves the iron core and high eddy currents are generated in the metallic part of the generator or transformer in which normally no current flows, and which is not designed to withstand overheating.

The frequency can deviate from the rated network frequency during start-up of the generator or at an unwanted disconnection of the load. In this case the generator is not connected to the network and the frequency is not kept at a "constant" value. If the generator is excited in this state and the frequency is below the rated value, then the flux may increase above the tolerated value. Similar problems may occur in distributed generating stations in case of island operation.

The overexcitation protection is designed to prevent this long-term overexcited state.



3.1.1.2. Mode of operation

3.1.1.2.1. Calculation of the flux

The flux is calculated continuously as the integral of the voltage. In case of the supposed sinusoidal voltage, the shape of the integrated flux will be sinusoidal too, the frequency of which is identical with that of the voltage. The magnitude of the flux can be found by searching for the maximum and the minimum values of the sinusoid.

3.1.1.2.2. Starting of the function

The magnitude can be calculated if at least one positive and one negative peak value have been found, and the function starts if the calculated flux magnitude is above the setting value. Accordingly, the starting delay of the function depends on the frequency: if the frequency is low, more time is needed to reach the opposite peak value. In case of energizing, the time to find the first peak depends on the starting phase angle of the sinusoidal flux. If the voltage is increased continuously by increasing the excitation of the generator, this time delay cannot be measured.

3.1.1.2.3. Operating characteristics

The most harmful effect of the overexcited state is unwanted overheating. As the heating effect of the distorted current is not directly proportional to the flux value, inverse type characteristics can be applied. The IEEE type characteristic can be selected for general applications or the user can specify a custom characteristic to fulfill any special needs. If the overexcitation increases, the operating time decreases. To meet simpler requirements, a definite-time characteristic is also offered as an alternative.

The supervised quantity is the calculated U/f value as a percentage of the nominal values (index N):

$$G = \frac{\frac{U}{f}}{\frac{U_N}{f_N}} 100[\%] = \frac{\frac{U}{U_N}}{\frac{f}{f_N}} 100[\%]$$

The over-dimensioning of generators in this respect is usually about 5%, that of the transformer about 10%, but for unit transformers this factor can be even higher.

By function pickup, the protection generates a start signal and a delayed alarm signal aimed to inform the controller to decrease the excitation. If the time delay (determined by the parameter values of the selected characteristics) expires, the function generates a trip command to decrease or to switch off the excitation and the generator.

3.1.1.2.3.1. Definite time characteristic

Operating time

$$t(G) = t_{OP} \text{ when } G > G_S$$

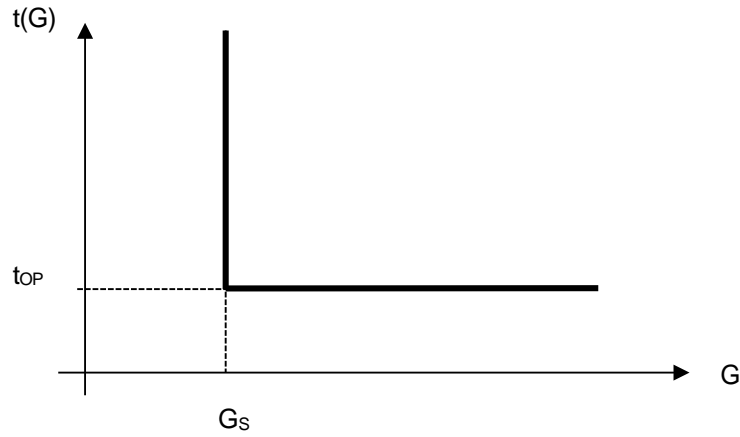


Figure 1-1 Overexcitation independent time characteristic

| | |
|--------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| t_{OP} (seconds) | theoretical operating time if $G > G_S$, fix, according to the parameter setting "Definite Time Delay". |
| G | measured value of the characteristic quantity; this is the $\frac{U}{f}$ peak value as a percentage of the rated $\frac{U_N}{f_N}$ value. |
| G_S | setting value of the characteristic quantity ("Start U/f HighSet"). This is the $\frac{U_{set}}{f_{set}}$ peak value as a percentage of the rated $\frac{U_N}{f_N}$ value. |

Reset time

$$t(G) = t_{Drop-off} \text{ when } G < 0.95 * G_S$$

where

$t_{Drop-off}$ (seconds) drop-off time if $G < 0.95 * G_S$, fix value.

3.1.1.2.3.2. Custom made inverse time characteristic

The custom characteristic can be defined by 7 points, where the user can select the desired U/f values and their corresponding time delays. Trip time between the points is determined by linear interpolation. The first U/f point of the characteristic will initiate the function start. Definite time characteristic settings in the previous section will be also effective on the custom-made trip curve.

Thermal counter

Once the actual U/f value initiates a function start, a thermal counter also starts. At counter value 100%, the function initiates a trip command.

Reset time

If the calculated flux is below the drop-off flux value (when $G < 0.95 * G_s$), then the calculated flux value decreases linearly to zero. The time to reach zero is defined by the parameter "Cooling Time".

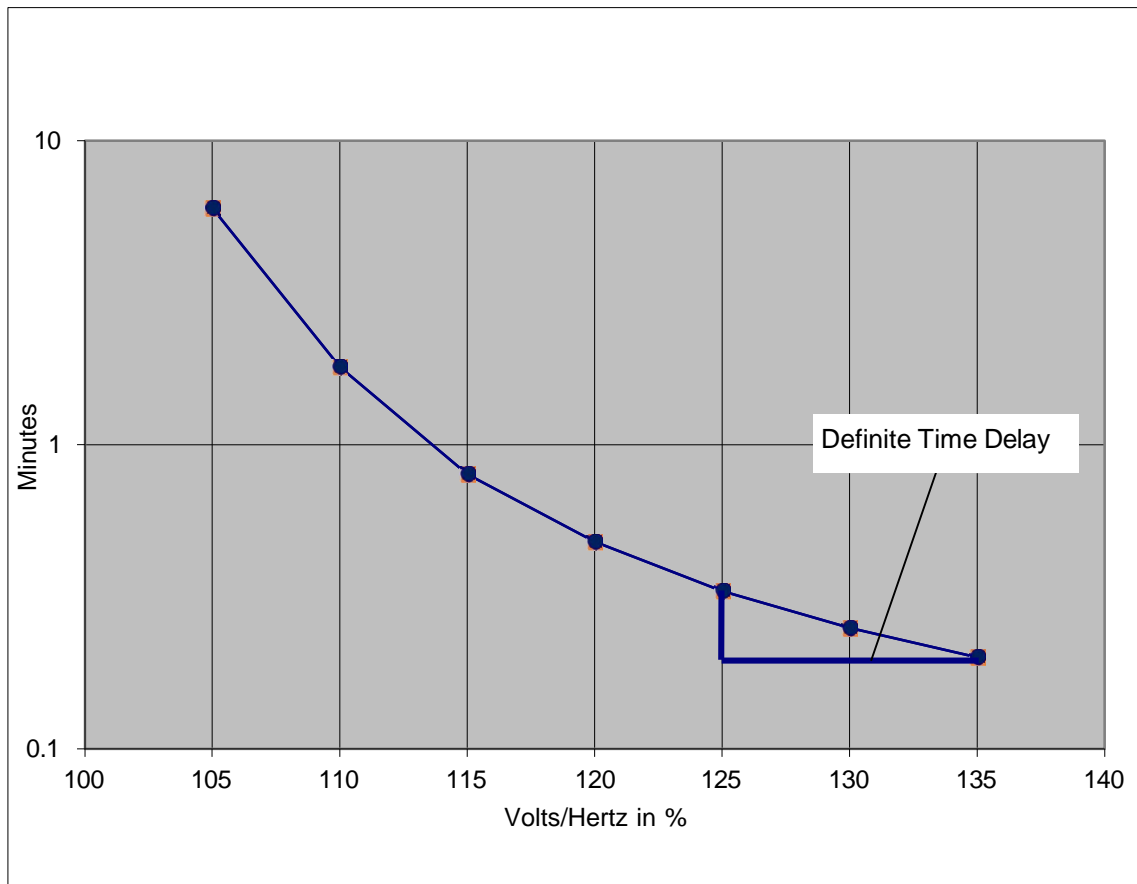


Figure 1-2 Custom inverse time characteristics

3.1.1.2.3.3. IEEE standard inverse time characteristic

Operating time in seconds

- “IEEE square law” acc. to IEEE Std C37.102

$$t = \frac{0.18 * TMS}{\left(\frac{U/f}{U_N/f_N} - \frac{U_{set}/f_{set}}{U_N/f_N}\right)^2} = \frac{0.18 * TMS}{(G - G_S)^2}$$

where

| | |
|------------------------------------|--------------------------------------------------------------|
| TMS = 1... 60, | time multiplier setting, |
| U/f | flux value calculated at the measured voltage and frequency, |
| U _N /f _N | flux at rated voltage and rated frequency, |
| U _{set} /f _{set} | flux setting value. |

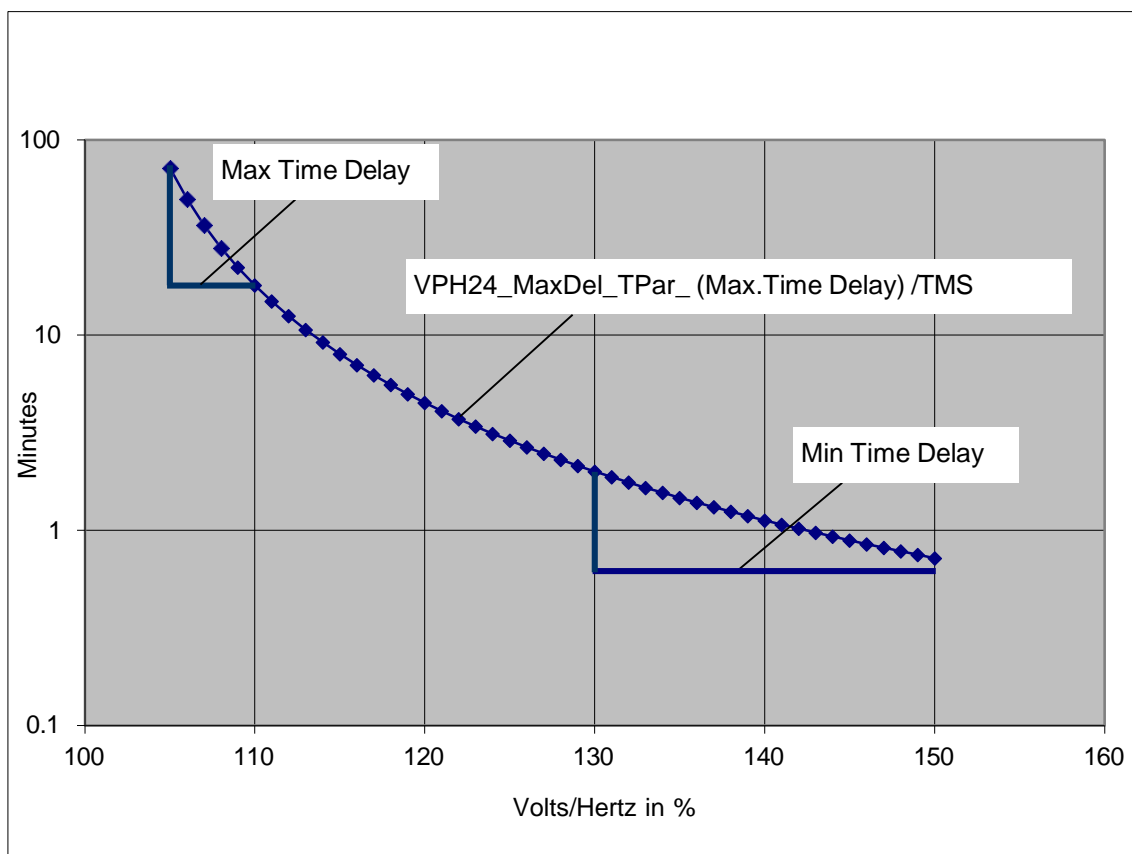
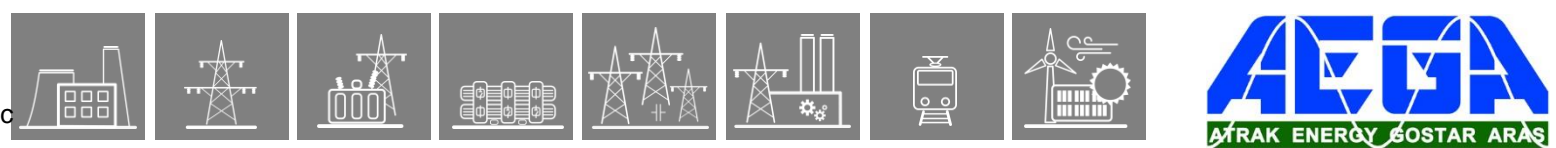


Figure 1-3 IEEE standard inverse time characteristics

If the function starts, the maximum tripping time is limited by the parameter “Max Time Delay”. This time delay is valid if the flux is above the preset value of “Start U/f LowSet”.

This inverse type characteristic is also combined with a minimum time delay, the value of which is set by user parameter “Min Time Delay”. This time delay is valid if the flux is above the setting value of “Start U/f HighSet”.



Reset time

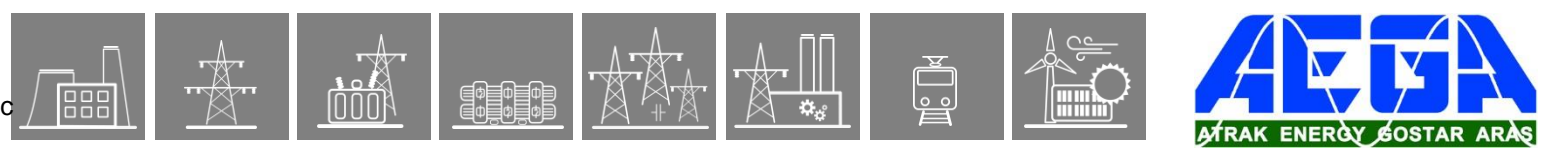
If the calculated flux is below the drop-off flux value (when $G < 0.95 * G_s$), then the calculated flux value decreases linearly to zero. The time to reach zero is defined by the parameter “*Cooling Time*”.



3.1.1.2.4. Analogue input of the function

Overexcitation is a typically symmetrical phenomenon. There are other dedicated protection functions against asymmetry. Accordingly, the processing of a single voltage is sufficient. In a network with isolated neutral, the phase voltage is not exactly defined due to the uncertain zero sequence voltage component. Therefore, line-to-line voltages are calculated based on the measured phase voltages, and one of them is assigned to overfluxing protection.

As overexcitation is a phenomenon which is typical if the generator or the generator transformer unit is not connected to the network, the voltage drop does not need any compensation. If the voltage is measured at the supply side of the unit transformer, then the voltage is higher than the voltage of the magnetization branch of the transformer's equivalent circuit. Thus, the calculated flux cannot be less than the real flux value. The protection operates with increased security.



3.1.1.3. Structure of the overexcitation protection algorithm

Fig.1-4 shows the structure of the overexcitation protection (VPH24) algorithm.

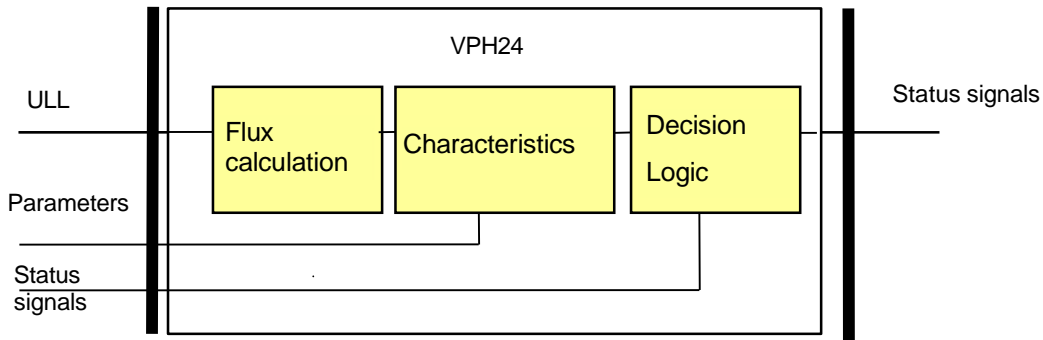


Figure 1-4 Structure of the overexcitation protection algorithm

The **inputs** are

- the sampled values of a line-to-line voltage (ULL),
- parameters,
- status signals.

The **outputs** are

- the binary output status signals.

The **software modules** of the overexcitation protection function:

Flux calculation

This module integrates the voltage to obtain the flux time-function and determines the magnitude of the flux.

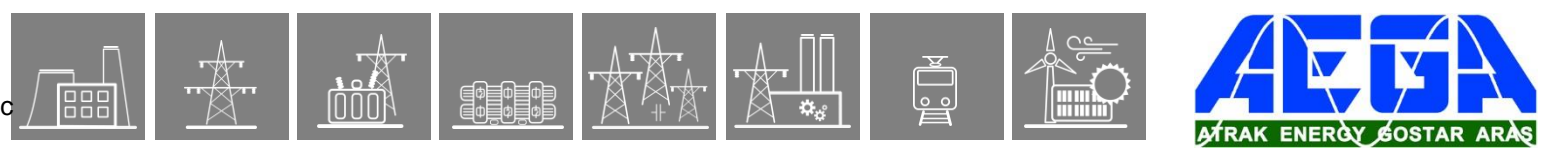
Characteristics

This module calculates the required time delay based on the magnitude of the flux and the parameter settings.

Decision logic

The decision logic module combines the status signals to generate the trip command of the function.

The following description explains the details of the individual components.



3.1.1.4. The flux calculation

This module integrates the voltage to obtain the flux time-function and determines the magnitude of the flux.

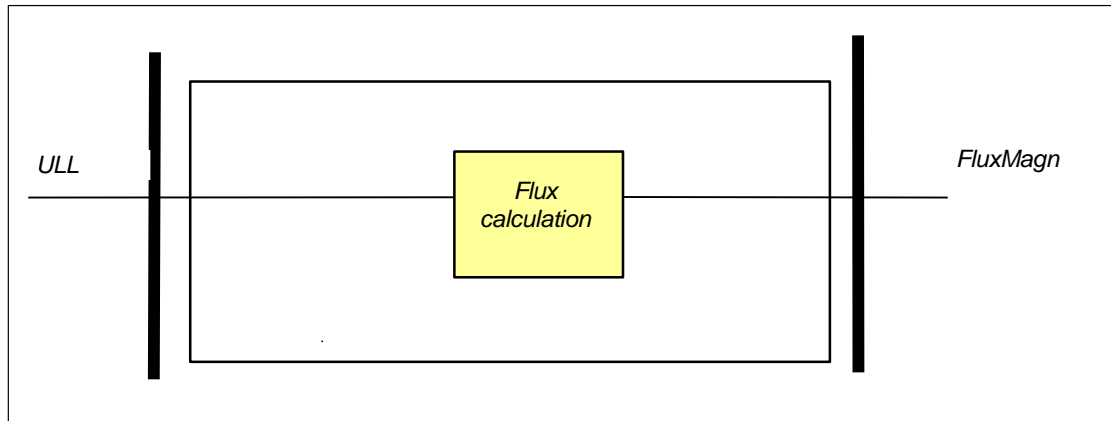


Figure 1-5 Principal scheme of the flux calculation

The **inputs** are the sampled values of a line-to-line voltage (ULL).

The **output** is the magnitude of the flux (FluxMagn), internal signal.

3.1.1.5. The definite time and the inverse type characteristics

This module calculates the required time delay based on the magnitude of the flux and the parameter settings.

The **inputs** are the magnitude of the flux (FluxMagn) and parameters.

The **outputs** are the internal status signals of the function. These indicate the started state and the generated trip command if the time delay determined by the characteristics expired.

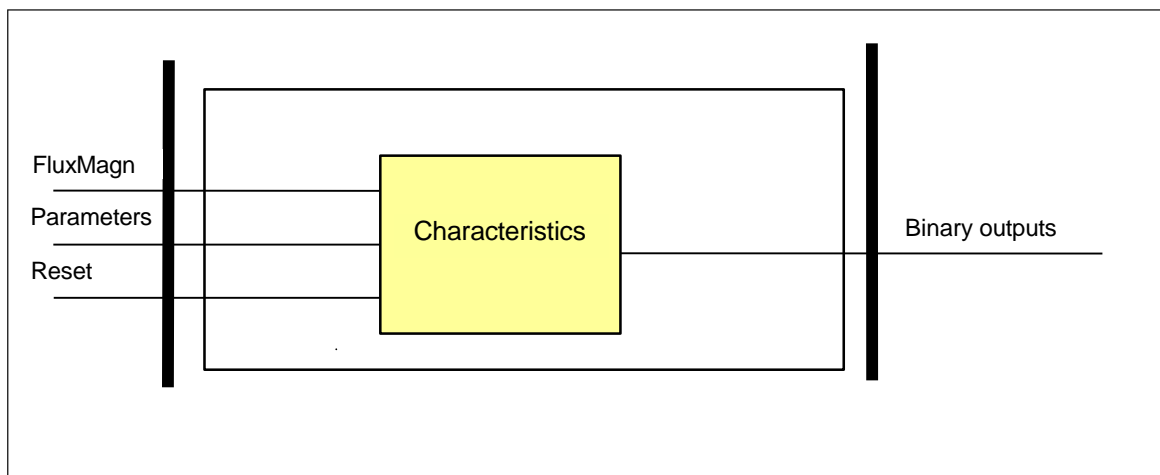


Figure 1-6 Schema of the characteristic calculation

Enumerated parameter

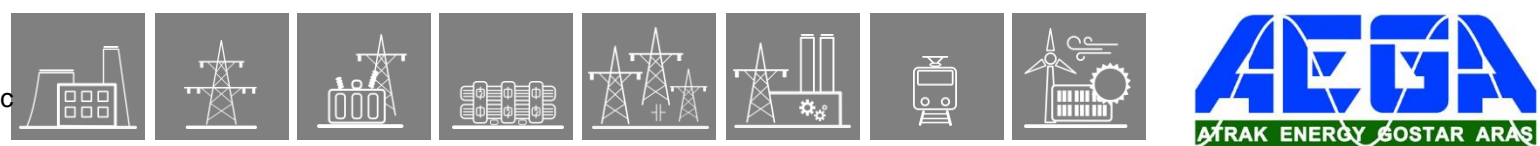
Table 1-1 The enumerated parameter of the overexcitation protection function

| PARAMETER NAME | TITLE | SELECTION RANGE | DEFAULT |
|------------------------------|-----------|--------------------------------------------------|---------------|
| Parameter for type selection | | | |
| VPH24_Operation_EPar_ | Operation | Off, Definite Time, Custom made, IEEE square law | Definite Time |

Integer parameters

Table 1-2 The integer parameters of the overexcitation protection function

| PARAMETER NAME | TITLE | UNIT | MIN | MAX | STEP | DEFAULT |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------|-----|-----|------|---------|
| Starting value of the IEEE characteristic | | | | | | |
| VPH24_EmaxCont_IPar_ | Start U/f LowSet | % | 80 | 140 | 1 | 110 |
| Flux value above which the IEEE and custom-made characteristics are replaced by the declared minimum time. It is also the setting for definite time operation. | | | | | | |
| VPH24_Emax_IPar_ | Start U/f HighSet | % | 100 | 140 | 1 | 140 |
| Time multiplier for IEEE characteristic | | | | | | |
| VPH24_k_IPar | Time Multiplier | | 1 | 100 | 1 | 10 |
| First point of custom characteristic | | | | | | |
| VPH24_E1_IPar | U/f value 1 | % | 100 | 140 | 1 | 105 |
| Second point of custom characteristic | | | | | | |
| VPH24_E2_IPar | U/f value 2 | % | 100 | 140 | 1 | 110 |
| Third point of custom characteristic | | | | | | |
| VPH24_E3_IPar | U/f value 3 | % | 100 | 140 | 1 | 115 |



| | | | | | | |
|----------------------------------------|-------------|---|-----|-----|---|-----|
| Fourth point of custom characteristic | | | | | | |
| VPH24_E4_IPar | U/f value 4 | % | 100 | 140 | 1 | 120 |
| Fifth point of custom characteristic | | | | | | |
| VPH24_E5_IPar | U/f value 5 | % | 100 | 140 | 1 | 125 |
| Sixth point of custom characteristic | | | | | | |
| VPH24_E6_IPar | U/f value 6 | % | 100 | 140 | 1 | 130 |
| Seventh point of custom characteristic | | | | | | |
| VPH24_E7_IPar | U/f value 7 | % | 100 | 140 | 1 | 135 |

Float parameters

Table 1-3 Timer parameters of the overexcitation protection function

| PARAMETER NAME | TITLE | UNIT | MIN | MAX | STEP | DEFAULT |
|--------------------------------------------------------------------|----------------|------|-----|------|------|---------|
| Minimum time delay for the IEEE characteristic | | | | | | |
| VPH24_MinDel_FPar_ | Min Time Delay | sec | 0.5 | 60.0 | 0.1 | 10.0 |
| Maximum time delay for the IEEE characteristic | | | | | | |
| VPH24_MaxDel_FPar_ | Max Time Delay | sec | 300 | 8000 | 1 | 3000 |
| Reset time delay for the inverse characteristics (IEEE and Custom) | | | | | | |
| VPH24_CoolDel_FPar_ | Cooling Time | sec | 1 | 8000 | 1 | 1000 |
| Time delay for definite time characteristic | | | | | | |
| VPH24_DTDelay_FPar_ | DT Time Delay | sec | 0.5 | 60.0 | 0.1 | 10.0 |
| Time delay for first point of custom characteristic | | | | | | |
| VPH24_Delay1_FPar_ | Delay1 | sec | 1 | 8000 | 1 | 1000 |
| Time delay for second point of custom characteristic | | | | | | |
| VPH24_Delay2_FPar_ | Delay2 | sec | 1 | 8000 | 1 | 900 |
| Time delay for third point of custom characteristic | | | | | | |
| VPH24_Delay3_FPar_ | Delay3 | sec | 1 | 8000 | 1 | 800 |
| Time delay for fourth point of custom characteristic | | | | | | |
| VPH24_Delay4_FPar_ | Delay4 | sec | 1 | 8000 | 1 | 700 |
| Time delay for fifth point of custom characteristic | | | | | | |
| VPH24_Delay5_FPar_ | Delay5 | sec | 1 | 8000 | 1 | 600 |
| Time delay for sixth point of custom characteristic | | | | | | |
| VPH24_Delay6_FPar_ | Delay6 | sec | 1 | 8000 | 1 | 500 |
| Time delay for seventh point of custom characteristic | | | | | | |
| VPH24_Delay7_FPar_ | Delay7 | sec | 1 | 8000 | 1 | 400 |

3.1.1.6. The decision logic

The decision logic module combines the status signals, binary and enumerated parameters to generate the trip command of the function.

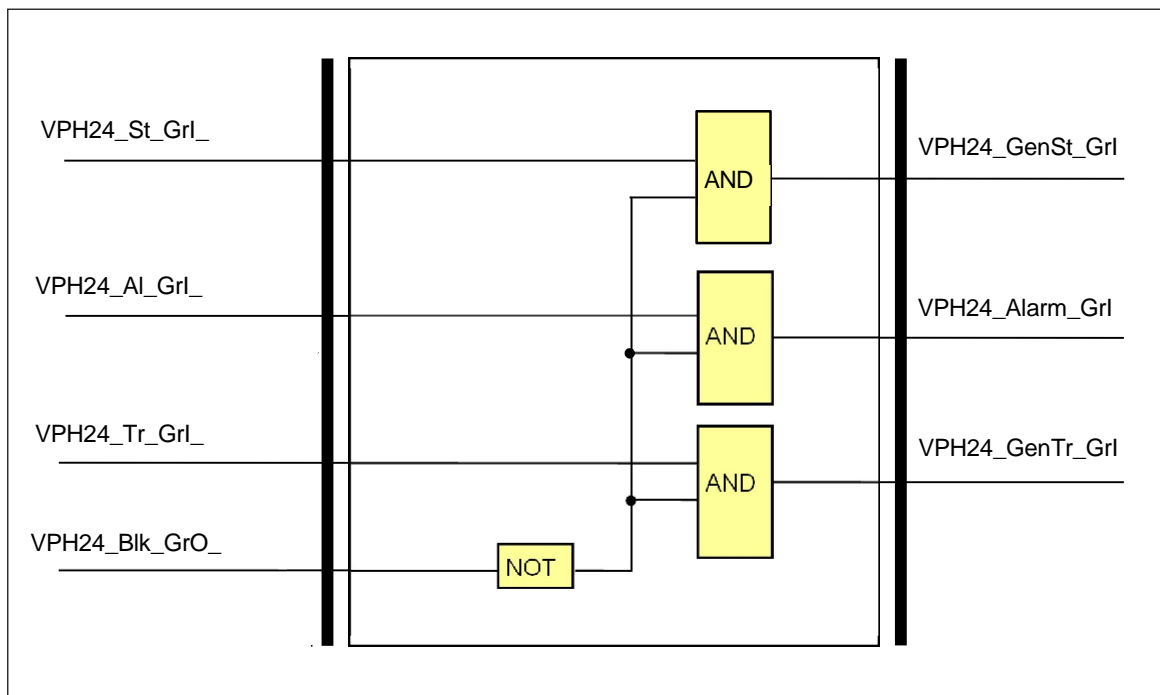


Figure 1-7 The logic scheme of the overexcitation protection function

Binary status signals

The overexcitation protection function has two **binary input signals**, which serve the purpose of disabling the function and resetting the thermal counter. **The conditions of disabling or resetting are defined by the user, applying the graphic equation editor.**

Table 1-4 The binary input signals of the overexcitation protection function

| BINARY STATUS SIGNAL | EXPLANATION |
|----------------------|------------------------------------------------------------------------------------------------------------|
| VPH24_Block_GrO_ | Output status of a graphic equation defined by the user to disable the overexcitation protection function. |
| VPH24_Reset_GrO_ | Output status of a graphic equation defined by the user to reset the thermal counter |

The **binary output status signals** of the overexcitation protection function are listed in **Error! Reference source not found.**

Table 1-5 The binary output status signals of the overexcitation protection function

| BINARY OUTPUT SIGNALS | SIGNAL TITLE | EXPLANATION |
|-----------------------|---------------|-------------------------------------------|
| VPH24_GenSt_Grl_ | General Start | General starting of the function |
| VPH24_Alarm_Grl_ | Alarm | Alarm generated 10sec after General Start |
| VPH24_GenTr_Grl_ | General Trip | General trip command of the function |

3.1.1.6.1. Overexcitation function overview

The graphic appearance of the function block of the overexcitation protection function is shown on Figure 2-1. The block shows all binary input and output status signals which are applicable in the graphic equation editor.

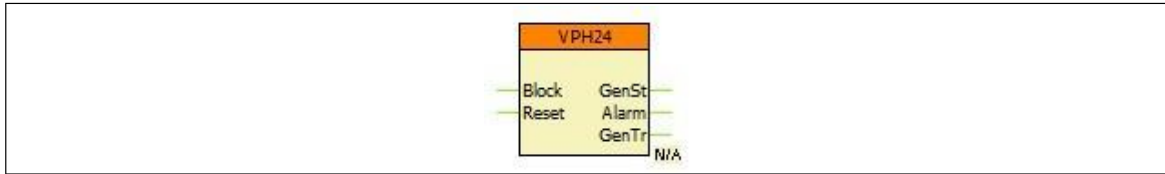


Figure 2-1 The graphic appearance of the function block of the overexcitation protection function

3.1.1.6.1.1. Settings

3.1.1.6.1.1.1. Parameters

Table 2-1 Parameters of the overexcitation protection function

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|-------------------------------------------------------------------------|-----|--------------------------------------------------|------|---------|----------------------------------------------------------------------------------------------------------------|
| Operation | - | Off, Definite Time, Custom made, IEEE square law | - | Off | Enabling and selecting the desired characteristic of the overexcitation function |
| <i>Parameters related to the definite time and IEEE characteristics</i> | | | | | |
| Start U/f HighSet | % | 100 – 140 | 1 | 140 | Setting value for definite time operation. Also effective for Custom and IEEE characteristics as a fast stage. |
| Start U/f LowSet | % | 80 – 140 | 1 | 110 | Pick up value and starting point for the IEEE characteristic. |
| Time Multiplier | - | 1 – 100 | 1 | 10 | Time multiplier for IEEE characteristic. |
| Definite Time Delay | sec | 0.5 – 60 | 0.1 | 10 | Setting value for definite time operation. Also effective for Custom characteristic as a fast stage. |
| Min Time Delay | sec | 0.5 – 60 | 0.1 | 10 | Minimum time delay applicable for IEEE characteristic if the U/f ratio exceeds the value of Start U/f HighSet. |
| Max Time Delay | sec | 300 – 8000 | 1 | 3000 | Maximum time delay applicable for IEEE characteristic to limit the tripping time. |
| Cooling Time | sec | 1 – 8000 | 1 | 1000 | Cooling time for the Custom and IEEE characteristics. |

| <i>Parameters related to the custom characteristic</i> | | | | | |
|--------------------------------------------------------|-----|-----------|---|------|--------------------------------------------------------------|
| U/f value1 | % | 100 – 140 | 1 | 105 | First point and pickup setting of the Custom characteristic. |
| U/f value2 | % | 100 – 140 | 1 | 110 | Second point of the Custom characteristic. |
| U/f value3 | % | 100 – 140 | 1 | 115 | Third point of the Custom characteristic. |
| U/f value4 | % | 100 – 140 | 1 | 120 | Fourth point of the Custom characteristic. |
| U/f value5 | % | 100 – 140 | 1 | 125 | Fifth point of the Custom characteristic. |
| U/f value6 | % | 100 – 140 | 1 | 130 | Sixth point of the Custom characteristic. |
| U/f value7 | % | 100 – 140 | 1 | 135 | Seventh point of the Custom characteristic. |
| Delay1 | sec | 1 – 8000 | 1 | 1000 | Time delay for the first point of Custom characteristic. |
| Delay2 | sec | 1 – 8000 | 1 | 900 | Time delay for the second point of Custom characteristic. |
| Delay3 | sec | 1 – 8000 | 1 | 800 | Time delay for the third point of Custom characteristic. |
| Delay4 | sec | 1 – 8000 | 1 | 700 | Time delay for the fourth point of Custom characteristic. |
| Delay5 | sec | 1 – 8000 | 1 | 600 | Time delay for the fifth point of Custom characteristic. |
| Delay6 | sec | 1 – 8000 | 1 | 500 | Time delay for the sixth point of Custom characteristic. |
| Delay7 | sec | 1 – 8000 | 1 | 400 | Time delay for the seventh point of Custom characteristic. |

3.1.1.6.2. Characteristics

The function offers three different characteristics to satisfy the different user requirements.

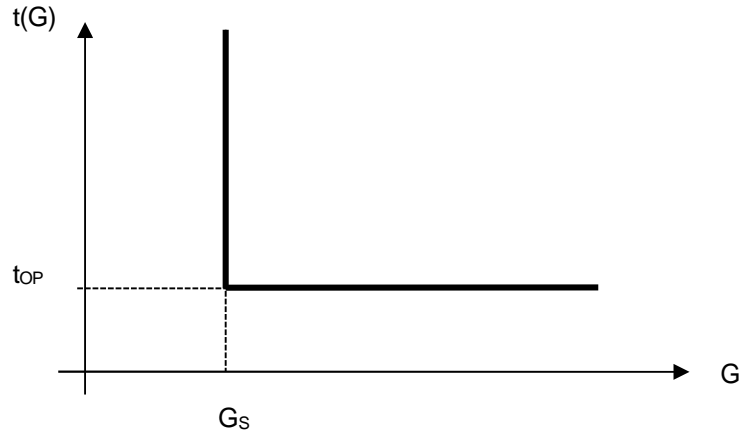


Figure 2-2 Overexcitation independent time characteristic

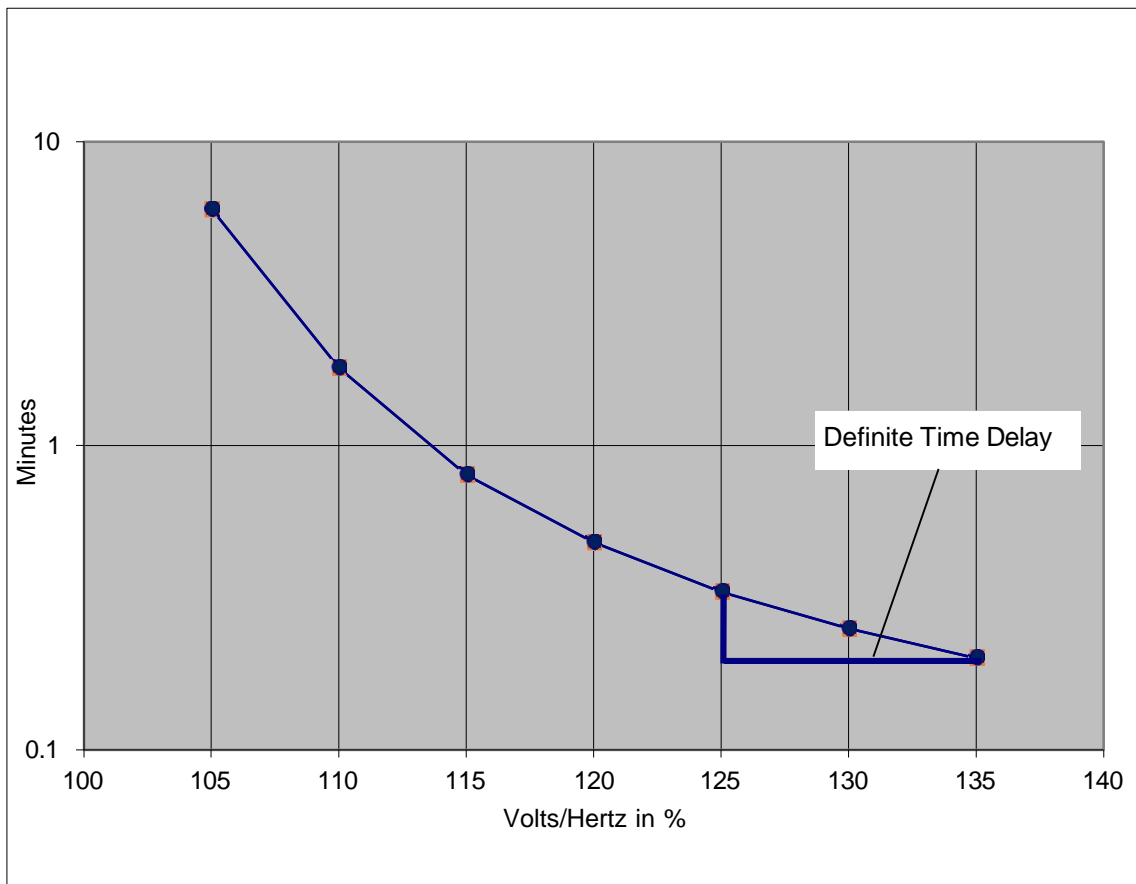


Figure 2-3 Custom inverse time characteristics

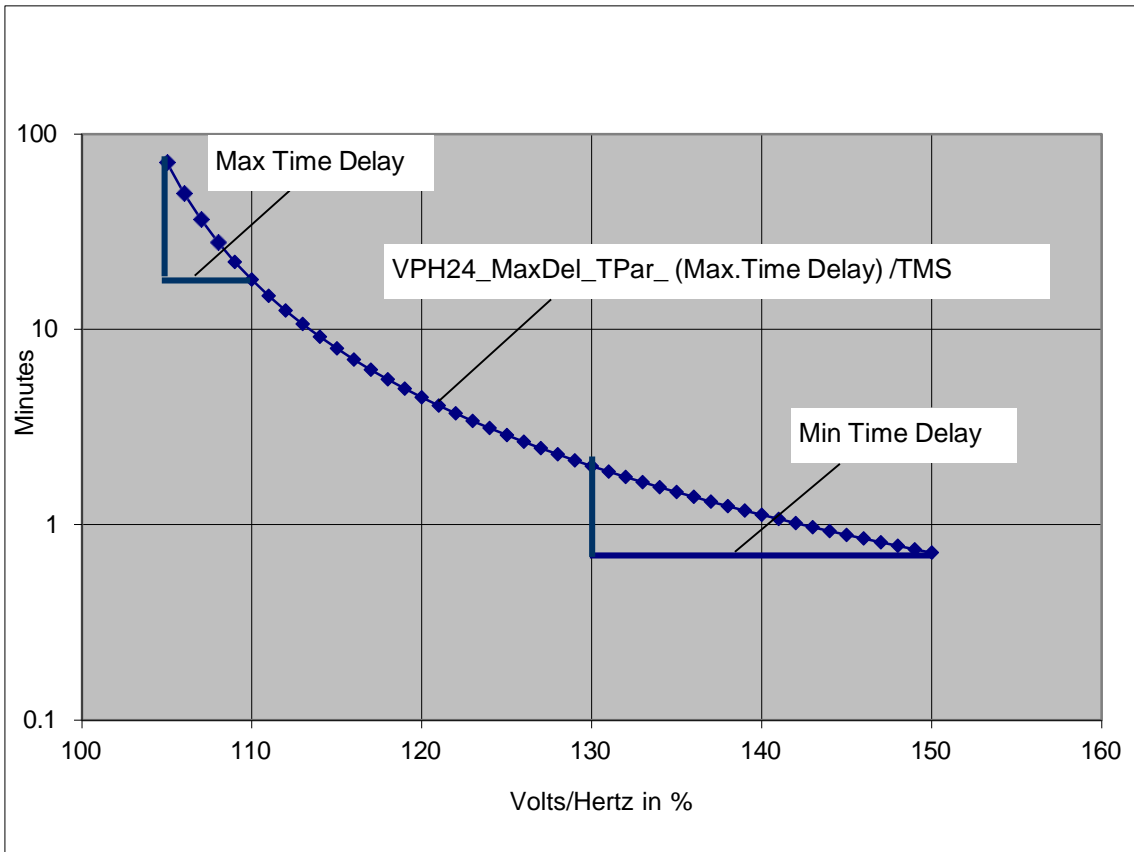


Figure 2-4 IEEE standard inverse time characteristics

3.1.1.7. Function I/O

This section describes briefly the analogue and digital inputs and outputs of the function block.

3.1.1.7.1. Analogue inputs

The function uses only one calculated line voltage, where the line voltage calculation is based on phase voltage sampled values.

3.1.1.7.2. Analogue outputs (measurements)

The measured value of the overexcitation protection function is listed in the table below.

Table 2-2 The measured analogue value of the overexcitation protection function

| MEASURED VALUE | DIMENSION | EXPLANATION |
|----------------|-----------|------------------------------------------------------------------------------------------------------|
| Actual Heat | % | Actual heat of the protected object. 100% corresponds to the inverse time characteristic trip value. |

Remark: Following a successful thermal trip operation, the counter starts a linear count-down from 100% to zero. Duration of the count-down corresponds to the cooling time parameter.

3.1.1.7.3. Binary input signals (graphed output statuses)

The conditions of the inputs are defined by the user, applying the graphic equation editor (logic editor). The part written in bold is seen on the function block in the logic editor.

Table 2-3 The binary input signals of the overexcitation protection function

| BINARY STATUS SIGNAL | EXPLANATION |
|---------------------------|------------------------------------------------------------------------------------------------------------|
| VPH24_ Block _GrO_ | Output status of a graphic equation defined by the user to disable the overexcitation protection function. |
| VPH24_ Reset _GrO_ | Output status of a graphic equation defined by the user to reset the thermal counter |

3.1.1.7.4. Binary output signals (graphed input statuses)

The binary output status signals of the overexcitation protection function. Parts written in **bold** are seen on the function block in the logic editor.

Table 2-4 The binary output status signals of the overexcitation protection function

| BINARY OUTPUT SIGNALS | SIGNAL TITLE | EXPLANATION |
|---------------------------|---------------|-------------------------------------------|
| VPH24_ GenSt _Grl_ | General Start | General starting of the function |
| VPH24_ Alarm _Grl_ | Alarm | Alarm generated 10sec after General Start |
| VPH24_ GenTr _Grl_ | General Trip | General trip command of the function |

3.1.1.7.5. On-line data

Visible values on the on-line data page:

Table 2-5 On-line data of the overexcitation protection function

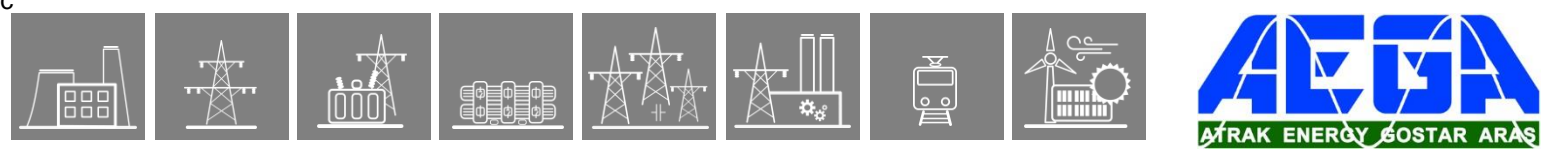
| SIGNAL TITLE | DIMENSION | EXPLANATION |
|---------------|-----------|-------------------------------------------|
| Alarm | - | Alarm generated 10sec after General Start |
| General Start | - | General starting of the function |
| General Trip | - | General trip command of the function |
| Actual Heat | % | Actual heat of the protected object. |

3.1.1.7.6. Events

The following events are generated in the event list, as well as sent to SCADA according to the configuration.

Table 2-6 On-line data of the overexcitation protection function

| EVENT | VALUE | EXPLANATION |
|---------------|---------|-------------------------------------------|
| General Start | off, on | General starting of the function |
| General Trip | off, on | General trip command of the function |
| Alarm | off, on | Alarm generated 10sec after General Start |



3.1.1.8. Technical data

Table 2-7 Technical data of the overexcitation protection function

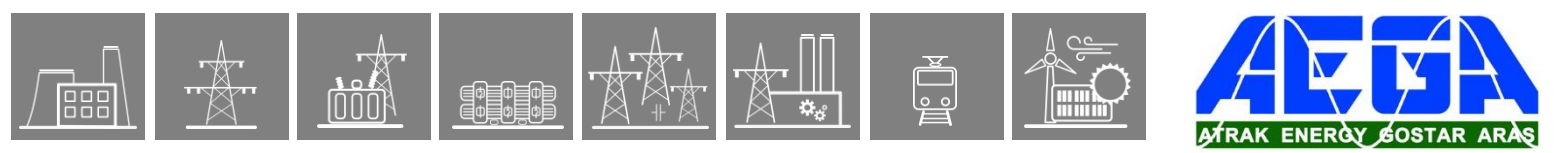
| FUNCTION | VALUE |
|-----------------------------------------|-------|
| U/f pick up accuracy | < 1% |
| U/f drop off ratio | 0.95 |
| DT and custom char. time delay accuracy | < 1% |
| IEEE char. time delay accuracy | < 5% |

3.1.1.8.1. Notes for testing

Alarm output of the function block is generated after a fix 10s following the Start signal.



When testing the custom or IEEE characteristics, attention must be paid to the value of the Actual Heat. To get an accurate trip time measurement, the Actual Heat shall be reset to zero before the test. This can be done with the reset input of the function itself, or by clicking the set parameters button.



3.1.2. Definite time undervoltage protection function

3.1.2.1. Application

The definite time undervoltage protection function measures three voltages. If any of them is below the level defined by parameter setting value (and above the defined minimum level), then a start signal is generated for the phases individually.

3.1.2.2. Mode of operation

The function generates start signals for the phases individually. The general start signal is set if the voltage in any of the three measured voltages is below the preset parameter setting value (and above the defined minimum level).

Note that in medium voltage applications the function uses the phase-to-phase voltages by default.

The function generates a trip command only if the time delay has expired and the parameter selection requires a trip command as well.

3.1.2.3. Operating characteristics

$$t(G) = t_{OP} \text{ when } G_{min} < G < G_S$$

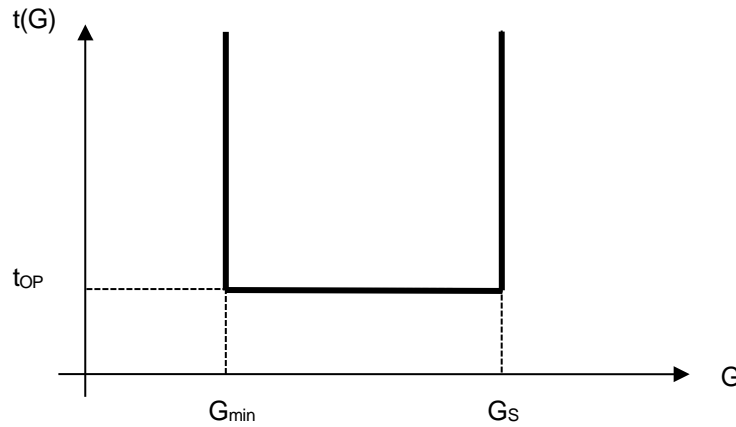


Figure 1-1 Undervoltage independent time characteristic

| | |
|--------------------|--------------------------------------------------------------------------------------------------------------------------|
| where | |
| t_{OP} (seconds) | theoretical operating time if $G_{min} < G < G_S$, fix, according to parameter setting value, |
| G | measured value of the characteristic quantity, Fourier base harmonic of the phase voltages (or phase-to-phase voltages), |
| G_S | setting value of the characteristic quantity. |

3.1.2.4. Structure of the definite time undervoltage protection algorithm

Fig.1-2 shows the structure of the definite time undervoltage protection (TUV27) algorithm.

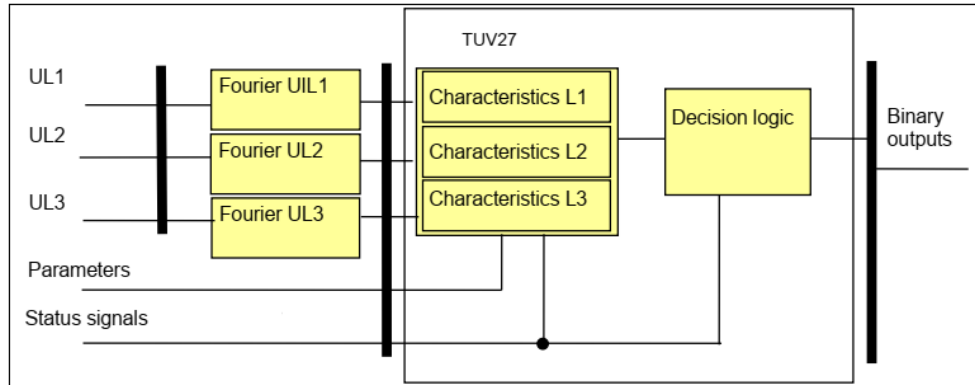


Figure 1-2 Structure of the definite time undervoltage protection algorithm

The **inputs** are

- the RMS values of the fundamental Fourier component of three phase (or phase-to-phase) voltages,
- parameters,
- status signals.

The **outputs** are

- the binary output status signals.

The **software modules** of the differential protection function:

Fourier calculations

These modules calculate the basic Fourier components of the phase voltages individually (not part of the TUV27 function). In medium voltage applications these are changed to phase-to-phase voltages.

Characteristics

This module calculates the required time delay based on the Fourier components of the phase (or phase-to-phase) voltages.

Decision logic

The decision logic module combines the status signals to generate the trip command of the function.

The following description explains the details of the individual components.

3.1.2.5. The Fourier calculation (Fourier)

These modules calculate the basic Fourier components of the phase voltages individually. They are not part of the TUV27 function; they belong to the preparatory phase.

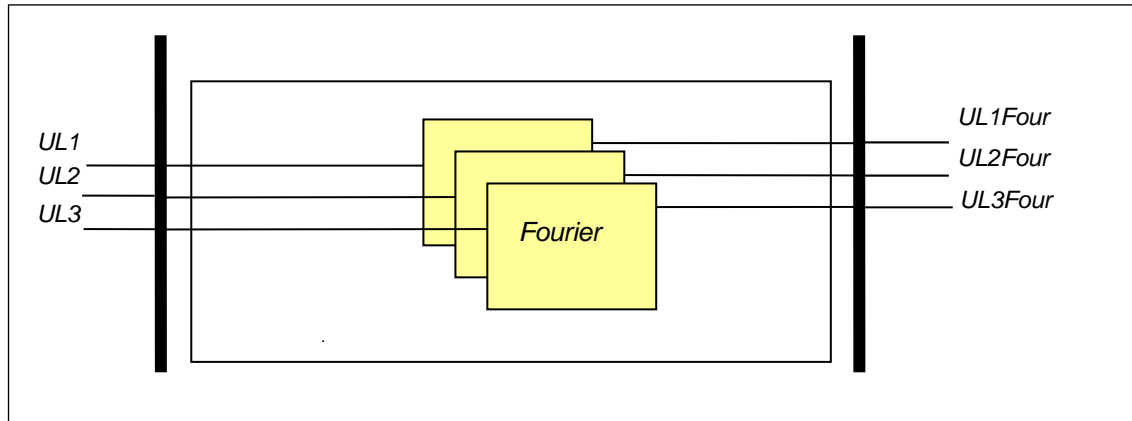


Figure 1-3 Schema of the Fourier calculation

The **inputs** are the sampled values of the three phase voltages (UL1, UL2, UL3)

The **outputs** are the basic Fourier components of the analyzed voltages (UL1Four, UL2Four, UL3Four).

The phase-to-phase voltages (if used) are also calculated here.

3.1.2.6. The definite time characteristics (Characteristics)

This module decides the stating of the function based on the Fourier components of the phase voltages and it counts the time delay. The time delay is defined by the parameter setting, if the voltages are below the setting value.

The **inputs** are the basic Fourier components of the phase (or the calculated phase-to-phase) voltages (UL1Four, UL2Four, UL3Four) and parameters.

The **outputs** are the status signals of the three phases individually. These indicate the started state and the generated trip command if the time delay determined by the setting is expired.

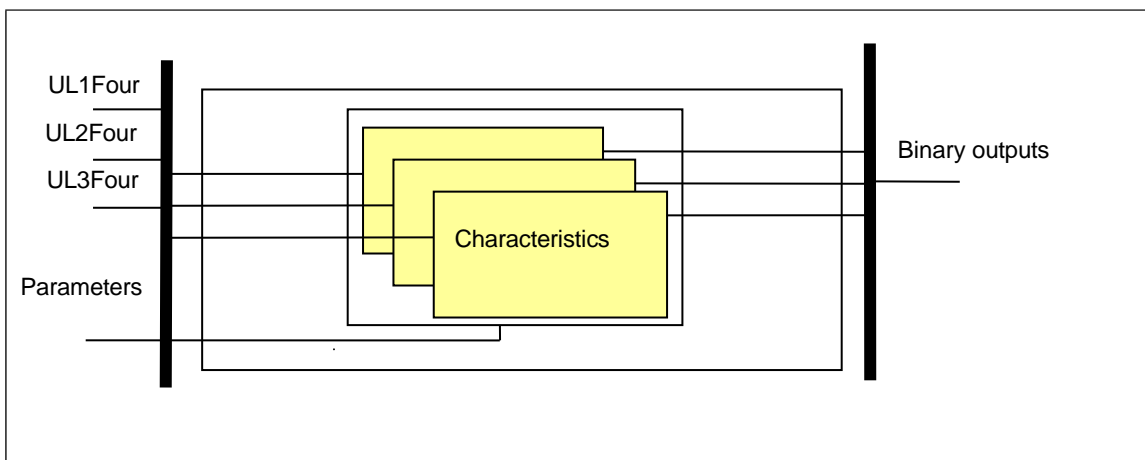


Figure 1-4 Schema of the definite time characteristic calculation

Enumerated parameter

| Parameter name | Title | Selection range | Default |
|------------------------------------------------------------|-----------|----------------------------------|---------|
| Enabling or disabling the undervoltage protection function | | | |
| TUV27_Oper_EPar_ | Operation | Off, 1 out of 3, 2 out of 3, All | Off |

Table 1-1 The enumerated parameter of the undervoltage protection function

Integer parameters

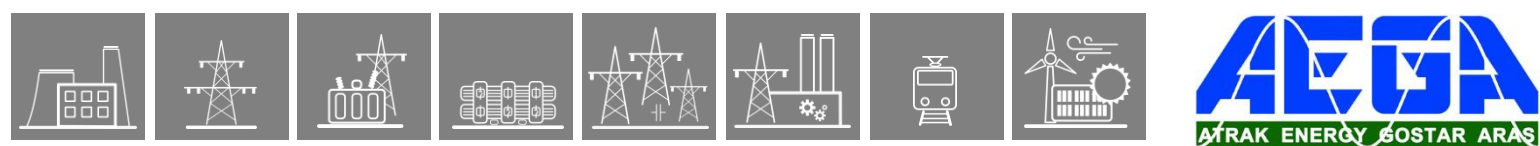
| Parameter name | Title | Unit | Min | Max | Step | Default |
|----------------------------------------------------------------------------------------------------------------------------|---------------|------|-----|-----|------|---------|
| Starting voltage level setting. If the measured voltage is below the setting value, the function generates a start signal. | | | | | | |
| TUV27_StVol_IPar_ | Start Voltage | % | 30 | 130 | 1 | 90 |
| Blocking voltage level setting. If the measured voltage is below the setting value, the function blocks the start signal. | | | | | | |
| TUV27_BlkVol_IPar_ | Block Voltage | % | 0 | 20 | 1 | 10 |

Table 1-2 Integer parameters of the undervoltage protection function

Floating point parameter

| Parameter name | Title | Unit | Min | Max | Step | Default |
|----------------------------------------------------------------------------------------------------------------------------|-------------|------|-----|-----|------|---------|
| Starting voltage level setting. If the measured voltage is below the setting value, the function generates a start signal. | | | | | | |
| TUV27_ResetRatio_FPar_ | Reset Ratio | % | 1 | 10 | 1 | 5 |

Table 1-3 Floating point parameter of the undervoltage protection function



Boolean parameter

| Parameter name | Title | Default | Explanation |
|--------------------|-------------------|---------|----------------------------------------------------------------------------------------------------------------------|
| TUV27_StOnly_BPar_ | Start Signal Only | 0 | Selection if starting and trip signal or starting signal only is to be generated. Set 0 for trip command generation. |

Table 1-4 The Boolean parameter of the undervoltage protection function

Timer parameter

| Parameter name | Title | Unit | Min | Max | Step | Default |
|-----------------------------------------------------|------------|------|-----|-------|------|---------|
| Time delay of the undervoltage protection function. | | | | | | |
| TUV27_Delay_TPar_ | Time Delay | ms | 50 | 60000 | 1 | 100 |

Table 1-5 Timer parameter of the undervoltage protection function

The **binary output status signals** of the three-phase definite time undervoltage protection function are listed in *Table 1-6*.

| Binary output signals | Signal title | Explanation |
|-----------------------|--------------|-------------------------------------------|
| TUV27_StL1_Grl_ | StL1 | Starting of the function in phase L1* |
| TUV27_TrL1_Grl_ | TrL1** | Trip command of the function in phase L1* |
| TUV27_StL2_Grl_ | StL2 | Starting of the function in phase L2* |
| TUV27_TrL2_Grl_ | TrL2** | Trip command of the function in phase L2* |
| TUV27_StL3_Grl_ | StL3 | Starting of the function in phase L3* |
| TUV27_TrL3_Grl_ | TrL3** | Trip command of the function in phase L3* |

*In case of phase-to-phase voltages, these are changed to L12, L23, L31 respectively.

**The trip signals are not published for the phases individually

Table 1-6 The binary output status signals of the definite time undervoltage protection function

3.1.2.7. The decision logic (Decision logic)

The decision logic module combines the status signals, binary and enumerated parameters to generate the trip command of the function.

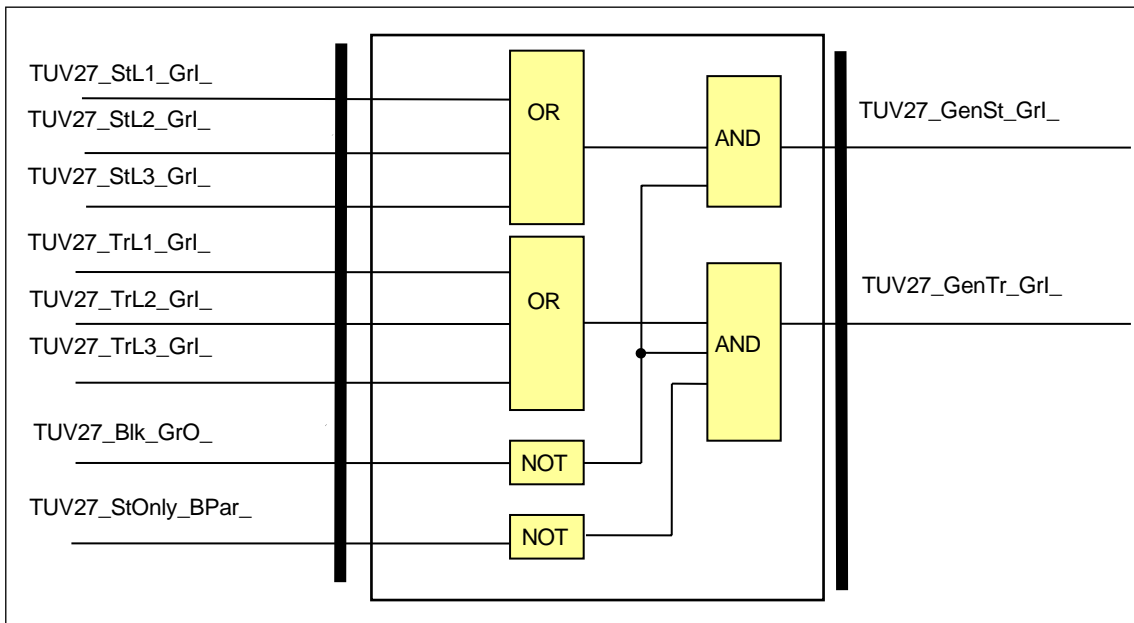


Figure 1-5 The logic scheme of the definite time undervoltage protection function

| Binary input signals | Signal title | Explanation |
|----------------------|--------------|-------------------------------------------|
| TUV27_StL1_Grl_ | StL1 | Starting of the function in phase L1* |
| TUV27_TrL1_Grl_ | TrL1** | Trip command of the function in phase L1* |
| TUV27_StL2_Grl_ | StL2 | Starting of the function in phase L2* |
| TUV27_TrL2_Grl_ | TrL2** | Trip command of the function in phase L2* |
| TUV27_StL3_Grl_ | StL3 | Starting of the function in phase L3* |
| TUV27_TrL3_Grl_ | TrL3** | Trip command of the function in phase L3* |

*In case of phase-to-phase voltages, these are changed to L12, L23, L31 respectively.

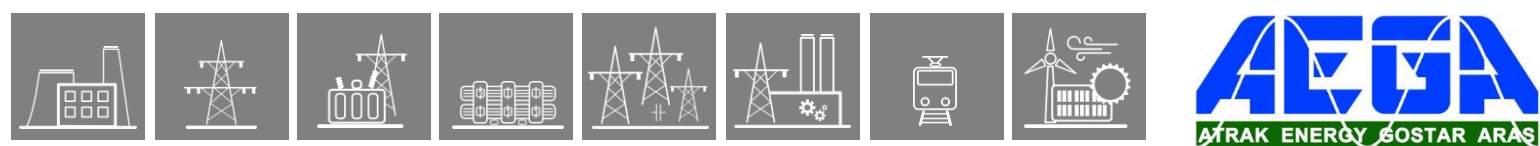
**The trip signals are not published for the phases individually

Table 1-7 The binary input signals of the definite time undervoltage protection function

Boolean parameter

| Parameter name | Title | Default |
|-----------------------------|-------------------|---------|
| Enabling start signal only: | | |
| TUV27_StOnly_BPar_ | Start Signal Only | FALSE |

Table 1-8 The Boolean parameter of the definite time undervoltage protection function



Binary status signals

The undervoltage protection function has a binary input signal, which serves the purpose of disabling the function. The conditions of disabling are defined by the user, applying the graphic equation editor.

| Binary input status signal | Signal title | Explanation |
|----------------------------|--------------|------------------------------------------------------------------------------------------------------------------------|
| TUV27_BlK_GrO_ | Blk | Output status of a graphic equation defined by the user to disable the definite time undervoltage protection function. |

Table 1-9 The binary input status signal of the definite time undervoltage protection function

| Binary output status signal | Signal title | Explanation |
|-----------------------------|--------------|--------------------------------------|
| TUV27_GenSt_Grl_ | GenSt | General starting of the function |
| TUV27_GenTr_Grl_ | GenTr | General trip command of the function |

Table 1-10 The binary output status signals of the definite time undervoltage protection function

3.1.2.8. Technical summary

3.1.2.8.1. Technical data

| Function | Value | Accuracy |
|---------------------------|-------|-----------------------|
| Pick-up starting accuracy | | $< \pm 0,5 \%$ |
| Blocking voltage | | $< \pm 1,5 \%$ |
| Reset time | | |
| $U > \rightarrow U_n$ | 50 ms | |
| $U > \rightarrow 0$ | 40 ms | |
| Operate time accuracy | | $< \pm 20 \text{ ms}$ |
| Minimum operate time | 50 ms | |

Table 1-11 Technical data of the undervoltage protection function

3.1.2.8.1.1. The parameters

The parameters are summarized in Chapters 3.1.2.5 and 3.1.2.6

3.1.2.8.2. Binary output status signals

The **binary output status signals** of undervoltage protection function are listed in Table 1-12

| Binary output status signal | Title | Explanation |
|-----------------------------|-------|----------------------|
| TUV27_StL1_Grl_ | StL1 | Start in phase L1* |
| TUV27_StL2_Grl_ | StL2 | Start in phase L2* |
| TUV27_StL3_Grl_ | StL3 | Start in phase L3* |
| TUV27_GenSt_Grl_ | GenSt | General start signal |
| TUV27_GenTr_Grl_ | GenTr | General trip command |

*In case of phase-to-phase voltages, these are changed to L12, L23, L31 respectively.

Table 1-12 The binary output status signals of the undervoltage protection function

3.1.2.8.3. Binary input status signals

Binary input signals

The undervoltage protection function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

| Binary status signal | Title | Explanation |
|----------------------|-------|--------------------------------------------------|
| TUV27_BlK_GrO_ | Blk | Blocking of the undervoltage protection function |

Table 1-13 The binary input signal of undervoltage protection function

3.1.2.8.4. The function block

The function block of undervoltage protection function is shown in Figure 1-6. This block shows all binary input and output status signals that are applicable in the graphic equation editor.

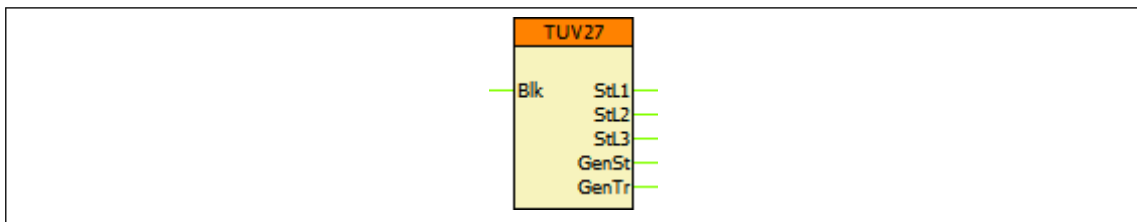


Figure 1-6 The function block of undervoltage protection function

3.1.3. Negative sequence overcurrent protection function

The negative sequence overcurrent protection function (TOC46) block operates if the negative sequence current is higher than the preset starting value.

In the negative sequence overcurrent protection function, definite-time or inverse-time characteristics are implemented, according to IEC or IEEE standards. The function evaluates a single measured current, which is the RMS value of the fundamental Fourier component of the negative sequence current. The characteristics are harmonized with IEC 60255-151, Edition 1.0, 2009-08.

3.1.3.1. Operating characteristics

3.1.3.1.1. Definite time characteristic

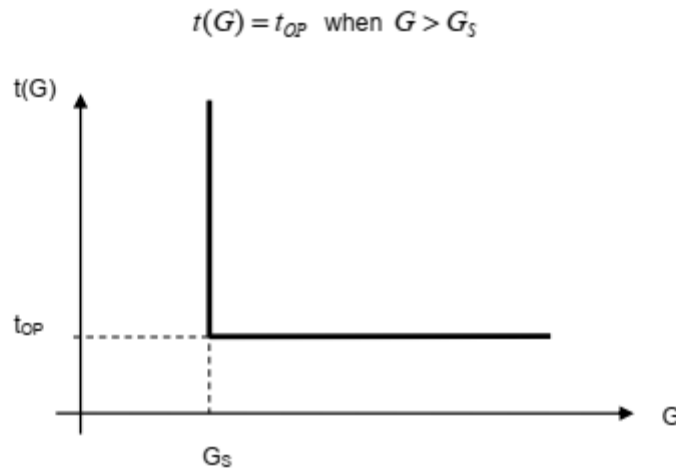


Figure 1-1 Overcurrent definite time characteristic

| | |
|--------------------|--------------------------------------------------------------------------------------------------------|
| where | |
| t_{OP} (seconds) | theoretical operating time if $G > G_s$, fix, according to the preset parameter, |
| G | measured value of the characteristic quantity, Fourier base harmonic of the negative sequence current, |
| G_s | preset starting value of the characteristic quantity (TOC46_StCurr_IPar_, Start current). |

3.1.3.1.2. Standard dependent time characteristics

Operating characteristics:

$$t(G) = TMS \left[\frac{k}{\left(\frac{G}{G_s}\right)^\alpha - 1} + c \right] \text{ when } G > G_s$$

where
 t(G)(seconds) theoretical operate time with constant value of G,
 k, c constants characterizing the selected curve (in seconds),
 α constant characterizing the selected curve (no dimension),
 G measured value of the characteristic quantity, Fourier base harmonic of the negative sequence current (INFour),
 G_s preset value of the characteristic quantity (TOC46_StCurr_IPar_, Start current),
 TMS preset time multiplier (no dimension).

| | IEC ref | | k _r | c | α |
|----|---------|------------------|----------------|--------|------|
| 1 | A | IEC Inv | 0,14 | 0 | 0,02 |
| 2 | B | IEC VeryInv | 13,5 | 0 | 1 |
| 3 | C | IEC ExtInv | 80 | 0 | 2 |
| 4 | | IEC LongInv | 120 | 0 | 1 |
| 5 | | ANSI Inv | 0,0086 | 0,0185 | 0,02 |
| 6 | D | ANSI ModInv | 0,0515 | 0,1140 | 0,02 |
| 7 | E | ANSI VeryInv | 19,61 | 0,491 | 2 |
| 8 | F | ANSI ExtInv | 28,2 | 0,1217 | 2 |
| 9 | | ANSI LongInv | 0,086 | 0,185 | 0,02 |
| 10 | | ANSI LongVeryInv | 28,55 | 0,712 | 2 |
| 11 | | ANSI LongExtInv | 64,07 | 0,250 | 2 |

Table 1-1 The constants of the standard dependent time characteristics

The end of the effective range of the dependent time characteristics (G_D) is:

$$G_D = 20 * G_s$$

Above this value the theoretical operating time is definite:

$$t(G) = TMS \left[\frac{k}{\left(\frac{G_D}{G_s}\right)^\alpha - 1} + c \right] \text{ when } G > G_D = 20 * G_s$$

The inverse characteristic is valid above G_T = 1,1 * G_s. Above this value the function is guaranteed to operate.

Resetting characteristics:

$$t_r(G) = TMS \left[\frac{k_r}{1 - \left(\frac{G}{G_s}\right)^\alpha} \right] \text{ when } G < G_s$$

where
 $t_r(G)$ (seconds) theoretical reset time with constant value of G,
 k_r constants characterizing the selected curve (in seconds),
 α constant characterizing the selected curve (no dimension),
 G measured value of the characteristic quantity, Fourier base harmonic of the phase current,
 G_s preset starting value of the characteristic quantity (TOC51_StCurr_IPar_, Start current),
 TMS preset time multiplier (no dimension).

| | IEC ref | | k_r | α |
|----|---------|------------------|---------------------------------------------------------------|----------|
| 1 | A | IEC Inv | Resetting after fix time delay, according to preset parameter | |
| 2 | B | IEC VeryInv | TOC46_Reset_TPar_ | |
| 3 | C | IEC ExtInv | "Reset delay" | |
| 4 | | IEC LongInv | 0,46 | 2 |
| 5 | | ANSI Inv | 4,85 | 2 |
| 6 | D | ANSI ModInv | 21,6 | 2 |
| 7 | E | ANSI VeryInv | 29,1 | 2 |
| 8 | F | ANSI ExtInv | 4,6 | 2 |
| 9 | | ANSI LongInv | 13,46 | 2 |
| 10 | | ANSI LongVeryInv | 30 | 2 |
| 11 | | ANSI LongExtInv | | |

Table 1-2 The resetting constants of the standard dependent time characteristics

The inverse type characteristics are also combined with a minimum time delay, the value of which is set by user parameter TOC46_MinDel_TPar_ (Min. Time Delay).

3.1.3.2. Structure of the negative sequence overcurrent protection algorithm

Fig.1-1 shows the structure of the negative sequence overcurrent protection (TOC46) algorithm.

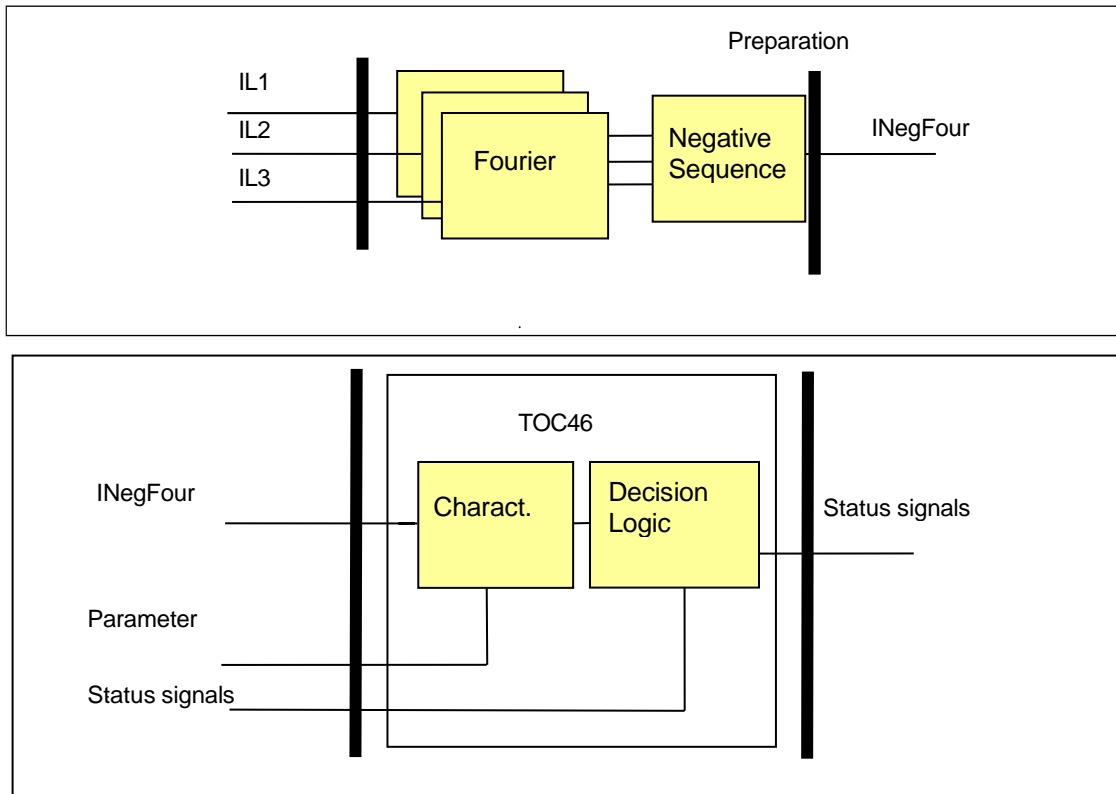


Figure 1-1 Structure of the negative sequence overcurrent protection algorithm

For the preparation (not part of the TOC46 function):

The **inputs** are

- the sampled values of the three phase currents (IL1, IL2, IL3),

The **output** is

- the RMS value of the fundamental Fourier components of the negative sequence component of the phase currents.

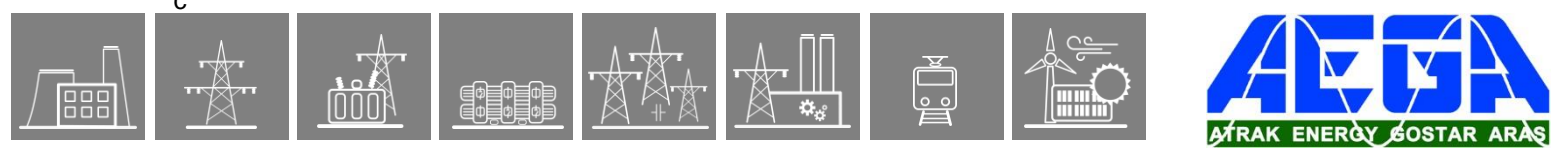
For the TOC46 function:

The **inputs** are

- the RMS value of the fundamental Fourier component of the negative sequence component of the phase currents,
- parameters,
- status signals.

The **outputs** are

- the binary output status signals.



The **software modules** applied in the negative sequence overcurrent protection function are:

Fourier calculations

These modules calculate the basic Fourier current components of the phase currents.

Negative sequence

This module calculates the basic Fourier current components of the negative sequence current, based on the Fourier components of the phase currents.

Characteristics

This module calculates the required time delay based on the Fourier components of the negative sequence current.

Decision logic

The decision logic module combines the status signals to generate the trip command of the function.

The following description explains the details of the individual components.

3.1.3.3. The Fourier calculation (Fourier)

These modules calculate the basic Fourier current components of the phase currents individually. These modules belong to the preparatory phase.

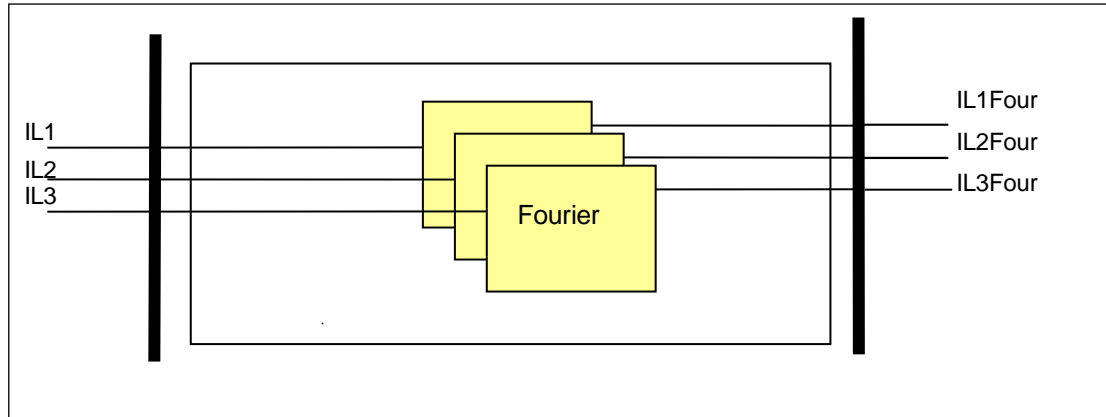


Figure 1-2 Schema of the Fourier calculation

The **inputs** are the sampled values of:
The three phase currents of the primary side (IL1, IL2, IL3)

The **outputs** are the basic Fourier components of the analyzed currents (IL1Four, IL2Four, IL3Four).



3.1.3.4. The negative phase sequence calculation (Negative sequence)

This module calculates the negative phase sequence components based on the Fourier components of the phase currents. This module belongs to the preparatory phase.

The **inputs** are the basic Fourier components of the phase currents (IL1Four, IL2Four, IL3Four).

The **output** is the basic Fourier component of the negative sequence current component (INegFour).

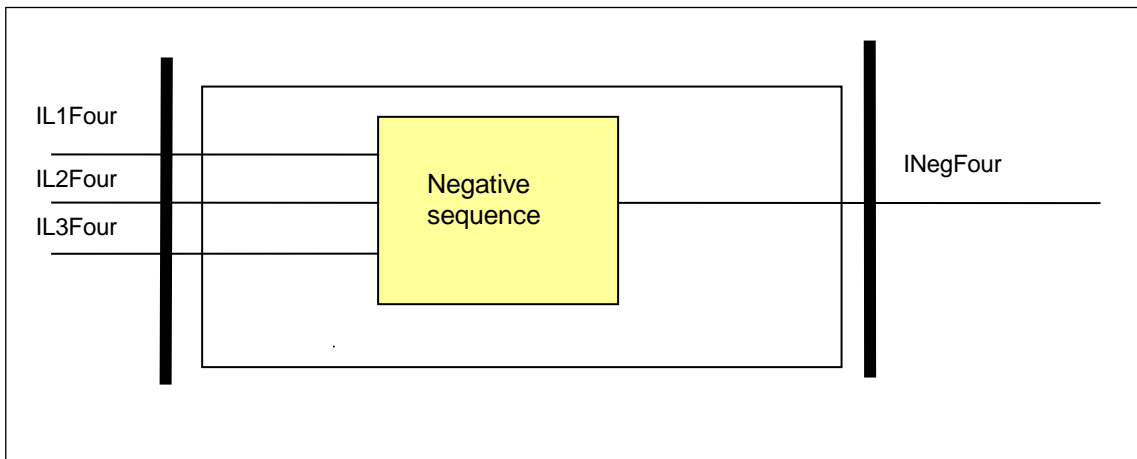


Figure 1-3 Schema of the negative sequence component calculation

3.1.3.5. The definite time and the inverse type characteristics (Characteristics)

This module calculates the required time delay based on the Fourier components of the negative sequence current. The formulas applied are described in Chapter 1.1.

The **input** is the basic Fourier component of the negative sequence current (INegFour) and parameters.

The **outputs** are the internal status signals of the function. These indicate the started state and the generated trip command if the time delay determined by the characteristics expired.

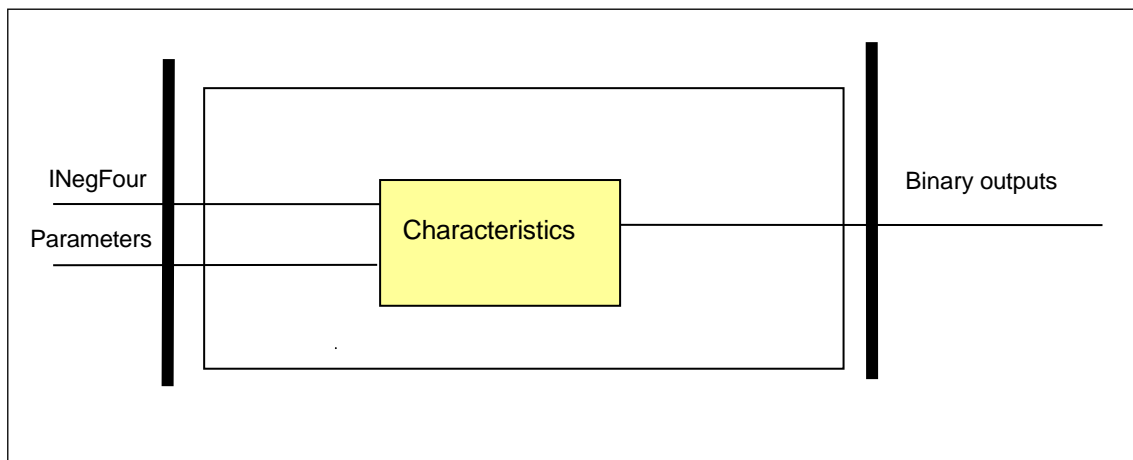


Figure 1-4 Schema of the characteristic calculation

Enumerated parameter

| Parameter name | Title | Selection range | Default |
|------------------------------|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|
| Parameter for type selection | | | |
| TOC46_Oper_EPar_ | Operation | Off, DefinitTime, IEC Inv, IEC VeryInv, IEC ExtInv, IEC LongInv, ANSI Inv, ANSI ModInv, ANSI VeryInv, ANSI ExtInv, ANSI LongInv, ANSI LongVeryInv, ANSI LongExtInv | Off |

Table 1-3 The enumerated parameters of the negative sequence overcurrent protection function

Integer parameter

| Parameter name | Title | Unit | Min | Max | Step | Default |
|-----------------------------|---------------|------|-----|------|------|---------|
| Starting current parameter: | | | | | | |
| TOC46_StCurr_IPar_ | Start Current | % | 10 | 1000 | 1 | 50 |

Table 1-4 The integer parameters of the negative sequence overcurrent protection function

3.1.3.6. The decision logic (Decision logic)

The decision logic module combines the binary status signals to generate the trip command of the function.

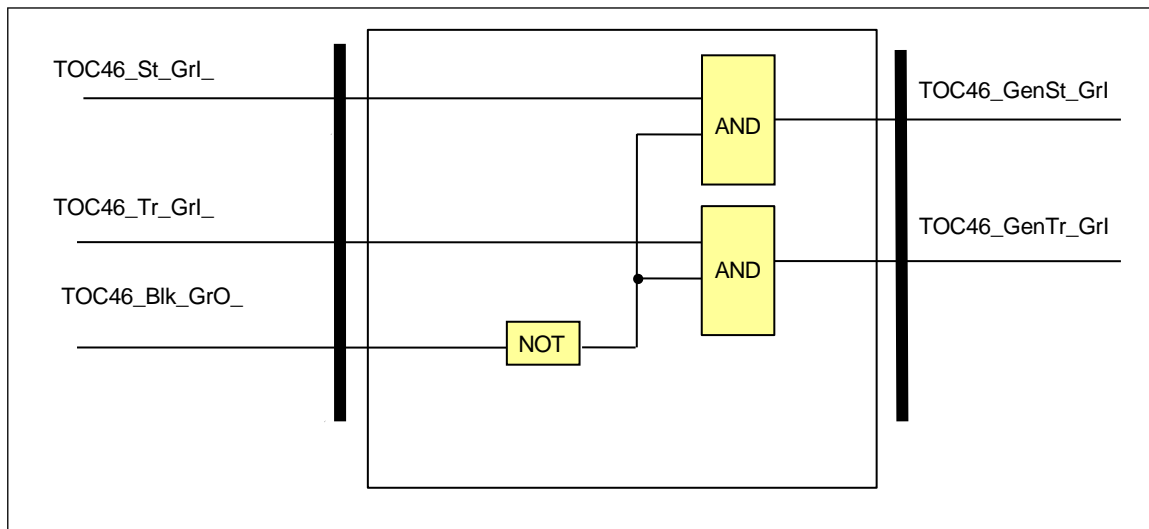


Figure 1-5 The logic scheme of the negative sequence overcurrent protection function

| Binary status signals | Signal title | Explanation |
|-----------------------|--------------|------------------------------|
| TOC46_St_Grl_ | Start | Starting of the function |
| TOC46_Tr_Grl_ | Trip | Trip command of the function |

Table 1-8 The binary status signals of the decision logic

Binary input status signal

The negative sequence overcurrent protection function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

| Binary input status signal | Explanation |
|----------------------------|---------------------------------------------------------------------------------------------------------------------------|
| TOC46_BlK_GrO_ | Output status of a graphic equation defined by the user to disable the negative sequence overcurrent protection function. |

Table 1-9 The binary input signal of the negative sequence overcurrent protection function

| Binary output signals | Signal title | Explanation |
|-----------------------|---------------|--------------------------------------|
| TOC46_GenSt_Grl_ | General Start | General starting of the function |
| TOC46_GenTr_Grl_ | General Trip | General trip command of the function |

Table 1-10 The binary output status signals of the negative sequence overcurrent protection function

3.1.3.7. Technical summary

3.1.3.7.1. Technical data

| Function | Value | Accuracy |
|-----------------------|-----------------------------|------------------------------------------------|
| Operating accuracy | $10 \leq G_s [\%] \leq 200$ | < 2 % |
| Operate time accuracy | | $\pm 5\%$ or ± 15 ms, whichever is greater |
| Reset ratio | 0,95 | |

| | | |
|----------------------------------------------------------------------|----------------|-------------------------------------------|
| Reset time * | | <2 % or ± 35 ms, whichever is greater |
| Dependent time charact. Definite time charact. | approx. 60 ms | |
| Transient overreach | | < 2 % |
| Pickup time at $2 \cdot G_s$ | <40 ms | |
| Overshot time | | |
| Dependent time charact. Definite time charact. | 25 ms 45 ms | |
| Influence of time varying value of the input current (IEC 60255-151) | | < 4 % |

Measured with signal contacts

Table 1-11 Technical data of the negative sequence overcurrent protection function

3.1.3.7.2. The parameters

The parameters are summarized in Chapter 3.1.1.5.

3.1.3.7.3. Binary output status signals

The **binary output status signals** of the negative sequence overcurrent protection function are listed in Table 1-12.

| Binary output signals | Signal title | Explanation |
|-----------------------|---------------|--------------------------------------|
| TOC46_GenSt_GrI_ | General Start | General starting of the function |
| TOC46_GenTr_GrI_ | General Trip | General trip command of the function |

Table 1-12 The binary output status signals of the negative sequence overcurrent protection function

3.1.3.7.4. The binary input status signals

Binary input signals

The negative sequence overcurrent protection function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

| Binary input signal | Explanation |
|---------------------|---------------------------------------------------------------------------------------------------------------------------|
| TOC46_Blk_GrO_ | Output status of a graphic equation defined by the user to disable the negative sequence overcurrent protection function. |

Table 1-13 The binary input signal of the negative sequence overcurrent protection function

3.1.3.7.5. The function block

The function block of the negative sequence overcurrent protection function is shown in Figure 1-6. This block shows all binary input and output status signals that are applicable in the graphic equation editor.

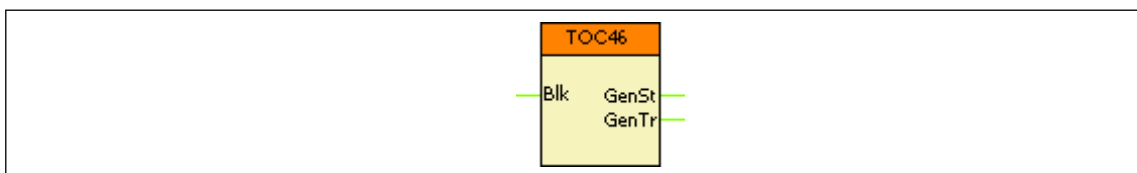


Figure 1-6 The function block of the negative sequence overcurrent protection function

3.1.4.4. Structure of the negative sequence definite time overvoltage protection algorithm

Fig.1-2 shows the structure of the negative sequence definite time overvoltage protection (TOV47) algorithm.

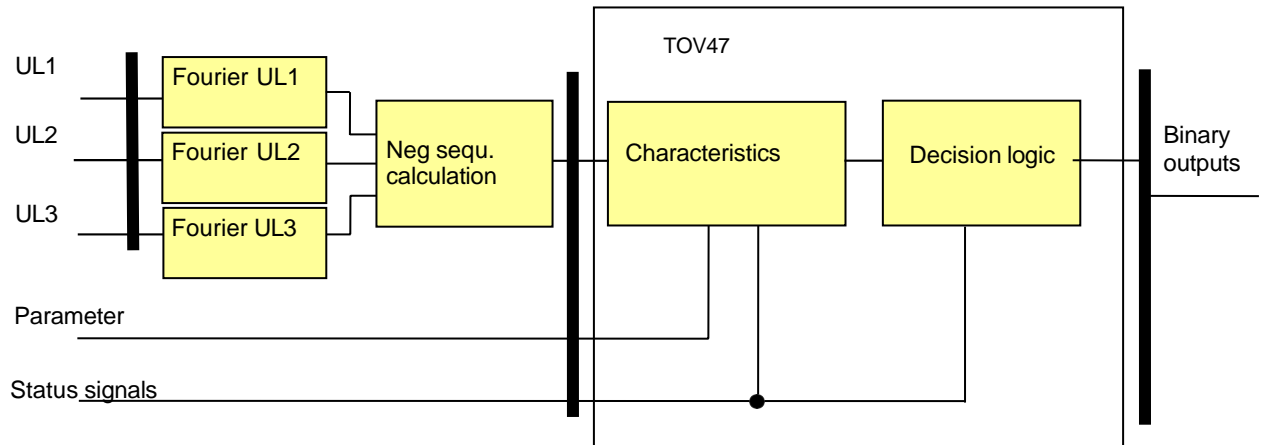


Figure 1-2 Structure of the negative sequence definite time overvoltage protection algorithm

The **inputs** are

- the RMS value of the negative sequence fundamental Fourier component, calculated using the sampled three phase voltages,
- parameters,
- status signals.

The **outputs** are

- the binary output status signals.

The **software modules** of the definite time overvoltage protection function:

Fourier calculations

These modules calculate the basic Fourier components of the phase voltages individually (not part of the TOV47 function).

Neg sequ. calculation

This module calculates the negative sequence basic Fourier component (not part of the TOV47 function).

Characteristics

This module calculates the required time delay based on the Fourier components of the negative sequence voltage component.

Decision logic

The decision logic module combines the status signals to generate the trip command of the function.

The following description explains the details of the individual components.

3.1.4.5. The Fourier calculation (Fourier)

These modules calculate the basic Fourier components of the phase voltages individually. They are not part of the TOV47 function; they belong to the preparatory phase.

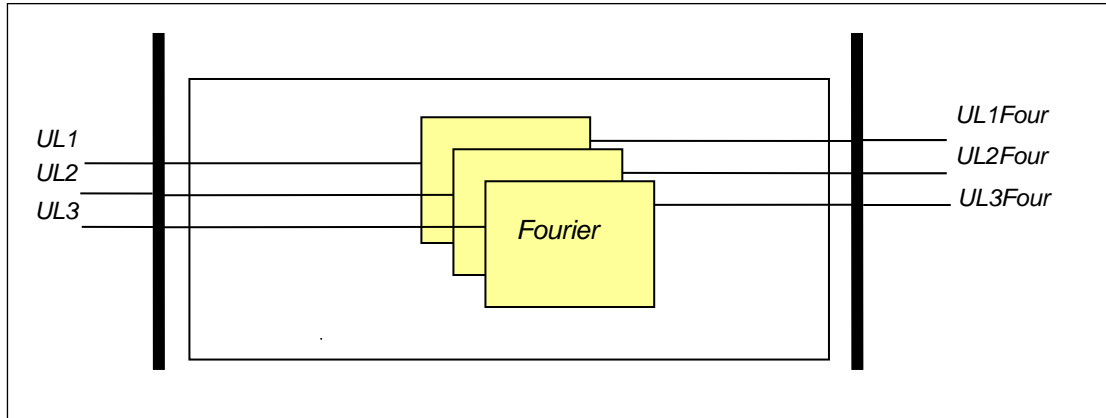


Figure 1-3 Schema of the Fourier calculation

The **inputs** are the sampled values of the three phase voltages (UL1, UL2, UL3)

The **outputs** are the RMS values of the basic Fourier components of the analyzed voltages (UL1Four, UL2Four, UL3Four).

3.1.4.6. The negative sequence component calculation (Neg sequ. Calculation)

This module calculates the negative sequent basic Fourier component. This is not part of the TOV47 function; it belongs to the preparatory phase.

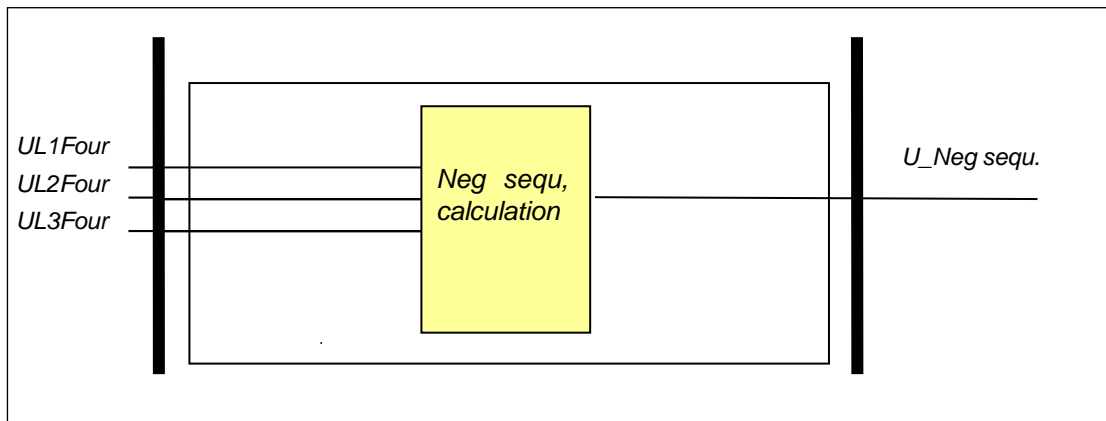


Figure 1-4 Schema of the negative sequence component calculation

The **inputs** are the RMS values of the basic Fourier components of the analyzed voltages (UL1Four, UL2Four, UL3Four).

The **output** is the RMS value of the negative sequence basic Fourier component voltage (U_Neg sequ.).

3.1.4.7. The definite time characteristics (Characteristics)

This module decides the stating of the function based on the negative sequence Fourier component voltage and it counts the time delay. The time delay is defined by the parameter setting, if the voltage is above the threshold value.

The **inputs** are the RMS value of the negative sequence basic Fourier component (U_neg sequ.) and parameters.

The internal **outputs** are the status signals. These indicate the started state and the generated trip command if the time delay determined by the setting is expired.

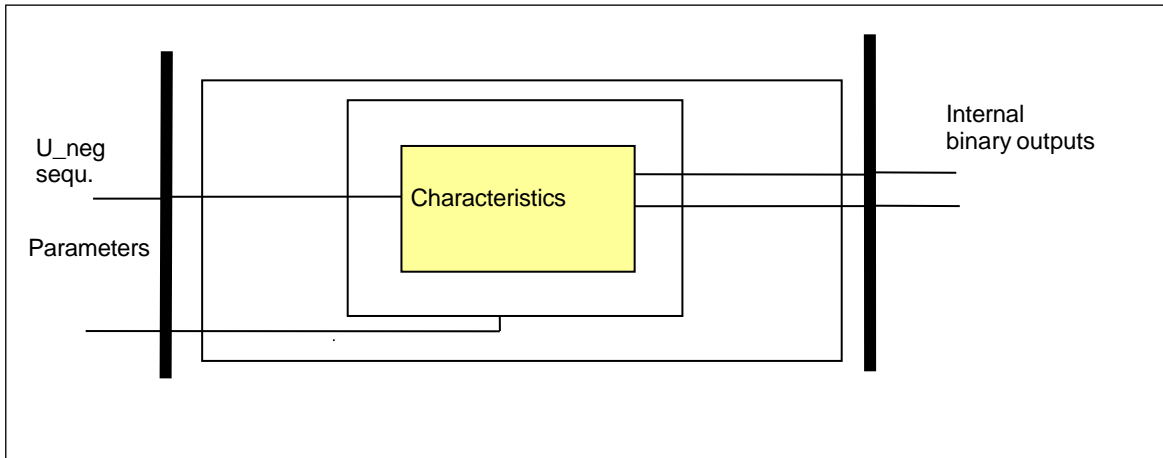


Figure 1-5 Schema of the definite time characteristic calculation

Integer parameter

| Parameter name | Title | Unit | Min | Max | Step | Default |
|----------------------------------------------------------------------------------------------------------|---------------|------|-----|-----|------|---------|
| Voltage level setting. If the voltage is above the setting value, the function generates a start signal. | | | | | | |
| TOV47_StVol_IPar__ | Start Voltage | % | 2 | 40 | 1 | 30 |

Table 1-1 Integer parameters of the negative sequence overvoltage protection function

Timer parameter

| Parameter name | Title | Unit | Min | Max | Step | Default |
|----------------------------------------------------|------------|------|-----|-------|------|---------|
| Time delay of the overvoltage protection function. | | | | | | |
| TOV47_Delay_TPar_ | Time Delay | ms | 50 | 60000 | 1 | 100 |

Table 1-2 The timer parameter of the negative sequence overvoltage protection function

The internal **binary output status signals** of the three-phase definite time overvoltage protection function are listed in Table 1-3 below.

| Binary output signals | Signal title | Explanation |
|-----------------------|--------------|------------------------------|
| Start | Start | Starting of the function |
| Trip | Trip | Trip command of the function |

Table 1-3 The internal binary output status signals of the negative sequence definite time overvoltage protection function

3.1.4.8. The decision logic (Decision logic)

The decision logic module combines the internal status signals, Boolean and binary parameters to generate the trip command of the function.

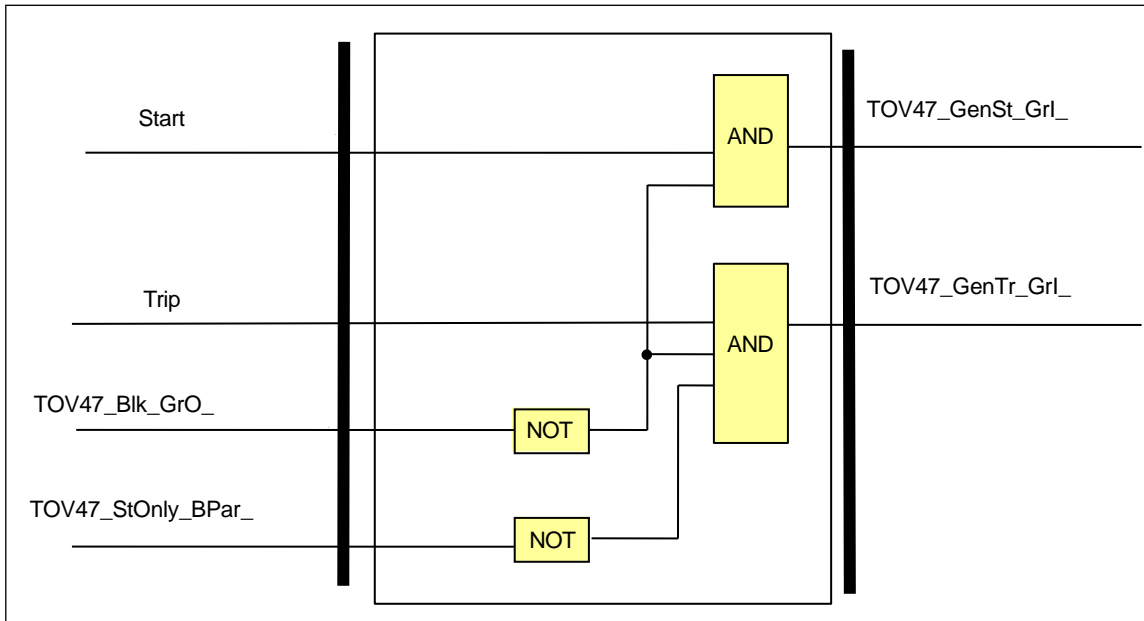


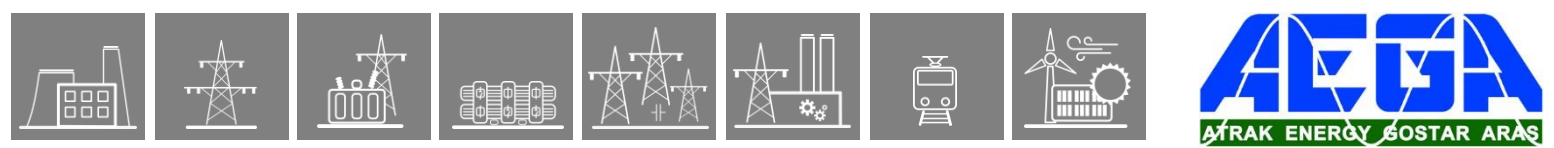
Figure 1-6 The decision logic scheme of the negative sequence definite time overvoltage protection function

Boolean parameter

| Parameter name | Title | Default |
|-----------------------------|-------------------|---------|
| Enabling start signal only: | | |
| TOV47_StOnly_BPar_ | Start Signal Only | FALSE |

Table 1-4 The Boolean parameter of the negative sequence definite time overvoltage protection function

The negative sequence overvoltage protection function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**



Binary input status signal

| Binary status signal | Explanation |
|----------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| TOV47_Blk_GrO_ | Output status of a graphic editor defined by the user to disable the negative sequence definite time overvoltage protection function. |

Table 1-5 The binary input signal of the negative sequence definite time overvoltage protection function

Binary output status signals

| Binary status signal | Title | Explanation |
|----------------------|---------------|----------------------|
| TOV47_GenSt_GrI_ | General Start | General start signal |
| TOV47_GenTr_GrI_ | General Trip | General trip command |

Table 1-6 The binary output status signals of the negative sequence definite time overvoltage protection function

3.1.4.9. Technical summary

3.1.4.9.1. Technical data

| Function | Value | Accuracy |
|---------------------------|-------|-----------|
| Pick-up starting accuracy | | < ± 0,5 % |
| Blocking voltage | | < ± 1,5 % |
| Reset time | | |
| U> → Un | 60 ms | |
| U> → 0 | 50 ms | |
| Operate time accuracy | | < ± 20 ms |
| Drop-off ratio | | ± 0.5 % |
| Minimum operate time | 50 ms | |

Table 1-7 Technical data of the negative sequence definite time overvoltage protection function

3.1.4.9.2. The parameters

The parameters are summarized in Chapter 1.7 Table 1-1, Table 1-2, and in Chapter 1.8 Table 1-4.

3.1.4.9.3. The status signals

The status signals are summarized in Chapter 1.8 Table 1-5 and Table 1-6.

3.1.4.9.4. The function block

The function block of the overvoltage protection function is shown in Figure 1-7. This block shows all binary input and output status signals that are applicable in the graphic logic editor.

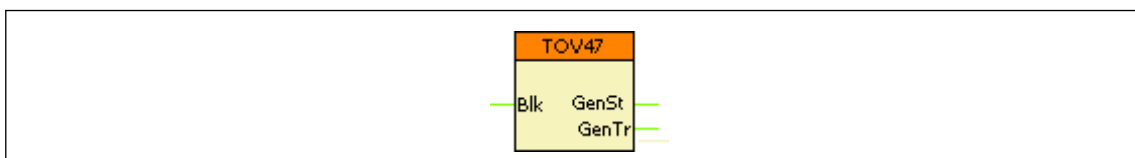
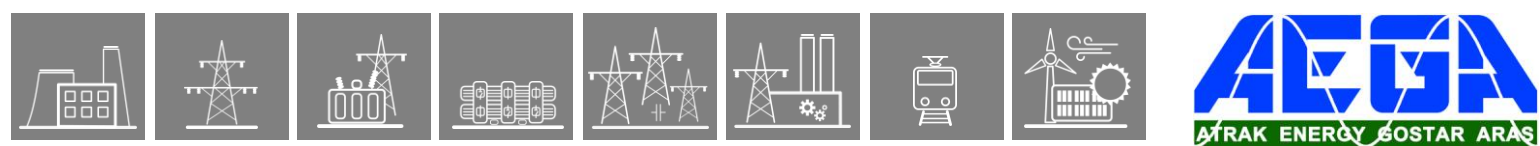


Figure 1-7 The function block of the negative sequence definite time overvoltage protection function



3.1.5. Line thermal protection function

Basically, line thermal protection measures the three sampled phase currents. RMS values are calculated and the temperature calculation is based on the highest RMS value of the phase currents.

The temperature calculation is based on the step-by-step solution of the thermal differential equation. This method yields “overtemperature”, meaning the temperature above the ambient temperature (of the environment). Accordingly, the temperature of the protected object is the sum of the calculated “overtemperature” and the ambient temperature.

The ambient temperature can be measured using e.g. a temperature probe generating electric analog signals proportional to the temperature. In the absence of such measurement, the temperature of the environment can be set using the dedicated parameter TTR49L_Amb_IPar_ (Ambient Temperature). The selection between parameter value and direct measurement is made by setting the binary parameter TTR49L_Sens_BPar_ (Temperature sensor). (Special HW input module is required.)

If the calculated temperature (calculated “overtemperature”+ambient temperature) is above the threshold values, status signals are generated:

TTR49L_Alm_IPar_ (Alarm temperature) TTR49L_Trip_IPar_ (Trip temperature)
 TTR49L_Unl_IPar_ (Unlock temperature)

For correct setting, the following values must be measured and set as parameters:

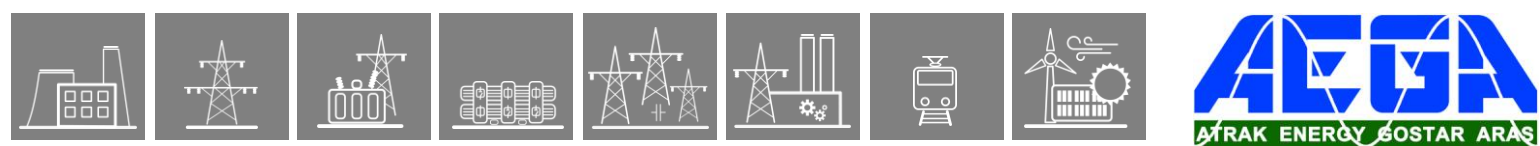
TTR49L_Inom_IPar_ (Rated load current: continuous current applied for the measurement)
 TTR49L_Max_IPar_ (Rated temperature: the steady state temperature at rated load current)
 TTR49L_Ref_IPar_ (Base Temperature: the temperature of the environment during the measurement of the rated values)
 TTR49L_pT_IPar_ (time constant: measured heating/cooling time constant of the exponential temperature function)

When energizing the protection device, the algorithm permits the definition of the starting temperature as the initial value of the calculated temperature:

TTR49L_Str_IPar_ (Startup Temp.: Initial temperature above the temperature of the environment as compared to the rated temperature above the base temperature)

The problem of metal elements (the protected line) exposed to the sun is that they are overheated as compared to the „ambient” temperature even without a heating current; furthermore, they are cooled mostly by the wind and the heat transfer coefficient is highly dependent on the effects of the wind. As the overhead lines are located in different geographical environments along the tens of kilometers of the route, the effects of the sun and the wind cannot be considered in detail. The best approximation is to measure the temperature of a piece of overhead line without current but exposed to the same environmental conditions as the protected line itself.

The application of thermal protection of the overhead line is a better solution than a simple overcurrent-based protection because thermal protection “remembers” the preceding load states of the line and the setting of the thermal protection does not need so a high security margin between the permitted current and the permitted continuous thermal current of the line. In a broad range of load states and in a broad range of ambient temperatures this



permits the better exploitation of the thermal and consequently current carrying capacity of the line.

3.1.5.1. Theory of the thermal replica calculations

3.1.5.1.1. The thermal differential equation

The theory of solving the thermal differential equation is described and explained in detail in the document ["The thermal differential equation"].

The source of the formulas below is that document. The

thermal differential equation to be solved is:

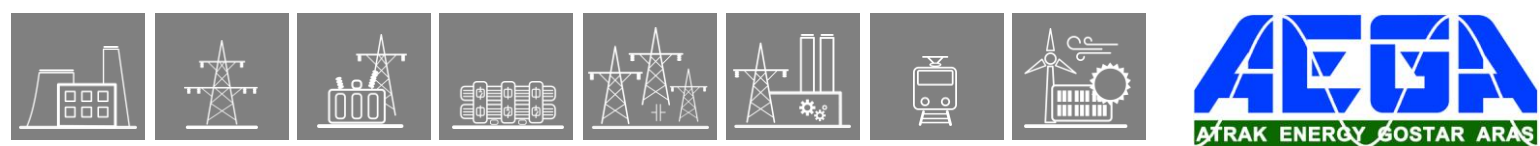
$$\frac{d\Theta}{dt} = \frac{1}{T} \left(\frac{I^2(t)R}{hA} - \Theta \right) \quad (1)$$

The definition of the heat time constant is:

$$T = \frac{cm}{hA}$$

In this differential equation:

| | |
|------------|---------------------------------------------------------------------|
| I(t) (RMS) | heating current, the RMS value usually changes over time; |
| R | resistance of the line; |
| c | specific heat capacity of the conductor; |
| m | mass of the conductor; |
| θ | rise of the temperature above the temperature of the environment; h |
| A | heat transfer coefficient of the surface of the conductor; |
| t | area of the surface of the conductor; |
| | time. |



3.1.5.1.2. The temperature-time function for constant current

The solution of the thermal differential equation for constant current is the temperature as the function of time. (The mathematical derivation of this equation is described in a separate document.)

$$\Theta(t) = \frac{I^2 R}{hA} \left(1 - e^{-\frac{t}{T}} \right) + \Theta_0 e^{-\frac{t}{T}} \quad (2)$$

Remember that the calculation of the measurable temperature is as follows:

Temperature(t) = $\Theta(t)$ + Temp_ambient

where

Temp_ambient is the ambient temperature.

In that separate document it is proven that some more easily measurable parameters can be introduced instead of the aforementioned ones. Thus, the general form of equation (2) is:

$$H(t) = \frac{\Theta(t)}{\Theta_n} = \frac{I^2}{I_n^2} \left(1 - e^{-\frac{t}{T}} \right) + \frac{\Theta_0}{\Theta_n} e^{-\frac{t}{T}} \quad (3)$$

where:

$H(t)$ is the „thermal level” of the heated object, **this is the temperature as a percentage of the Θ_n reference temperature.** (This is a dimensionless quantity but it can also be expressed in a percentage form.)

Θ_0 is the starting temperature above the temperature of the environment

Θ_n is the reference temperature above the temperature of the environment, which can be measured in steady state, in case of a continuous I_n reference current.

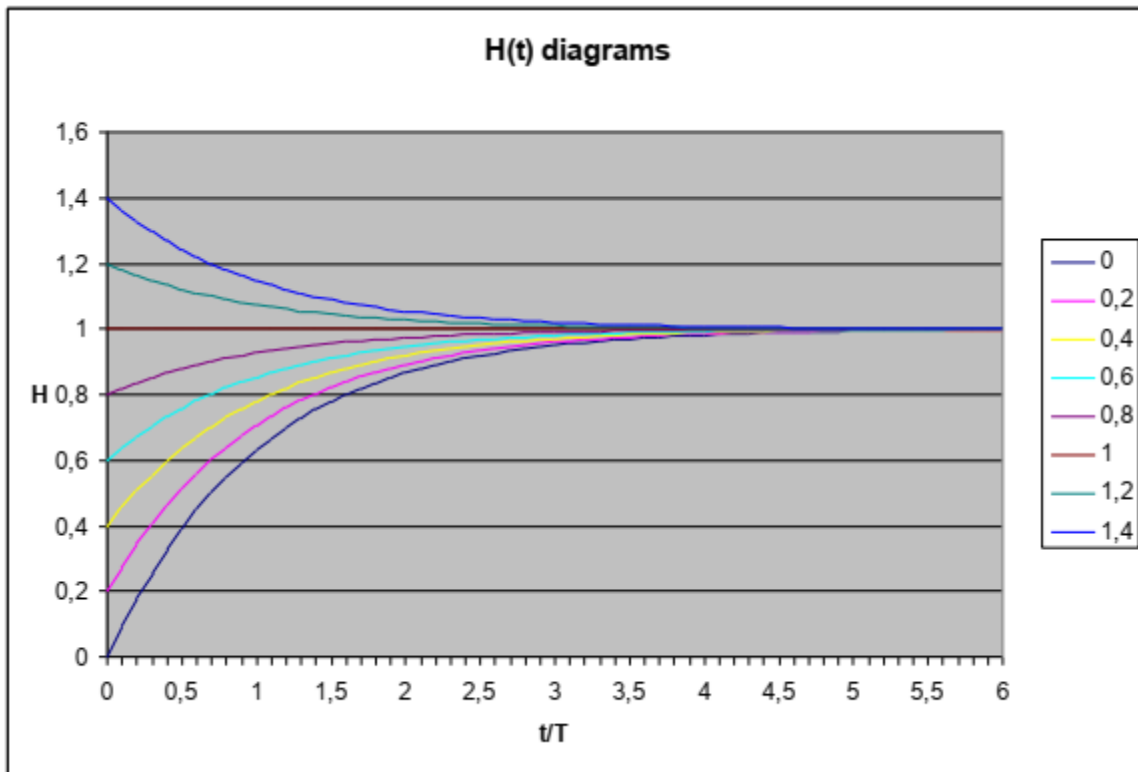
I_n is the reference current (can be considered as the nominal current of the heated object). If it flows continuously, then the reference temperature can be measured in steady state.

3.1.5.1.3. Formulas for checking the thermal protection functions

Equation (3) offers a general formula to check the operation of the thermal protection using constant current.

The changes of temperature over time, (above the temperature of the environment), described by equation (3), are plotted in the diagram below. Parameter is the starting

temperature related to the reference temperature $\frac{\Theta_o}{\Theta_n}$



For further tests, the time needed to reach a specific temperature value can be calculated based on equation (3). The derived formula with relative quantities is:

$$\frac{t}{T} = \ln \left(\frac{\frac{\Theta_s - \Theta_o}{\Theta_n - \Theta_n}}{\frac{\Theta_s - \Theta_{set}}{\Theta_n - \Theta_n}} \right) \quad (4)$$

where:

$\Theta_s = \frac{I^2 \Theta_n}{I_n^2}$ is the steady state temperature in case of continuous I current,

Θ_{set} is the momentary temperature above the ambient temperature; the time to reach this is to be calculated,

Θ_o is the starting „overtemperature”,

Θ_n is the reference temperature above the temperature of the environment, which can be measured in steady state, in case of a continuous I_n reference current.

To be able to compare the current–time characteristics of the thermal protection with that of the inverse characteristics, formula (4) can be rearranged using currents and per unit quantities:

$$\frac{t}{T} = \ln \frac{\frac{I^2}{I_{set}^2} - \frac{I_0^2}{I_{set}^2}}{\frac{I^2}{I_{set}^2} - 1} \quad (5)$$

where:

I_0 is the continuous current that results Θ_0 steady state “overtemperature” at the beginning of the calculation,

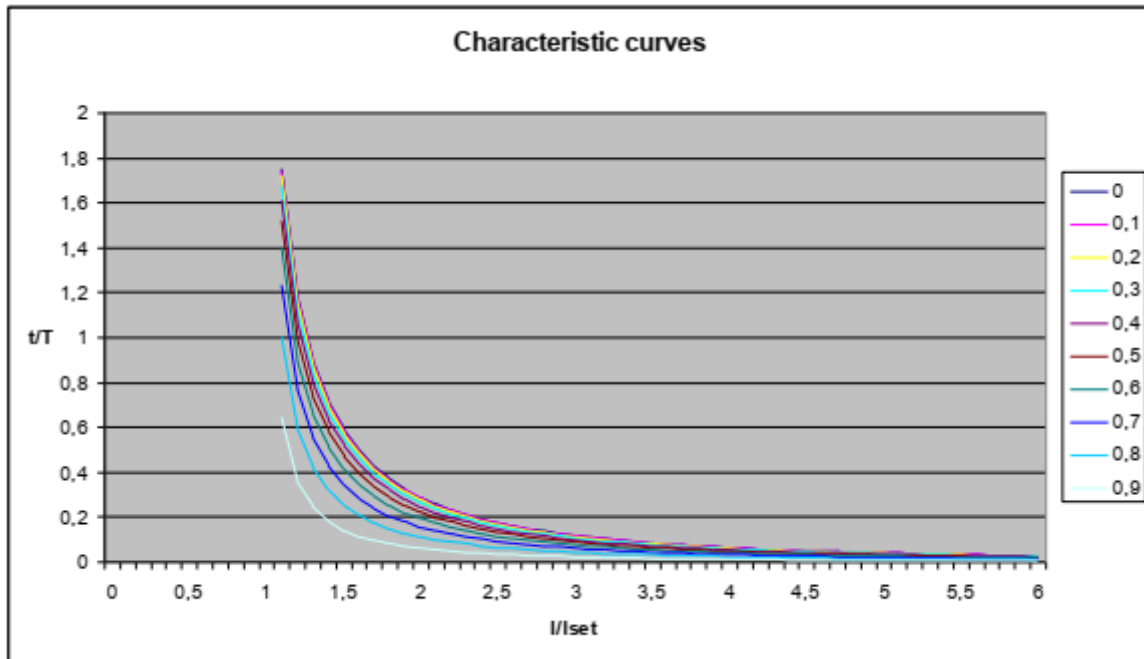
I is the current that is applied to reach the steady state Θ_S “overtemperature”,

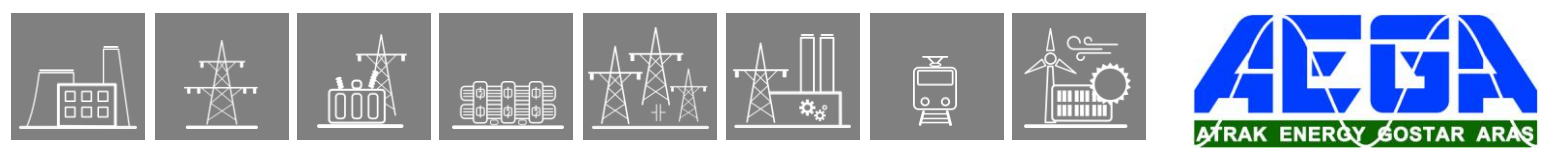
$$(\Theta_S = \frac{I^2 \Theta_n}{I_n^2}).$$

I_{set} would be the setting current of the equivalent „overcurrent” function.

The plots according to equation (5) can be seen below. They show how much time is left to reach the „trip temperature” in case of a continuous I (RMS) current. The parameter is the continuous I_0 current related to the I_n rated current, which generates the steady state starting temperature. The topmost curve is the „cold curve”.

The plots below clearly show that the thermal replica method “remembers” the starting temperature. If the starting temperature (I_0 pre-faulty steady state current) is increased, the time to trip at a fault current $I/I_{set} > 1$ automatically decreases.





3.1.5.1.4. Numerical solution of the thermal differential equation

The formulas (2-5) above refer to a constant current and can be used to test the thermal protection. In reality, the RMS value of the current changes over time; consequently, differential equation (1) must be solved using a numerical method. The separate document explains the steps to obtain the calculation formula:

$$H_k = \frac{\Theta_k}{\Theta_n} = \left(1 - \frac{\Delta t}{T}\right) \frac{\Theta_{k-1}}{\Theta_n} + \frac{\Delta t}{T} \frac{I^2}{I_n^2} \quad (6)$$

where:

- Θ_k is the temperature (above the temperature of the environment) at the k-th calculation step;
- Θ_{k-1} is the temperature (above the temperature of the environment) one calculation step before.

(The line thermal protection is calculating the temperature based on the formula (6) above, the user of the thermal protection does not need to apply it.)

3.1.5.2. Structure of the line thermal protection

Fig.1-1 shows the structure of the line thermal protection (TTR49L) algorithm.

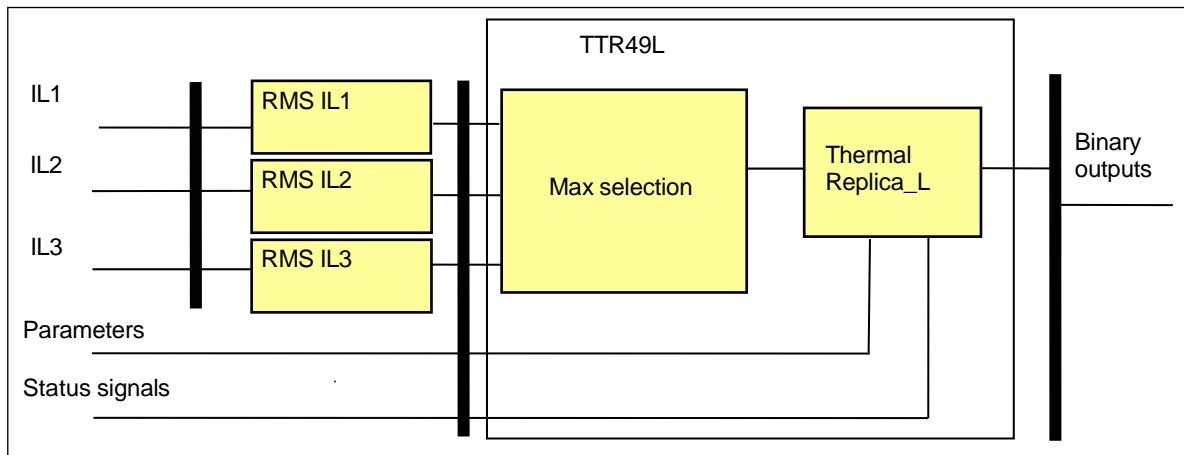


Figure 1-1 Structure of the line thermal protection algorithm

The **inputs** are the RMS values of three primary phase currents, parameters, status signals.

The **outputs** are the binary output status signals.

The **software modules** of the line thermal protection function:

RMS calculations

These modules calculate the RMS values of the phase currents individually. The sampling frequency of the calculations is 1 kHz; therefore, theoretically, the frequency components below 500Hz are considered correctly in the RMS values. This module is not part of the thermal function; it belongs to the preparatory phase.

Max selection

This module selects the maximal value of the RMS phase currents.

Thermal replica

This module solves the first order thermal differential equation using a simple step-by-step method and compares the calculated temperature to the values set by parameters.

The following description explains the details of the individual components.

3.1.5.3. RMS calculation (RMS)

These modules calculate the true RMS values of the phase currents individually. The sampling frequency of the calculations is 1 kHz; therefore, theoretically, the frequency components below 500Hz are considered correctly in the RMS values. This module is not part of the thermal function; it belongs to the preparatory phase.

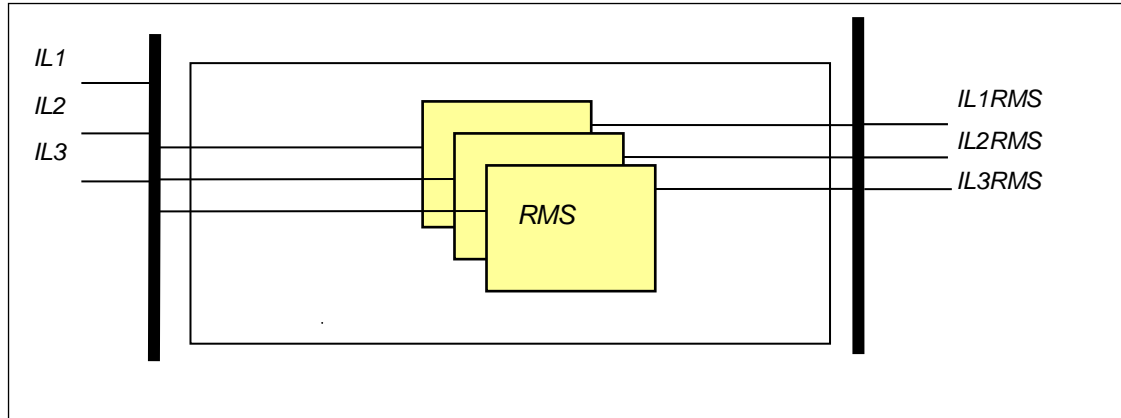


Figure 1-2 Principal scheme of the current RMS calculation

The **inputs** are the sampled values of the three phase currents (IL1, IL2, IL3)

The **outputs** are the RMS values of the analyzed currents (IL1RMS, IL2RMS, IL3RMS).

3.1.5.4. The maximum selection (Max selection)

This module selects the maximum of the three RMS values.

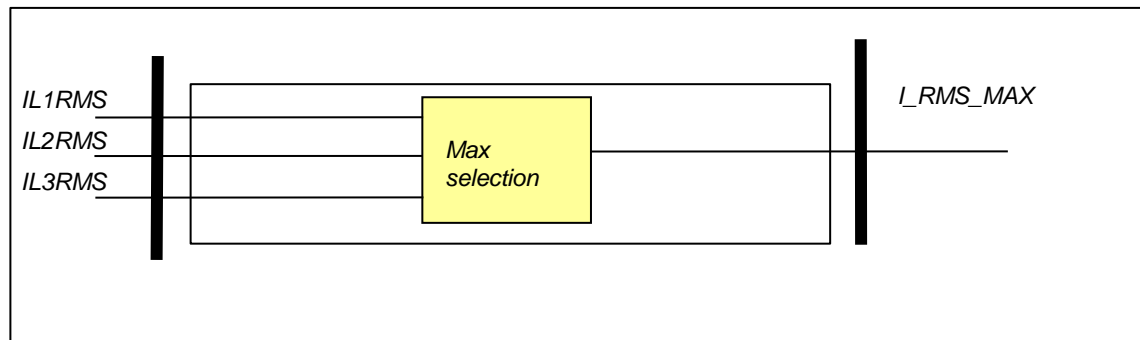
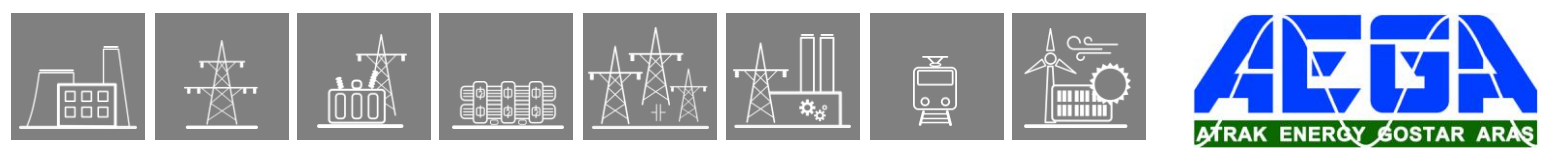


Figure 1-3 Principal scheme of the maximum selection

The **inputs** are the RMS values of the analyzed currents (IL1RMS, IL2RMS, IL3RMS). The

output is the selected maximum of the three RMS values.



3.1.5.5. The temperature calculation and decision (Thermal replic)

This module solves the first order thermal differential equation using a simple step-by-step method and compares the calculated temperature to the values set by parameters.

The **inputs** are

- The selected maximum of the three RMS values of the phase currents,
- The value proportional to the ambient temperature (this signal is optional, defined at parameter setting),
- Binary input status signals,

Parameters.

The **outputs** are the status signals. These indicate the generated trip command if the temperature is above the preset current value.

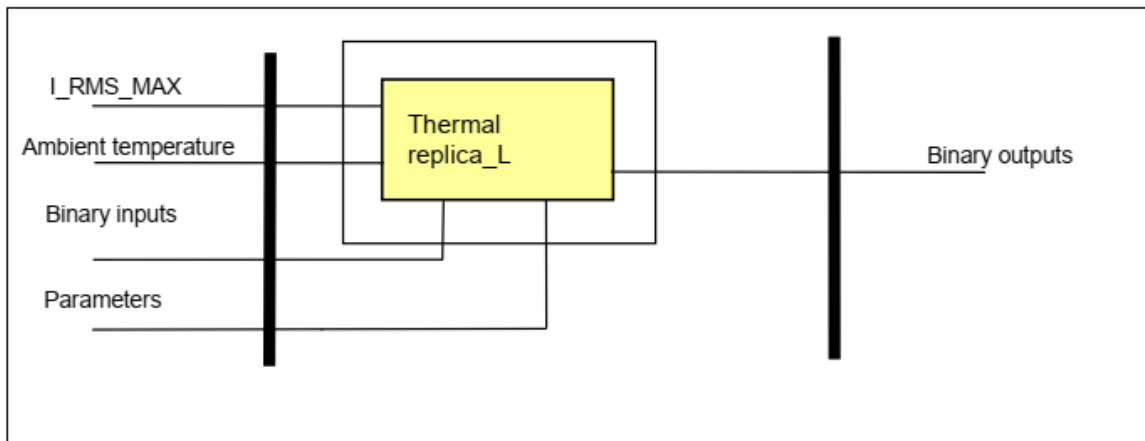
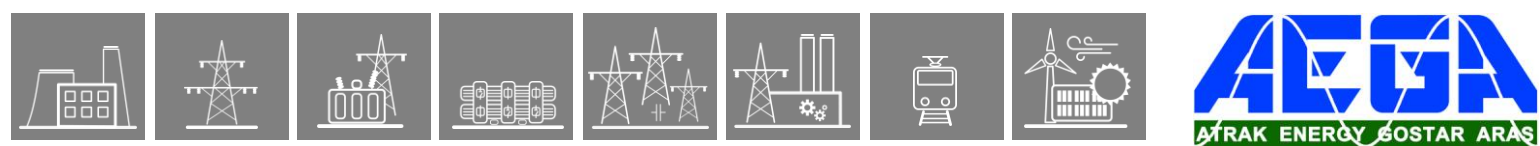


Figure 1-4 Principal scheme of the thermal replica calculation



Enumerated parameter

| Parameter name | Title | Selection range | Default |
|---------------------------------|-----------|---------------------|---------|
| Parameter for mode of operation | | | |
| TTR49L_Oper_EPar_ | Operation | Off, Pulsed, Locked | Pulsed |

Table 1-1 The enumerated parameters of the line thermal protection function

The meaning of the enumerated values is as follows:

- Off The function is switched off; no output status signals are generated;
- Pulsed The function generates a trip pulse if the calculated temperature exceeds the trip value
- Locked The function generates a trip signal if the calculated temperature exceeds the trip value. It resets only if the temperature cools below the “Unlock temperature”.

Integer parameters

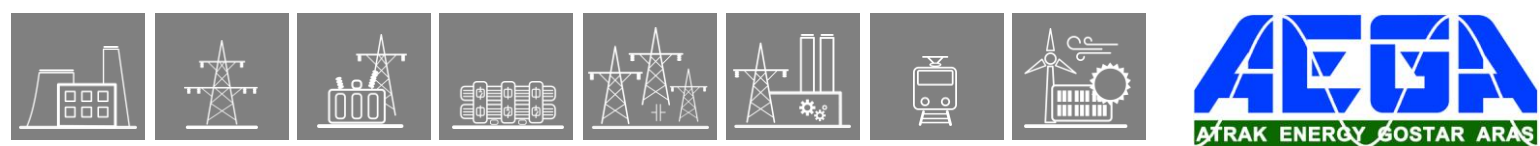
| Parameter name | Title | Unit | Min | Max | Step | Default |
|---------------------|---------------------|------|-----|-----|------|---------|
| Alarm Temperature | | | | | | |
| TTR49L_Alm_IPar_ | Alarm Temperature | deg | 60 | 200 | 1 | 80 |
| Trip Temperature | | | | | | |
| TTR49L_Trip_IPar_ | Trip Temperature | deg | 60 | 200 | 1 | 100 |
| Rated Temperature | | | | | | |
| TTR49L_Max_IPar_ | Rated Temperature | deg | 60 | 200 | 1 | 100 |
| Base Temperature | | | | | | |
| TTR49L_Ref_IPar_ | Base Temperature | deg | 0 | 40 | 1 | 25 |
| Unlock Temperature | | | | | | |
| TTR49L_Unl_IPar_ | Unlock Temperature | deg | 20 | 200 | 1 | 60 |
| Ambient Temperature | | | | | | |
| TTR49L_Amb_IPar_ | Ambient Temperature | deg | 0 | 40 | 1 | 25 |
| Startup Term. | | | | | | |
| TTR49L_Str_IPar | Startup Term | % | 0 | 60 | 1 | 0 |
| Rated Load Current | | | | | | |
| TTR49L_Inom_IPar_ | Rated Load Current | % | 20 | 150 | 1 | 100 |
| Time constant | | | | | | |
| TTR49L_pT_IPar_ | Time Constant | min | 1 | 999 | 1 | 10 |

Table 1-2 The integer parameters of the line thermal protection function

Boolean parameter

| Boolean parameter | Signal title | Selection range | Default |
|--------------------------------------------------------------------------------------------|--------------------|-----------------|---------|
| Parameter for ambient temperature sensor application (Special HW input module is required) | | | |
| TTR49L_Sens_BPar_ | Temperature Sensor | No, Yes | No |

Table 1-3 The Boolean parameter of the line thermal protection function



The **binary output status signals** of the line thermal protection function are shown in Table 1-4.

| Binary output signals | Signal title | Explanation |
|-----------------------|----------------|----------------------------------------------------------------------|
| TTR49L_Alm_Grl_ | Alarm | Alarm signal of the line thermal protection function |
| TTR49L_GenTr_Grl_ | General Trip | General trip signal of the line thermal protection function |
| TTR49L_Lock_Grl_ | Reclose locked | Line reclose blocking signal of the line thermal protection function |

Table 1-4 The binary output status signals of the line thermal protection function

Binary input status signals

The line thermal protection function has two binary input status signals. One of them serves to disable the function; the other one resets the accumulated heat. Resetting serves test purposes only, if the heating calculation needs to start at a clearly defined temperature. Using this signal, the testing engineer need not wait until the cooling reaches the required starting temperature of the subsequent heating test.

Both binary input status signals are defined by the user, applying the graphic equation editor.

The binary input status signals of the line thermal protection function are shown in Table 1-5.

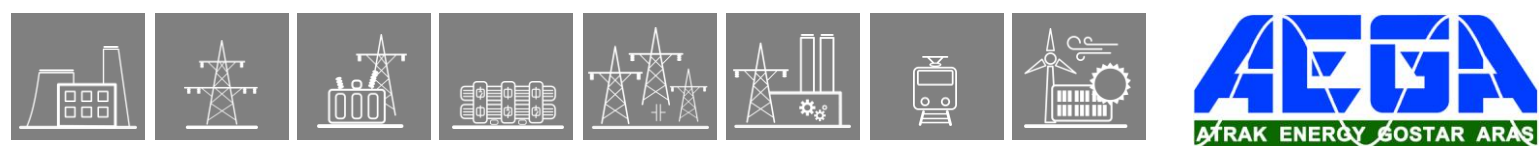
| Binary input status signals | Title | Explanation |
|-----------------------------|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TTR49L_BlK_GrO_ | Block | Output status of a graphic equation defined by the user to disable the line thermal protection function. |
| TTR49L_Reset_GrO_ | Reset | Output status of a graphic equation defined by the user to reset the accumulated heat and set the temperature to the defined value for the subsequent heating test procedure. |

Table 1-5 The binary input signals of the line thermal protection function

On-line measured value

| On-line measured value | Explanation |
|------------------------|-----------------------------|
| TTR49L_Temp_OLM_ | The calculated temperature. |

Table 1-6 The on-line measured value of the line thermal protection function



3.1.5.6. Technical summary

3.1.5.6.1. Technical data

| Function | Accuracy |
|------------------------------------------|------------------|
| Operate time at $I > 1.2 \cdot I_{trip}$ | <3 % or <+ 20 ms |

Table 1-7 Technical data of the line thermal protection function

3.1.5.6.2. The parameters

The parameters are summarized in Chapter 1.5.

3.1.5.6.3. The binary input status signals

The line thermal replica protection function has a binary input signal that serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

The other binary input signal serves the purpose of resetting the stored temperature (supports testing the function). **The conditions of resetting the temperature are defined by the user, applying the graphic equation editor.**

| Binary input signal | Explanation |
|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TTR49L_Blk_GrO_ | Output status of a graphic equation defined by the user to disable the line thermal protection function. |
| TTR49L_Reset_GrO_ | Output status of a graphic equation defined by the user to reset the accumulated heat and set the temperature to the defined value for the subsequent heating test procedure. |

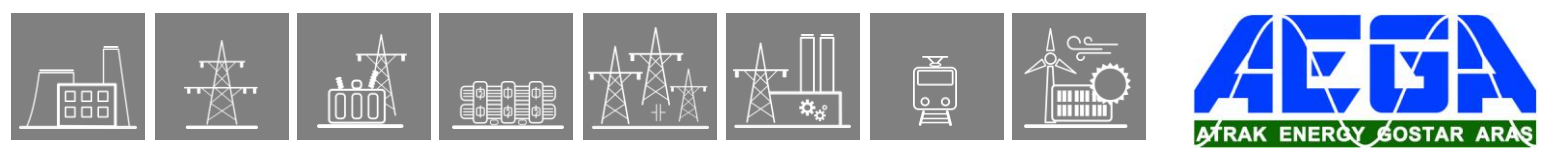
Table 1-8 The binary input signal of the line thermal protection function

3.1.5.6.4. Binary output status signals

The **binary output status signals** of the restricted earth-fault protection function are listed in Table 1-9.

| Binary output signals | Signal title | Explanation |
|-----------------------|----------------|----------------------------------------------------------------------|
| TTR49L_Alm_GrI_ | Alarm | Alarm signal of the line thermal protection function |
| TTR49L_GenTr_GrI_ | General Trip | General trip signal of the line thermal protection function |
| TTR49L_Lock_GrI_ | Reclose locked | Line reclose blocking signal of the line thermal protection function |

Table 1-9 The binary output status signals of the line thermal protection function



3.1.5.6.5. The function block

The function block of the line thermal protection function is shown in Figure 1-5. This block shows all binary input and output status signals that are applicable in the graphic equation editor.

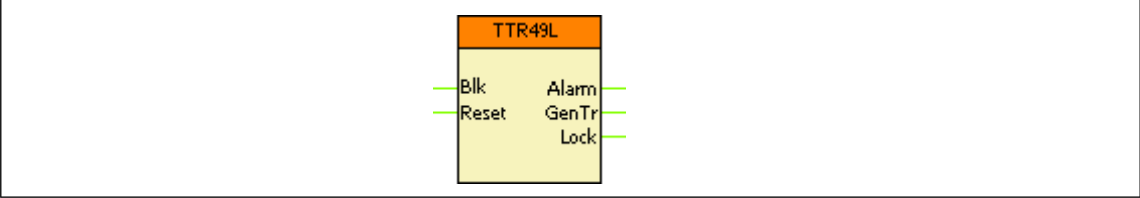


Figure 1-5 The function block of the line thermal protection function



3.1.6. Three-phase instantaneous Overcurrent Protection

3.1.6.1. Application

The instantaneous overcurrent protection function operates according to instantaneous characteristics, using the three sampled phase currents. The setting value is a parameter, and it can be doubled by graphic programming of the dedicated input binary signal.

The basic calculation can be based on peak value selection or on Fourier basic harmonic calculation, according to the parameter setting. When Fourier calculation is selected then the accuracy of the operation is high, the operation time however is above one period of the network frequency. If the operation is based on peak values, then fast sub-cycle operation can be expected, but the transient overreach can be high.

3.1.6.1.1. Operating Characteristics

$$t(I) = t_{OP} \text{ when } I > I_s$$

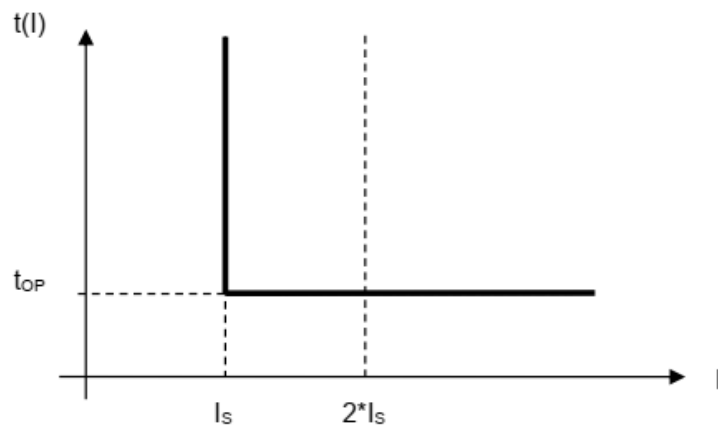


Figure 1-1 Overcurrent independent time characteristic

where:

- t_{OP} (sec.) theoretical operating time if $I > I_{Gs}$ (without additional time delay),
- I measured value of the characteristic quantity, peak values or Fourier base harmonic of the phase currents,
- I_s setting value of the characteristic quantity (*Start current*)

3.1.6.1.2. Structure of the Protection Algorithm

Figure 1-2 shows the structure of the instantaneous overcurrent protection (IOC50) algorithm.

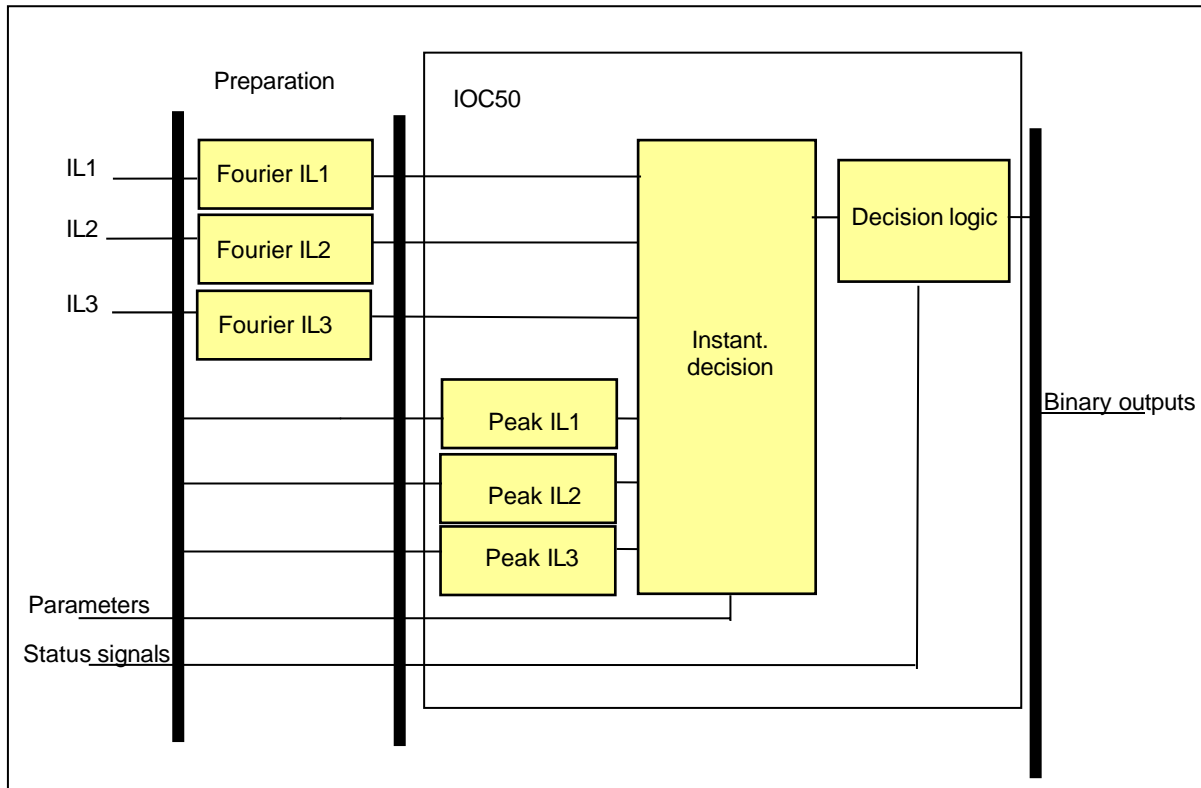


Figure 1-2 Structure of the instantaneous overcurrent protection algorithm

The **inputs** are

- the sampled values of three phase currents,
- the RMS values of the fundamental Fourier component of three phase currents,
- parameters,
- status signals.

The **outputs** are

- the binary output status signals.

The **software modules** of the three-phase instantaneous overcurrent protection function are:

Fourier calculations

These modules calculate the RMS values of the fundamental Fourier component of three phase currents individually (not part of the IOC50 function).

Peak selection

These modules select the peak values of the phase currents individually.

Instantaneous decision

This module compares the peak value or the Fourier basic harmonic components of the phase currents with the setting value.

Decision logic

The decision logic modules generate the trip command of the function.

3.1.6.1.3. The Fourier Calculation (Fourier)

The following description explains the details of the individual components.

These modules calculate the RMS values of the fundamental Fourier component of the three phase currents individually. They are not part of the IOC50 function; they belong to the preparatory phase.

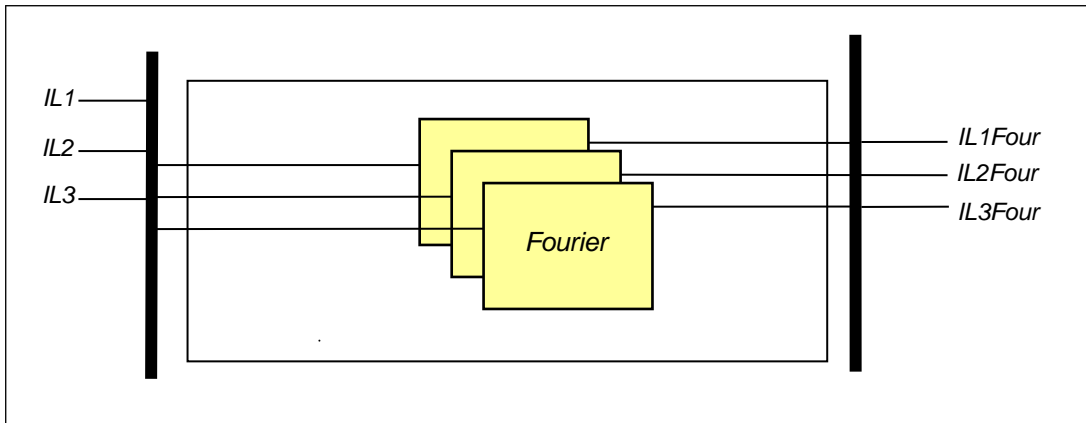


Figure 1-3 Principal scheme of the Fourier calculation

The **inputs** are the sampled values of the three phase currents (IL1, IL2, IL3).

The **outputs** are the RMS values of the fundamental Fourier component of three phase currents (IL1Four, IL2Four, IL3Four).

3.1.6.1.4. The Peak Selection (Peak selection)

These modules select the peak values of the phase currents individually.

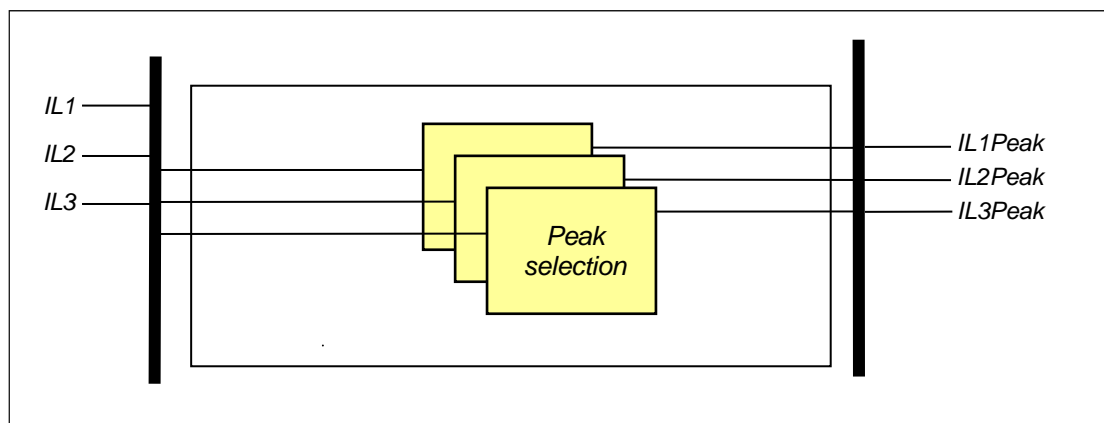


Figure 1-4 Principal scheme of the peak selection

The **inputs** are the sampled values of the three phase currents (IL1, IL2, IL3).

The **outputs** are the peak values of the analyzed currents (IL1Peak, IL2 Peak, IL3 Peak).

3.1.6.1.5. The Instantaneous Decision (Instantaneous decision)

This module generates trip commands for the phases without additional time delay based on the Fourier components of the phase currents or based on the peak values, if the detected values are above the current setting value.

The **inputs** are the RMS values of the fundamental Fourier component of three phase currents (IL1Four, IL2Four, IL3Four), the peak values (IL1Peak, IL2 Peak, IL3 Peak), parameters and status signals.

The **outputs** are the status signals of the three phases individually. These indicate the generated trip commands if the currents are above the current setting value.

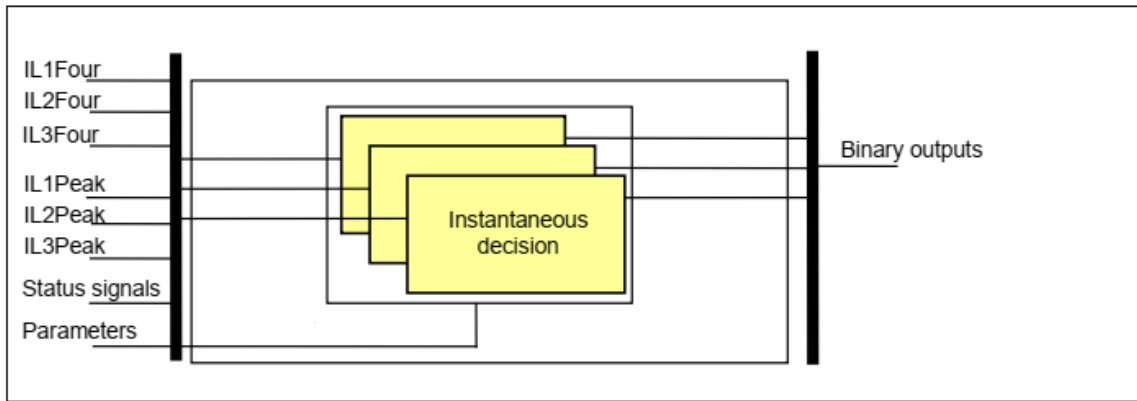


Figure 1-5 Principal scheme of the instantaneous characteristic calculation

Enumerated parameters

Table 1-1 The enumerated parameters of the instantaneous OC protection function

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|-----------|-----|------------------------------------|------|---------|---------------------------------------------------------|
| Operation | - | Off, Peak value, Fundamental value | - | Off | Parameter for enabling the function and selection type. |

Integer parameters

Table 1-2 The integer parameter of the instantaneous OC protection function

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|---------------|-----|-----------|------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Start Current | % | 20 – 3000 | 1 | 200 | Start setting of the function. If the current exceeds this value, the function picks up and trips after the minimum operation time of the relay (t_{OP}). |

Binary status signals

The decision block of the instantaneous overcurrent protection function has binary input signals, which serve the purpose of blocking the function and doubling the setting value of the function.

The conditions are defined by the user, applying the graphic equation editor.

Table 1-3 The binary input signals for the decision block of the IOC protection function

| BINARY STATUS SIGNAL | SIGNAL TITLE | EXPLANATION |
|----------------------|--------------|------------------------------------------------------------------|
| IOC50_Blk_GrO_ | Block | Input for disabling the function |
| IOC50_Double_GrO_ | Double | Input used to double the value of the parameter “Start Current”. |

The **binary output status signals** of the three-phase instantaneous overcurrent protection function are listed in Table 1-4 below.

Table 1-4 The binary output status signals of the IOC protection function

| BINARY OUTPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|----------------------|--------------|------------------------------------------|
| IOC50_TrL1_GrI_ | Trip L1 | Trip command of the function in phase L1 |
| IOC50_TrL2_GrI_ | Trip L2 | Trip command of the function in phase L2 |
| IOC50_TrL3_GrI_ | Trip L3 | Trip command of the function in phase L3 |

3.1.6.1.6. The Decision Logic (Decision logic)

The decision logic module combines the status signals to generate the general trip command of the function.

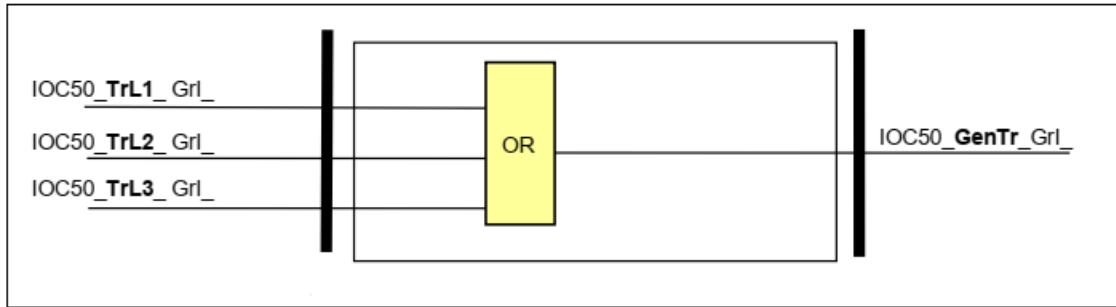


Figure 1-6 The logic scheme of the instantaneous overcurrent protection function

Table 1-5 The binary input status signals of the decision logic

| BINARY INPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|---------------------|--------------|------------------------------------------|
| IOC50_TrL1_Grl_ | Trip L1 | Trip command of the function in phase L1 |
| IOC50_TrL2_Grl_ | Trip L2 | Trip command of the function in phase L2 |
| IOC50_TrL3_Grl_ | Trip L3 | Trip command of the function in phase L3 |

Table 1-6 The binary output status signal of the decision logic

| BINARY OUTPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|----------------------|--------------|--------------------------------------|
| IOC50_GenTr_Grl_ | General Trip | General trip command of the function |

3.1.6.2. 3-Phase Instantaneous OC Function Overview

The graphic appearance of the 3-phase instantaneous overcurrent protection function block is shown in Figure 2-1. This block shows all binary input and output status signals that are applicable in the graphic equation editor.

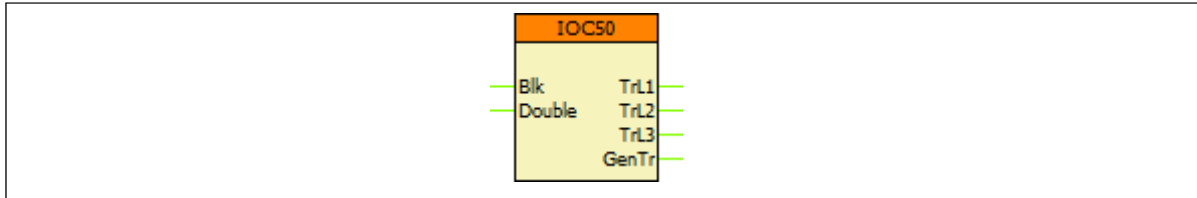


Figure 2-1 The function block of the 3-phase instantaneous overcurrent protection

3.1.6.2.1. Settings

3.1.6.2.1.1. Parameters

The available parameters are listed below in order of their appearance in the *parameters* menu. If the setting range of a parameter should be extended, contact Protecta Support.

Table 2-1 Parameters of the 3-phase instantaneous overcurrent protection function

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|---------------|-----|------------------------------------|------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Operation | - | Off, Peak value, Fundamental value | - | Off | Parameter for enabling the function and selection type. |
| Start Current | % | 20 – 3000 | 1 | 200 | Start setting of the function. If the current exceeds this value, the function picks up and trips after the minimum operation time of the relay (t_{OP}). |

3.1.6.2.2. Function I/O

This section briefly describes the analogue and digital inputs and outputs of the function block.

3.1.6.2.2.1. Analogue inputs

The analogue inputs are the RMS values of the fundamental Fourier component of the three phase currents.

3.1.6.2.2.2. Binary input signals (graphed output statuses)

The conditions of the binary inputs are defined by the user, applying the graphic equation editor (*Logic Editor*). Parts written in **bold** are seen on the left side of the function block in the Logic editor.

Table 2-2 The binary input signals of the 3ph IOC function

| BINARY INPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|----------------------------|--------------|------------------------------------------------------------------|
| IOC50_ Blk _GrO_ | Block | Input for disabling the function |
| IOC50_ Double _GrO_ | Double | Input used to double the value of the parameter "Start Current". |

3.1.6.2.2.3. Binary output signals (graphed input statuses)

These signals can be used in EuroCAP to assign to LED, user LCD object etc. Parts written in **bold** are seen on the right side of the function block in the *Logic Editor*.

Table 2-3 The binary output signals of the 3ph IOC function

| BINARY OUTPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|---------------------------|--------------|------------------------------------------------------------------|
| IOC50_ TrL1 _GrI_ | Trip L1 | Trip command of the function in phase L1 |
| IOC50_ TrL2 _GrI_ | Trip L2 | Trip command of the function in phase L2 |
| IOC50_ TrL3 _GrI_ | Trip L3 | Trip command of the function in phase L3 |
| IOC50_ GenTr _GrI_ | General Trip | Trip command of the function in at least one of the three phases |

3.1.6.2.2.4. Online data

The following values are visible in the *online data* page.

Table 2-4 Online data of the 3ph IOC function

| SIGNAL TITLE | DIMENSION | EXPLANATION |
|--------------|-----------|------------------------------------------------------------------|
| Trip L1 | - | Trip command of the function in phase L1 |
| Trip L2 | - | Trip command of the function in phase L2 |
| Trip L3 | - | Trip command of the function in phase L3 |
| General Trip | - | Trip command of the function in at least one of the three phases |

3.1.6.2.2.5. Events

The following events are generated in the event list, as well as sent to the SCADA according to the configuration.

Table 2-5 Generatable events of the 3ph IOC function

| EVENT | VALUE | EXPLANATION |
|--------------|---------|------------------------------------------------------------------|
| Trip L1 | off, on | Trip command of the function in phase L1 |
| Trip L2 | off, on | Trip command of the function in phase L2 |
| Trip L3 | off, on | Trip command of the function in phase L3 |
| General Trip | off, on | Trip command of the function in at least one of the three phases |

3.1.6.2.3. Technical Data

Table 2-6 Technical data of the 3-phase IOC protection function

| FUNCTION | VALUE | ACCURACY |
|-------------------------------------------------------|---------------|----------|
| <i>Using peak value calculation</i> | | |
| Operating characteristic | Instantaneous | < 6% |
| Reset ratio | 0.85 | |
| Operate time at 2*Is | < 15 ms | |
| Reset time* | < 40 ms | |
| Transient overreach | 90% | |
| <i>Using Fourier fundamental harmonic calculation</i> | | |
| Operating characteristic | Instantaneous | < 2% |
| Reset ratio | 0.85 | |
| Operate time at 2*Is | < 25 ms | |
| Reset time* | < 60 ms | |
| Transient overreach | 15% | |

* Measured with signal contacts

3.1.6.2.4. Notes for Testing

Normally in the EuroProt+ devices the trip contacts are assigned to the Trip Logic function block, and not to the protection function blocks. Because of this, the testing personnel must make sure that the Trip Logic is switched on ('Operation' parameter is set to other than 'Off') before starting the tests, otherwise there will be no physical trip on the relay.

Being an instantaneous function, its connection to the Trip Logic function is done in the Fast Equations (by default) and not in the Logic Editor (usually, there are comments inserted in the Logic Editor if such connections exist). This can be checked in EuroCAP.

The analogue sources can be changed by the user (i.e. if there are multiple CT modules in a device, it might be possible to assign the measurements of either CT module to the function's inputs). This can be checked in the function block properties in EuroCAP.

3.1.7. Residual Instantaneous Overcurrent Protection

3.1.7.1. Application

The residual instantaneous overcurrent protection function operates according to instantaneous characteristics, using the residual current ($I_N=3I_0$). The setting value is a parameter, and it can be doubled by a binary input signal defined by the user, applying the graphic programming.

The basic calculation can be based on peak value selection or on the RMS values of the fundamental Fourier component of the residual current, according to the parameter setting. When Fourier calculation is selected then the accuracy of the operation is high, the operation time, however, is above one period of the network frequency. If the operation is based on peak values, then fast sub-cycle operation can be expected, but the transient overreach can be high.

3.1.7.1.1. Operating Characteristics

$$t(I) = t_{OP} \text{ when } I > I_S$$

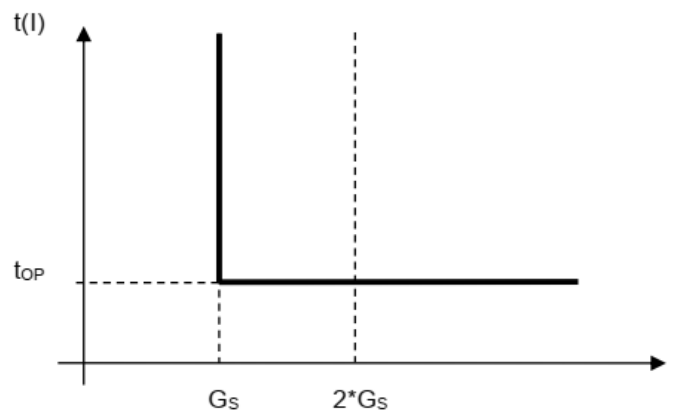


Figure 1-1 Overcurrent independent time characteristic

where:

- t_{OP} (sec.) theoretical operating time if $G > G_s$ (without additional time delay),
- G measured value of the characteristic quantity, peak values or Fourier base harmonic of the phase currents,
- G_s setting value of the characteristic quantity (*Start current*)

3.1.7.1.2. Structure of the Protection Algorithm

Figure 1-2 shows the structure of the residual instantaneous overcurrent protection (IOC50N) algorithm.

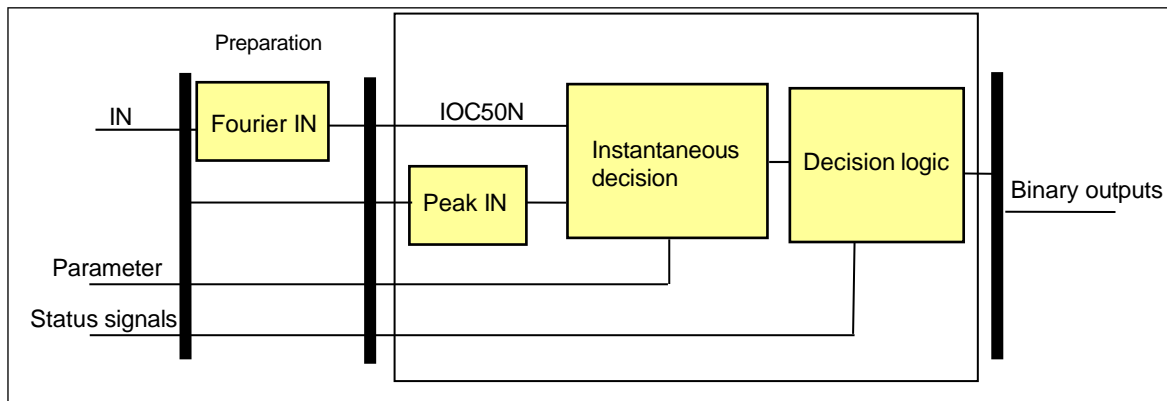


Figure 1-2 Structure of the residual instantaneous overcurrent protection algorithm

The **inputs** are

- the sampled values of the residual current,
- the RMS value of the fundamental Fourier component of the residual current,
- parameters,
- status signals.

The **outputs** are

- the binary output status signals.

The **software modules** of the differential protection function are:

Fourier calculation

This module calculates the basic Fourier current components of the residual current. It is not part of the residual instantaneous overcurrent protection function; it belongs to the preparatory phase.

Peak selection

This module selects the peak value of the residual current.

Instantaneous decision

This module compares the peak value or the Fourier basic harmonic components of the residual current with the setting value.

Decision logic

The decision logic modules generate the trip command of the function.

The following description explains the details of the individual components.

3.1.7.1.3. The Fourier Calculation (Fourier)

This module calculates the basic Fourier current components of the residual current. It is not part of the residual instantaneous overcurrent protection function; it belongs to the preparatory phase.

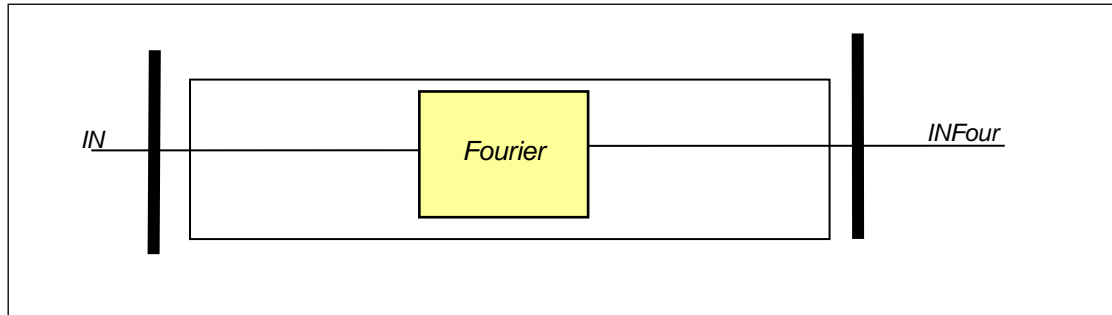


Figure 1-3 Principal scheme of the Fourier calculation

The **inputs** are the sampled values of the residual current (IN).

The **output** is the RMS value of the fundamental Fourier component of the residual current (INFour).

3.1.7.1.4. The Peak Selection (Peak selection)

This module selects the peak values of the residual current.

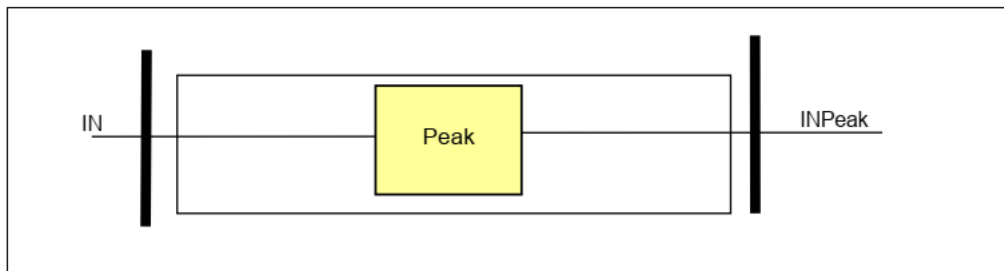


Figure 1-4 Principal scheme of the peak selection

The **inputs** are the sampled values of the residual current (IN).

The **outputs** are the peak values of the analyzed current (INPeak).

3.1.7.1.5. The Instantaneous Decision (Instantaneous decision)

This module generates an internal trip command without additional time delay based on the Fourier components of the residual current, or based on the peak values if the detected values are above the current setting value.

The **inputs** are the basic Fourier components of the residual current (INFour), the peak values (INPeak), parameters and status signals.

The **outputs** are the status signals. These indicate the generated internal trip command if the current is above the current setting value.

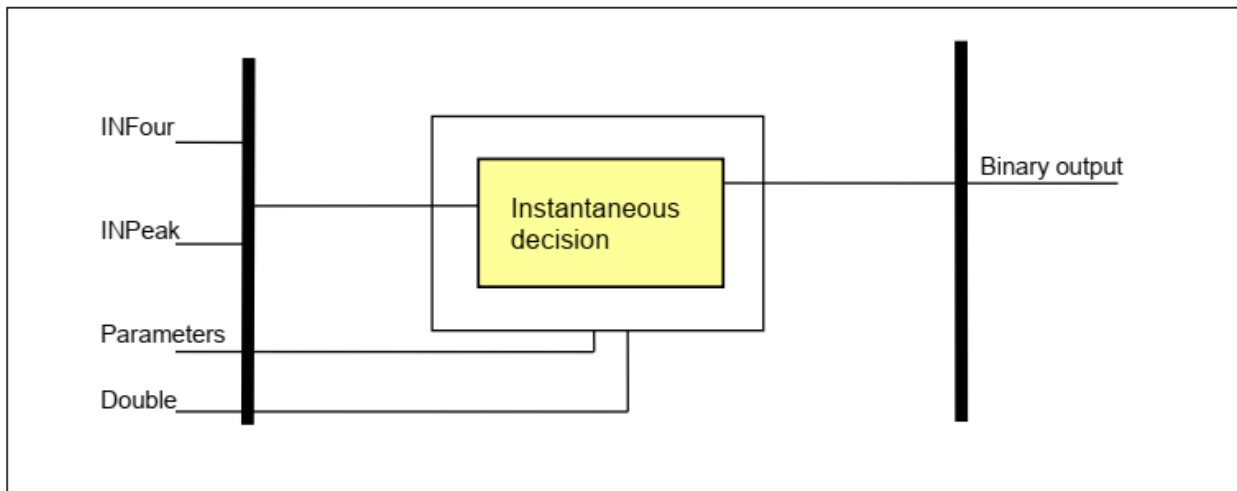


Figure 1-5 Principal scheme of the residual instantaneous characteristic calculation

Enumerated parameters

Table 1-1 The enumerated parameters of the residual IOC protection function

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|-----------|-----|------------------------------------|------|---------|---------------------------------------------------------|
| Operation | - | Off, Peak value, Fundamental value | - | Off | Parameter for enabling the function and selection type. |

Integer parameters

Table 1-2 The integer parameters of the residual IOC protection function

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|---------------|-----|------------|------|---------|--------------------------------|
| Start Current | % | 20 – 3000* | 1 | 200 | Setting value of the function. |

Binary status signals

The decision block of the residual instantaneous overcurrent protection function has a binary input signal, which serves the purpose of doubling the setting value of the function. **The conditions are defined by the user, applying the graphic equation editor.**

Table 1-3 The binary input signals for the decision block of the residual IOC protection function

| BINARY STATUS SIGNAL | SIGNAL TITLE | EXPLANATION |
|----------------------|--------------|------------------------------------------------------------------|
| IOC50N_Double_GrO_ | Double | Input used to double the value of the parameter "Start Current". |

The **binary output status signal** of the residual instantaneous overcurrent protection function is shown in Table 1-4.

Table 1-4 The binary output status signal of the residual IOC protection function

| BINARY OUTPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|----------------------|---------------------|---------------------------------------|
| IOC50N_TrN_ | Trip N _i | Internal trip command of the function |

3.1.7.1.6. The Decision Logic (Decision logic)

The decision logic module combines the status signal binary and the binary parameter to generate the general trip command of the function.

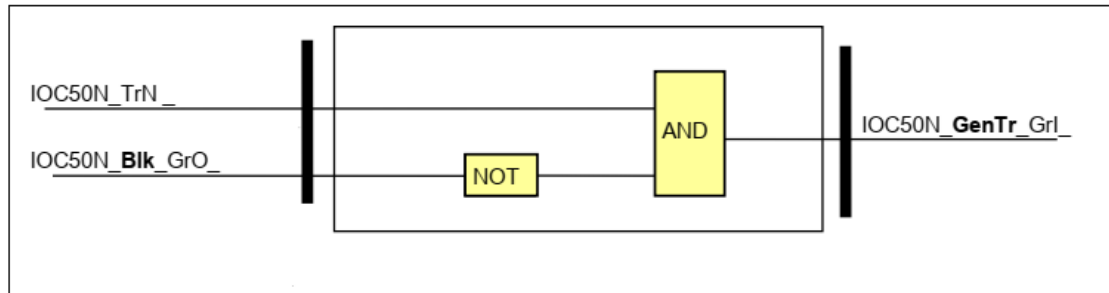


Figure 1-6 The logic scheme of the residual IOC protection function

Table 1-5 The binary input status signal of the residual IOC protection function

| BINARY INPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|---------------------|--------------|---------------------------------------|
| IOC50N_TrN_ | Trip N | Internal trip command of the function |

Binary status signal

The residual instantaneous overcurrent protection function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

Table 1-6 The binary input signal of the residual IOC protection function

| BINARY STATUS SIGNAL | SIGNAL TITLE | EXPLANATION |
|----------------------|--------------|----------------------------------|
| IOC50N_Blk_GrO_ | Block | Input for disabling the function |

Table 1-7 The binary output status signal of the decision logic

| BINARY OUTPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|----------------------|--------------|--------------------------------------|
| IOC50N_GenTr_GrI_ | General Trip | General trip command of the function |

3.1.7.2. Residual Instantaneous OC Function Overview

The graphic appearance of the residual instantaneous overcurrent protection function block is shown in Figure 2-1. This block shows all binary input and output status signals that are applicable in the graphic equation editor.

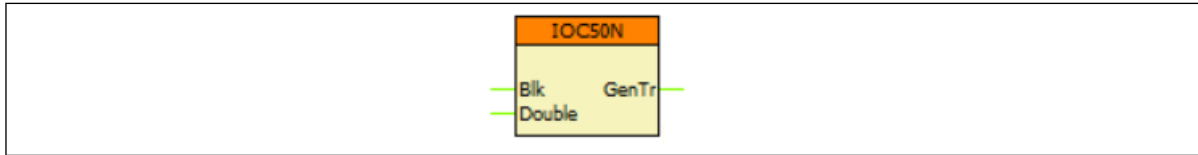


Figure 2-1 The function block of the residual instantaneous overcurrent protection

3.1.7.2.1. Settings

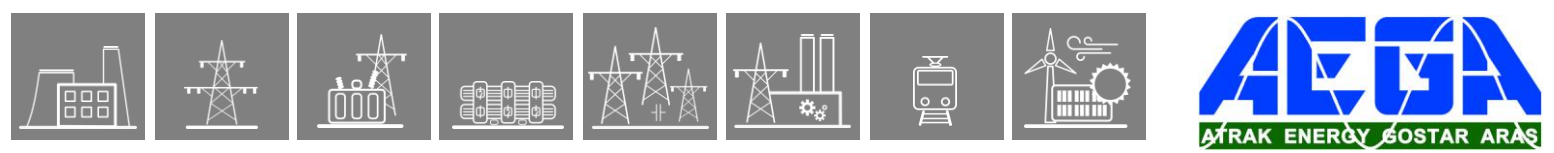
3.1.7.2.1.1. Parameters

The available parameters are listed below in order of their appearance in the *parameters* menu. If the setting range of a parameter should be extended, contact Protecta Support.

Table 2-1 Parameters of the residual instantaneous overcurrent protection function

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|---------------|-----|------------------------------------|------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Operation | - | Off, Peak value, Fundamental value | - | Off | Parameter for enabling the function and selection type. |
| Start Current | % | 10 – 1000* | 1 | 200 | Start value of the function, if the current exceeds this value, the function picks up and trips after the minimum operation time of the relay (t_{OP}). |

*extendable to 3000 when using CT+/5151 module



3.1.7.2.2. Function I/O

This section briefly describes the analogue and digital inputs and outputs of the function block.

3.1.7.2.2.1. Analogue inputs

The analogue inputs are the sampled values of the residual current.

3.1.7.2.2.2. Binary input signals (graphed output statuses)

The conditions of the binary inputs are defined by the user, applying the graphic equation editor (*Logic Editor*). Parts written in **bold** are seen on the left side of the function block in the Logic editor.

Table 2-2 The binary input signals of the residual IOC function

| BINARY INPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|-----------------------------|--------------|------------------------------------------------------------------|
| IOC50N_ Blk _GrO_ | Block | Input for disabling the function |
| IOC50N_ Double _GrO_ | Double | Input used to double the value of the parameter "Start Current". |

3.1.7.2.2.3. Binary output signals (graphed input statuses)

These signals can be used in EuroCAP to assign to LED, user LCD object etc. Parts written in **bold** are seen on the right side of the function block in the *Logic Editor*.

Table 2-3 The binary output signals of the residual IOC function

| BINARY OUTPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|----------------------------|--------------|--------------------------------------|
| IOC50N_ GenTr _GrI_ | General Trip | General trip command of the function |

3.1.7.2.2.4. Online data

The following values are visible in the *online data* page.

Table 2-4 Online data of the residual IOC function

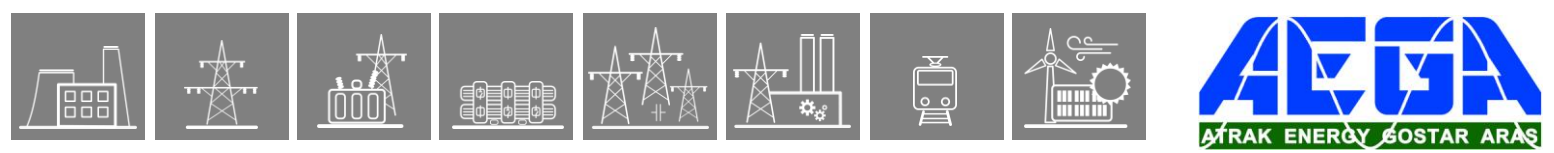
| SIGNAL TITLE | DIMENSION | EXPLANATION |
|--------------|-----------|--------------------------------------|
| General Trip | - | General trip command of the function |

3.1.7.2.2.5. Events

The following events are generated in the event list, as well as sent to the SCADA according to the configuration.

Table 2-5 Generatable events of the residual IOC function

| EVENT | VALUE | EXPLANATION |
|--------------|---------|--------------------------------------|
| General Trip | off, on | General trip command of the function |



3.1.7.2.3. Technical Data

Table 2-6 Technical data of the residual IOC protection function

| FUNCTION | VALUE | ACCURACY |
|-------------------------------------------------------|---------------|----------|
| <i>Using peak value calculation</i> | | |
| Operating characteristic ($I > 0.1I_n$) | Instantaneous | < 6% |
| Reset ratio | 0.85 | |
| Operate time at 2*Is | < 15 ms | |
| Reset time* | < 40 ms | |
| Transient overreach | 85% | |
| <i>Using Fourier fundamental harmonic calculation</i> | | |
| Operating characteristic ($I > 0.1I_n$) | Instantaneous | < 3% |
| Reset ratio | 0.85 | |
| Operate time at 2*Is | < 25 ms | |
| Reset time* | < 60 ms | |
| Transient overreach | 15% | |

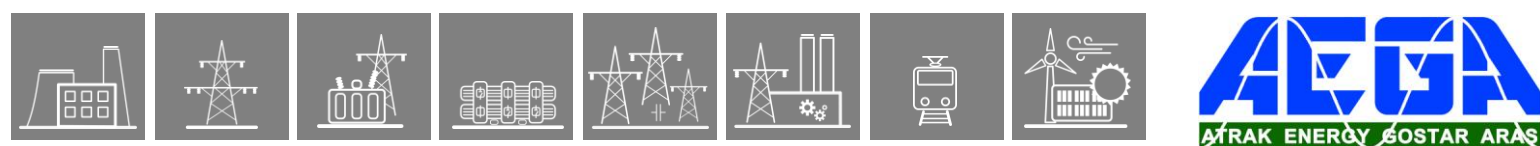
* Measured with signal contacts

3.1.7.2.4. Notes for Testing

Normally in the EuroProt+ devices the trip contacts are assigned to the Trip Logic function block, and not to the protection function blocks. Because of this, the testing personnel must make sure that the Trip Logic is switched on ('Operation' parameter is set to other than 'Off') before starting the tests, otherwise there will be no physical trip on the relay.

Being an instantaneous function, its connection to the Trip Logic function is done in the Fast Equations (by default) and not in the Logic Editor (usually, there are comments inserted in the Logic Editor if such connections exist). This can be checked in EuroCAP.

As the analogue sources can be changed by the user, it is possible to assign calculated or measured residual current to the input of the function block. This can be checked in the function block properties in EuroCAP.



3.1.8. Breaker failure protection

3.1.8.1. Application

After a protection function generates a trip command, it is expected that the circuit breaker opens and the fault current drops below the pre-defined normal level.

If not, then an additional trip command must be generated for all backup circuit breakers to clear the fault. At the same time, if required, a repeated trip command can be generated to the circuit breaker(s) which are expected to open.

The breaker failure protection function can be applied to perform this task.

In EuroProt+ product family two versions of breaker failure protection function can be applied:

“BRF50” – Breaker Failure:

This version of the breaker failure protection can be applied to perform the task to give command to the backup circuit breakers. It can be applied if only common-phase handling is sufficient, and phase selectivity is not required.

BRF50SP

“BRF50SP” - Single-pole Breaker Failure:

If repeated trip command (retrip) is needed besides the backup trip, this version of breaker failure protection function must be used.

Both versions of breaker failure protection function receive the trip requirements of the protective functions implemented in the device and combines the binary signals and parameters to the outputs of the device.

3.1.8.1.1. Mode of operation

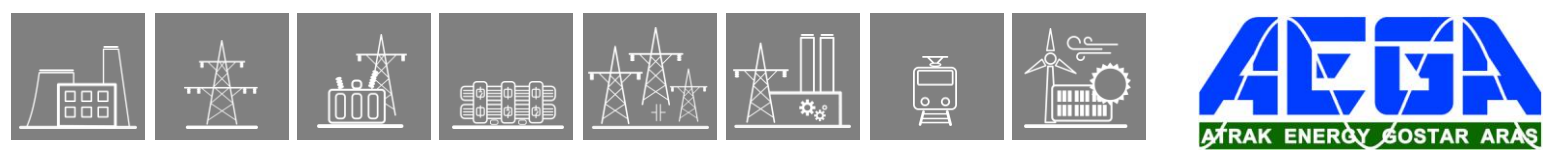
The starting signal of the breaker failure protection function is usually the trip command of any other protection function. The user has the task to define these starting signals using the graphic equation editor as the “General Start” (BRF50_GenSt_GrO_), or if the operation of the individual phases is needed, then the start signals for the phases individually.

The phase start signals are: “Start L1” (BRF50_StL1_GrO_), “Start L2” (BRF50_StL2_GrO_) and “Start L3” (BRF50_StL3_GrO_).

Dedicated timers start at the rising edge of the start signals, one for the backup trip command and one for the repeated trip command, separately for operation in the individual phases. During the running time of the timers the function optionally monitors the currents, the closed state of the circuit breakers or both, according to the user’s choice. The selection is made using the enumerated parameter “Operation”:

- If this parameter setting is “Current”, the current limit values “Start Ph Current” and “Start Res Current” must be set correctly. The binary input indicating the status of the circuit breaker has no meaning.
- If this parameter setting is “Contact”, the current limit values “Start current Ph” and “Start current N” have no meaning. The binary input indicating the status of the circuit breaker must be programmed correctly using the graphic equation editor.
 - By using “BRF50” variant: the input variable to be programmed is: BRF50_CBClosed_GrO_ (CB Closed),
 - By using “BRF50SP” variant: the input variables to be programmed are: BRF50_CBCIL1_GrO_ (CB closed L1), BRF50_CBCIL2_GrO_ (CB closed L2) and BRF50_CBCIL3_GrO_ (CB closed L3).
- If this parameter setting is “Current/Contact”, the current parameters and the status signal must be set correctly. The breaker failure protection function resets only if all conditions for faultless state are fulfilled.

BRF50SP



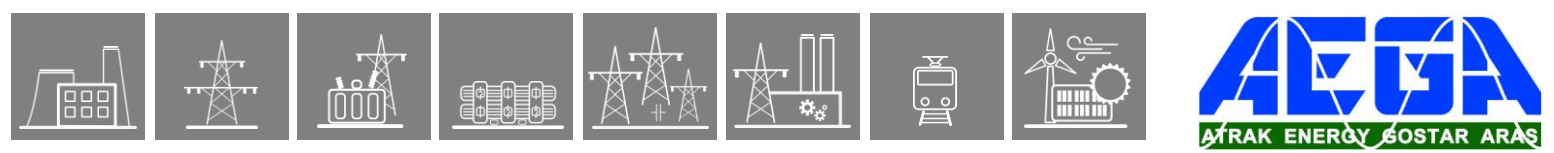
- The breaker failure protection function can be disabled by setting this parameter to “Off”. If at the end of the running time of the backup timer the currents do not drop below the pre-defined level, and/or the monitored circuit breaker is still in closed position, then a backup trip command is generated. The time delay is defined using the parameter “Backup Time Delay”.

The pulse duration of the trip command is not shorter than the time defined by setting the parameter “Pulse Duration”.

If repeated trip command is to be generated for the circuit breakers that are expected to open, then the enumerated parameter “Retrip” must be set to “On”. In this case, at the end of the retrip timer(s) the delay of which is set by the timer parameter “Retrip Time Delay”, a repeated trip command is also generated in the phase(s) where the backup timer(s) run off.

BRF50SP

Dynamic blocking is possible using the binary input BRF50_ **Bik**_GrO_ (Block). The conditions are to be programmed by the user, using the graphic equation editor.



3.1.8.1.2. Operation principles

The decision logic module combines status signals, binary and enumerated parameters to generate the backup trip signal.

Binary status signals

The breaker failure protection function has binary input signals. **The conditions are defined by the user, applying the graphic equation editor.**

The **binary input status signals** of the breaker failure protection function are listed in Table 1-1.

Table 1-1 The binary input status signals of the decision logic

| BINARY STATUS SIGNAL | TITLE | EXPLANATION |
|----------------------|-----------------|-----------------------------------------------------------------------|
| BRF50_BIk_GrO_ | Block | Blocking of the breaker failure protection function |
| BRF50_CBClosed_GrO_ | CB closed | Signal indicating the closed state of the circuit breaker |
| BRF50SP_CBCIL1_GrO_ | CB closed L1 | Signal indicating the closed state of the circuit breaker in phase L1 |
| BRF50SP_CBCIL2_GrO_ | CB closed L2 | Signal indicating the closed state of the circuit breaker in phase L2 |
| BRF50SP_CBCIL3_GrO_ | CB closed L3 | Signal indicating the closed state of the circuit breaker in phase L3 |
| BRF50_GenSt_GrO_ | General Start | General starting signal |
| BRF50SP_StL1_GrO_ | Start L1 | Starting signal in phase L1 |
| BRF50SP_StL2_GrO_ | Start L2 | Starting signal in phase L2 |
| BRF50SP_StL3_GrO_ | Start L3 | Starting signal in phase L3 |
| BRF50_IoSt_GrO_ | Start Io | Starting signal for the residual current |
| Internal signal: | IL1> | Current in phase L1 is above the preset parameter value |
| Internal signal: | IL2> | Current in phase L2 is above the preset parameter value |
| Internal signal: | IL3> | Current in phase L3 is above the preset parameter value |
| Internal signal: | Io> | Current 3Io is above the preset parameter value |
| Enumerated parameter | Current/Contact | The monitored condition is current, contact or both |

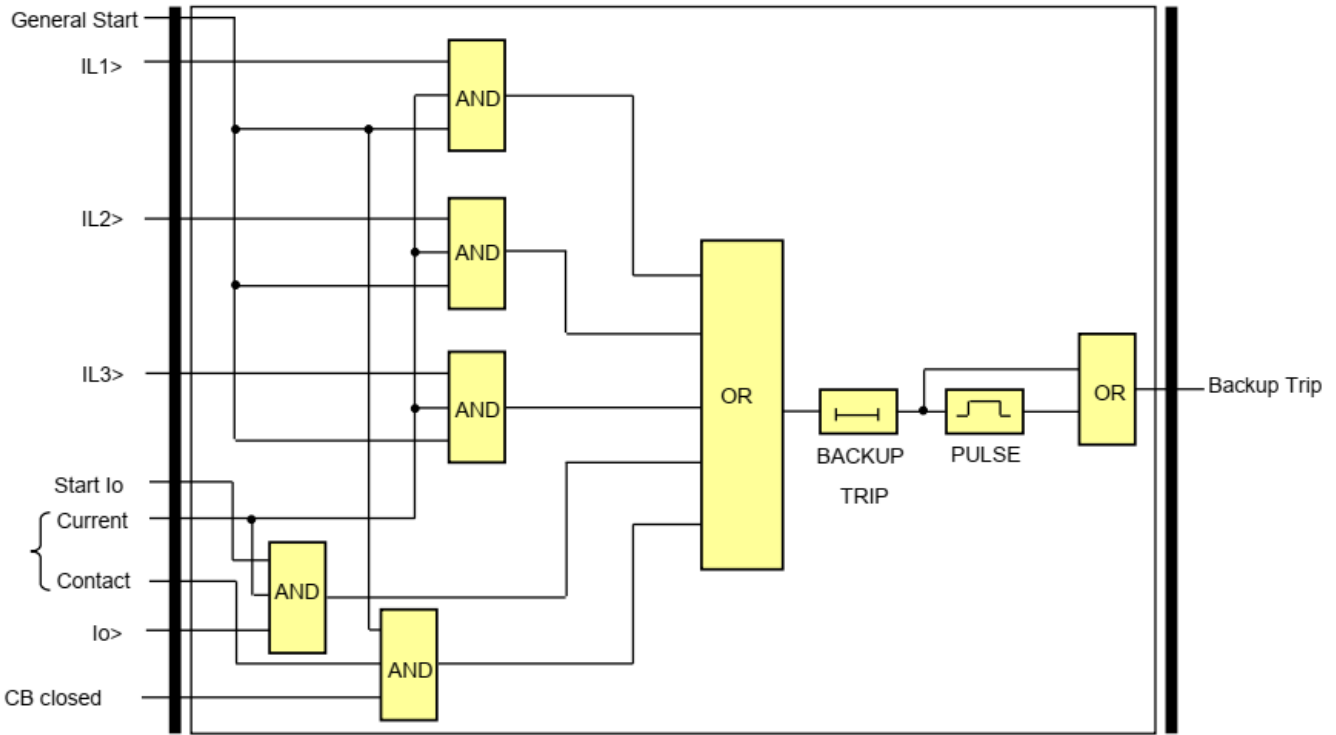


Figure 1-1 The logic scheme of the decision logic of "BRF50" variant

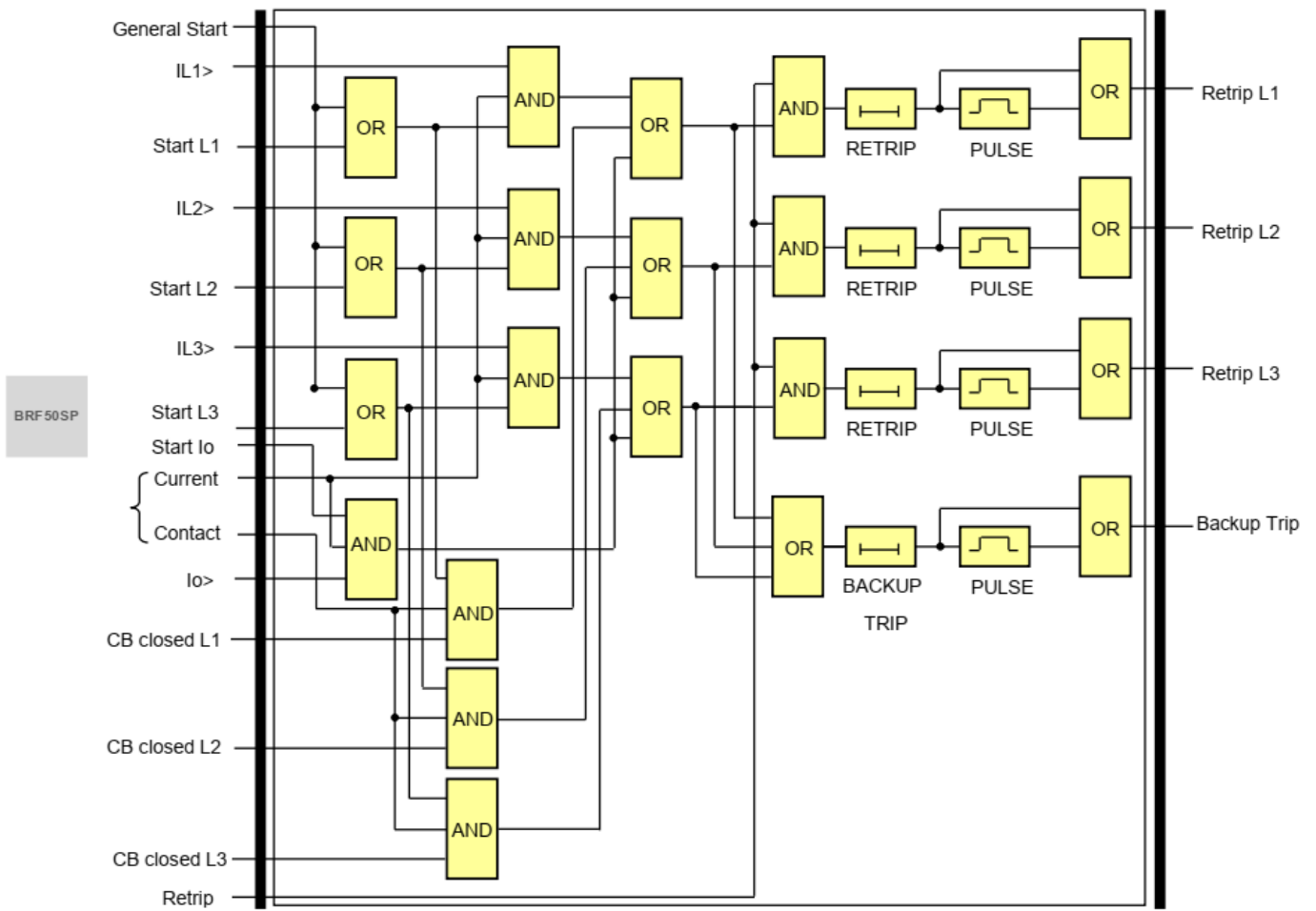
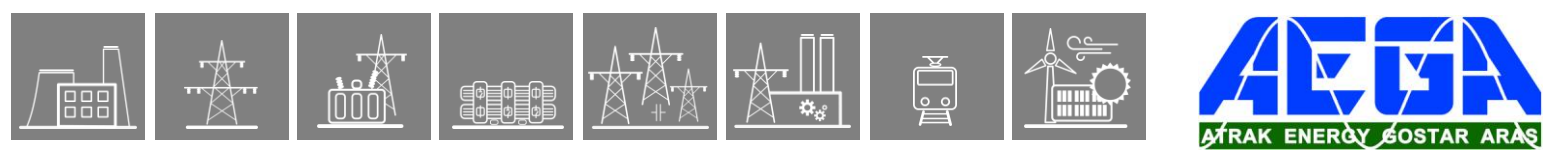


Figure 1-2 The logic scheme of the decision logic of "BRF50SP" variant



The **binary output status signals** of the breaker failure protection function is detailed in Table 1-2.

Table 1-2 The binary output status signal of the decision logic

BRF50SP

| BINARY STATUS SIGNAL | TITLE | EXPLANATION |
|-----------------------------|------------------|--------------------------------------------------------|
| BRF50_BuTr_Grl_ | Backup Trip | Trip command generated for the backup circuit breakers |
| BRF50_TrL1_Grl_ | <i>Retrip L1</i> | <i>Repeated trip command in phase L1</i> |
| BRF50_TrL2_Grl_ | <i>Retrip L2</i> | <i>Repeated trip command in phase L2</i> |
| BRF50_TrL3_Grl_ | <i>Retrip L3</i> | <i>Repeated trip command in phase L3</i> |

3.1.8.2. Breaker failure protection function overview

The graphic appearance of the variants the breaker failure protection function blocks are shown below. The blocks show all binary input and output status signals which are applicable in the graphic equation editor.

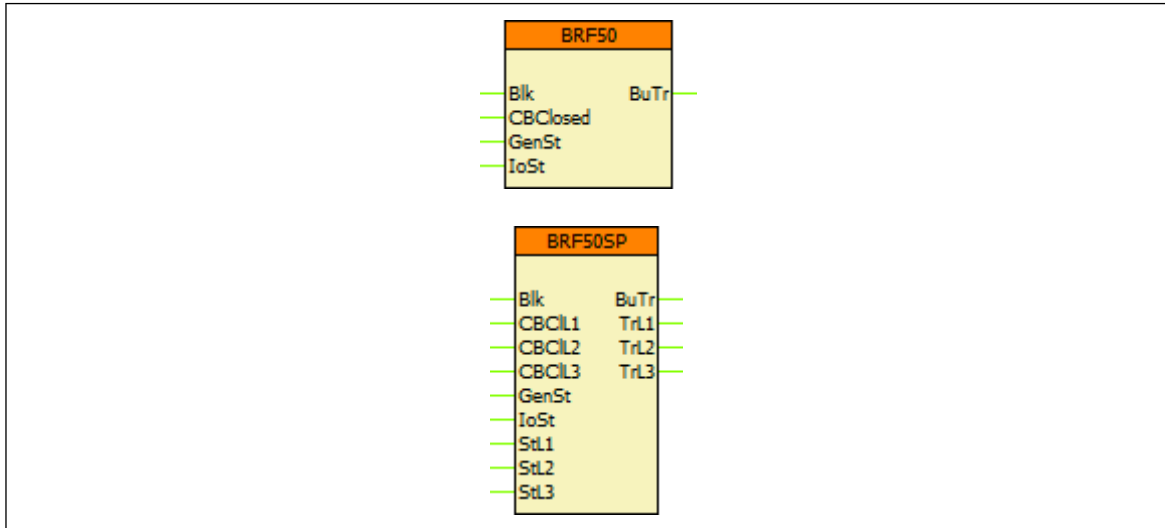


Figure 2-1 Graphic appearance of the variants of the breaker failure protection function block

3.1.8.2.1. Settings

3.1.8.2.1.1. Parameters

The available parameters are listed below in order of their appearance in the *parameters* menu. If the setting range of a parameter should be extended, contact Protecta Support.

Table 2-1 Parameters of the breaker failure protection function

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|---------------------------|------|----------------------------------------|------|---------|--------------------------------------------------------------------------|
| Operation | - | Off, Current, Contact, Current/Contact | - | Off | Enabling the function |
| BRF50SP Retrip | - | Off, On | - | Off | Enabling the retrip function |
| Start Ph Current | % | 20 – 200 | 1 | 30 | Phase current setting |
| Start Res Current | % | 10 – 200 | 1 | 20 | Residual current setting |
| BRF50SP Retrip Time Delay | msec | 0 – 1000 | 1 | 100 | Time delay for retrip command generation |
| Backup Time Delay | msec | 100 – 60000 | 1 | 1000 | Time delay for trip command generation for the backup circuit breaker(s) |
| Pulse Duration | msec | 0 – 60000 | 1 | 100 | Trip command impulse duration |

3.1.8.2.2. Function I/O

This section describes briefly the analogue and digital inputs and outputs of the function block.

3.1.8.2.2.1. Analogue inputs

The function uses the sampled values of a current input. This is defined in the configuration.

3.1.8.2.2.2. Binary input signals (graphed output statuses)

The conditions of the binary inputs are defined by the user, applying the graphic equation editor (*Logic Editor*). Parts written in **bold** are seen on the left side function block in the Logic editor.

Table 2-2 The binary input signals of the breaker failure protection functions

| BINARY STATUS SIGNAL | TITLE | EXPLANATION |
|------------------------------------|---------------------|------------------------------------------------------------------------------|
| BRF50_ Bi k_GrO_ | Block | Blocking of the breaker failure protection function |
| BRF50_ CB Closed_GrO_ | CB closed | Signal indicating the closed state of the circuit breaker |
| <i>BRF50SP_ CBCIL1_GrO_</i> | <i>CB closed L1</i> | <i>Signal indicating the closed state of the circuit breaker in phase L1</i> |
| <i>BRF50SP_ CBCIL2_GrO_</i> | <i>CB closed L2</i> | <i>Signal indicating the closed state of the circuit breaker in phase L2</i> |
| <i>BRF50SP_ CBCIL3_GrO_</i> | <i>CB closed L3</i> | <i>Signal indicating the closed state of the circuit breaker in phase L3</i> |
| BRF50_ Gen St_GrO_ | General Start | General starting signal |
| <i>BRF50SP_ StL1_GrO_</i> | <i>Start L1</i> | <i>Starting signal in phase L1</i> |
| <i>BRF50SP_ StL2_GrO_</i> | <i>Start L2</i> | <i>Starting signal in phase L2</i> |
| <i>BRF50SP_ StL3_GrO_</i> | <i>Start L3</i> | <i>Starting signal in phase L3</i> |
| BRF50_ Io St_GrO_ | Start Io | Starting signal for the residual current |

3.1.8.2.2.3. Binary output signals (graphed input statuses)

These signals can be used in EuroCAP to assign to LED, user LCD object etc. Parts written in **bold** are seen on the right side of the function block in the *Logic Editor*.

Table 2-3 The binary output signals of the breaker failure protection function

| BINARY STATUS SIGNAL | TITLE | EXPLANATION |
|--------------------------------|------------------|--------------------------------------------------------|
| BRF50_ Bu Tr_GrI_ | Backup Trip | Trip command generated for the backup circuit breakers |
| <i>BRF50_ TrL1_GrI_</i> | <i>Retrip L1</i> | <i>Repeated trip command in phase L1</i> |
| <i>BRF50_ TrL2_GrI_</i> | <i>Retrip L2</i> | <i>Repeated trip command in phase L2</i> |
| <i>BRF50_ TrL3_GrI_</i> | <i>Retrip L3</i> | <i>Repeated trip command in phase L3</i> |

3.1.8.2.2.4. Online data

Visible values on the *online data* page.

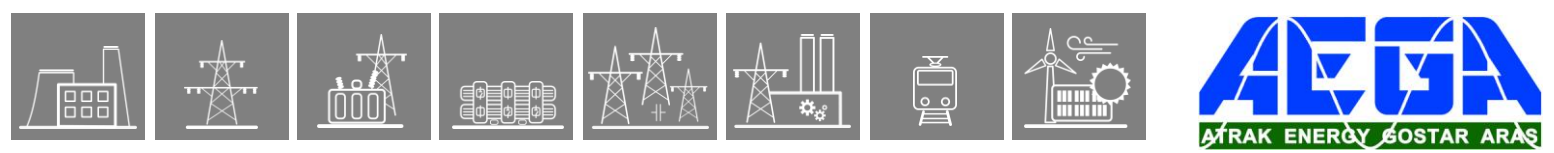


Table 2-4 Online displayed data of the breaker failure protection function

| | SIGNAL TITLE | DIMENSION | EXPLANATION |
|---------|---------------------|------------------|--------------------------------------------------------|
| | Backup Trip | - | Trip command generated for the backup circuit breakers |
| BRF50SP | <i>Retrip L1</i> | - | <i>Repeated trip command in phase L1</i> |
| | <i>Retrip L2</i> | - | <i>Repeated trip command in phase L2</i> |
| | <i>Retrip L3</i> | - | <i>Repeated trip command in phase L3</i> |

3.1.8.2.2.5. Events

The following events are generated in the event list, as well as sent to the SCADA according to the configuration.

Table 2-5 Generated events of the breaker failure protection function

BRF50SP

| EVENT | VALUE | EXPLANATION |
|-------------|---------|-------------------------------------|
| Backup Trip | off, on | Backup trip command of the function |
| Retrip L1 | off, on | Repeated trip command in phase L1 |
| Retrip L2 | off, on | Repeated trip command in phase L2 |
| Retrip L3 | off, on | Repeated trip command in phase L3 |

3.1.8.2.3. Technical data

Table 2-6 Technical data of the breaker failure protection function

| FUNCTION | VALUE | ACCURACY |
|---------------------------|---------------|-------------------------------------|
| Pick-up starting accuracy | | < 2 % |
| Operate time accuracy | | ±5% or ±15 ms, whichever is greater |
| Retrip time | approx. 15 ms | |
| Reset ratio | 0.9 | |
| Current reset time | 16 – 25 ms | |

3.1.8.2.4. Notes for testing

Note that the time delay parameter incorporates the algorithm time as well, so the time delay *does not mean the time difference between the appearance of the start and trip signals* of the function. In other words: it is not the delay between the detection of the fault and the trip that follows it. This should be taken into consideration when checking the disturbance records.

Instead the time delay parameter defines the elapsed time from the appearance of the faulty state to the trip. Because of this, while testing, the delay measurement should start *from the moment of the fault injection* until the trip signal.

3.1.9. Three-phase time overcurrent protection

3.1.9.1. Operation principle

The overcurrent protection function realizes definite time or inverse time characteristics according to IEC or IEEE standards, based on three phase currents. The characteristics are harmonized with IEC 60255-151, Edition 1.0, 2009-08. This function can be applied as main protection for medium-voltage applications or backup or overload protection for high-voltage network elements.

3.1.9.1.1. Operating characteristics

3.1.9.1.1.1. Independent time characteristic

$$t(G) = t_{OP} \text{ when } G > G_S$$

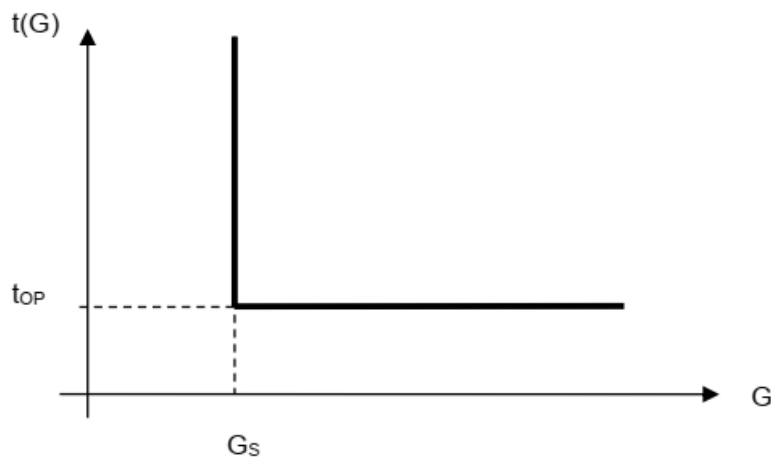


Figure 1-1 Overcurrent independent time characteristic

where

- t_{OP} (seconds) theoretical operating time if $G > G_S$, fix, according to the preset parameter,
- G measured value of the characteristic quantity, Fourier base harmonic of the phase currents,
- G_S preset value of the characteristic quantity ("Start current" parameter).

3.1.9.1.1.2. Standard dependent time characteristics

Operating characteristics:

$$t(G) = TMS \left[\frac{k}{\left(\frac{G}{G_s}\right)^\alpha - 1} + c \right] \text{ when } G > G_s$$

where

- t(G)(seconds) theoretical operate time with constant value of G,
- k, c constants characterizing the selected curve (in seconds),
- α constants characterizing the selected curve (no dimension),
- G measured value of the characteristic quantity, Fourier base harmonic of the phase currents (IL1Four, IL2Four, IL3Four),
- G_s preset value of the characteristic quantity (“Start current” parameter),
- TMS preset time multiplier (no dimension).

Table 1-1 The constants of the standard dependent time characteristics

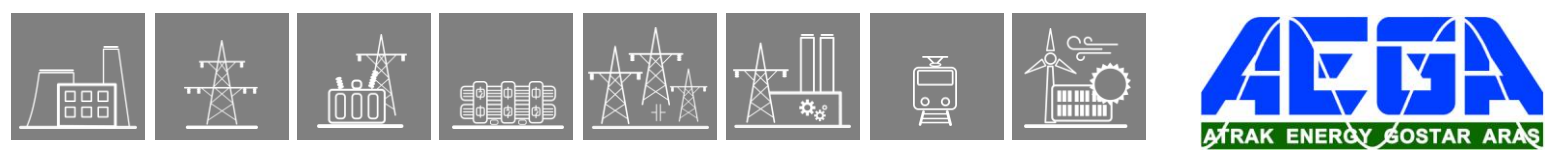
| | IEC REF | TITLE | kr | c | α |
|----|---------|------------------|--------|--------|----------|
| 1 | A | IEC Inv | 0,14 | 0 | 0,02 |
| 2 | B | IEC VeryInv | 13,5 | 0 | 1 |
| 3 | C | IEC ExtInv | 80 | 0 | 2 |
| 4 | | IEC LongInv | 120 | 0 | 1 |
| 5 | | ANSI Inv | 0,0086 | 0,0185 | 0,02 |
| 6 | D | ANSI ModInv | 0,0515 | 0,1140 | 0,02 |
| 7 | E | ANSI VeryInv | 19,61 | 0,491 | 2 |
| 8 | F | ANSI ExtInv | 28,2 | 0,1217 | 2 |
| 9 | | ANSI LongInv | 0,086 | 0,185 | 0,02 |
| 10 | | ANSI LongVeryInv | 28,55 | 0,712 | 2 |
| 11 | | ANSI LongExtInv | 64,07 | 0,250 | 2 |

The end of the effective range of the dependent time characteristics (G_D) is:

$$G_D = 20 * G_s$$

Above this value the theoretical operating time is definite:

$$t(G) = TMS \left[\frac{k}{\left(\frac{G_D}{G_s}\right)^\alpha - 1} + c \right] \text{ when } G > G_D = 20 * G_s$$



Additionally, a minimum time delay can be defined by parameter “Min Time Delay”. This delay is valid if it is longer than $t(G)$, defined by the formula above.

The inverse characteristic is valid above $G_T = 1,1 * G_s$. Above this value the function is guaranteed to operate.

Resetting characteristics:

- For IEC type characteristics the resetting is after a fix time delay defined by “Reset delay”,
- for ANSI types however according to the formula below:

$$t_r(G) = TMS \left[\frac{k_r}{1 - \left(\frac{G}{G_s}\right)^\alpha} \right] \text{ when } G < G_s$$

where

- $t(G)$ (seconds) theoretical reset time with constant value of G ,
- k_r constants characterizing the selected curve (in seconds),
- α constants characterizing the selected curve (no dimension),
- G measured value of the characteristic quantity, Fourier base harmonic of the phase currents,
- G_s preset value of the characteristic quantity (“Start current” parameter),
- TMS preset time multiplier (no dimension).

Table 1-2 The resetting constants of the standard dependent time characteristics

| | IEC REF | TITLE | kr | α |
|----|---------|------------------|-----------------------------------------------------------------------------|---|
| 1 | A | IEC Inv | Resetting after fix time delay, according to preset parameter “Reset delay” | |
| 2 | B | IEC VeryInv | | |
| 3 | C | IEC ExtInv | | |
| 4 | | IEC LongInv | | |
| 5 | | ANSI Inv | 0,46 | 2 |
| 6 | D | ANSI ModInv | 4,85 | 2 |
| 7 | E | ANSI VeryInv | 21,6 | 2 |
| 8 | F | ANSI ExtInv | 29,1 | 2 |
| 9 | | ANSI LongInv | 4,6 | 2 |
| 10 | | ANSI LongVeryInv | 13,46 | 2 |
| 11 | | ANSI LongExtInv | 30 | 2 |

3.1.9.1.2. Structure of the overcurrent protection algorithm

Fig.1-2 shows the structure of the overcurrent protection (TOC51) algorithm.

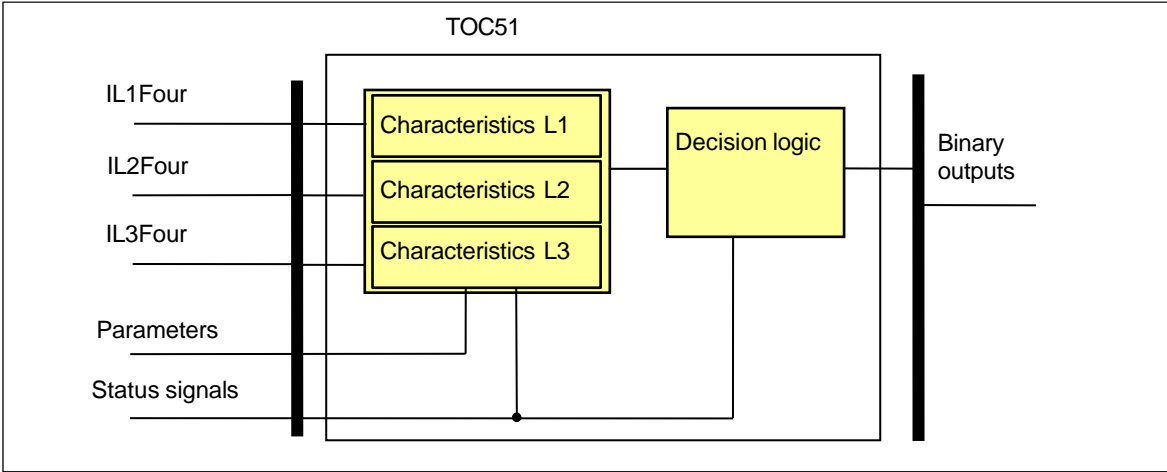


Figure 1-2 Structure of the overcurrent protection algorithm

The **inputs** are

- the RMS value of the fundamental Fourier component of three phase currents,
- parameters,
- status signals.

The **outputs** are

- the binary output status signals.

The **software modules** of the overcurrent protection function:

Characteristics

This module calculates the required time delay based on the Fourier components of the phase currents.

Decision logic

The decision logic module combines the status signals to generate the trip command of the function.

The following description explains the details of the individual components.

3.1.9.1.3. The definite time and the inverse type characteristics (characteristics)

This module calculates the required time delay based on the Fourier components of the phase currents. The formulas applied are described in Chapter 1.1.

The **inputs** are the RMS value of the fundamental Fourier component of the phase currents (IL1Four, IL2Four, IL3Four) and parameters.

The **outputs** are the status signals of the three phases individually. These indicate the started state and the generated trip command if the time delay determined by the characteristics expired.

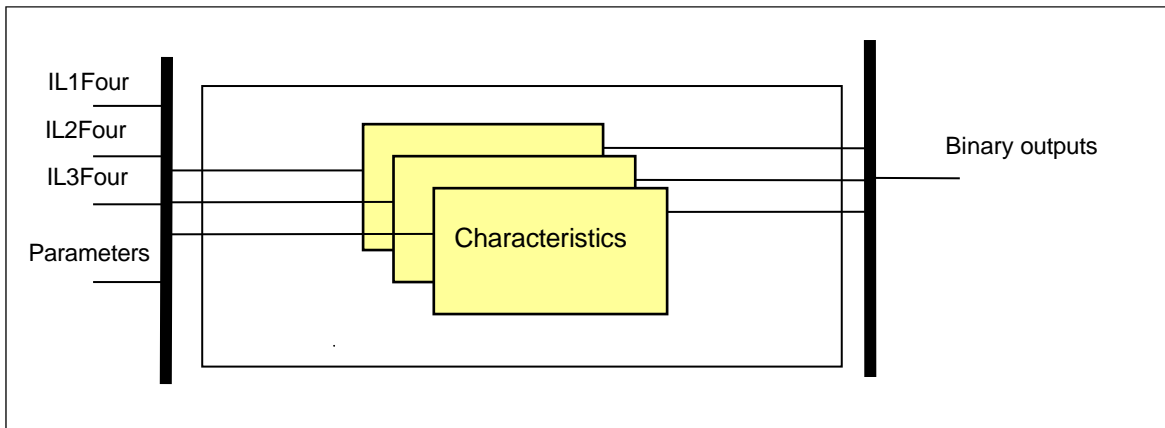


Figure 1-3 Schema of the characteristic calculation

The inverse type characteristics are also presented graphically on the following pages. These diagrams assume 100% setting value for the Start current parameter (GS), 1 for the Time multiplier (TMS) and 0 for the Min. time delay.

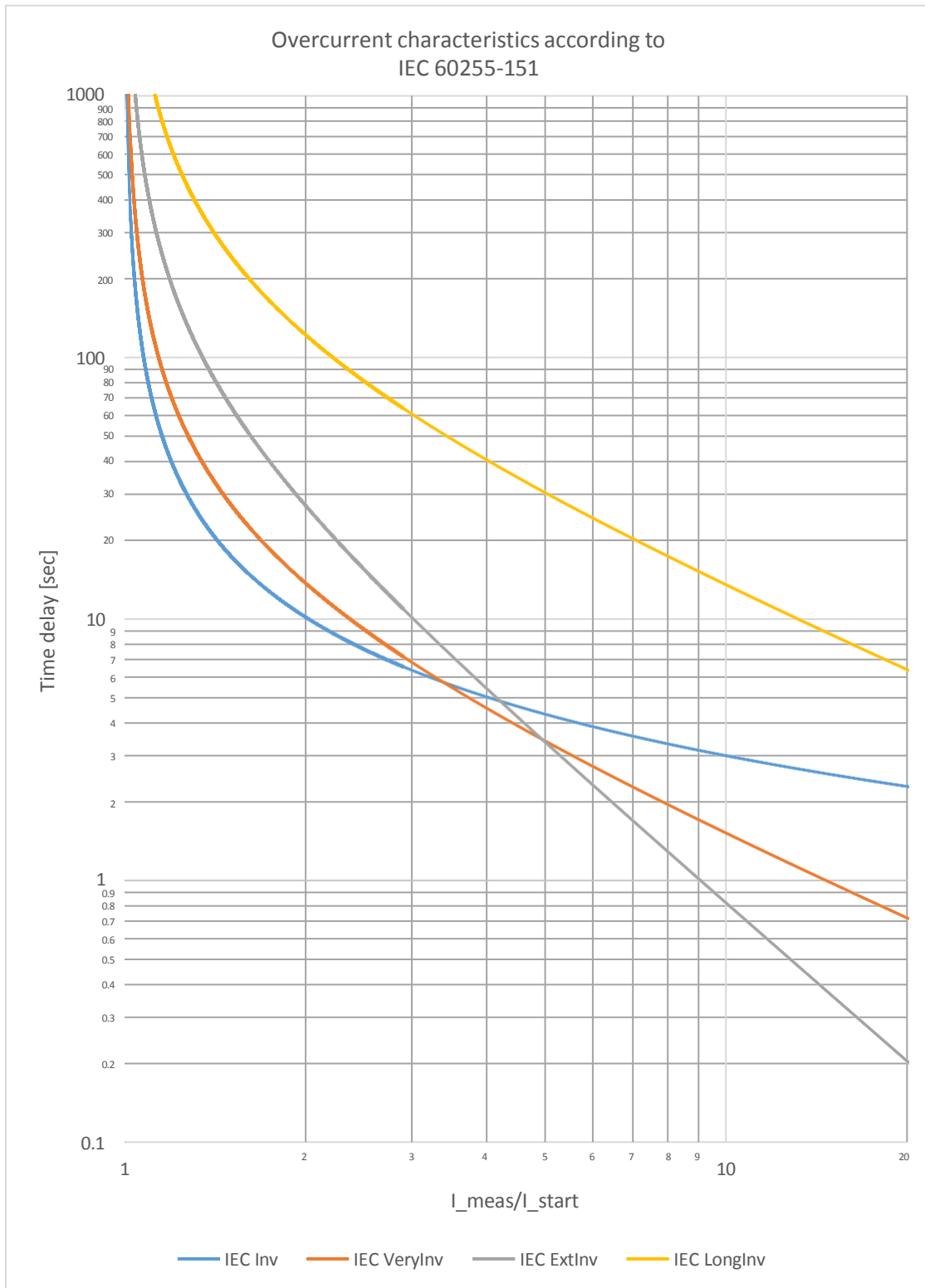


Figure 1-4 Overcurrent characteristics according to IEC 60255-151

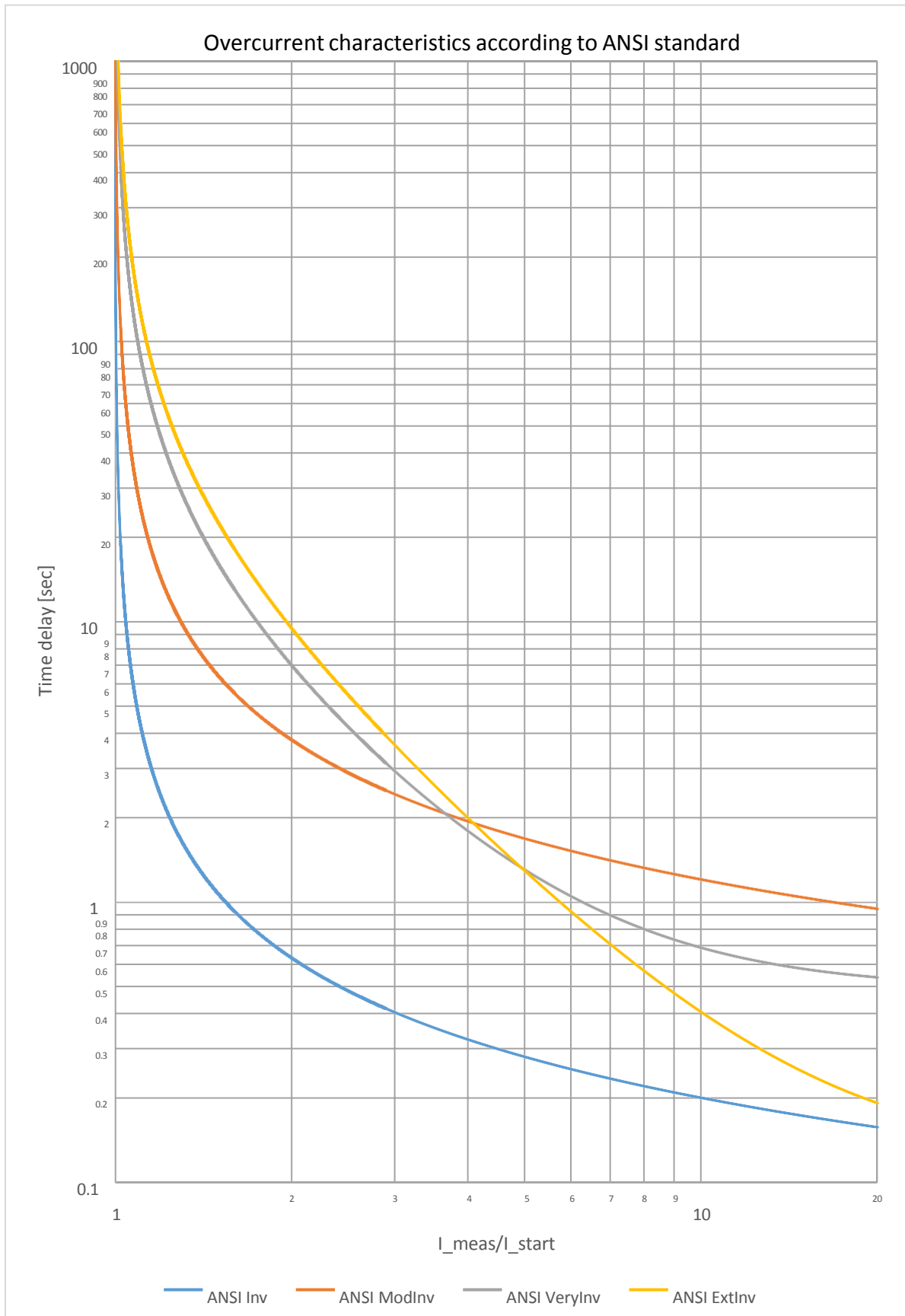


Figure 1-5 Overcurrent characteristics according to ANSI standard

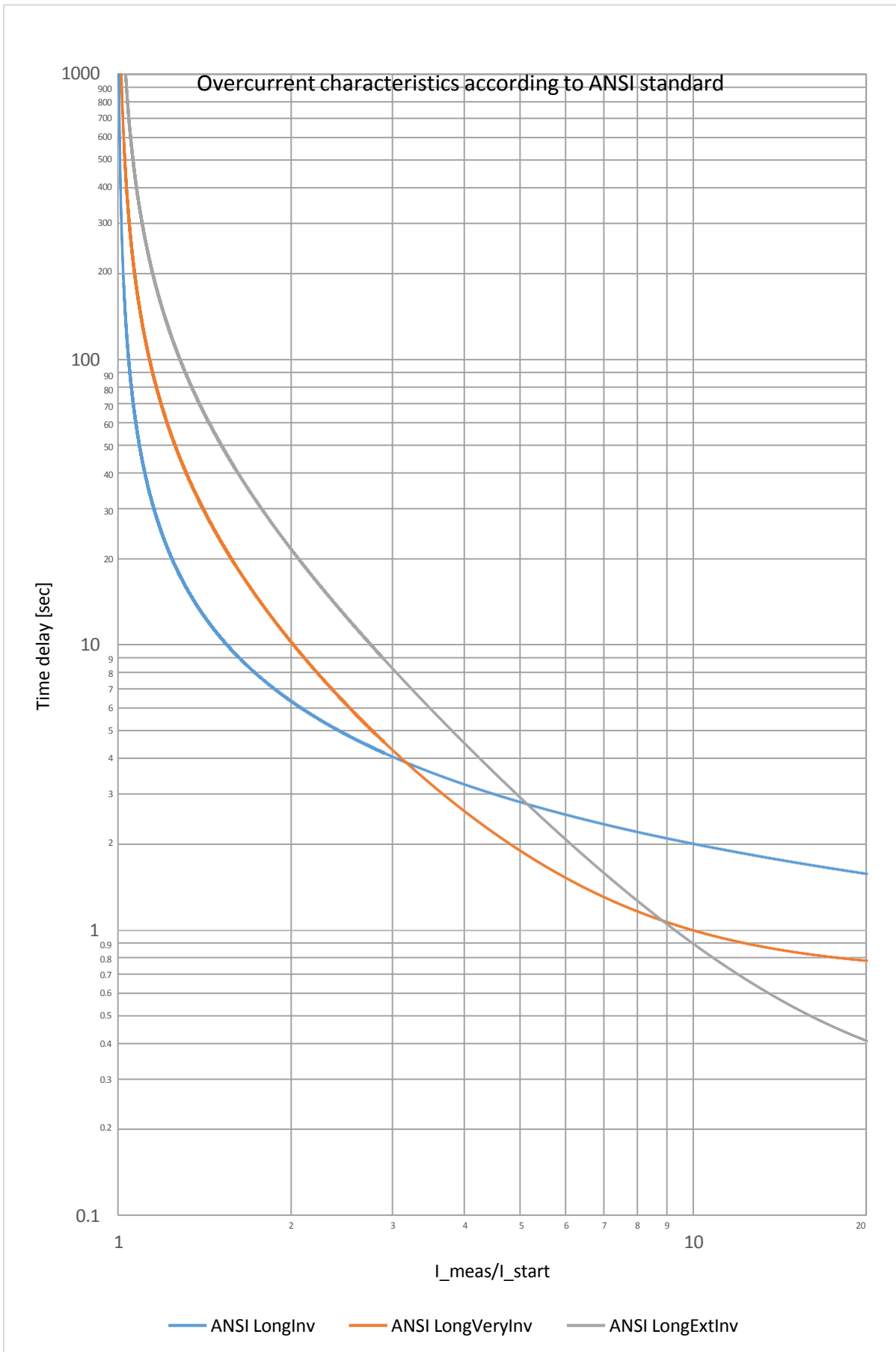


Figure 1-6 Overcurrent characteristics according to ANSI standard

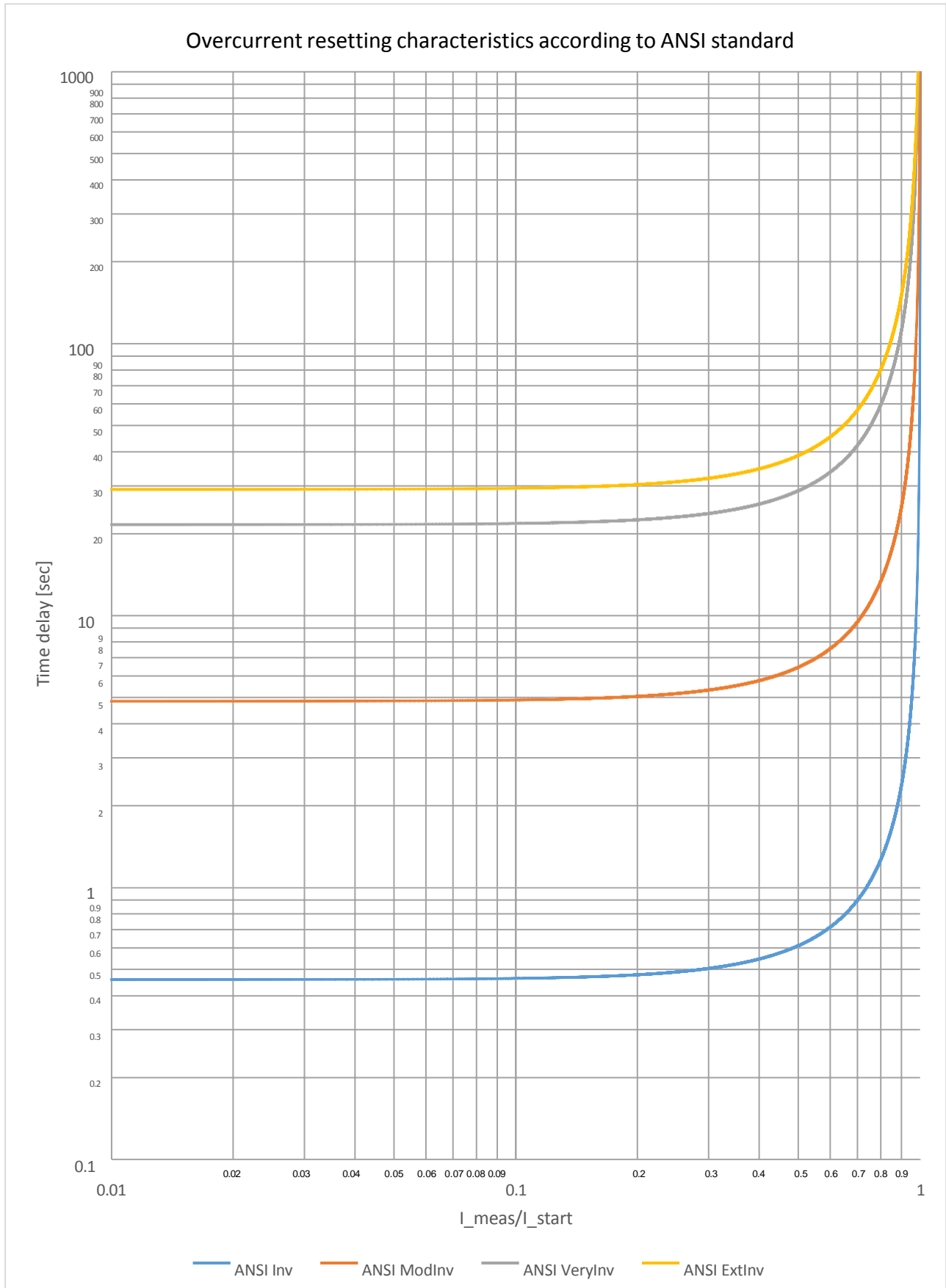


Figure 1-7 Overcurrent resetting characteristics according to ANSI standard

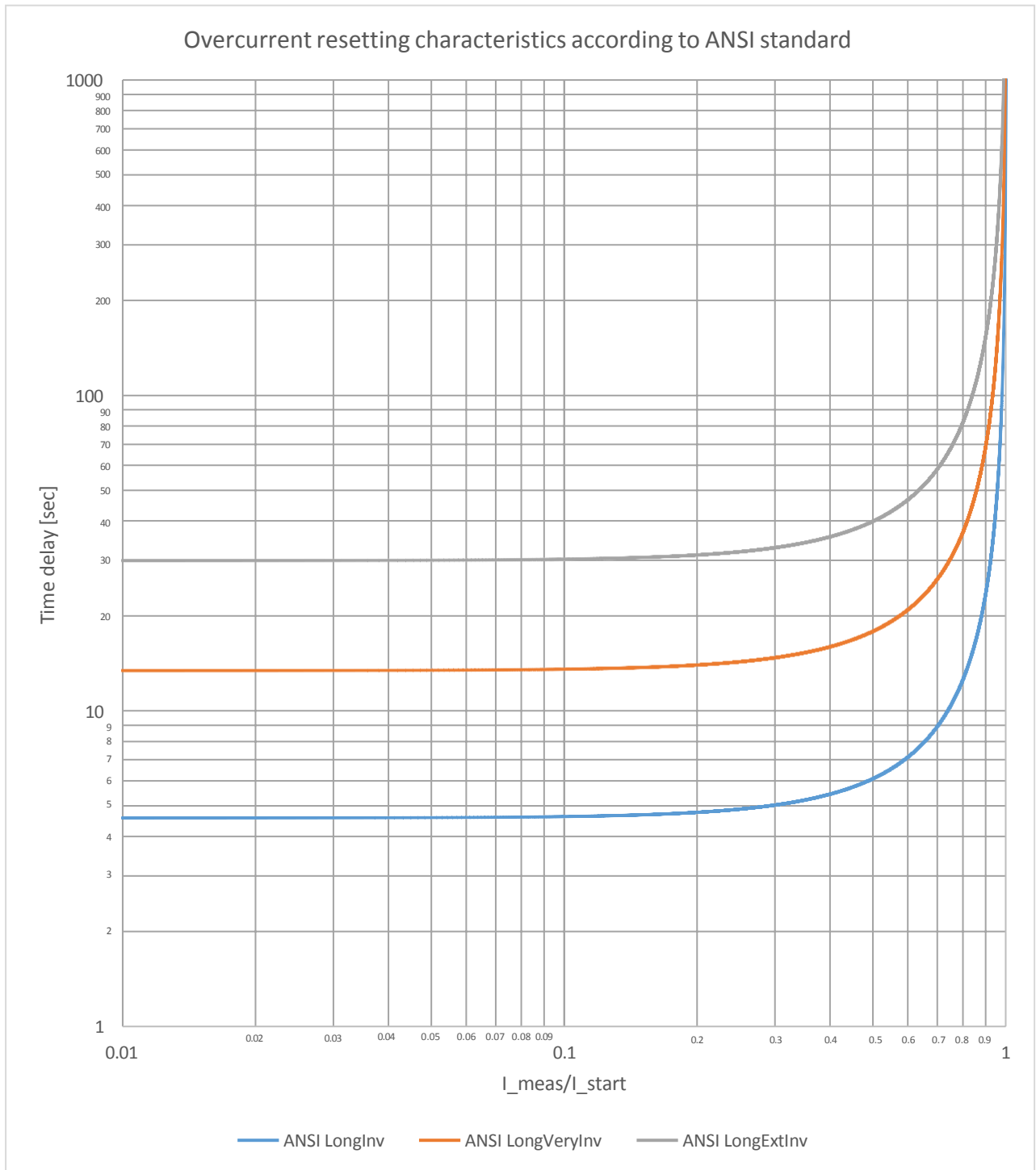


Figure 1-8 Overcurrent resetting characteristics according to ANSI standard

3.1.9.1.4. The decision logic (Decision logic)

The decision logic module combines the status signals to generate the general start signal and general trip command of the function.

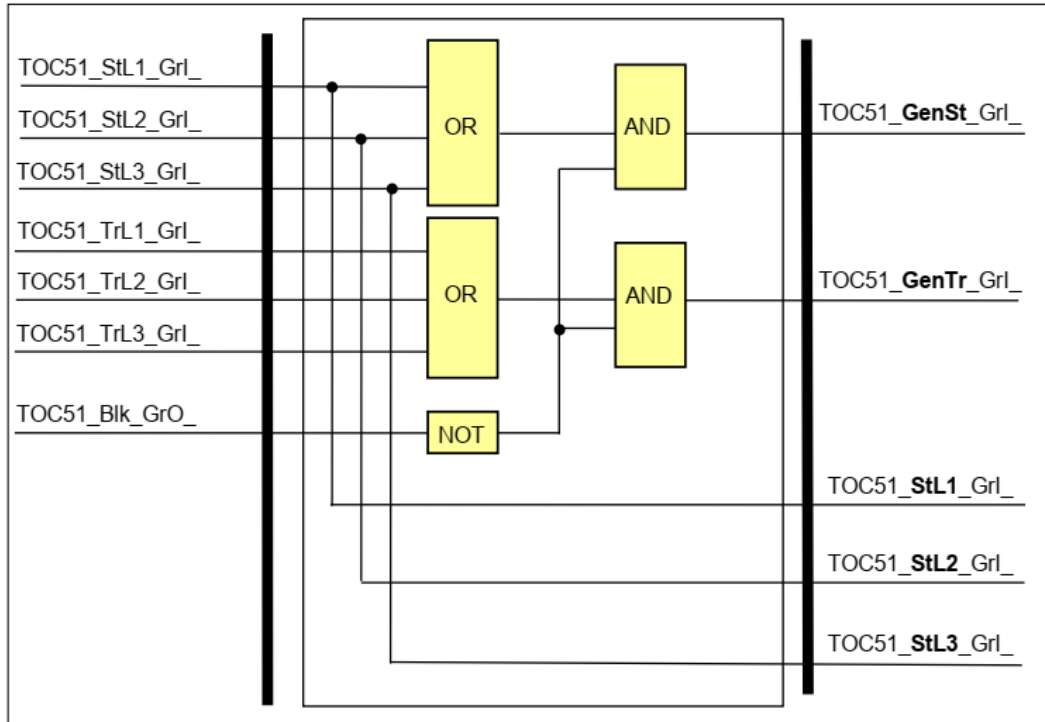
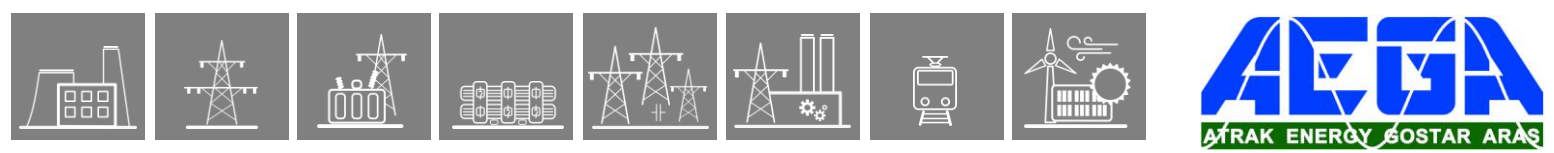


Figure 1-9 The logic scheme of the overcurrent protection function

Table 1-3 The binary input status signals of the overcurrent protection function

| BINARY INPUT SIGNALS | SIGNAL TITLE | EXPLANATION |
|----------------------|--------------|------------------------------------------|
| TOC51_StL1_Grl_ | Start L1 | Starting of the function in phase L1 |
| TOC51_TrL1_Grl_ | Trip L1 | Trip command of the function in phase L1 |
| TOC51_StL2_Grl_ | Start L2 | Starting of the function in phase L2 |
| TOC51_TrL2_Grl_ | Trip L2 | Trip command of the function in phase L2 |
| TOC51_StL3_Grl_ | Start L3 | Starting of the function in phase L3 |
| TOC51_TrL3_Grl_ | Trip L3 | Trip command of the function in phase L3 |



Binary status signals

The overcurrent protection function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

Table 1-4 The binary input signal of the overcurrent protection function

| BINARY STATUS SIGNAL | EXPLANATION |
|----------------------|---------------------------------------------------------------------------------------------------------|
| TOC51_Blk_GrO_ | Output status of a graphic equation defined by the user to disable the overcurrent protection function. |

Table 1-5 The binary output status signals of the overcurrent protection function

| BINARY OUTPUT SIGNALS | SIGNAL TITLE | EXPLANATION |
|-----------------------|--------------|--------------------------------------|
| TOC51_StL1_Grl_ | Start L1 | Starting of the function in phase L1 |
| TOC51_StL2_Grl_ | Start L2 | Starting of the function in phase L2 |
| TOC51_StL3_Grl_ | Start L3 | Starting of the function in phase L3 |
| | | |
| TOC51_GenSt_Grl_ | Gen. Start | General starting of the function |
| TOC51_GenTr_Grl_ | Gen. Trip | General trip command of the function |

3.1.9.2. 3ph overcurrent protection function overview

The function block of the three-phase overcurrent protection function is shown in Figure 2-1. This block shows all binary input and output status signals that are applicable in the graphic equation editor.

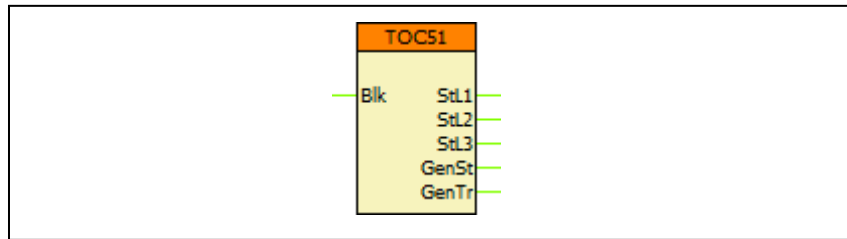


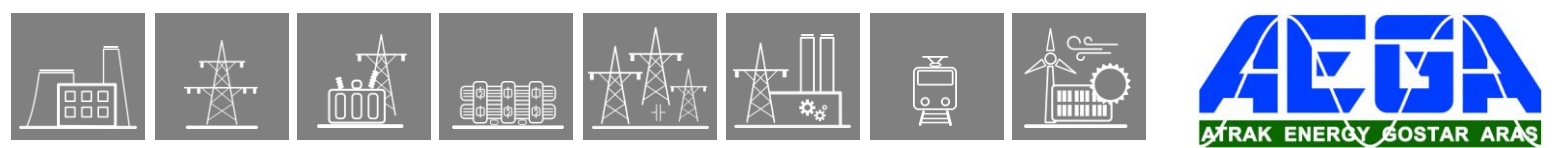
Figure 2-1 The function block of the overcurrent protection function

3.1.9.2.1. Settings

3.1.9.2.1.1. Parameters

Table 2-1 Parameters of the 3ph overcurrent protection function

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|---------------------|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|---------|------------------------------------------------------------|
| Operation | - | Off, Definite Time, IEC Inv, IEC VeryInv, IEC ExtInv, IEC LongInv, ANSI Inv, ANSI ModInv, ANSI VeryInv, ANSI ExtInv, ANSI LongInv, ANSI LongVeryInv, ANSI LongExtInv | - | Off | Enabling the function by choosing the characteristics. |
| Start Current | % | 10 – 3000 | 1 | 200 | Starting current of the function. |
| Time Multiplier | - | 0.05 – 15.0 | 0.01 | 200 | Time multiplier of the inverse characteristics (OC module) |
| Min Time Delay | msec | 40 – 60000 | 1 | 100 | Minimal time delay for the inverse characteristics |
| Definite Time Delay | msec | 40 – 60000 | 1 | 100 | Time delay setting for the definite time characteristics |
| Reset Time | msec | 60 – 60000 | 1 | 100 | Reset time for the IEC inverse characteristics |



3.1.9.2.2. Function I/O

This section describes briefly the analogue and digital inputs and outputs of the function block.

3.1.9.2.2.1. Analogue inputs

The function uses the sampled values of the three phase currents.

3.1.9.2.2.2. Binary output signals (graphed input statuses)

The **binary output status signals** of the three-phase overcurrent protection function are listed in Table 2-2. **Parts** written in **bold** are seen on the function block in the logic editor.

Table 2-2 The binary output status signals of the 3ph overcurrent protection function

| BINARY OUTPUT SIGNALS | SIGNAL TITLE | EXPLANATION |
|---------------------------|---------------|------------------------------------------|
| TOC51_ St L1_Grl_ | Start L1 | Starting of the function in phase L1 |
| TOC51_TrL1_Grl_ | Trip L1 | Trip command of the function in phase L1 |
| TOC51_ St L2_Grl_ | Start L2 | Starting of the function in phase L2 |
| TOC51_TrL2_Grl_ | Trip L2 | Trip command of the function in phase L2 |
| TOC51_ St L3_Grl_ | Start L3 | Starting of the function in phase L3 |
| TOC51_TrL3_Grl_ | Trip L3 | Trip command of the function in phase L3 |
| TOC51_ GenSt _Grl_ | General Start | General start of the function |
| TOC51_ GenTr _Grl_ | General Trip | General trip command of the function |

3.1.9.2.2.3. Binary input signals (graphed output statuses)

The overcurrent protection function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

Table 2-3 The binary input status signals of the 3ph overcurrent protection function

| BINARY INPUT SIGNAL | EXPLANATION |
|-------------------------|---------------------------------------------------------------------------------------------------------|
| TOC51_ BIk _GrO_ | Output status of a graphic equation defined by the user to disable the overcurrent protection function. |

3.1.9.2.2.4. On-line data

Visible values on the on-line data page:

Table 2-4 On-line data of the 3ph overcurrent protection function

| SIGNAL TITLE | DIMENSION | EXPLANATION |
|---------------|-----------|------------------------------------------|
| Start L1 | - | Starting of the function in phase L1 |
| Trip L1 | - | Trip command of the function in phase L1 |
| Start L2 | - | Starting of the function in phase L2 |
| Trip L2 | - | Trip command of the function in phase L2 |
| Start L3 | - | Starting of the function in phase L3 |
| Trip L3 | - | Trip command of the function in phase L3 |
| General Start | - | General start of the function |
| General Trip | - | General trip command of the function |

3.1.9.2.2.5. Events

The following events are generated in the event list, as well as sent to SCADA according to the configuration.

Table 2-5 Events of the 3ph overcurrent protection function

| EVENT | VALUE | EXPLANATION |
|---------------|---------|----------------------------------------------------------------------------------|
| Start L1 | off, on | Start of the three-phase overcurrent protection function in measuring element L1 |
| Start L2 | off, on | Start of the three-phase overcurrent protection function in measuring element L2 |
| Start L3 | off, on | Start of the three-phase overcurrent protection function in measuring element L3 |
| General Start | off, on | General start of the three-phase overcurrent protection function |
| General Trip | off, on | General trip command of the three-phase overcurrent protection function |

3.1.9.2.3. Technical data

Table 2-6 Technical data of the 3ph overcurrent protection function

| FUNCTION | VALUE | ACCURACY |
|----------------------------------------------------------------------|------------------------|------------------------------------------------|
| Operating accuracy | $20 \leq GS \leq 1000$ | < 2 % |
| Operate time accuracy | | $\pm 5\%$ or ± 15 ms, whichever is greater |
| Reset ratio | 0,95 | |
| Reset time * Dependent time char. Definite time char. | Approx. 60 ms | < 5% or ± 35 ms, whichever is greater |
| Transient overreach | | < 2 % |
| Pickup time * | < 40 ms | |
| Overshot time Dependent time char. Definite time char. | 30 ms 50 ms | |
| Influence of time varying value of the input current (IEC 60255-151) | | < 4 % |

* Measured with signal relay contact

3.1.9.2.3.1. Notes for testing

Normally in the EuroProt+ devices the trip contacts are assigned to the Trip Logic function block, and not to the protection function blocks. Because of this, the testing personnel must make sure that the Trip Logic is switched on ('Operation' parameter is set to other than 'Off') before starting the testing, otherwise there will be no physical trip on the relay.

The reset time of the IDMT characteristics can be tested only indirectly by injecting the same fault currents again after a successful trip: if the time elapsed between the two injections is less than the reset time, the second injection will result in a quicker operation than the first.

3.1.10. Residual overcurrent protection function

The residual overcurrent protection function can realize definite time or inverse time characteristics according to IEC or IEEE standards, based on the RMS value of the fundamental Fourier component of a single measured current, which can be the measured residual current at the neutral point ($3I_0$) or the calculated zero sequence current component. The characteristics are harmonized with IEC 60255-151, Edition 1.0, 2009-08.

3.1.10.1. Operating characteristics

3.1.10.1.1. Independent time characteristic

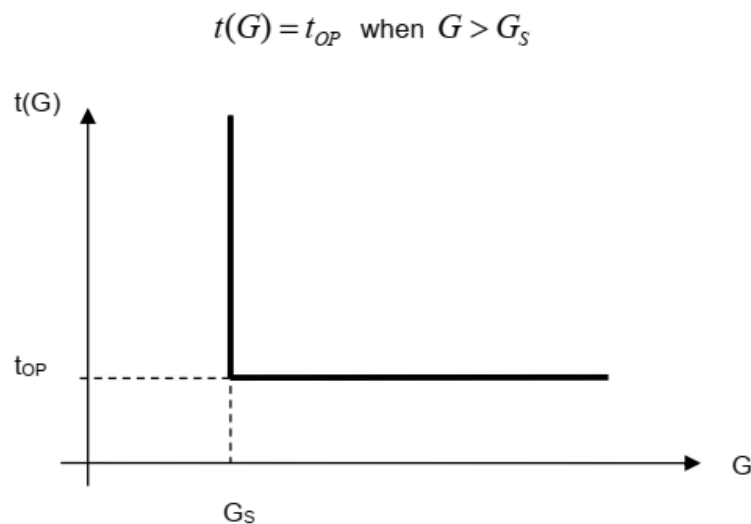


Figure 1-1 Overcurrent independent time characteristic

| | |
|--------------------|-----------------------------------------------------------------------------------------------|
| where | |
| t_{OP} (seconds) | theoretical operating time if $G > G_s$, fix, according to the preset parameter, |
| G | measured value of the characteristic quantity, Fourier base harmonic of the residual current, |
| G_s | preset value of the characteristic quantity (TOC51N_StCurr_IPar_, Start current). |

3.1.10.1.2. Standard dependent time characteristics

Operating characteristics:

$$t(G) = TMS \left[\frac{k_r}{\left(\frac{G}{G_s}\right)^\alpha - 1} + c \right] \text{ when } G > G_s$$

where
 t(G)(seconds) theoretical operate time with constant value of G,
 k_r, c constants characterizing the selected curve (in seconds),
 α constant characterizing the selected curve (no dimension),
 G measured value of the characteristic quantity, Fourier base harmonic of the residual current (INFour),
 G_s preset value of the characteristic quantity (TOC51N_StCurr_IPar_ Start current),
 TMS preset time multiplier (no dimension).

| | IEC ref | | k _r | c | α |
|----|---------|------------------|----------------|--------|------|
| 1 | A | IEC Inv | 0,14 | 0 | 0,02 |
| 2 | B | IEC VeryInv | 13,5 | 0 | 1 |
| 3 | C | IEC ExtInv | 80 | 0 | 2 |
| 4 | | IEC LongInv | 120 | 0 | 1 |
| 5 | | ANSI Inv | 0,0086 | 0,0185 | 0,02 |
| 6 | D | ANSI ModInv | 0,0515 | 0,1140 | 0,02 |
| 7 | E | ANSI VeryInv | 19,61 | 0,491 | 2 |
| 8 | F | ANSI ExtInv | 28,2 | 0,1217 | 2 |
| 9 | | ANSI LongInv | 0,086 | 0,185 | 0,02 |
| 10 | | ANSI LongVeryInv | 28,55 | 0,712 | 2 |
| 11 | | ANSI LongExtInv | 64,07 | 0,250 | 2 |

Table 1-1 The constants of the standard dependent time characteristics

Resetting characteristics:

$$t_r(G) = TMS \left[\frac{k_r}{1 - \left(\frac{G}{G_s}\right)^\alpha} \right] \text{ when } G < G_s$$

where

$t_r(G)$ (seconds)

k_r

α

G

G_s

TMS

theoretical reset time with constant value of G ,
 constants characterizing the selected curve (in seconds),
 constant characterizing the selected curve (no dimension),
 measured value of the characteristic quantity, Fourier base harmonic of the residual current,
 preset value of the characteristic quantity (TOC51N_StCurr_IPar_, Start current),
 preset time multiplier (no dimension).

| | IEC ref | | k_r | α |
|----|---------|------------------|------------------------------------------------------------------------------------------------|----------|
| 1 | A | IEC Inv | Resetting after fix time delay, according to preset parameter TOC51N_Reset_TPar_ "Reset delay" | |
| 2 | B | IEC VeryInv | | |
| 3 | C | IEC ExtInv | | |
| 4 | | IEC LongInv | | |
| 5 | | ANSI Inv | 0,46 | 2 |
| 6 | D | ANSI ModInv | 4,85 | 2 |
| 7 | E | ANSI VeryInv | 21,6 | 2 |
| 8 | F | ANSI ExtInv | 29,1 | 2 |
| 9 | | ANSI LongInv | 4,6 | 2 |
| 10 | | ANSI LongVeryInv | 13,46 | 2 |
| 11 | | ANSI LongExtInv | 30 | 2 |

Table 1-2 The resetting constants of the standard dependent time characteristics

The inverse type characteristics are also combined with a minimum time delay, the value of which is set by user parameter TOC51N_MinDel_TPar_ (Min. Time Delay).

The end of the effective range of the dependent time characteristics (G_D) is:

$$G_D = 20 * G_s$$

Above this value the theoretical operating time is definite:

$$t(G) = TMS \left[\frac{k_r}{\left(\frac{G_D}{G_s}\right)^\alpha - 1} + c \right] \text{ when } G > G_D = 20 * G_s$$

The combined logic requires expiry both the time defined by the inverse characteristic with the definite section AND the expiry of the minimum time defined by the "Min. Time Delay" parameter.

The inverse characteristic is valid above $G_T = 1,1 * G_s$. Above this value the function is guaranteed to operate.

3.1.10.2. Structure of the residual overcurrent protection algorithm

Fig.1-2 shows the structure of the residual overcurrent protection (TOC51N) algorithm.

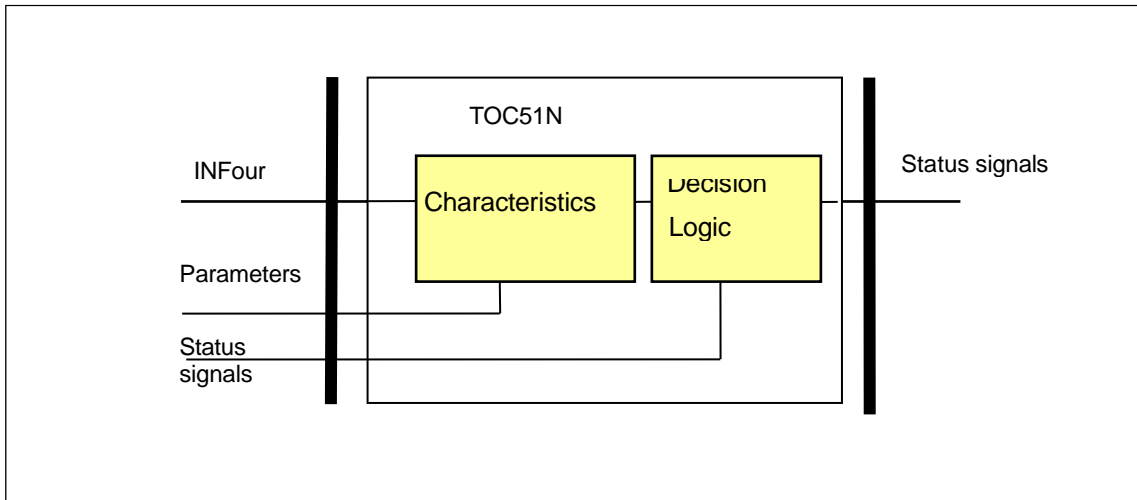


Figure 1-2 Structure of the residual overcurrent protection algorithm

The **inputs** are

the RMS value of the fundamental Fourier component of the residual current ($I_N=3I_0$),
parameters,
status signals.

The **outputs** are

the binary output status signals.

The **software modules** of the residual overcurrent protection function:

Characteristics

This module calculates the required time delay based on the RMS value of the fundamental Fourier component of the residual current.

Decision logic

The decision logic module combines the status signals to generate the trip command of the function.

The following description explains the details of the individual components.

3.1.10.3. The definite time and the inverse type characteristics

This module calculates the required time delay based on the Fourier components of the residual current. The formulas applied are described in Chapter 1.1.

The **inputs** are the basic Fourier components of the residual current (INFour) and parameters.

The **outputs** are the internal status signals of the function. These indicate the started state and the generated trip command if the time delay determined by the characteristics expired.

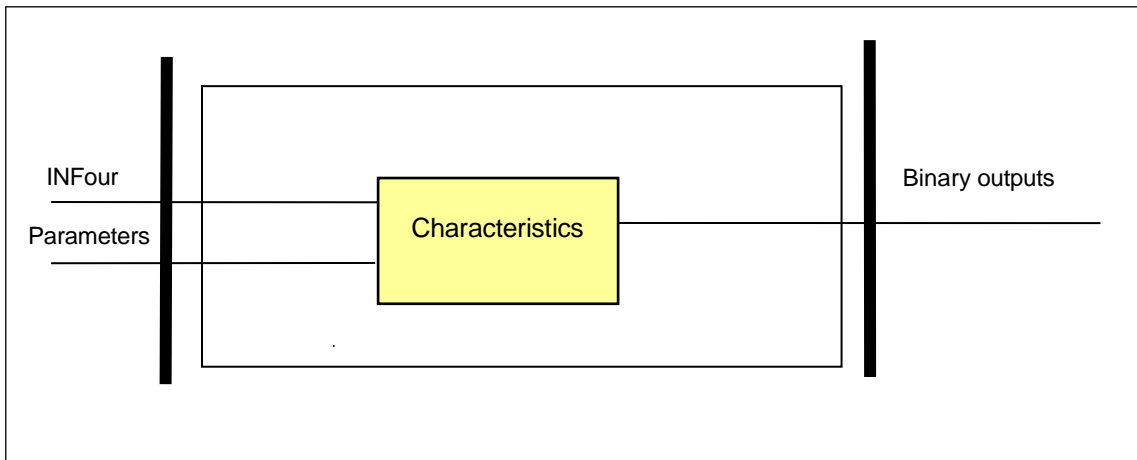


Figure 1-3 Schema of the characteristic calculation

Enumerated parameter

| Parameter name | Title | Selection range | Default |
|------------------------------|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|
| Parameter for type selection | | | |
| TOC51N_Oper_EPar_ | Operation | Off, DefinitTime, IEC Inv, IEC VeryInv, IEC ExtInv, IEC LongInv, ANSI Inv, ANSI ModInv, ANSI VeryInv, ANSI ExtInv, ANSI LongInv, ANSI LongVeryInv, ANSI LongExtInv | Off |

Table 1-3 The enumerated parameters of the residual overcurrent protection function

Integer parameters

| Parameter name | Title | Unit | Min | Max | Step | Default |
|-----------------------------|------------------|------|-----|------|------|---------|
| Starting current parameter: | | | | | | |
| TOC51N_StCurr_IPar_ | Start Current * | % | 10 | 1000 | 1 | 50 |
| TOC51N_StCurr_IPar_ | Start Current ** | % | 5 | 1000 | 1 | 50 |

* In = 1 A or 5 A

** In = 200 mA or 1 A

Table 1-4 The integer parameters of the residual overcurrent protection function

Float parameter

| Parameter name | Title | Unit | Min | Max | Step | Default |
|------------------------------------------------------------|-----------------|------|------|-----|------|---------|
| Time multiplier of the inverse characteristics (OC module) | | | | | | |
| TOC51N_Multip_FPar_ | Time Multiplier | | 0.05 | 15 | 0.01 | 1.0 |

Table 1-5 Float parameter of the OC function block

Timer parameters

| Parameter name | Title | Unit | Min | Max | Step | Default |
|-----------------------------------------------------|------------------------|------|-----|-------|------|---------|
| Minimal time delay for the inverse characteristics: | | | | | | |
| TOC51N_MinDel_TPar_ | Min Time Delay * | msec | 40 | 60000 | 1 | 100 |
| Definite time delay: | | | | | | |
| TOC51N_DefDel_TPar_ | Definite Time Delay ** | msec | 40 | 60000 | 1 | 100 |
| Reset time delay for the inverse characteristics: | | | | | | |
| TOC51N_Reset_TPar_ | Reset Time* | msec | 60 | 60000 | 1 | 100 |

*Valid for inverse type characteristics only

**Valid for definite type characteristics only

Table 1-6 Timer parameters of the residual overcurrent protection function

The **binary output status signals** of the residual overcurrent protection function are listed in Table 1-7.

| Binary output signals | Signal title | Explanation |
|-----------------------|--------------|------------------------------|
| TOC51N_St_Grl_ | Start L1 | Starting of the function |
| TOC51N_Tr_Grl_ | Trip L1 | Trip command of the function |

Table 1-7 The binary output status signals of the residual overcurrent protection function

3.1.10.4. The decision logic (Decision logic)

The decision logic module combines the status signals to generate the trip command of the function.

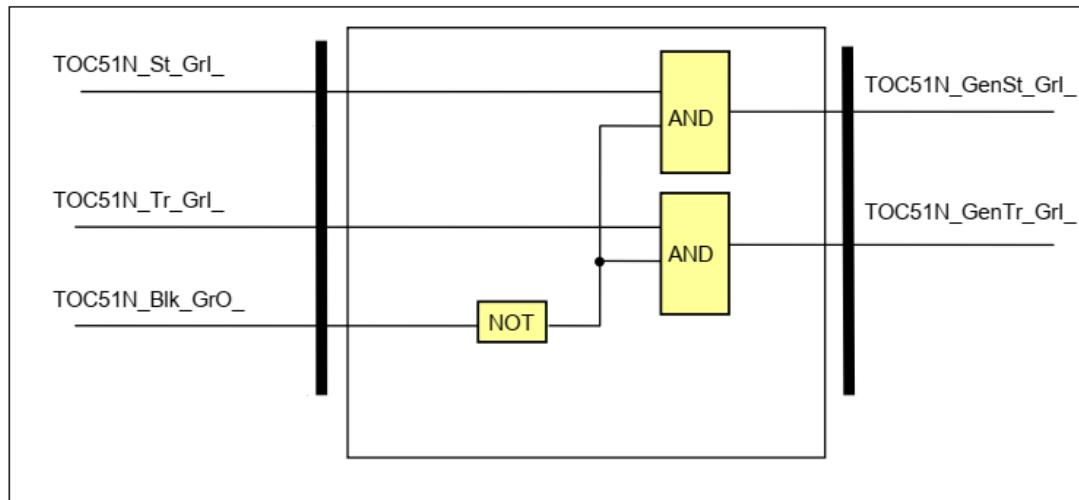


Figure 1-4 The (simplified) logic scheme of the residual overcurrent protection function

| Binary input signals | Signal title | Explanation |
|----------------------|--------------|------------------------------|
| TOC51N_St_Grl_ | Start | Starting of the function |
| TOC51N_Tr_Grl_ | Trip | Trip command of the function |

Table 1-8 The binary input status signals of the residual overcurrent protection function

Binary status signals

The residual overcurrent protection function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

| Binary status signal | Explanation |
|----------------------|------------------------------------------------------------------------------------------------------------------|
| TOC51N_Blk_GrO_ | Output status of a graphic equation defined by the user to disable the residual overcurrent protection function. |

Table 1-9 The binary input signal of the residual overcurrent protection function

| Binary output signals | Signal title | Explanation |
|-----------------------|---------------|--------------------------------------|
| TOC51N_GenSt_Grl_ | General Start | General starting of the function |
| TOC51N_GenTr_Grl_ | General Trip | General trip command of the function |

Table 1-10 The binary output status signals of the residual overcurrent protection function

3.1.10.5. Technical summary

3.1.10.5.1. Technical data

| Function | Value | Accuracy |
|----------------------------------------------------------------------|-------------------------|------------------------------------------------|
| Operating accuracy * | $20 \leq G_s \leq 1000$ | < 3 % |
| Operate time accuracy | | $\pm 5\%$ or ± 15 ms, whichever is greater |
| Reset ratio | 0,95 | |
| Reset time * Dependent time char. Definite time char. | Approx 60 ms | < 5% or ± 35 ms, whichever is greater |
| Transient overreach | | 2 % |
| Pickup time | ≤ 40 ms | |
| Overshot time Dependent time char. Definite time char. | 30 ms 50 ms | |
| Influence of time varying value of the input current (IEC 60255-151) | | < 4 % |

* Measured in version $I_n = 200$ mA

Table 1-11 Technical data of the residual overcurrent protection function

3.1.10.5.2. The parameters

The parameters are summarized in Chapter 1.3.

3.1.10.5.3. The binary input status signals

Binary input signal

The residual overcurrent protection function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

| Binary input signal | Explanation |
|---------------------|------------------------------------------------------------------------------------------------------------------|
| TOC51N_Blk_GrO_ | Output status of a graphic equation defined by the user to disable the residual overcurrent protection function. |

Table 1-12 The binary input signal of the residual overcurrent protection function

3.1.10.5.4. The binary output status signals

The **binary output status signals** of the residual overcurrent protection function are listed in Table 1-13.

| Binary output signals | Signal title | Explanation |
|-----------------------|---------------|--------------------------------------|
| TOC51N_GenSt_Grl_ | General Start | General starting of the function |
| TOC51N_GenTr_Grl_ | General Trip | General trip command of the function |

Table 1-13 The binary output status signals of the residual overcurrent protection function

3.1.10.5.5. The function block

The function block of the residual overcurrent protection function is shown in Figure 1-5. This block shows all binary input and output status signals that are applicable in the graphic equation editor.

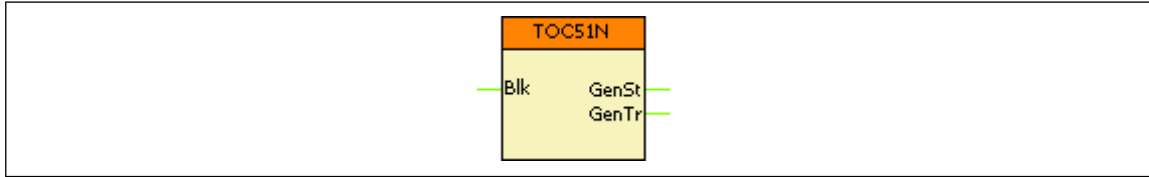


Figure 1-5 The function block of the residual overcurrent protection function

3.1.11. Definite time overvoltage protection function

3.1.11.1. Application

The definite time overvoltage protection function measures three voltages. If any of them is above the level defined by parameter setting, then a start signal is generated for the phases individually.

3.1.11.2. Mode of operation

The function generates start signals for the phases individually. The general start signal is generated if the voltage in any of the three measured voltages is above the level defined by parameter setting value.

Note that in medium voltage applications the function uses the phase-to-phase voltages by default.

The function generates a trip command only if the time delay has expired and the parameter selection requires a trip command as well.

3.1.11.3. Operating characteristics

$$t(G) = t_{OP} \text{ when } G > G_S$$

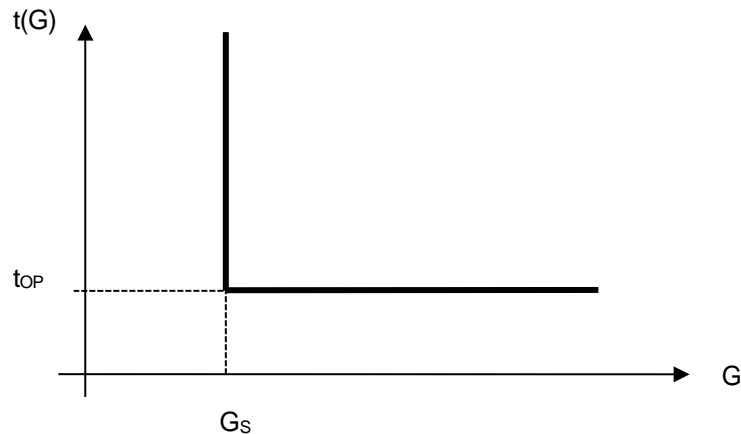


Figure 1-1 Overvoltage definite time characteristic

where

t_{OP} (seconds)

theoretical operating time if $G > G_S$, fix, according to the parameter setting,

G

measured value of the characteristic quantity, Fourier base harmonic of the phase voltages (or phase-to-phase voltages),

G_S

setting value of the characteristic quantity.

3.1.11.4. Structure of the definite time overvoltage protection algorithm

Fig.1-2 shows the structure of the definite time overvoltage protection (TOV59) algorithm.

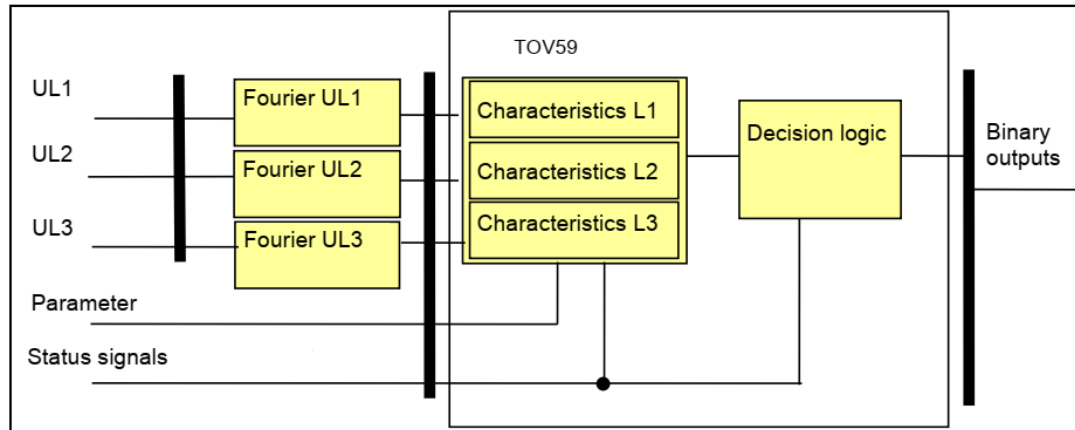


Figure 1-2 Structure of the definite time overvoltage protection algorithm

The **inputs** are

- the RMS values of the fundamental Fourier component of three phase voltages,
- parameters,
- status signals.

The **outputs** are

- the binary output status signals.

The **software modules** of the definite time overvoltage protection function:

Fourier calculations

These modules calculate the basic Fourier components of the phase voltages individually (not part of the TOV59 function). In medium voltage applications these are changed to phase-to-phase voltages.

Characteristics

This module calculates the required time delay based on the Fourier components of the phase (or phase-to-phase) voltages.

Decision logic

The decision logic module combines the status signals to generate the trip command of the function.

The following description explains the details of the individual components.

3.1.11.5. The Fourier calculation (Fourier)

These modules calculate the basic Fourier components of the phase voltages individually. They are not part of the TOV59 function; they belong to the preparatory phase.

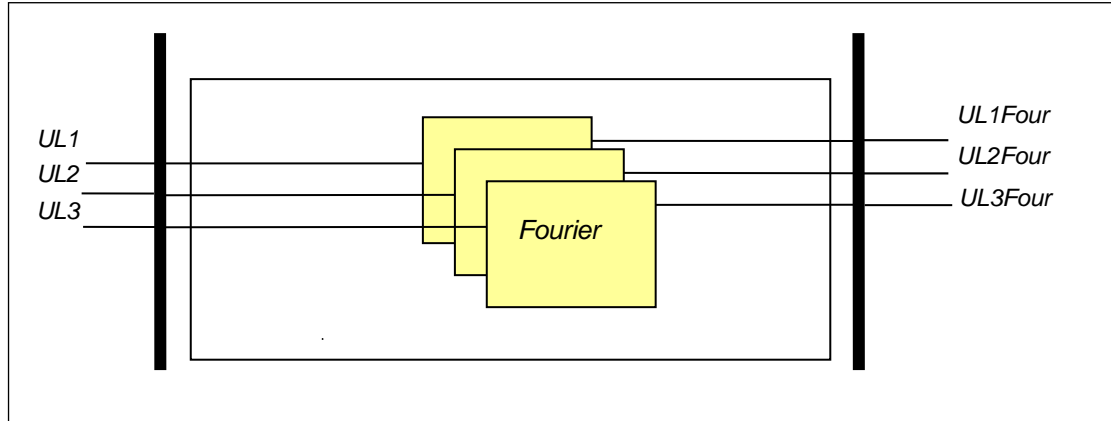


Figure 1-3 Schema of the Fourier calculation

The **inputs** are the sampled values of the three phase voltages (UL1, UL2, UL3)

The **outputs** are the RMS values of the basic Fourier components of the analyzed voltages (UL1Four, UL2Four, UL3Four).

The phase-to-phase voltages (if used) are also calculated here.

3.1.11.6. The definite time characteristics (Characteristics)

This module decides the stating of the function based on the Fourier components of the phase voltages and it counts the time delay. The time delay is defined by the parameter setting, if the voltages are above the setting value.

The **inputs** are the RMS values of the basic Fourier components of the phase (or the calculated phase-to-phase) voltages (UL1Four, UL2Four, UL3Four) and parameters.

The **outputs** are the status signals of the three phases individually. These indicate the started state and the generated trip command if the time delay determined by the setting is expired.

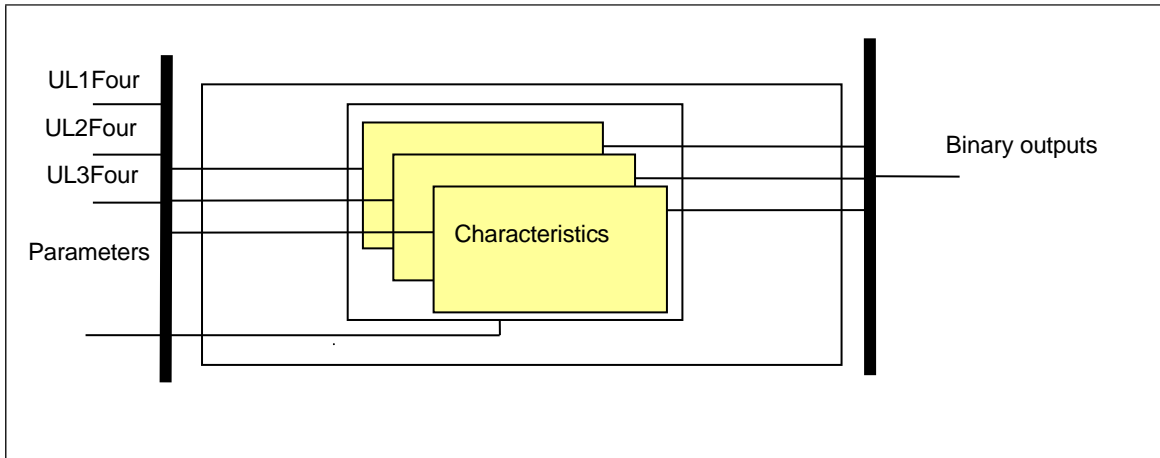


Figure 1-4 Schema of the definite time characteristic calculation

Enumerated parameter

| Parameter name | Title | Selection range | Default |
|-----------------------------------------------------------|-----------|-----------------|---------|
| Enabling or disabling the overvoltage protection function | | | |
| TOV59_Oper_EPar_ | Operation | Off, On | Off |

Table 1-1 The enumerated parameter of the overvoltage protection function

Integer parameter

| Parameter name | Title | Unit | Min | Max | Step | Default |
|-------------------------------------------------------------------------------------------------------------------|---------------|------|-----|-----|------|---------|
| Voltage level setting. If the measured voltage is above the setting value, the function generates a start signal. | | | | | | |
| TOV59_StVol_IPar_ | Start Voltage | % | 30 | 130 | 1 | 110 |

Table 1-2 Integer parameter of the overvoltage protection function

Floating point parameter

| Parameter name | Title | Unit | Min | Max | Step | Default |
|-------------------------------------------------------------------------------------------------------------------------|-------------|------|-----|-----|------|---------|
| After starting the function drops off if the measured voltage is below the start voltage with at least this percentage. | | | | | | |
| TOV59_ResetRatio_FPar_ | Reset Ratio | % | 1 | 10 | 1 | 5 |

Table 1-3 Floating point parameter of the overvoltage protection function

Boolean parameter

| Parameter name | Title | Default | Explanation |
|--------------------|-------------------|---------|----------------------------------------------------------------------------------------------------------------------|
| TOV59_StOnly_BPar_ | Start Signal Only | 0 | Selection if starting and trip signal or starting signal only is to be generated. Set 0 for trip command generation. |

Table 1-4 The Boolean parameters of the overvoltage protection function

Timer parameter

| Parameter name | Title | Unit | Min | Max | Step | Default |
|----------------------------------------------------|------------|------|-----|-------|------|---------|
| Time delay of the overvoltage protection function. | | | | | | |
| TOV59_Delay_TPar_ | Time Delay | ms | 0 | 60000 | 1 | 100 |

Table 1-5 The timer parameter of the overvoltage protection function

The **binary output status signals** of the three-phase definite time overvoltage protection function are listed in . *In case of phase-to-phase voltages, these are changed to L12, L23, L31 respectively.

**The trip signals are not published for the phases individually

Table 1-6 below.

| Binary output status signal | Signal title | Explanation |
|-----------------------------|--------------|-------------------------------------------|
| TOV59_StL1_Grl_ | StL1 | Starting of the function in phase L1* |
| TOV59_TrL1_Grl_ | TrL1** | Trip command of the function in phase L1* |
| TOV59_StL2_Grl_ | StL2 | Starting of the function in phase L2* |
| TOV59_TrL2_Grl_ | TrL2** | Trip command of the function in phase L2* |
| TOV59_StL3_Grl_ | StL3 | Starting of the function in phase L3* |
| TOV59_TrL3_Grl_ | TrL3** | Trip command of the function in phase L3* |

*In case of phase-to-phase voltages, these are changed to L12, L23, L31 respectively.

**The trip signals are not published for the phases individually

Table 1-6 The binary output status signals of the definite time overvoltage protection function

3.1.11.7. The decision logic (Decision logic)

The decision logic module combines binary signals and Boolean parameters to generate the trip command of the function.

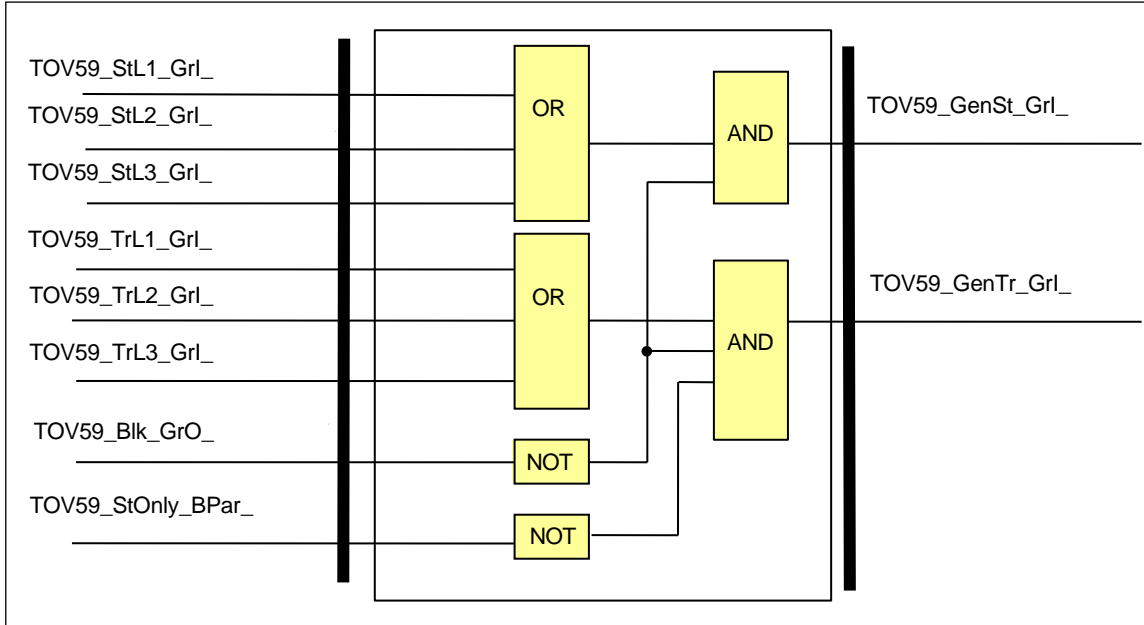


Figure 1-5 The decision logic scheme of the definite time overvoltage protection function

| Binary input signal | Signal title | Explanation |
|---------------------|--------------|-------------------------------------------|
| TOV59_StL1_Grl_ | StL1 | Starting of the function in phase L1* |
| TOV59_TrL1_Grl_ | TrL1** | Trip command of the function in phase L1* |
| TOV59_StL2_Grl_ | StL2 | Starting of the function in phase L2* |
| TOV59_TrL2_Grl_ | TrL2** | Trip command of the function in phase L2* |
| TOV59_StL3_Grl_ | StL3 | Starting of the function in phase L3* |
| TOV59_TrL3_Grl_ | TrL3** | Trip command of the function in phase L3* |

*In case of phase-to-phase voltages, these are changed to L12, L23, L31 respectively.

**The trip signals are not published for the phases individually

Table 1-7 The binary input signals of the definite time overvoltage protection function

Boolean parameter

| Parameter name | Title | Default |
|-----------------------------|-------------------|---------|
| Enabling start signal only: | | |
| TOV59_StOnly_BPar_ | Start Signal Only | FALSE |

Table 1-8 The Boolean parameter of the definite time overvoltage protection function

Binary status signals

The overvoltage protection function has a binary input signal, which serves the purpose of disabling the function. The conditions of disabling are defined by the user, applying the graphic equation editor.

| Binary input status signal | Explanation |
|----------------------------|-----------------------------------------------------------------------------------------------------------------------|
| TOV59_BlK_GrO_ | Output status of a graphic equation defined by the user to disable the definite time overvoltage protection function. |

Table 1-9 The binary input signal of the definite time overvoltage protection function

| Binary output status signal | Title | Explanation |
|-----------------------------|-------|----------------------|
| TOV59_StL1_Grl_ | StL1 | Start in phase L1* |
| TOV59_StL2_Grl_ | StL2 | Start in phase L2* |
| TOV59_StL3_Grl_ | StL3 | Start in phase L3* |
| TOV59_GenSt_Grl_ | GenSt | General start signal |
| TOV59_GenTr_Grl_ | GenTr | General trip command |

*In case of phase-to-phase voltages, these are changed to L12, L23, L31 respectively.

Table 1-10 The binary output status signals of the definite time overvoltage protection function

3.1.11.8. Technical summary

3.1.11.8.1. Technical data

| Function | Value | Accuracy |
|---------------------------------|----------------|-----------|
| Pick-up starting accuracy | | < ± 0,5 % |
| Reset time U> → Un U> → 0 | 60 ms 50 ms | |
| Operate time accuracy | | < ± 20 ms |
| Minimum operate time | 50 ms | |

Table 1-11 Technical data of the overvoltage protection function

3.1.11.8.2. Parameters

The parameters are summarized in Chapter 1.6 Table 1-1, Table 1-2, Table 1-3, Table 1-4, Table 1-5.

3.1.11.8.3. Binary output status signals

The **binary output status signals** of overvoltage protection function are listed in Table 1-12
The binary output status signals of the overvoltage protection function

| Binary status signal | Title | Explanation |
|----------------------|-------|----------------------|
| TOV59_StL1_Grl_ | StL1 | Start in phase L1 |
| TOV59_StL2_Grl_ | StL2 | Start in phase L2 |
| TOV59_StL3_Grl_ | StL3 | Start in phase L3 |
| TOV59_GenSt_Grl_ | GenSt | General start signal |
| TOV59_GenTr_Grl_ | GenTr | General trip command |

Table 1-12 The binary output status signals of the overvoltage protection function

3.1.11.8.4. Binary input status signals

Binary input signals

The overvoltage protection function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

| Binary status signal | Title | Explanation |
|----------------------|-------|-------------------------------------------------|
| TOV59_BlK_GrO_ | Blk | Blocking of the overvoltage protection function |

Table 1-13 The binary input signal of the overvoltage protection function

3.1.11.8.5. The function block

The function block of the overvoltage protection function is shown in Figure 1-6. This block shows all binary input and output status signals that are applicable in the graphic equation editor.

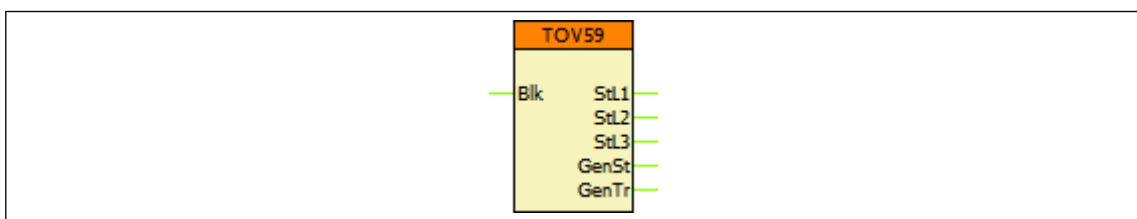


Figure 1-6 The function block of the overvoltage protection function

3.1.12. Residual definite time overvoltage protection function

The residual definite time overvoltage protection function operates according to definite time characteristics, using the RMS values of the fundamental Fourier component of the zero sequence voltage ($U_N=3U_0$).

3.1.12.1. Operating characteristics

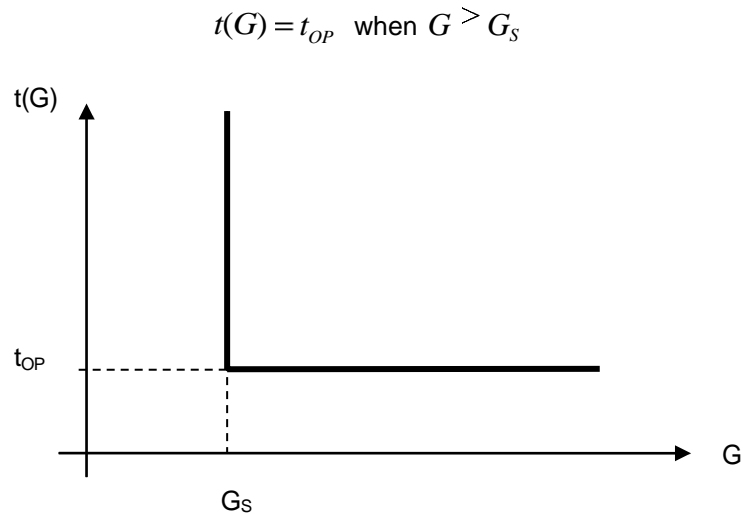


Figure I-1 Overvoltage independent time characteristic

| | |
|--------------------|---------------------------------------------------------------------------------------------|
| where | |
| t_{OP} (seconds) | theoretical operating time if $G > G_s$, fix, according to the parameter setting value, |
| G | measured value of the characteristic quantity, Fourier base harmonic of the phase voltages, |
| G_s | setting value of the characteristic quantity (TOV59N_StCurr_IPar_, Start voltage). |

3.1.12.2. Structure of the residual definite time overvoltage protection algorithm

Fig.1-2 shows the structure of the residual definite time overvoltage protection (TOV59N) algorithm.

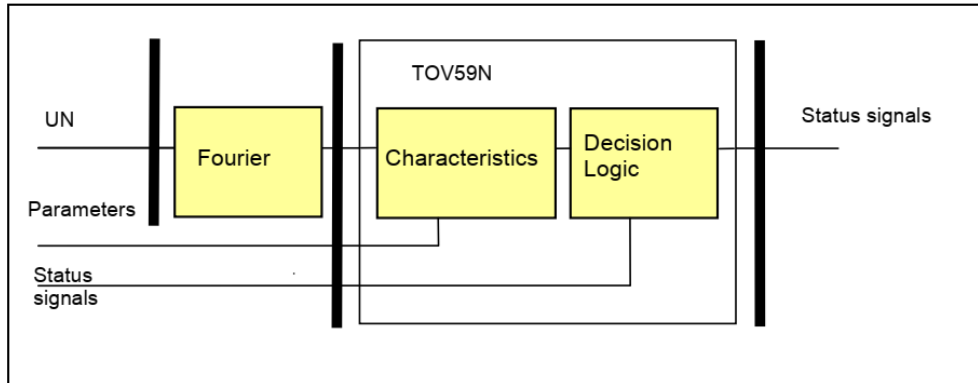


Figure 1-2 Structure of the definite time residual overvoltage protection algorithm

The **inputs** are

- the RMS values of the fundamental Fourier component of the residual or neutral voltage ($UN=3U_0$),
- parameters,
- status signals.

The **outputs** are

- the binary output status signals.

The **software modules** of the differential protection function:

Fourier calculations

These modules calculate the basic Fourier components of the residual voltage (not part of the TOV59 function).

Characteristics

This module calculates the required time delay based on the Fourier components of the residual voltage.

Decision logic

The decision logic module combines the status signals to generate the trip command of the function.

The following description explains the details of the individual components.

3.1.12.3. The Fourier calculation (Fourier)

This module calculates the RMS value of the fundamental Fourier component of the residual or neutral voltage ($UN=3U_0$). This module is not part of the TOV59N function; it belongs to the preparatory phase.

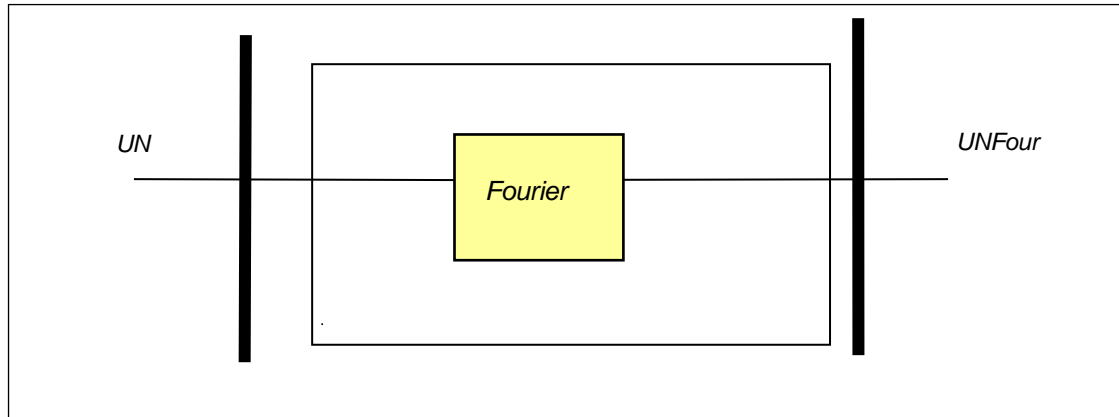


Figure 1-3 Schema of the Fourier calculation

The **input** is the sampled value of the residual voltage ($UN=3U_0$).

The **output** is the RMS value of the fundamental Fourier component of the residual or neutral voltage ($UNFour$).

3.1.12.4. The definite time characteristics (Characteristics)

This module decides the starting of the function and counts the required time delay based on the Fourier components of the residual voltage. The time delay is defined by the parameter setting value, if the voltage is above the voltage setting value.

The **inputs** are:

- the RMS value of the fundamental Fourier component of the residual or neutral voltage ($UNFour$),
- parameters.

The **outputs** are the status signals of the function. These indicate the started state of the function.

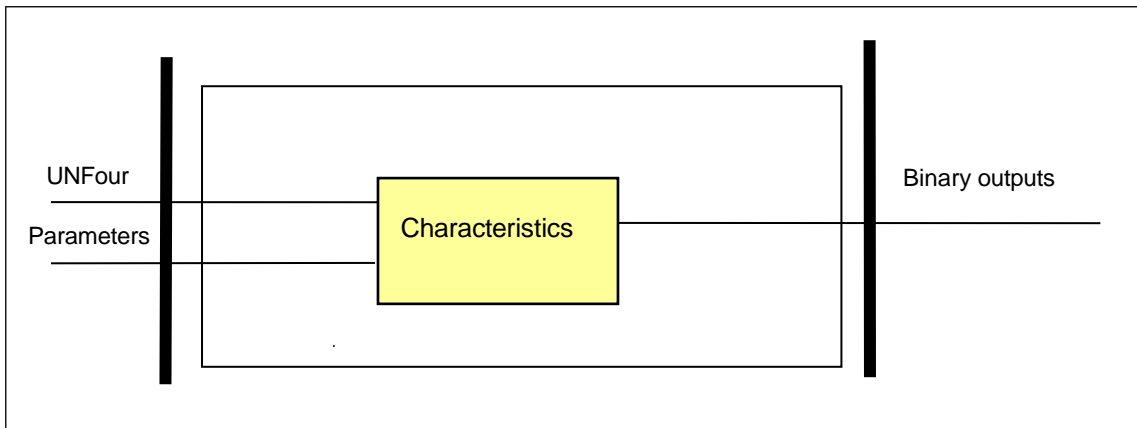


Figure 1-4 Schema of the residual definite time characteristic calculation

Enumerated parameter

| Parameter name | Title | Selection range | Default |
|-----------------------------------------------|-----------|-----------------|---------|
| Parameter for enabling/disabling the function | | | |
| TOV59N_Oper_EPar_ | Operation | Off, On | On |

Table 1-1 The enumerated parameters of the residual definite time overvoltage protection function

Integer parameter

| Parameter name | Title | Unit | Min | Max | Step | Default |
|-----------------------------|---------------|------|-----|-----|------|---------|
| Starting voltage parameter: | | | | | | |
| TOV59N_StVol_IPar_ | Start Voltage | % | 2 | 60 | 1 | 30 |

Table 1-2 The integer parameters of the residual definite time overvoltage protection function

Timer parameter

| Parameter name | Title | Unit | Min | Max | Step | Default |
|----------------------|------------|------|-----|-------|------|---------|
| Definite time delay: | | | | | | |
| TOV59N_Delay_TPar_ | Time Delay | msec | 0 | 60000 | 1 | 100 |

Table 1-3 Timer parameter of the residual definite time overvoltage protection function

The **binary output status signals** of the residual definite time overvoltage protection function are listed in Table 1-4.

| Binary output signals | Signal title | Explanation |
|-----------------------|--------------|------------------------------|
| TOV59N_St_Grl_ | Start L1 | Starting of the function |
| TOV59N_Tr_Grl_ | Trip L1 | Trip command of the function |

Table 1-4 The binary output status signals of the residual definite time overvoltage protection function

3.1.12.5. The decision logic (Decision logic)

The decision logic module combines the status signals, binary and enumerated parameters to generate the trip command of the function.

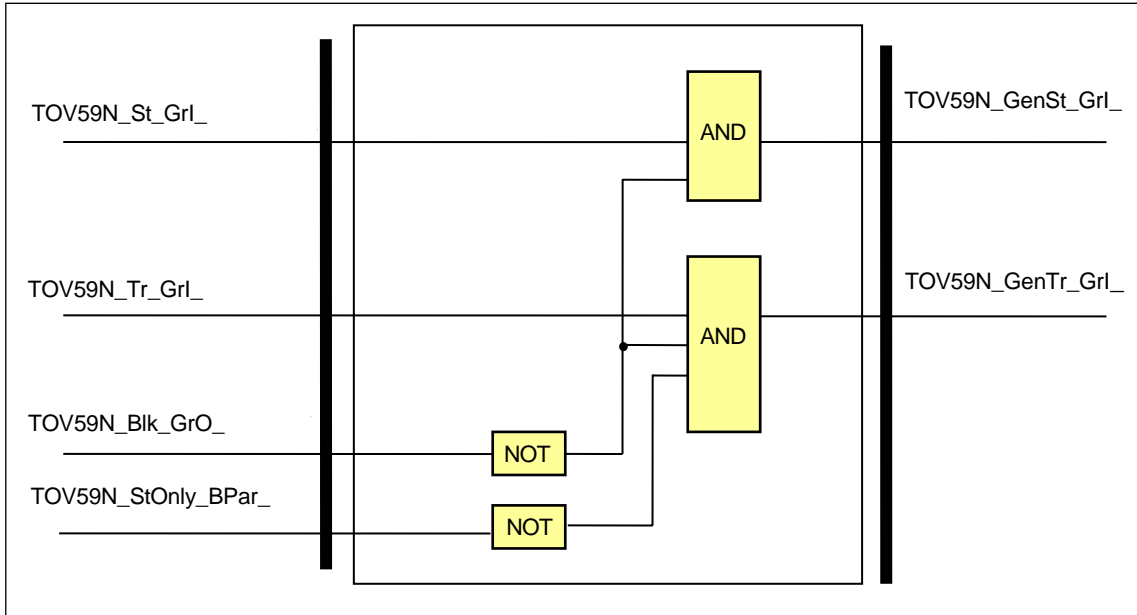


Figure 1-5 The logic scheme of the residual definite time overvoltage protection function

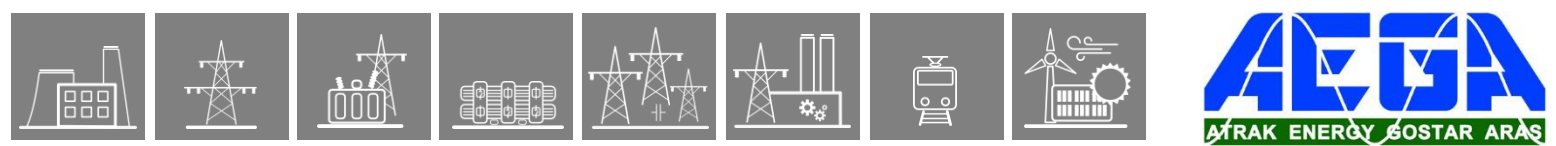
| Binary input signals | Signal title | Explanation |
|----------------------|--------------|------------------------------|
| TOV59N_St_GrI_ | Start L1 | Starting of the function |
| TOV59N_Tr_GrI_ | Trip L1 | Trip command of the function |

Table 1-5 The binary input status signals of the decision logic scheme for the residual definite time overvoltage protection function

Boolean parameter

| Parameter name | Title | Default |
|-----------------------------|-------------------|---------|
| Enabling start signal only: | | |
| TOV59N_StOnly_BPar_ | Start Signal Only | FALSE |

Table 1-6 The Boolean parameter of the residual definite time overvoltage protection function



Binary status signals

The overvoltage protection function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

| Binary status signal | Explanation |
|----------------------|--------------------------------------------------------------------------------------------------------------------------------|
| TOV59N_Blk_GrO_ | Output status of a graphic equation defined by the user to disable the residual definite time overvoltage protection function. |

Table 1-7 The binary input signal of the residual definite time overvoltage protection function

| Binary output signals | Signal title | Explanation |
|-----------------------|---------------|--------------------------------------|
| TOV59N_GenSt_Grl_ | General Start | General starting of the function |
| TOV59N_GenTr_Grl_ | General Trip | General trip command of the function |

Table 1-8 The binary output status signals of the residual definite time overvoltage protection function

3.1.12.6. Technical summary

3.1.12.6.1. Technical data

| Function | Value | Accuracy |
|---------------------------------|---------------------|----------------------|
| Pick-up starting accuracy | 2 – 8 % 8 – 60 % | < ± 2 % < ± 1.5 % |
| Reset time U> → Un U> → 0 | 60 ms 50 ms | |
| Operate time | 50 ms | < ± 20 ms |

Table 1-9 Technical data of the residual definite time overvoltage protection function

3.1.12.6.2. The parameters

The parameters are summarized in Chapters 1.4 and 1.5.

3.1.12.6.3. The binary output status signals

The **binary output status signals** of the residual definite time overvoltage protection function are listed in Table 1-10.

| Binary output signals | Signal title | Explanation |
|-----------------------|---------------|--------------------------------------|
| TOV59N_GenSt_Grl_ | General Start | General starting of the function |
| TOV59_N_GenTr_Grl_ | General Trip | General trip command of the function |

Table 1-10 The binary output status signals of the residual definite time overvoltage protection function

3.1.12.6.4. The binary input status signals

The residual definite time overvoltage protection function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

| Binary input signal | Explanation |
|---------------------|--------------------------------------------------------------------------------------------------------------------------------|
| TOV59N_BlK_GrO_ | Output status of a graphic equation defined by the user to disable the residual definite time overvoltage protection function. |

Table 1-11 The binary input signal of the residual definite time overvoltage protection function

3.1.12.6.5. The function block

The function block of the residual overvoltage protection function is shown in Figure 1-6. This block shows all binary input and output status signals that are applicable in the graphic equation editor.

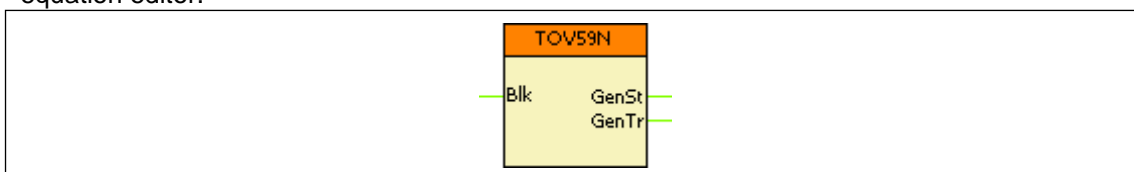


Figure 1-6 The function block of the residual overvoltage protection function

3.1.13. Directional residual overcurrent protection function

3.1.13.1. Application

The main application area of the directional residual overcurrent protection function is the earth-fault protection.

3.1.13.2. Mode of operation

The inputs of the function are the Fourier basic harmonic components of the zero sequence current and those of the zero sequence voltage.

The block of the directional decision generates a signal of TRUE value if the $U_N=3U_0$ zero sequence voltage and the $I_N=-3I_0$ current are sufficient for directional decision, and the angle difference between the vectors is within the preset range. This decision enables the output start and trip signals of the residual overcurrent protection function block (TOC51N).

Note: the position of the vectors in *Figure 1-1* indicates a forward fault, i.e., the location of the earth fault is on the protected line (the positive direction of the current is from the busbar to the line).

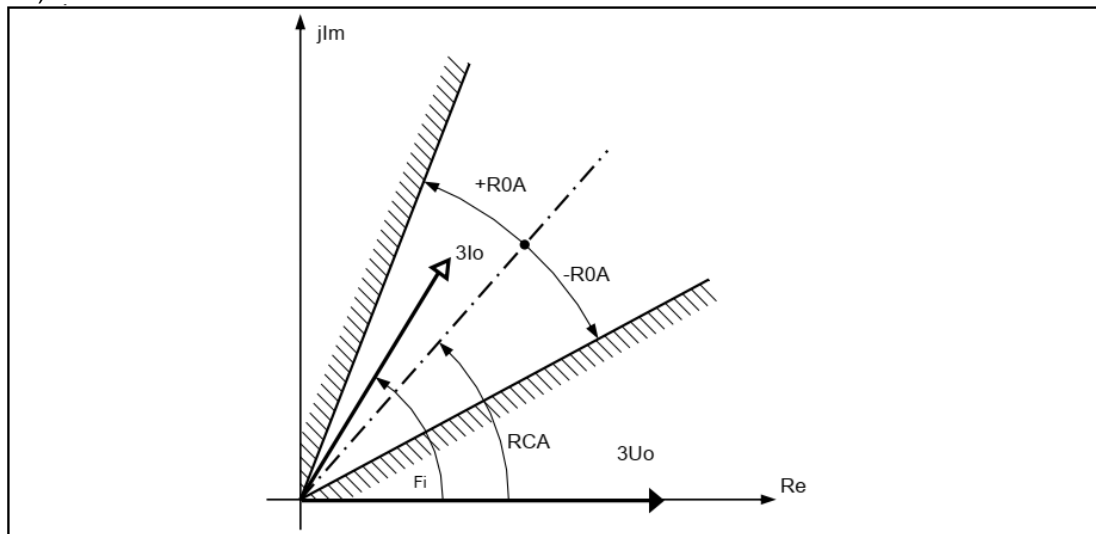


Figure 1-1 The directional decision

3.1.13.3. Structure of the directional residual overcurrent protection algorithm

Fig.1-2 shows the structure of the directional residual overcurrent protection (TOC51N) algorithm.

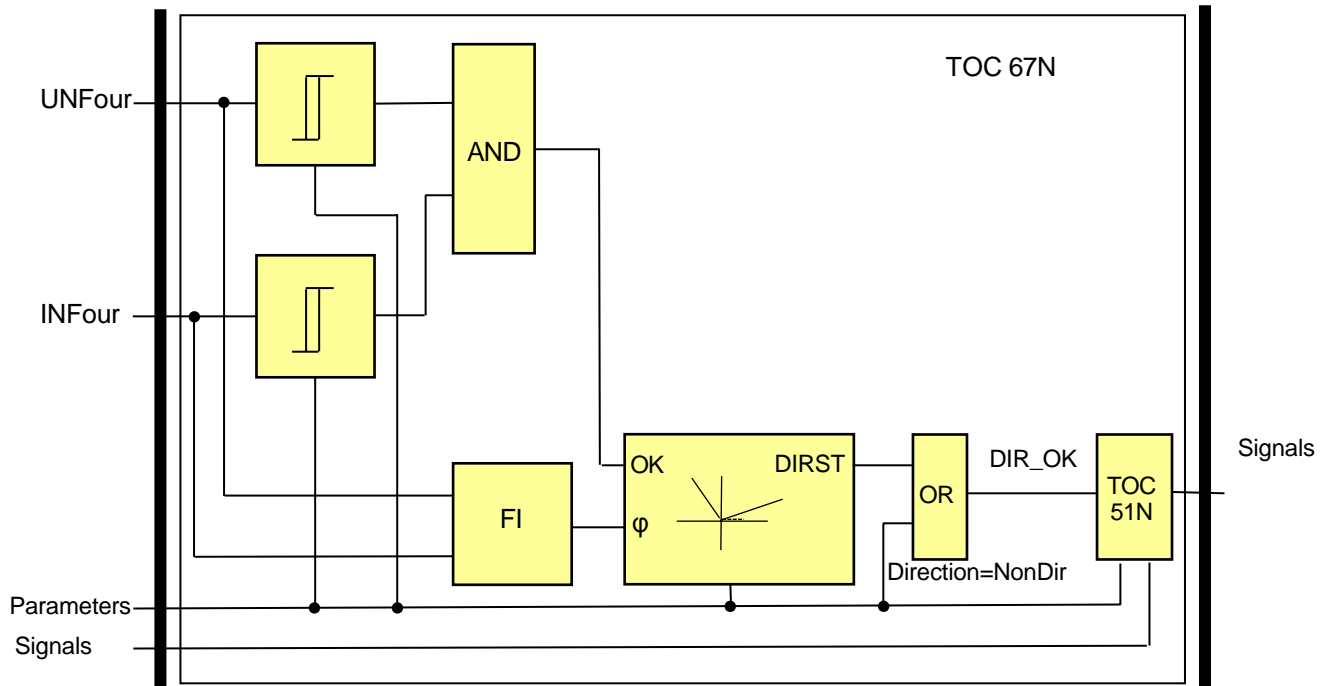


Figure 1-2 Structure of the residual directional overcurrent protection algorithm

The **inputs** are

- the RMS value of the fundamental Fourier component of the residual current ($IN=3I_0$),
- the RMS value of the fundamental Fourier component of the residual voltage ($UN=3U_0$),
- parameters,
- status signals.

The **outputs** are

- the binary output status signals.

The **software modules** of the residual directional overcurrent protection function:

Comparison

These modules decide if the RMS values of the fundamental Fourier component of the residual current and voltage are above the limits needed for correct directional decision.

FI calculation

This module calculates the vector angle between the residual voltage and the residual current.

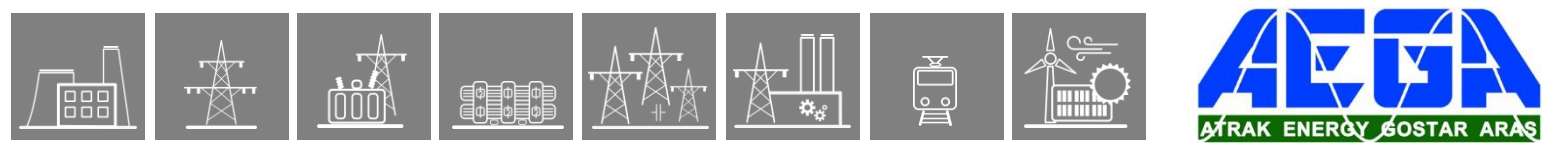
DIRST

The directional decision.

TOC51N

Non-directional residual overcurrent protection function.

The following description explains the details of the individual components.



3.1.13.3.1. Enabling the directional decision (Comparison)

These modules decide if the RMS values of the fundamental Fourier component of the residual current and voltage are above the limits needed for correct directional decision.

Integer parameters

| Parameter name | Title | Unit | Min | Max | Step | Default |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|------|-----|-----|------|---------|
| The threshold value for the $3U_0$ zero sequence voltage, below which no directionality is possible. % of the rated voltage of the voltage transformer input. | | | | | | |
| TOC67N_UoMin_IPar_ | Min Res Voltage | % | 1 | 20 | 1 | 2 |
| The threshold value for the $3I_0$ zero sequence current, below which no operation is possible. % of the rated current of the current transformer input. | | | | | | |
| TOC67N_IoMin_IPar_ | Min Res Current | % | 1 | 50 | 1 | 5 |

Table 1-1 The integer parameters for enabling the directional decision

The **input signals** are the RMS values of the fundamental Fourier component of the residual current and voltage.

The **internal output status signal** for enabling the directional decision is true if both the residual voltage and the residual current is above the preset limits.

3.1.13.3.2. Calculation of the vector angle (FI calculation)

This module calculates the phase angle between the residual voltage and the residual current. The reference signal is the residual voltage according to [Figure 1-1](#).

The **input signals** are the fundamental Fourier components of the residual current and voltage.

The **internal output signal** is the calculated phase angle.

3.1.13.3.3. Directional decision (DIRST)

This module decides if the phase angle between the residual voltage and the residual current is within the limit range defined by the preset parameter. The operation of this function is explained in [Figure 1-1](#).

The input signals are

- The enabling status signal from the Comparison modules in AND relationship.
- The calculated phase angle between the residual voltage and the residual current.
- Parameters.

The **internal output signal** of the directional decision is TRUE if the phase angle between the residual voltage and the residual current is within the limit range defined by the preset parameters OR if non-directional operation is selected by the preset parameter TOC67N_Dir_EPar_ (Direction=NonDir).

Enumerated parameters

| Parameter name | Title | Selection range | Default |
|--------------------------------|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| Directionality of the function | | | |
| TOC67N_Dir_EPar_ | Direction | NonDir,Forward-Angle,Backward-Angle,Forward-I*cos(fi),Backward-I*cos(fi),Forward-I*sin(fi),Backward-I*sin(fi),Forward-I*sin(fi+45),Backward-I*sin(fi+45) | Forward-Angle |

*The forward direction is defined by the RCA characteristic angle (See Tables 1-5 below).

Table 1-2 The enumerated parameters of the directional decision

Short explanation of the enumerated parameter selection

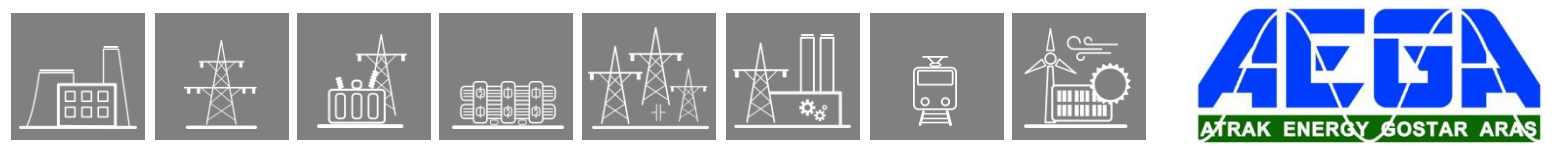
| Selected value | Explanation |
|-----------------------|--------------------------------------------------------------------------|
| NonDir, | Operation according to non-directional TOC51N |
| Forward-Angle | See <u>Figure 1-1</u> , set ROA and RCA as required |
| Backward-Angle | RCA=RCAset+180°, set ROA and RCA as required |
| Forward-I*cos(fi) | RCA=0°fix, ROA=85°fix, the setting values RCA and ROA are not applied |
| Backward-I*cos(fi) | RCA=180°fix, ROA=85°fix, the setting values RCA and ROA are not applied |
| Forward-I*sin(fi) | RCA=90°fix, ROA=85°fix, the setting values RCA and ROA are not applied |
| Backward-I*sin(fi) | RCA=-90°fix, ROA=85°fix, the setting values RCA and ROA are not applied |
| Forward-I*sin(fi+45) | RCA=45°fix, ROA=85°fix, the setting values RCA and ROA are not applied |
| Backward-I*sin(fi+45) | RCA=-135°fix, ROA=85°fix, the setting values RCA and ROA are not applied |

Table 1-3 Explanation of the enumerated parameter “Direction”

Integer parameters

| Parameter name | Title | Unit | Min | Max | Step | Default |
|-----------------------------------------------|----------------------|------|------|-----|------|---------|
| Operating angle (See <u>Figure 1-1</u>) | | | | | | |
| TOC67N_ROA_IPar_ | Operating Angle | deg | 30 | 85 | 1 | 60 |
| Characteristic angle (See <u>Figure 1-1</u>) | | | | | | |
| TOC67N_RCA_IPar_ | Characteristic Angle | deg | -180 | 180 | 1 | 60 |

Table 1-4 Integer parameters of the directional decision



3.1.13.3.4. Non-directional residual overcurrent protection function (TOC51N)

This module is equivalent to the TOC51N function block described in a separate document.

Summary of the parameters:

Enumerated parameters

| Parameter name | Title | Selection range | Default |
|---------------------------------------------------------|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------|---------|
| Operating characteristic selection of the TOC51N module | | | |
| TOC67N_Oper_EPar_ | Operation | Off,DefiniteTime,IEC Inv,IEC VeryInv,IEC ExtInv,IEC LongInv,ANSI Inv,ANSI ModInv,ANSI VeryInv,ANSI ExtInv,ANSI LongInv,ANSI LongVeryInv,ANSI LongExtInv | Off |

Tables 1-5 The enumerated parameters of the TOC51N function block

Integer parameters

| Parameter name | Title | Unit | Min | Max | Step | Default |
|-------------------------------|------------------|------|-----|------|------|---------|
| Start current (TOC51N module) | | | | | | |
| TOC67N_StCurr_IPar_ | Start Current * | % | 10 | 1000 | 1 | 50 |
| TOC67N_StCurr_IPar_ | Start Current ** | % | 5 | 1000 | 1 | 50 |

* In = 1 A or 5 A

** In = 200 mA or 1 A

Table 1-6 Integer parameters of the TOC51N function block

Float parameters

| Parameter name | Title | Unit | Min | Max | Step | Default |
|----------------------------------------------------------------|-----------------|------|------|-----|------|---------|
| Time multiplier of the inverse characteristics (TOC51N module) | | | | | | |
| TOC67N_Multip_FPar_ | Time Multiplier | | 0.05 | 15 | 0.01 | 1.0 |

Table 1-7 Float parameters of the TOC51N function block

Timer parameters

| Parameter name | Title | Unit | Min | Max | Step | Default |
|----------------------------------------------------------------------|------------------------|------|-----|-------|------|---------|
| Minimal time delay for the inverse characteristics (TOC 51N module): | | | | | | |
| TOC67N_MinDel_TPar | Min Time Delay * | msec | 30 | 60000 | 1 | 100 |
| Definite time delay (TOC 51N module): | | | | | | |
| TOC67N_DefDel_TPar_ | Definite Time Delay ** | msec | 30 | 60000 | 1 | 100 |
| Reset time delay for the inverse characteristics (TOC 51N module): | | | | | | |
| TOC67N_Reset_TPar_ | Reset Time * | msec | 60 | 60000 | 1 | 100 |

*Valid for inverse type characteristics only

**Valid for definite type characteristics only

Table 1-8 Timer parameters of the TOC51N function block

The **output status signals** of the TOC51N function block are identical with those of the TOC67N function:

| Binary status signal | Title | Explanation |
|----------------------|-------|--------------------------------------|
| TOC67N_GenSt_Grl_ | Start | General start signal of the function |
| TOC67N_GenTr_Grl_ | Trip | General trip command of the function |

Table 1-9 The binary output status signals of the TOC51N function block

3.1.13.4. Technical summary

3.1.13.4.1. Technical data

| Function | Value | Accuracy |
|------------------------------------------|--------------|-------------------------------------|
| Operating accuracy | | < ±2 % |
| Operate time accuracy | | ±5% or ±15 ms, whichever is greater |
| Accuracy in minimum time range | | ±35 ms |
| Reset ratio | 0,95 | |
| Reset time | Approx 50 ms | ±35 ms |
| Transient overreach | <2 % | |
| Pickup time with non-directional setting | 25 – 30 ms | |
| Pickup time with directional setting | <100ms | |
| Angular accuracy | | |
| $I_0 \leq 0.1 I_n$ | | < ±10° |
| $0.1 I_n < I_0 \leq 0.4 I_n$ | | < ±5° |
| $0.4 I_n < I_0$ | | < ±2° |
| Angular reset ratio | | |
| Forward and backward | 10° | |
| All other selection | 5° | |

Table 1-10 Technical data of the directional residual overcurrent protection function

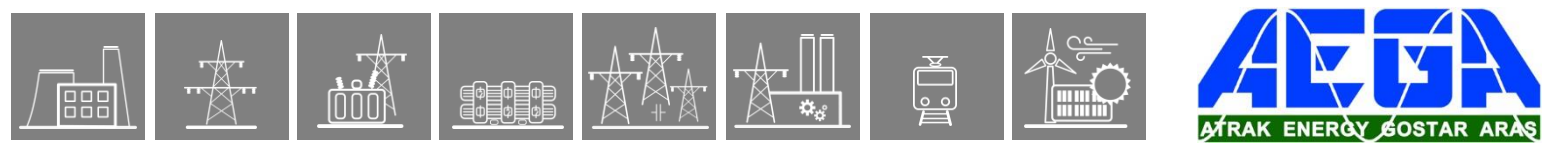
3.1.13.4.2. Summary of the parameters

Enumerated parameters

| Parameter name | Title | Selection range | Default |
|---------------------------------------------------------|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| Directionality of the function | | | |
| TOC67N_Dir_EPar_ | Direction* | NonDir,Forward-Angle,Backward-Angle,Forward- $I \cdot \cos(\phi_i)$,Backward- $I \cdot \cos(\phi_i)$,Forward- $I \cdot \sin(\phi_i)$,Backward- $I \cdot \sin(\phi_i)$,Forward- $I \cdot \sin(\phi_i+45)$,Backward- $I \cdot \sin(\phi_i+45)$ | Forward-Angle |
| Operating characteristic selection of the TOC51N module | | | |
| TOC67N_Oper_EPar_ | Operation | Off,DefiniteTime,IEC Inv,IEC VeryInv,IEC ExtInv,IEC LongInv,ANSI Inv,ANSI ModInv,ANSI VeryInv,ANSI ExtInv,ANSI LongInv,ANSI LongVeryInv,ANSI LongExtInv | Off |

* See table 1-3.

Table 1-11 The enumerated parameters of the directional residual overcurrent protection function



Integer parameters

| Parameter name | Title | Unit | Min | Max | Step | Default |
|------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|------|------|------|------|---------|
| The threshold value for the 3Uo zero sequence voltage, below which no directionality is possible. % of the rated voltage of the voltage transformer input. | | | | | | |
| TOC67N_UoMin_IPar_ | Min Res Voltage | % | 1 | 20 | 1 | 2 |
| The threshold value for the 3Io zero sequence current, below which no operation is possible. % of the rated current of the current transformer input. | | | | | | |
| TOC67N_IoMin_IPar_ | Min Res Current | % | 1 | 50 | 1 | 5 |
| Operating angle (See <i>Figure 1-1</i>) | | | | | | |
| TOC67N_ROA_IPar_ | Operating Angle | deg | 30 | 85 | 1 | 60 |
| Characteristic angle (See <i>Figure 1-1</i>) | | | | | | |
| TOC67N_RCA_IPar_ | Characteristic Angle | deg | -180 | 180 | 1 | 60 |
| Start current (TOC51N module) | | | | | | |
| TOC67N_StCurr_IPar_ | Start Current * | % | 10 | 1000 | 1 | 50 |
| TOC67N_StCurr_IPar_ | Start Current ** | % | 5 | 1000 | 1 | 50 |

* In = 1 A or 5 A

** In = 200 mA or 1 A

Table 1-12 Integer parameters of the directional residual overcurrent protection function

Float parameter

| Parameter name | Title | Unit | Min | Step | Step | Default |
|----------------------------------------------------------------|-----------------|------|------|------|------|---------|
| Time multiplier of the inverse characteristics (TOC51N module) | | | | | | |
| TOC67N_Multip_FPar_ | Time Multiplier | | 0.05 | 15 | 0.01 | 1.0 |

Table 1-13 Float parameter of the directional residual overcurrent protection function

Timer parameters

| Parameter name | Title | Unit | Min | Max | Step | Default |
|----------------------------------------------------------------------|------------------------|------|-----|-------|------|---------|
| Minimal time delay for the inverse characteristics (TOC 51N module): | | | | | | |
| TOC67N_MinDel_TPar_ | Min Time Delay * | msec | 30 | 60000 | 1 | 100 |
| Definite time delay (TOC 51N module): | | | | | | |
| TOC67N_DefDel_TPar_ | Definite Time Delay ** | msec | 30 | 60000 | 1 | 100 |
| Reset time delay for the inverse characteristics (TOC 51N module): | | | | | | |
| TOC67N_Reset_TPar_ | Reset Time * | msec | 60 | 60000 | 1 | 100 |

*Valid for inverse type characteristics only

**Valid for definite type characteristics only

Table 1-14 Timer parameters of the directional residual overcurrent protection function

3.1.13.4.3. Summary of the generated output signals

| Binary status signal | Title | Explanation |
|----------------------|-------|--------------------------------------|
| TOC67N_GenSt_Grl_ | Start | General start signal of the function |
| TOC67N_GenTr_Grl_ | Trip | General trip command of the function |

Table 1-15 The binary output status signals of the directional residual overcurrent protection function

3.1.13.4.4. Summary of the input signals

Binary status signals

The directional residual overcurrent protection function has a binary input status signal. **The conditions are defined by the user applying the graphic equation editor.**

| Binary status signal | Title | Explanation |
|----------------------|-------|------------------------------|
| TOC67N_BlK_GrO_ | Block | Blocking input status signal |

Table 1-16 The binary input signal of the directional residual overcurrent protection function

3.1.13.4.5. The function block

The function block of the residual directional overcurrent protection function is shown in [Figure 1-3](#). This block shows all binary input and output status signals that are applicable in the graphic equation editor.

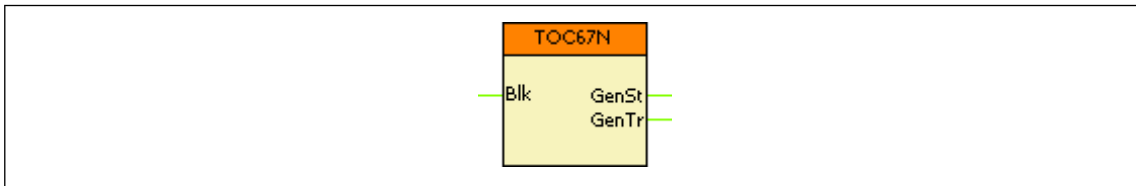
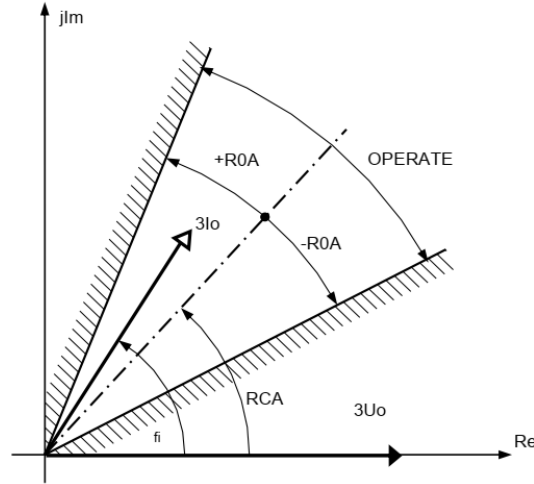


Figure 1-3 The function block of the residual overcurrent protection function

The names of the input and output signals are parts of the “Binary status signal” names listed in [Table 1-15](#) and [Table 1-16](#) above.

3.1.13.5. APPENDIX Pre-configured setting values of the directional residual overcurrent protection function

3.1.13.5.1. Setting: Direction = Forward-Angle

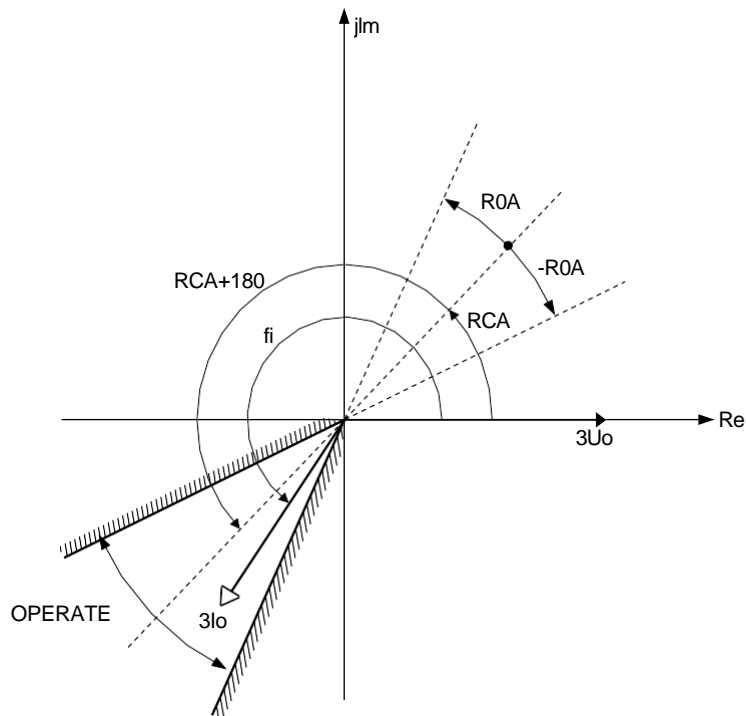


For the operation the residual current ($3I_o$) must be within the “OPERATE” area.

Additional conditions for operation:

- The magnitude of the residual current is above the setting value:
 $|3I_o| > \text{“Start current”}$
- The magnitude of the residual voltage is above the setting value:
 $|3U_o| > \text{“Min Res Voltage”}$

3.1.13.5.2. Setting: Direction = Backward-Angle

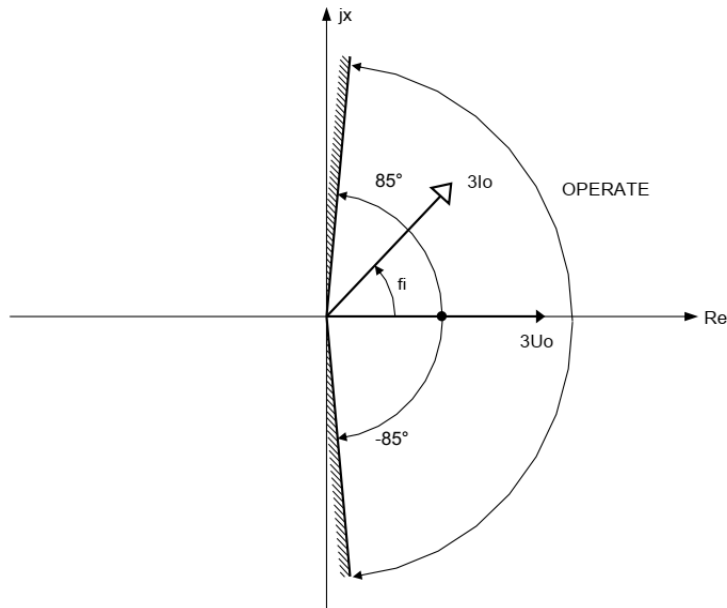


For the operation the residual current ($3I_0$) must be within the “OPERATE” area.

Additional conditions for operation:

- The magnitude of the residual current is above the setting value:
 $|3I_0| > \text{“Start current”}$
- The magnitude of the residual voltage is above the setting value:
 $|3U_0| > \text{“Min Res Voltage”}$

3.1.13.5.3. Setting: Direction = Forward- $I \cdot \cos(\phi_i)$

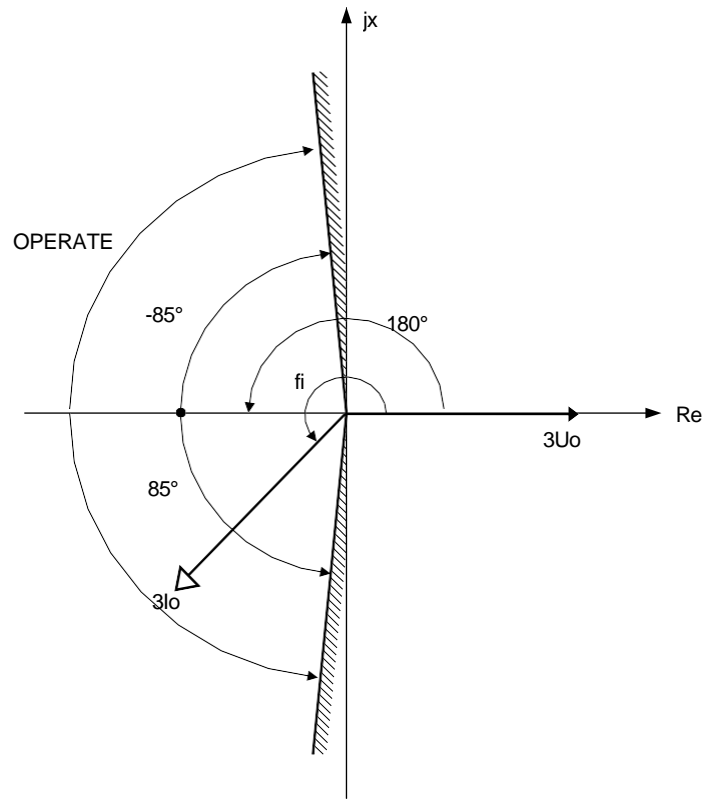


For the operation the residual current ($3I_0$) must be within the “OPERATE” area.

Additional conditions for operation:

- The magnitude of the residual current projected to the real axis is above the setting value:
 $|3I_0| \cdot \cos(\phi_i) > \text{“Start current”}$
- The magnitude of the residual voltage is above the setting value:
 $|3U_0| > \text{“Min Res Voltage”}$

3.1.13.5.4. Setting: Direction = Backward- $I \cdot \cos(\phi_i)$



For the operation the residual current ($3I_o$) must be within the “OPERATE” area.

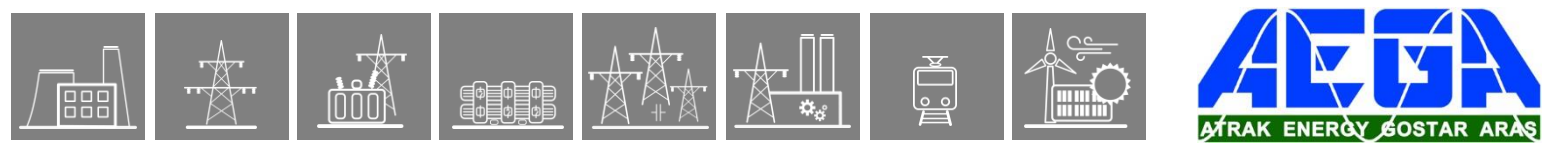
Additional conditions for operation:

- The magnitude of the residual current projected to the negative real axis is above the setting value:

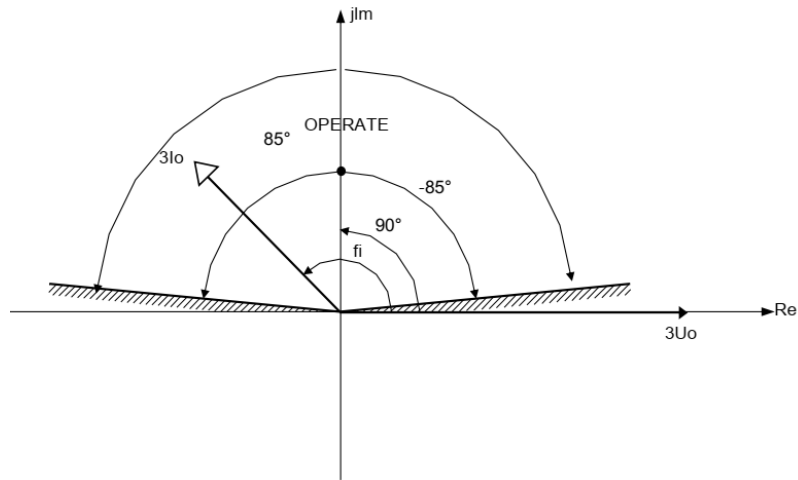
$$|3I_o| \cdot \cos(\phi_i - 180) > \text{“Start current”}$$

- The magnitude of the residual voltage is above the setting value:

$$|3U_o| > \text{“Min Res Voltage”}$$



3.1.13.5.5. Setting: Direction = Forward- $I \cdot \sin(\phi_i)$



For the operation the residual current ($3I_o$) must be within the “OPERATE” area.

Additional conditions for operation:

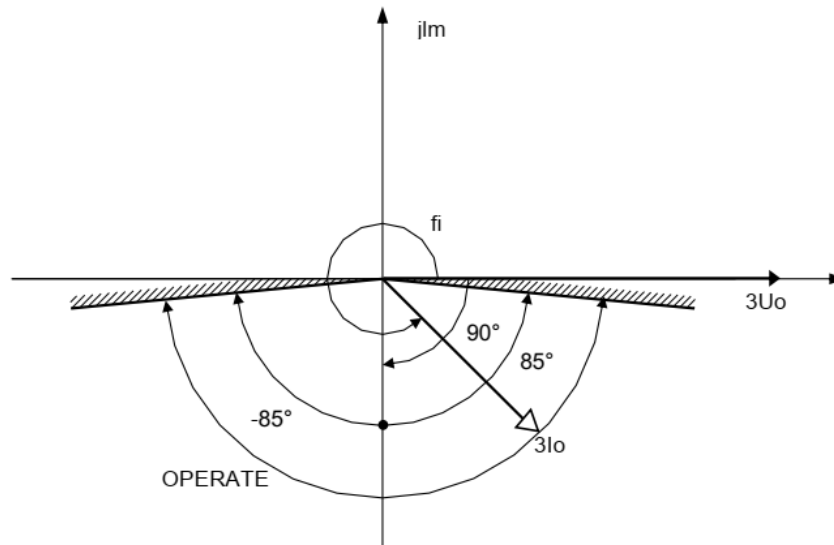
- The magnitude of the residual current projected to the imaginary axis is above the setting value:

$$|3I_o| \cdot \sin(\phi_i) > \text{“Start current”}$$

- The magnitude of the residual voltage is above the setting value:

$$|3U_o| > \text{“Min Res Voltage”}$$

3.1.13.5.6. Setting: Direction = Backward- $I \cdot \sin(\phi_i)$



For the operation the residual current ($3I_o$) must be within the “OPERATE” area.

Additional conditions for operation:

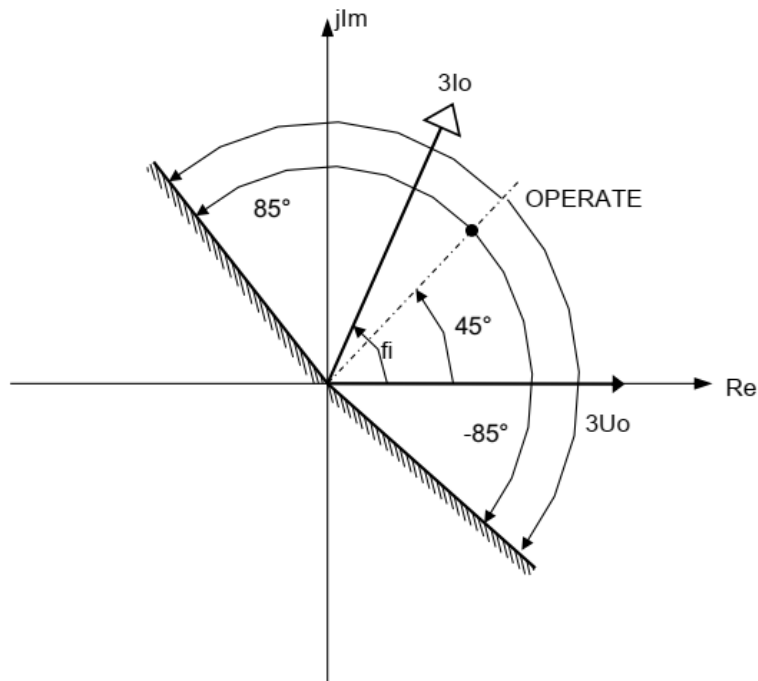
- The magnitude of the residual current projected to the negative imaginary axis is above the setting value:

$$|3I_o| \cdot \sin(\phi_i - 180) > \text{“Start current”}$$

- The magnitude of the residual voltage is above the setting value:

$$|3U_o| > \text{“Min Res Voltage”}$$

3.1.13.5.7. Setting: Direction = Forward- $I \cdot \sin(\phi_i + 45^\circ)$



For the operation the residual current ($3I_o$) must be within the “OPERATE” area.

Additional conditions for operation:

- The magnitude of the residual current projected to the line of the characteristic angle (45°) is above the setting value:

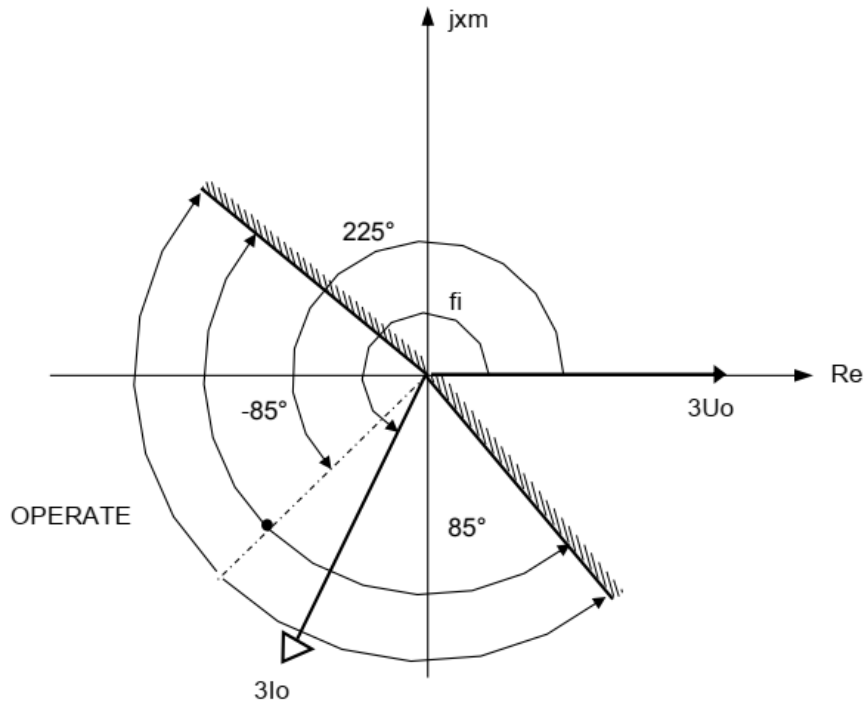
$$|3I_o| \cdot \cos(\phi_i - 45^\circ) > \text{“Start current”}$$

- The magnitude of the residual voltage is above the setting value:

$$|3U_o| > \text{“Min Res Voltage”}$$

Note: Because of the characteristic angle is 45° ,
 $\cos(\phi_i - 45^\circ) = \sin(\phi_i + 45^\circ)$

3.1.13.5.8. Setting: Direction = Backward- $I \cdot \sin(\phi_i + 45^\circ)$



For the operation the residual current ($3I_o$) must be within the “OPERATE” area. Additional conditions for operation:

- The magnitude of the residual current projected to the line of the characteristic angle (225°) is above the setting value:

$$|3I_o| \cdot \cos(\phi_i - 225^\circ) > \text{“Start current”}$$

- The magnitude of the residual voltage is above the setting value:

$|3U_o| > \text{“Min Res Voltage”}$ Note: Because of the characteristic

$$\text{angle is } 225^\circ, \cos(\phi_i - 225^\circ) = \sin(\phi_i + 45^\circ)|_{BW}$$

3.1.13.6. Setting guide to the directional overcurrent protection

3.1.13.6.1. Example for application

The example in this guide supposes that the device is connected to instrument transformers and to the circuit breakers according to *Figure 1-1*.

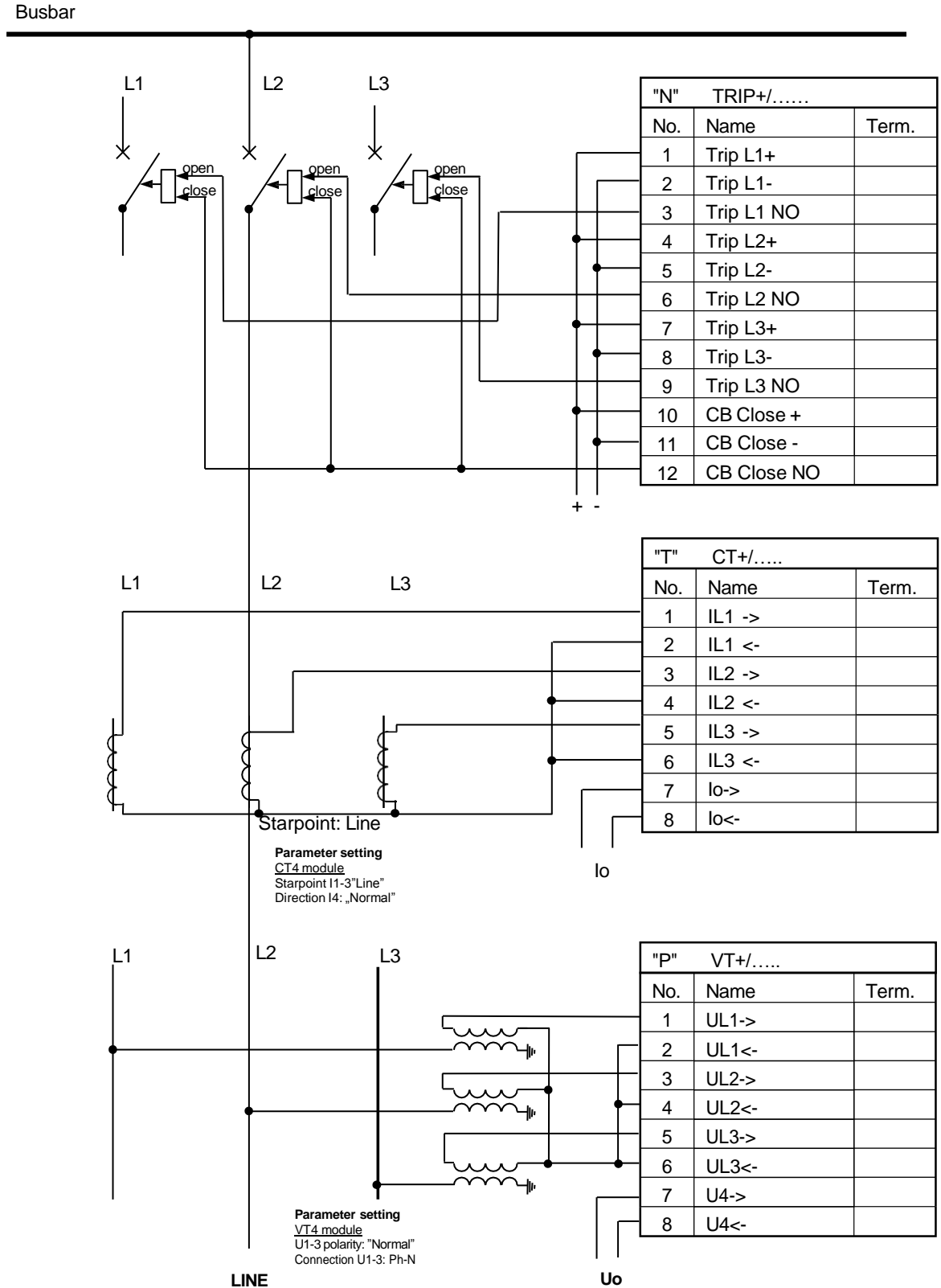


Figure 1-1 Connection example

The directional three-phase overcurrent protection function can be applied on solidly grounded networks, where the overcurrent protection must be supplemented with a directional decision. In these networks the fault is considered to be in “Forward” direction, if the measured fault impedance, using the positive directions shown in *Figure 1-2*, is inductive i.e. the calculated φ impedance angle is $0^\circ \leq \varphi \leq 90^\circ$.

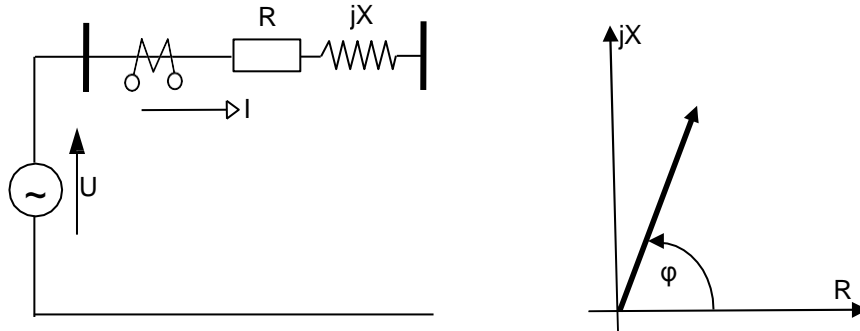


Figure 1-2 The fault impedance

The voltage and current vectors for this fault loop are shown in *Figure 1-3*.

In *Figure 1-3.a*), the voltage vector is the reference, the current lags relative to the voltage, the φ angle is negative. To change this angle to a positive value (as the value of the impedance angle is) the current is considered to be the reference. This is shown in *Figure 1-3.b*). The directional overcurrent protection function applies this coordinate system of *Figure 1-3.b*).

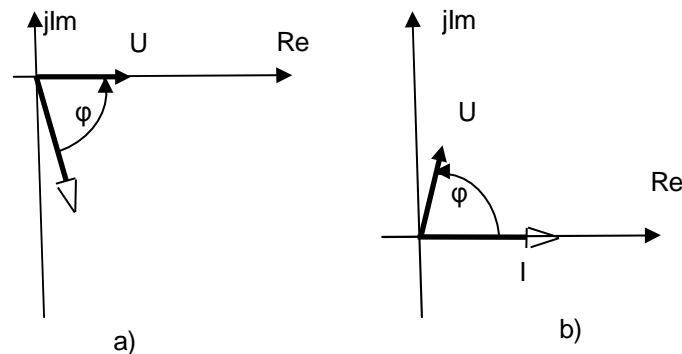


Figure 1-3 Voltage and current vectors in the faulty loop

Figure 1-4 below shows that the considered voltages are „loop” voltages and the considered currents are „loop” currents. The indicated operating range is valid if the “Direction” parameter is set “Forward”. If the direction parameter is set “Backward” then the operation range is mirrored to the origin of *Figure 1-4*. The setting “NonDir” for this parameter means that only the magnitude of the current is considered, the phase angles are neglected.

The „loop” voltages and the „loop” currents are selected according to the smallest loop impedance, depending on the detected fault type, according to Table 1-1.

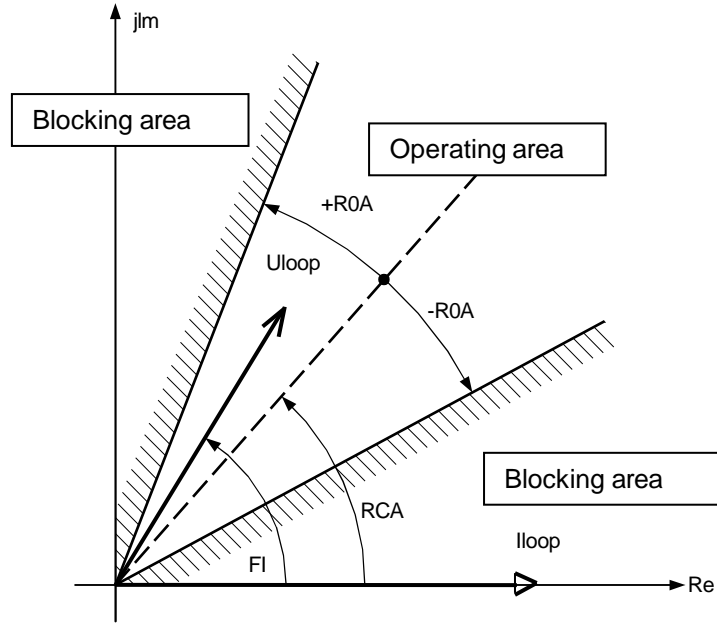


Figure 1-4 The directional decision

Based on the measured voltages and currents, from among the six loops (L1L2, L2L3, L3L1, L1N, L2N, L3N) the block selects the one with the smallest calculated loop impedance.

| Fault | U_{loop} | I_{loop} |
|-----------|------------------------------|--------------------------------|
| L1L2L3(N) | $U_{loop} = U_{L2} - U_{L3}$ | $I_{loop} = I_{L2} - I_{L3}$ |
| L1L2 | $U_{loop} = U_{L1} - U_{L2}$ | $I_{loop} = I_{L1} - I_{L2}$ |
| L2L3 | $U_{loop} = U_{L2} - U_{L3}$ | $I_{loop} = I_{L2} - I_{L3}$ |
| L3L1 | $U_{loop} = U_{L3} - U_{L1}$ | $I_{loop} = I_{L3} - I_{L1}$ |
| L1L2N | $U_{loop} = U_{L1} - U_{L1}$ | $I_{loop} = I_{L1} - I_{L2}$ |
| L2L3N | $U_{loop} = U_{L2} - U_{L3}$ | $I_{loop} = I_{L2} - I_{L3}$ |
| L3L1N | $U_{loop} = U_{L3} - U_{L1}$ | $I_{loop} = I_{L3} - I_{L1}$ |
| L1N | $U_{loop} = U_{L1}$ | $I_{loop} = I_{L1} + 3I_o K_N$ |
| L2N | $U_{loop} = U_{L2}$ | $I_{loop} = I_{L2} + 3I_o K_N$ |
| L3N | $U_{loop} = U_{L3}$ | $I_{loop} = I_{L3} + 3I_o K_N$ |

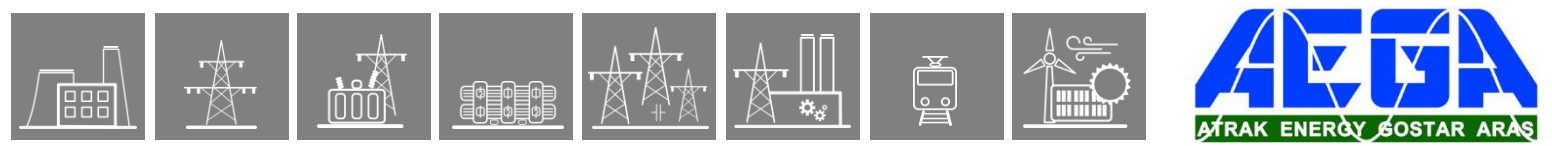
Table 1-1 Loop voltage and current selection

In Table 1-1 I_o is the zero sequence current component, and the zero sequence current compensation factor is:

$$K_N = \frac{Z_o - Z_1}{3Z_1} = \frac{1}{3} \left(\frac{Z_o}{Z_1} - 1 \right)$$

If the device configuration includes also the distance protection, then this value is set for the distance protection function block. If the distance protection function is not applied then

$$K_N = 1$$



The function applies also the polarization method used for the distance protection:

- If the loop voltage is above 5% of the rated voltage input, then this loop voltage is applied for the decision.
- If the loop voltage is below 5% of the rated voltage input and there is healthy voltage available, then the healthy voltage is applied for the directional decision.
- If the loop voltage is below 5% of the rated voltage input and there is no healthy voltage available, then the voltage vectors stored in the memory are applied for the directional decision.
- If the loop voltage is below 5% of the rated voltage input and there is no healthy voltage available, and there are no voltage vectors stored in the memory then no decision is performed.

Based on the loop voltage and loop current of the selected loop the directional decision generates a signal of TRUE value if the voltage and the current is sufficient for directional decision, and the angle difference between the vectors is within the setting range. This decision enables the output start and trip signals of an overcurrent protection function block, based on the selected current.

The description above indicates that the basic concept of the directionality is the impedance angle, detected in the faulty loop.

3.1.13.6.2. Parameter setting

Parameters can be set in the parameter screen of a WEB browser, when there is Internet connection with the device

NOTE: the parameters can be set also using the local LCD touch-screen of the device, if no internet connection is available.

3.1.13.6.2.1. Setting the CT4 input function block

In the EuroProt+ devices the CT inputs are assigned to CT function blocks. They need parameter setting and also displaying functions are assigned to them.

The parameters of the current input function are explained in the following tables.

Enumerated parameters

| Parameter name | Title | Selection range | Default |
|------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|---------------------|---------|
| Rated secondary current of the first three input channels. 1A or 5A is selected by parameter setting, no hardware modification is needed. | | | |
| CT4_Ch13Nom_EPar_ | Rated Secondary I1-3 | 1A,5A | 1A |
| Rated secondary current of the fourth input channel. 1A or 5A (0.2A, 1A) is selected by parameter setting, no hardware modification is needed. | | | |
| CT4_Ch4Nom_EPar_ | Rated Secondary I4 | 1A,5A (0.2A, 1A) | 1A |
| Definition of the positive direction of the first three currents, given by location of the secondary star connection point | | | |
| CT4_Ch13Dir_EPar_ | Starpoint I1-3 | Line,Bus | Line |
| Definition of the positive direction of the fourth current, given as normal or inverted | | | |
| CT4_Ch4Dir_EPar_ | Direction I4 | Normal,Inverted | Normal |

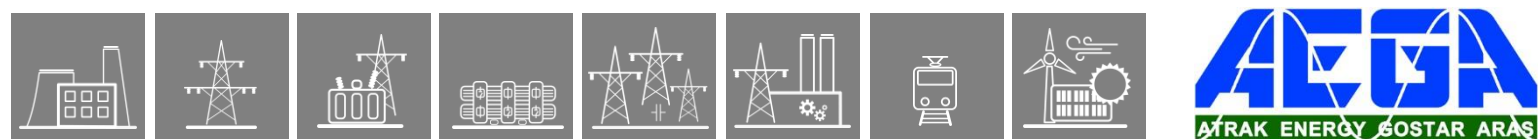
Table 2-1 The enumerated parameters of the current input function

Floating point parameters

| Parameter name | Title | Dim. | Min | Max | Default |
|-------------------------------------|--------------------|------|-----|------|---------|
| Rated primary current of channel1-3 | | | | | |
| CT4_Pr113_FPar_ | Rated Primary I1-3 | A | 100 | 4000 | 1000 |
| Rated primary current of channel4 | | | | | |
| CT4_Pr14_FPar_ | Rated Primary I4 | A | 100 | 4000 | 1000 |

Table 2-2 The floating point parameters of the current input function

NOTE: The rated primary current of the channels is not needed for the current input function block itself. These values are passed on to the subsequent function blocks.



Using the information given in the connection example above, the following setting values are assigned:

CT4:

| | | |
|----------------------|------|-------------------------------------------------------------------------------------------------------------------------|
| Rated Secondary I1-3 | 1A | Selected, according to the CT applied . |
| Rated Secondary I4 | 1A | Not applied, the value is not considered. |
| Starpoint I1-3 | Line | “Line” in this case means that the starpoint of the CT-s is “Toward protected object = Line” (See <i>Figure I-1</i>) |
| Direction I4 | | Not applied, the value is not considered. |
| Rated Primary I1-3 | 1000 | Setting, according to the CT applied at the primary side. This parameter is used for scaling the displayed values only. |
| Rated Primary I4 | | Not applied, the value is not considered. |

Table 2-3 Example of the CT parameter setting

3.1.13.6.2.2. Setting the VT4 input function blocks

In the EuroProt+ devices the VT inputs are assigned to VT function blocks. They need parameter setting and also displaying functions are assigned to them.

The parameters of the voltage input function are explained in the following tables.

Enumerated parameters

| Parameter name | Title | Selection range | Default |
|------------------------------------------------------------------------------------------------------------------------------------|-----------------|----------------------------|----------|
| Rated secondary voltage of the input channels. 100 V or 200V is selected by parameter setting, no hardware modification is needed. | | | |
| VT4_Type_EPar_ | Range | Type 100,Type 200 | Type 100 |
| Connection of the first three voltage inputs (main VT secondary) | | | |
| VT4_Ch13Nom_EPar_ | Connection U1-3 | Ph-N, Ph-Ph, Ph-N-Isolated | Ph-N |
| Selection of the fourth channel input: phase-to-neutral or phase-to-phase voltage | | | |
| VT4_Ch4Nom_EPar_ | Connection U4 | Ph-N,Ph-Ph | Ph-Ph |
| Definition of the positive direction of the first three input channels, given as normal or inverted | | | |
| VT4_Ch13Dir_EPar_ | Direction U1-3 | Normal,Inverted | Normal |
| Definition of the positive direction of the fourth voltage, given as normal or inverted | | | |
| VT4_Ch4Dir_EPar_ | Direction U4 | Normal,Inverted | Normal |

Table 2-4 The enumerated parameters of the voltage input function

Integer parameter

| Parameter name | Title | Unit | Min | Max | Step | Default |
|--------------------|---------------|------|-----|-----|------|---------|
| Voltage correction | | | | | | |
| VT4_CorrFact_IPar_ | VT correction | % | 100 | 115 | 1 | 100 |

Table 2-5 The integer parameter of the voltage input function

Floating point parameters

| Parameter name | Title | Dim. | Min | Max | Default |
|-----------------------------------|--------------------|------|-----|------|---------|
| Rated primary voltage of channel1 | | | | | |
| VT4_PriU13_FPar | Rated Primary U1-3 | kV | 1 | 1000 | 100 |
| Rated primary voltage of channel4 | | | | | |
| VT4_PriU4_FPar | Rated Primary U4 | kV | 1 | 1000 | 100 |

Table 2-6 The floating point parameters of the voltage input function

NOTE: The rated primary voltage of the channels is not needed for the voltage input function block itself. These values are passed on to the subsequent function blocks.

VT4:

| | | |
|--------------------|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Range | Type 100 | The type indicates the rated secondary voltage of the VT. This can be 100 V (in this example) or 200V |
| Connection U1-3 | Ph-N | This indicates that the VT primary is connected between the conductor and the ground (in this example). This could be Ph-Ph in other application. (NOTE: If the neutral of the system is not grounded, select Ph-N-Isolated) |
| Connection U4 | | Not applied, the selection is not considered. |
| Direction U1-3 | Normal | <i>Figure 1-1</i> shows the normal VT connection. Select "Inverted" in case of inverted connection. NOTE: The inversion can be solved also when setting the directional overcurrent protection function, see below. |
| Direction U4 | | Not applied, the selection is not considered. |
| VT correction | 100 | If the rated secondary value of the VT is e.g. 110 V then select this correction value to 110 |
| Rated Primary U1-3 | 120 | Setting, according to the VT applied at the primary side. This parameter is used for scaling the displayed values only. |
| Rated Primary U4 | | Not applied, the selection is not considered. |

Table 2-7 Example of the VT parameter setting

3.1.13.6.2.3. Parameter setting for the directional overcurrent protection function

Enumerated parameters

| Parameter name | Title | Selection range | Default |
|--------------------------------------------------------|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|
| Directionality of the function | | | |
| TOC67_Dir_EPar_ | Direction | NonDir, Forward, Backward | Forward |
| Operating characteristic selection of the TOC51 module | | | |
| TOC67_Oper_EPar_ | Operation | Off,DefiniteTime,IEC Inv,IEC VeryInv,IEC ExtInv,IEC LongInv,ANSI Inv,ANSI ModInv,ANSI VeryInv,ANSI ExtInv,ANSI LongInv,ANSI LongVeryInv,ANSI LongExtInv | DefiniteTime |

Table 2-8 The enumerated parameters of the directional three-phase overcurrent protection function

Integer parameters

| Parameter name | Title | Unit | Min | Max | Step | Default |
|-----------------------------------------------------------------------------------|----------------------|------|-----|------|------|---------|
| Operating angle (See Figure 1-4) | | | | | | |
| TOC67_ROA_IPar_ | Operating Angle | deg | 30 | 80 | 1 | 60 |
| Characteristic angle (See Figure 1-4) | | | | | | |
| TOC67_RCA_IPar_ | Characteristic Angle | deg | 40 | 90 | 1 | 60 |
| Start current (OC module), related to the rated input current of the device, in % | | | | | | |
| TOC67_StCurr_IPar_ | Start Current | % | 10 | 1000 | 1 | 50 |

Table 2-9 Integer parameters of the directional three-phase overcurrent protection function

Float parameters

| Parameter name | Title | Unit | Min | Max | Digits | Default |
|------------------------------------------------------------|-----------------|------|------|-----|--------|---------|
| Time multiplier of the inverse characteristics (OC module) | | | | | | |
| TOC67_Multip_FPar_ | Time Multiplier | | 0.05 | 999 | -2 | 1.0 |

Table 2-10 Float parameters of the directional three-phase overcurrent protection function

Timer parameters

| Parameter name | Title | Unit | Min | Max | Step | Default |
|------------------------------------------------------------------|---------------|------|-----|-------|------|---------|
| Minimal time delay for the inverse characteristics (OC module): | | | | | | |
| TOC67_MinDel_TPar_ | Min. Time | msec | 50 | 60000 | 1 | 100 |
| Definite time delay for the inverse characteristics (OC module): | | | | | | |
| TOC67_DefDel_TPar_ | Definite Time | msec | 0 | 60000 | 1 | 100 |
| Reset time delay for the inverse characteristics (OC module): | | | | | | |
| TOC67_Reset_TPar_ | Reset Time | msec | 0 | 60000 | 1 | 100 |

Table 2-11 Timer parameters of the directional three-phase overcurrent protection function

The parameters with the selected settings for the example application for the differential protection function are summarized in Table 2-12 below. Some parameters need basic considerations some of them need also calculation. This is explained in the paragraphs below:

According to the example above the following setting is proposed.

| | | |
|----------------------|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Direction | Forward | If the connection of <i>Figure 1-1</i> is applied, select “Forward”. If the direction should be inverted, select “Backward”. When “NonDir” is selected then the angle is not evaluated. NOTE: The direction can be inverted also: <ul style="list-style-type: none"> • With CT connection • in CT input module, parameter setting Starpoit =“Bus”, • with VT connection • in VT input module parameter setting Direction= U1-3 “Inverted” |
| Operation | Definite Time | This is the default setting. If any of the inverse characteristics should be applied, select accordingly |
| Operating Angle | 80 | This is the “opening” of the directional characteristic, defining the trip range |
| Characteristic Angle | 45 | This is theoretically the angle of the protected positive sequence impedance, considering additional fault resistance |
| Start Current | 250 | This means 250% of the rated current input. When 1 A is selected for parameter “Rated Secondary I1-3” then this means that above 2500mA secondary “loop” current value the function is operable. |
| Time Multiplier | | In the example this parameter has no meaning, it is applied for inverse type operating mode only |
| Min. Time | | In the example this parameter has no meaning, it is applied for inverse type operating mode only, this is the IDMT minimum type |
| Definite Time | 500 | This definite time should be coordinated to other protections of the network. (For inverse characteristics this parameter has no meaning.) |
| Reset Time | | In the example this parameter has no meaning, it is applied for inverse type operating mode only, this is the reset time |

Table 2-12 Example of the directional overcurrent function parameter setting

3.1.13.6.2.3.1. Setting the directionality

The directionality depends on several factors:

- The physical connection of the CT-s (See example in *Figure 1-1*)
- CT parameter setting (See 2.1)
- The physical connection of the VT-s (See example in *Figure 1-1*)
- VT parameter setting (See 2.2)
- Setting the “Direction” parameter “Forward or Backward” (
- Setting the parameter “Characteristic Angle”
- Setting the parameter “Operating Angle”

Figure 1-1 illustrates the following setting:

- Direction=Forward
- Characteristic Angle=45 degrees
- Operating Angle=20 degrees

Based on the example setting, all other variations can be realized.

3.1.13.6.2.3.2. Setting the “Start current”

The correct value for the „Start Current” parameter is calculated by fault simulation procedure. The setting is correct if the function starts in any case when fault occurs within the protected zone, considering also the highest possible fault resistance at the fault location. The setting value should be below the calculated minimal fault current, considering the usual tolerance band. The setting is correct only if the maximum load current does not result starting the function.

These setting considerations of the „Start Current” are valid also for any IDMT type characteristics.

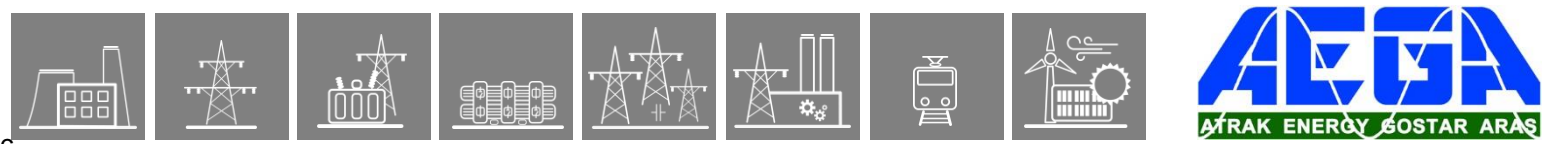
3.1.13.6.2.3.3. Setting the “Operation” operating mode and related parameters

When any of the IDMT type characteristics is selected then the details of the selected characteristic, including the parameter values and the formulas for the mathematical description, are described in the document TOC 51 „Three-phase overcurrent protection function block description”. When selecting one of the available eleven IDMT characteristics, the operating curve is to be matched to all other overcurrent protections of the network. The available characteristic types are: IEC Inv, IEC VeryInv, IEC ExtInv, IEC LongInv, ANSI Inv, ANSI ModInv, ANSI VeryInv, ANSI ExtInv, ANSI LongInv, ANSI LongVeryInv, ANSI LongExtInv.

For coordination of the selected IDMT characteristic to all other similar protection of the network, the correct setting of the following parameters are needed: „Start Current” as it is described above, for shifting the characteristic along the current axis, the „Time Multiplier” parameter to compress or expand the characteristic along the time axis, „Min Time Delay” to limit the fastest operation, and additionally „Reset time” to control the reset behavior of the function. NOTE: When selecting „DefiniteTime” characteristic, only the parameter „Start Current” and “Definite time” time delay are considered, all other parameters mentioned in this paragraph are automatically neglected.

| Binary status signal | Title | Explanation |
|----------------------|----------------|--------------------------------------------------------------------------------|
| TOC67_Blk_GrO_ | Block | Blocking input status signal |
| TOC67_VTS_GrO_ | Block from VTS | Blocking input status signal from the voltage transformer supervision function |

Table 2-13 The binary input signal of the directional three-phase overcurrent protection function



3.1.14. Over-frequency protection function

3.1.14.1. Application

The deviation of the frequency from the rated system frequency indicates unbalance between the generated power and the load demand. If the available generation is large compared to the consumption by the load connected to the power system, then the system frequency is above the rated value. The overfrequency protection function is usually applied to decrease generation to control the system frequency.

Another possible application is the detection of unintended island operation of distributed generation and some consumers. In the island, there is low probability that the power generated is the same as the consumption; accordingly, the detection of high frequency can be one of the indications of island operation.

3.1.14.1.1. Mode of operation

Depending on the hardware-software configuration, the frequency measurement is usually based on channel No. 1 (line voltage) and channel No. 4 (busbar voltage) of any voltage input module.

The accurate frequency measurement is performed by measuring the time period between two rising edges and also between two falling edges at zero crossing of a voltage signal. The frequency value is calculated by the average of these two values. At each zero crossing the average value (and the frequency) is recalculated.

For the acceptance of the measured frequency, at least four subsequent valid measurements are needed. Similarly, four invalid measurements are needed to reset the measured frequency from the last valid value to zero.

The minimum voltage condition can be set as a parameter for enabling the evaluation of the frequency. This parameter is called U limit.

The overfrequency protection function generates a start signal if at least five measured frequency values are above the preset level.

3.1.14.2. Overfrequency protection function overview

The graphic appearance of the function block of the overfrequency protection function is shown below. The block shows all binary input and output status signals which are applicable in the graphic equation editor.

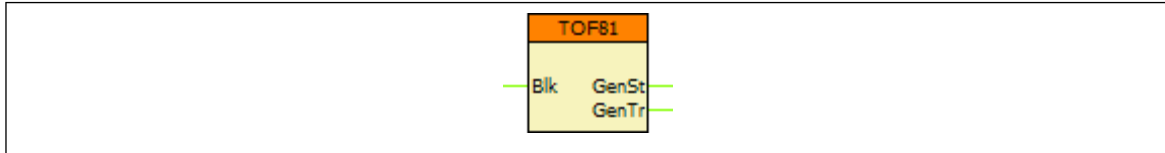


Figure 2-1 Graphic appearance of the function block of the overfrequency protection function

3.1.14.2.1. Settings

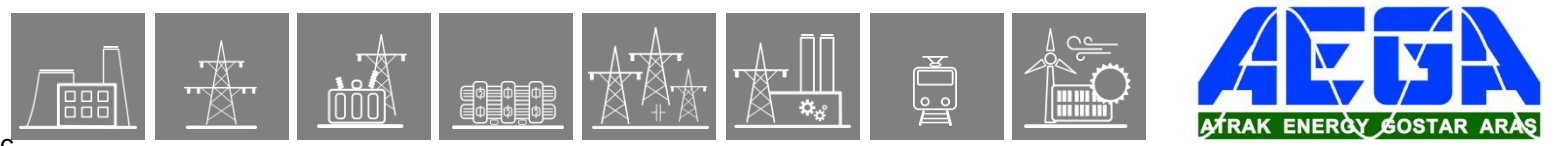
3.1.14.2.1.1. Parameters

The available parameters are listed below in order of their appearance in the *parameters* menu. If the setting range of a parameter should be extended, contact Protecta Support.

Table 2-1 Parameters of the overfrequency protection function

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|-------------------|------|---------------|------|---------|---------------------------------------------------------------------------------|
| Operation | - | Off, On | - | Off | Enabling the function |
| Start Signal Only | - | FALSE, TRUE | - | FALSE | Enabling start signal only |
| Start Frequency | Hz | 40.00 – 70.00 | 0.01 | 51.00 | Setting value of the comparison |
| U limit | - | 0.1Un – 1Un | 0.01 | 0.45 | Minimum voltage condition for enabling the operation of the function |
| Time Delay | msec | 140* – 10000 | 1 | 200 | Time delay (including the algorithm time, see Chapter 2.4 for more explanation) |

*The minimum operate time is lower than the settable minimum delay, however below this value the timing is less accurate, see Chapter 2.3 for details



3.1.14.2.2. Function I/O

This section describes briefly the analogue and digital inputs and outputs of the function block.

3.1.14.2.2.1. Analogue inputs

The function uses the sampled values of a voltage input or a calculated line-to-line voltage. This is defined in the configuration.

3.1.14.2.2.2. Analogue outputs (measurements)

The frequency measurement is displayed *MXU_F* – frequency measurement function which is an independent function.

3.1.14.2.2.3. Binary input signals (graphed output statuses)

The conditions of the binary inputs are defined by the user, applying the graphic equation editor (*Logic Editor*). Parts written in **bold** are seen on the left side function block in the Logic editor.

Table 2-2 The binary input signal of the overfrequency protection function

| BINARY OUTPUT SIGNAL | EXPLANATION |
|-------------------------|--------------------------------|
| TOF81_ Blk _GrO_ | Blocking input of the function |

3.1.14.2.2.4. Binary output signals (graphed input statuses)

These signals can be used in EuroCAP to assign to LED, user LCD object etc. Parts written in **bold** are seen on the right side of the function block in the *Logic Editor*.

Table 2-3 The binary output signals of the overfrequency protection function

| BINARY OUTPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|---------------------------|---------------|--------------------------------------|
| TOF81_ GenSt _Grl_ | General Start | General start signal of the function |
| TOF81_ GenTr _Grl_ | General Trip | General trip command of the function |

3.1.14.2.2.5. Online data

Visible values on the *online data* page.

Table 2-4 Online displayed data of the overfrequency protection function

| SIGNAL TITLE | DIMENSION | EXPLANATION |
|---------------|-----------|--------------------------------------|
| General Start | - | General start signal of the function |
| General Trip | - | General trip command of the function |

3.1.14.2.2.6. Events

The following events are generated in the event list, as well as sent to the SCADA according to the configuration.

Table 2-5 Generated events of the overfrequency protection function

| EVENT | VALUE | EXPLANATION |
|---------------|---------|--------------------------------------|
| General Start | off, on | General start of the function |
| General Trip | off, on | General trip command of the function |

3.1.14.2.3. Technical data

The technical data, except for the min. operate voltage, are based on the function block testing according to the directives of the **IEC 60255-181:2019** standard.

Table 2-6 Technical data of the overfrequency protection function

| FUNCTION | VALUE | ACCURACY |
|-------------------------|--------------------------------------------------------|------------------------------|
| Operate range | 40 - 60 Hz (50 Hz system) 50 - 70 Hz (60 Hz system) | ± 3 mHz (20 mHz*) |
| Effective range | 45 - 55 Hz (50 Hz) 55 - 65 Hz (60 Hz) | ± 3 mHz (10 mHz*) |
| Min. operate time | 93 ms (50 Hz) 73 ms (60 Hz) | ± 32 ms ± 27 ms |
| Time delay | 140 – 60000 ms <140 ms (50 Hz) <140 ms (60 Hz) | ± 4 ms ± 32 ms ± 27 ms |
| Reset frequency | [Start freq.] – 101 mHz | ± 1 mHz |
| Reset time | 98 ms (50 Hz) 85 ms (60 Hz) | ± 6 ms |
| Reset ratio for U limit | 0.8 | |

**with the harmonic content according to the standard*

3.1.14.2.4. Notes for testing

Normally in the EuroProt+ devices the trip contacts are assigned to the Trip Logic function block, and not to the protection function blocks. Because of this, the testing personnel must make sure that the Trip Logic is switched on ('Operation' parameter is set to other than 'Off') before starting the tests, otherwise there will be no physical trip on the relay.

Note that the time delay parameter incorporates the algorithm time as well, so the time delay **does not mean the time difference between the appearance of the start and trip signals** of the function. In other words: it is not the delay between the detection of the fault and the trip that follows it. This should be taken into consideration when checking the disturbance records.

Instead the time delay parameter defines the elapsed time from the appearance of the faulty state to the trip. Because of this, while testing, the delay measurement should start *from the moment of the fault injection* until the trip signal.

The source voltage for frequency measurement is defined by the voltage input of the functionblock. This can be checked in the functionblock properties in EuroCAP

Before the fault injection at least 1 second pre-fault should be simulated with nominal frequency and voltage.

Based on IEC 60255-181 standard recommendations, the operation time shall be measured with a frequency of 0.5Hz higher than the setting value for Start frequency.



3.1.15. Underfrequency protection function

3.1.15.1. Application

The deviation of the frequency from the rated system frequency indicates unbalance between the generated power and the load demand. If the available generation is small compared to the consumption by the load connected to the power system, then the system frequency is below the rated value. The underfrequency protection function is usually applied to increase generation or for load shedding to control the system frequency.

Another possible application is the detection of unintended island operation of distributed generation and some consumers. In the island, there is low probability that the power generated is the same as the consumption; accordingly, the detection of low frequency can be one of the indications of island operation.

3.1.15.1.1. Mode of operation

Depending on the hardware-software configuration, the frequency measurement is usually based on channel No. 1 (line voltage) and channel No. 4 (busbar voltage) of any voltage input module.

The accurate frequency measurement is performed by measuring the time period between two rising edges and also between two falling edges at zero crossing of a voltage signal. The frequency value is calculated by the average of these two values. At each zero crossing the average value (and the frequency) is recalculated.

For the acceptance of the measured frequency, at least four subsequent valid measurements are needed. Similarly, four invalid measurements are needed to reset the measured frequency from the last valid value to zero.

The minimum voltage condition can be set as a parameter for enabling the evaluation of the frequency. This parameter is called U limit.

The underfrequency protection function generates a start signal if at least five measured frequency values are below the preset level.

3.1.15.2. Underfrequency protection function overview

The graphic appearance of the function block of the underfrequency protection function is shown below. The block shows all binary input and output status signals which are applicable in the graphic equation editor.

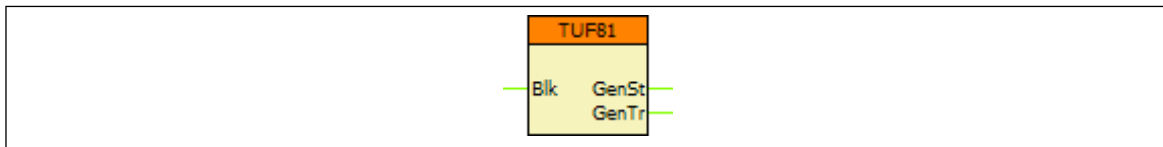


Figure 2-1 Graphic appearance of the function block of the underfrequency protection function

3.1.15.2.1. Settings

3.1.15.2.1.1. Parameters

The available parameters are listed below in order of their appearance in the *parameters* menu. If the setting range of a parameter should be extended, contact Protecta Support.

Table 2-1 Parameters of the underfrequency protection function

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|-------------------|------|---------------|------|---------|-------------------------------------------------------------------------------------------------|
| Operation | - | Off, On | - | Off | Enabling the function |
| Start Signal Only | - | FALSE, TRUE | - | FALSE | Enabling start signal only |
| Start Frequency | Hz | 40.00 – 70.00 | 0.01 | 49.00 | Setting value of the comparison |
| U limit | - | 0.1Un – 1Un | 0.01 | 0.45 | Minimum voltage condition for enabling the operation of the function |
| Time Delay | msec | 140* – 10000 | 1 | 200 | Time delay (including the algorithm time, see Chapter 2.4 for more explanation) |

*The minimum operate time is lower than the settable minimum delay, however below this value the timing is less accurate, see Chapter [2.3](#) for details

3.1.15.2.2. Function I/O

This section describes briefly the analogue and digital inputs and outputs of the function block.

3.1.15.2.2.1. Analogue inputs

The function uses the sampled values of a voltage input or a calculated line-to-line voltage. This is defined in the configuration.

3.1.15.2.2.2. Analogue outputs (measurements)

The frequency measurement is displayed *MXU_F* – frequency measurement function which is an independent function.

3.1.15.2.2.3. Binary input signals (graphed output statuses)

The conditions of the binary inputs are defined by the user, applying the graphic equation editor (*Logic Editor*). Parts written in **bold** are seen on the left side function block in the Logic editor.

Table 2-2 The binary input signal of the underfrequency protection function

| BINARY OUTPUT SIGNAL | EXPLANATION |
|-------------------------|--------------------------------|
| TUF81_ Blk _GrO_ | Blocking input of the function |

3.1.15.2.2.4. Binary output signals (graphed input statuses)

These signals can be used in EuroCAP to assign to LED, user LCD object etc. Parts written in **bold** are seen on the right side of the function block in the *Logic Editor*.

Table 2-3 The binary output signals of the underfrequency protection function

| BINARY OUTPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|---------------------------|---------------|--------------------------------------|
| TUF81_ GenSt _Grl_ | General Start | General start signal of the function |
| TUF81_ GenTr _Grl_ | General Trip | General trip command of the function |

3.1.15.2.2.5. Online data

Visible values on the *online data* page.

Table 2-4 Online displayed data of the underfrequency protection function

| SIGNAL TITLE | DIMENSION | EXPLANATION |
|---------------|-----------|--------------------------------------|
| General Start | - | General start signal of the function |
| General Trip | - | General trip command of the function |

3.1.15.2.2.6. Events

The following events are generated in the event list, as well as sent to the SCADA according to the configuration.

Table 2-5 Generated events of the underfrequency protection function

| EVENT | VALUE | EXPLANATION |
|---------------|---------|--------------------------------------|
| General Start | off, on | General start of the function |
| General Trip | off, on | General trip command of the function |

3.1.15.2.3. Technical data

The technical data, except for the min. operate voltage, are based on the function block testing according to the directives of the **IEC 60255-181:2019** standard.

Table 2-6 Technical data of the underfrequency protection function

| FUNCTION | VALUE | ACCURACY |
|-------------------------|--------------------------------------------------------|------------------------------|
| Operate range | 40 - 60 Hz (50 Hz system) 50 - 70 Hz (60 Hz system) | ± 3 mHz (20 mHz*) |
| Effective range | 45 - 55 Hz (50 Hz) 55 - 65 Hz (60 Hz) | ± 3 mHz (10 mHz*) |
| Min. operate time | 93 ms (50 Hz) 73 ms (60 Hz) | ± 32 ms ± 27 ms |
| Time delay | 140 – 60000 ms <140 ms (50 Hz) <140 ms (60 Hz) | ± 4 ms ± 32 ms ± 27 ms |
| Reset frequency | [Start freq.] + 101 mHz | ± 1 mHz |
| Reset time | 98 ms (50 Hz) 85 ms (60 Hz) | ± 6 ms |
| Reset ratio for U limit | 0.8 | |

**with the harmonic content according to the standard*

3.1.15.2.4. Notes for testing

Normally in the EuroProt+ devices the trip contacts are assigned to the Trip Logic function block, and not to the protection function blocks. Because of this, the testing personnel must make sure that the Trip Logic is switched on ('Operation' parameter is set to other than 'Off') before starting the tests, otherwise there will be no physical trip on the relay.

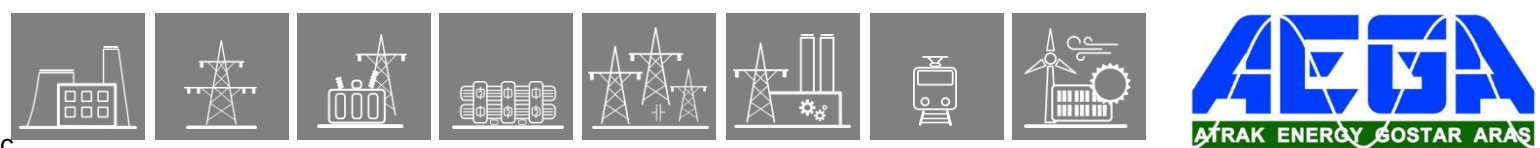
Note that the time delay parameter incorporates the algorithm time as well, so the time delay **does not mean the time difference between the appearance of the start and trip signals** of the function. In other words: it is not the delay between the detection of the fault and the trip that follows it. This should be taken into consideration when checking the disturbance records.

Instead the time delay parameter defines the elapsed time from the appearance of the faulty state to the trip. Because of this, while testing, the delay measurement should start *from the moment of the fault injection* until the trip signal.

The source voltage for frequency measurement is defined by the voltage input of the functionblock. This can be checked in the functionblock properties in EuroCAP.

Before the fault injection at least 1 second pre-fault should be simulated with nominal frequency and voltage.

Based on IEC 60255-181 standard recommendations, the operation time shall be measured with a frequency of 0.5Hz lower than the setting value for Start frequency.



3.1.16. Rate of change of frequency protection function

3.1.16.1. Application

The deviation of the frequency from the rated system frequency indicates unbalance between the generated power and the load demand. If the available generation is large compared to the consumption by the load connected to the power system, then the system frequency is above the rated value, and if it is small, the frequency is below the rated value. If the unbalance is large, then the frequency changes rapidly. The rate of change of frequency protection function is usually applied to reset the balance between generation and consumption to control the system frequency.

Another possible application is the detection of unintended island operation of distributed generation and some consumers. In the island, there is low probability that the power generated is the same as consumption; accordingly, the detection of a high rate of change of frequency can be one of the indications of island operation.

3.1.16.1.1. Mode of operation

Depending on the hardware-software configuration, the frequency measurement is usually based on channel No. 1 (line voltage) and channel No. 4 (busbar voltage) of any voltage input module.

The accurate frequency measurement is performed by measuring the time period between two rising edges and also between two falling edges at zero crossing of a voltage signal. The frequency value is calculated by the average of these two values. At each zero crossing the average value (and the frequency) is recalculated.

For the acceptance of the measured frequency, at least four subsequent valid measurements are needed. Similarly, four invalid measurements are needed to reset the measured frequency from the last valid value to zero.

Other basic criterion is that the evaluated voltage should be above 10% of the rated voltage value.

The rate of change of frequency protection function generates a start signal if the df/dt value is above the setting value. The rate of change of frequency is calculated as the difference of the frequency at the present sampling and at 5 periods earlier; the df/dt comparator has a built-in delay of 100 ms to filter out unwanted operations.

3.1.16.2. Rate of change of frequency protection function overview

The graphic appearance of the function block of the rate of change of frequency protection function is shown below. The block shows all binary input and output status signals which are applicable in the graphic equation editor.

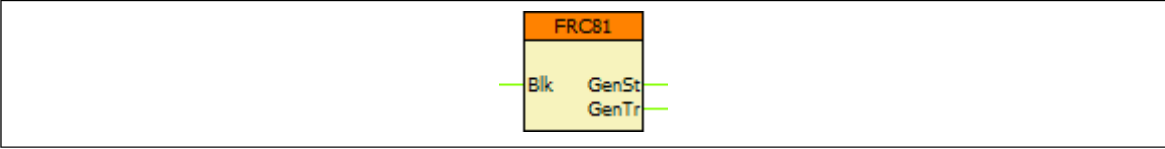


Figure 2-1 Graphic appearance of the function block of the rate of change of frequency protection function

3.1.16.2.1. Settings

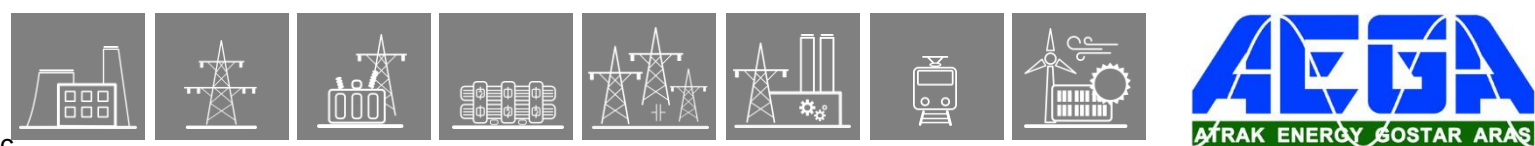
3.1.16.2.1.1. Parameters

The available parameters are listed below in order of their appearance in the *parameters* menu. If the setting range of a parameter should be extended, contact Protecta Support.

Table 2-1 Parameters of the rate of change of frequency protection function

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|-------------------|--------|--------------|------|---------|---------------------------------------------------------------------------------|
| Operation | - | Off, On | - | Off | Enabling the function |
| Start Signal Only | - | FALSE, TRUE | - | FALSE | Enabling start signal only |
| Start df/dt | Hz/sec | -5.00 – 5.00 | 0.01 | 0.50 | Setting value of the comparison |
| Time Delay | msec | 200* – 10000 | 1 | 200 | Time delay (including the algorithm time, see Chapter 2.4 for more explanation) |

**the minimum operate time is lower than the settable minimum delay, however below this value the timing is less accurate, see Chapter 2.3 for details*



3.1.16.2.2. Function I/O

This section describes briefly the analogue and digital inputs and outputs of the function block.

3.1.16.2.2.1. Analogue inputs

The function uses the sampled values of a voltage input or a calculated line-to-line voltage. This is defined in the configuration.

3.1.16.2.2.2. Binary input signals (graphed output statuses)

The conditions of the binary inputs are defined by the user, applying the graphic equation editor (*Logic Editor*). Parts written in **bold** are seen on the left side function block in the Logic editor.

Table 2-2 The binary input signal of the rate of change of frequency protection function

| BINARY OUTPUT SIGNAL | EXPLANATION |
|-------------------------|--------------------------------|
| FRC81_ Blk _GrO_ | Blocking input of the function |

3.1.16.2.2.3. Binary output signals (graphed input statuses)

These signals can be used in EuroCAP to assign to LED, user LCD object etc. Parts written in **bold** are seen on the right side of the function block in the *Logic Editor*.

Table 2-3 The binary output signals of the rate of change of frequency protection function

| BINARY OUTPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|---------------------------|---------------|--------------------------------------|
| FRC81_ GenSt _Grl_ | General Start | General start signal of the function |
| FRC81_ GenTr _Grl_ | General Trip | General trip command of the function |

3.1.16.2.2.4. Online data

Visible values on the *online data* page.

Table 2-4 Online displayed data of the rate of change of frequency protection function

| SIGNAL TITLE | DIMENSION | EXPLANATION |
|---------------|-----------|--------------------------------------|
| General Start | - | General start signal of the function |
| General Trip | - | General trip command of the function |

3.1.16.2.2.5. Events

The following events are generated in the event list, as well as sent to the SCADA according to the configuration.

Table 2-5 Generated events of the rate of change of frequency protection function

| EVENT | VALUE | EXPLANATION |
|---------------|---------|--------------------------------------|
| General Start | off, on | General start of the function |
| General Trip | off, on | General trip command of the function |

3.1.16.2.3. Technical data

The technical data, except for the min. operate voltage, are based on the function block testing according to the directives of the **IEC 60255-181:2019** standard.

Table 2-6 Technical data of the rate of change of frequency protection function

| FUNCTION | VALUE | ACCURACY |
|--------------------------------------------|---------------------------------------|------------------------|
| Min. operate voltage | 0.1 Un | |
| Operate range | ± 10 Hz/s | ± 50 mHz/s (60 mHz/s*) |
| Effective range | ± 5 Hz/s | ± 15 mHz/s (50 mHz/s*) |
| Min. operate time | 191 ms (50 Hz) 159 ms (60 Hz) | ± 40 ms ± 39 ms |
| Time delay (at 0.2 Hz/s) | 200 – 60000 ms (50 Hz) | ± 2 ms |
| Reset ratio (drop/pick in absolute values) | 0.92 (>0.5 Hz/s) 0.999 (<0.5 Hz/s) | -0.03 -0.072 |
| Reset time | 187 ms (50 Hz) 157 ms (60 Hz) | ± 44 ms ± 38 ms |

*with the harmonic content according to the standard

3.1.16.2.4. Notes for testing

Normally in the EuroProt+ devices the trip contacts are assigned to the Trip Logic function block, and not to the protection function blocks. Because of this, the testing personnel must make sure that the Trip Logic is switched on ('Operation' parameter is set to other than 'Off') before starting the tests, otherwise there will be no physical trip on the relay.

Note that the time delay parameter incorporates the algorithm time as well, so the time delay does **not** mean the time difference between the appearance of the start and trip signals of the function. In other words: it is not the delay between the detection of the fault and the trip that follows it. This should be taken into consideration when checking the disturbance records.

Instead the time delay parameter defines the elapsed time from the appearance of the faulty state to the trip. Because of this, while testing, the delay measurement should start *from the moment of the fault injection* until the trip signal.

3.1.17. Restricted earth-fault protection function

The restricted earth-fault protection function is basically a low-impedance differential protection function based on zero sequence current components. It can be applied to transformers with grounded neutral. The function compares the measured neutral current at the star point and the calculated zero sequence current component of the phase currents and generates a trip command if the difference of these currents is above the characteristics.

3.1.17.1. Structure of the restricted earth-fault protection algorithm

Fig.1-1 shows the structure of the restricted earth-fault protection (DIF87N) algorithm.

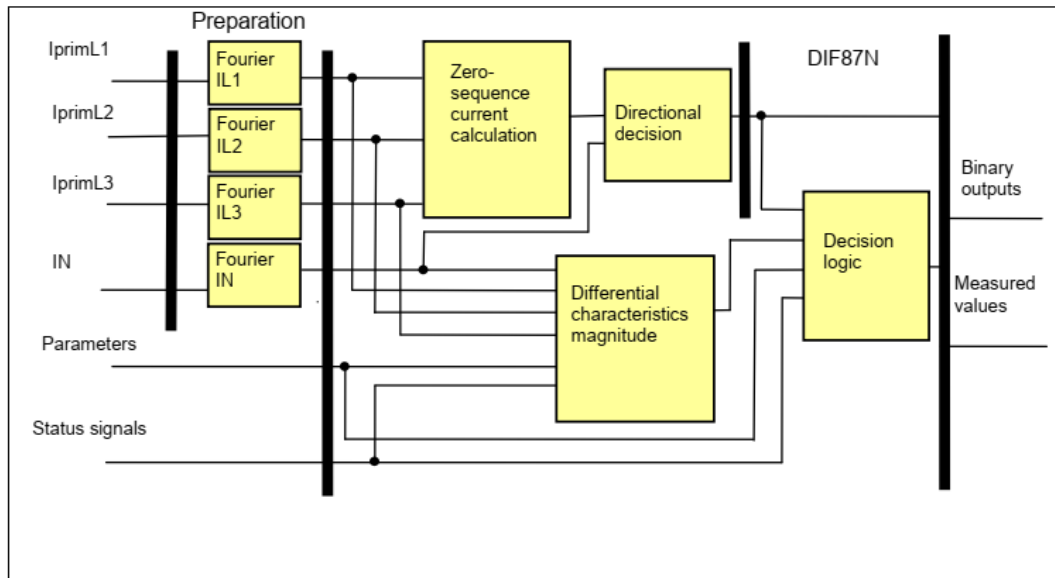


Figure 1-1 Structure of the restricted earth-fault protection algorithm

The **inputs** for the preparation are:

- the sampled values of three primary phase currents,
- the sampled value of the neutral current.

The **outputs** of the preparation are:

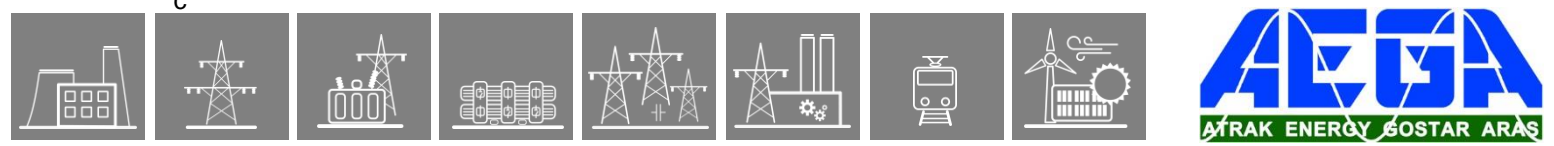
- the RMS values of the fundamental Fourier components of the phase currents and that of the neutral current.

The **inputs** for the DIF87N function are:

- the RMS values of the fundamental Fourier components of the phase currents and that of the neutral current,
- parameters,
- status signal.

The **outputs** of the DIF87N function are:

- the binary output status signal,
- the measured values for displaying.



The **software modules** of the restricted earth-fault protection function:

Fourier calculations

These modules calculate the basic Fourier current components of the phase currents and that of the neutral current individually. These modules belong to the preparatory phase.

Zero sequence current calculation

This module calculates the zero sequence current components based on the Fourier components of the phase currents. These modules belong to the preparatory phase.

Directional decision

This module compares the direction of the neutral current and that of the calculated zero sequence current. In case of small zero sequence components of the high fault currents in the phases, this decision improves the stability of the function.

Differential characteristics

This module performs the necessary calculations for the evaluation of the “percentage differential characteristics” and decides if the differential current is above the characteristic curve of the restricted earth-fault protection function. This curve is the function of the restraint current, which is the maximum of the phase currents and the current of the neutral point. The result of this calculation is needed for the decision logic.

Decision logic

The decision logic module combines the status signals, binary and enumerated parameters to generate the trip command of the function.

The following description explains the details of the individual components.

3.1.17.2. The Fourier calculation (Fourier)

These modules calculate the basic Fourier current components of the phase currents and that of the neutral current individually. The magnitudes of these currents are matched to each other using the current transformer rated current values. These modules belong to the preparatory phase.

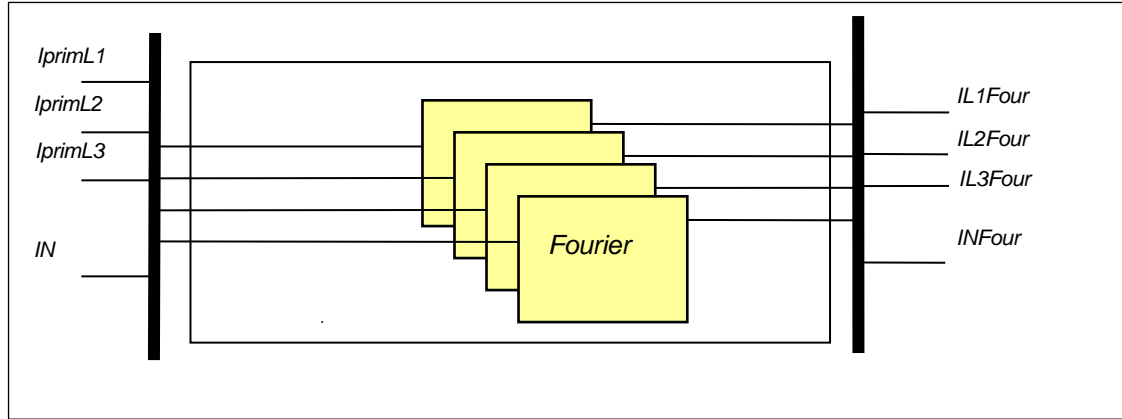


Figure 1-2 Principal scheme of the Fourier calculation

The **inputs** are the sampled values of:

- the three phase currents of the primary side (IprimL1, IprimL2, IprimL3)
- the current measured at the neutral point (IN)

The **outputs** are the basic Fourier components of the analyzed currents (IL1Four, IL2Four, IL3Four, INFour).

The **integer parameters** of the Fourier calculation are listed in (% related to the input rated current)

Table 1-1.

| Parameter name | Title | Unit | Min | Max | Step | Default |
|----------------------------------------------------|-----------------|------|-----|------|------|---------|
| Parameters for the current magnitude compensation: | | | | | | |
| DIF87N_TRPri_IPar_ | TR Primary Comp | % | 20 | 500 | 1 | 100 |
| DIF87N_TRNeut_IPar_ | TR Neutral | % | 100 | 1000 | 1 | 500 |

(% related to the input rated current)

Table 1-1 The integer parameters of the Fourier calculation

3.1.17.3. The zero sequence current calculation (Zero sequence current calculation)

This module calculates the zero sequence current component based on the Fourier components of the phase currents. This module belongs to the preparatory phase.

The **inputs** are the basic Fourier components of the phase currents (IL1Four, IL2Four, IL3Four).

The **outputs** are the Fourier components of the calculated zero sequence current (3IoFour).

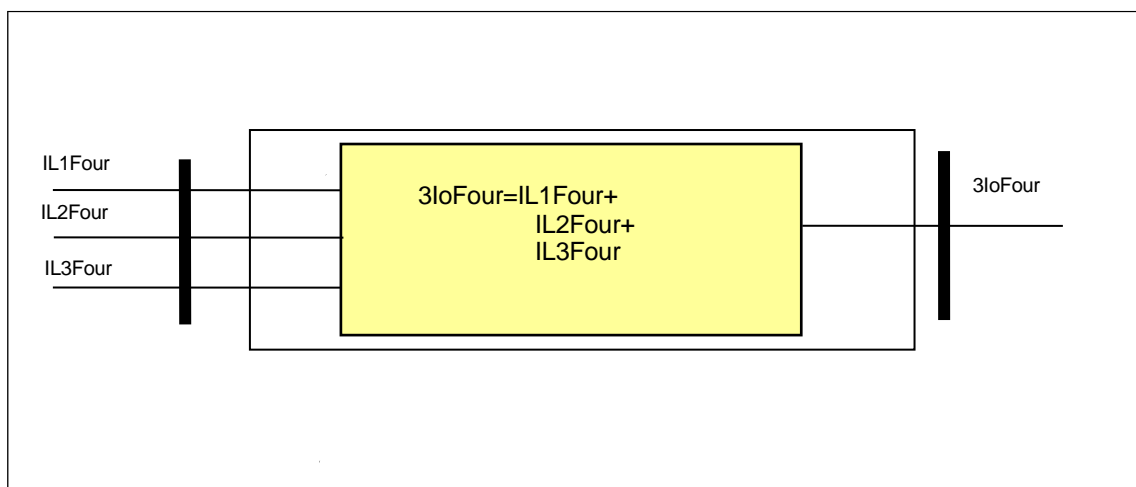


Figure 1-3 Principal scheme of the zero sequence current calculation

3.1.17.4. Directional decision (Directional decision)

This module compares the direction of the neutral current and that of the calculated zero sequence current. In case of small zero sequence component of the high fault currents in the phases, this decision improves the stability of the function.

For the directional decision, the positive directions are drawn in Figure 1-4. In this system, if the angle between the calculated zero sequence current $3I_0$ and the measured neutral current I_N is out of the range of ± 90 degrees, then the restricted earth fault protection can be blocked, the status signal DIF87N_StDir_Gr1_ (Dir.element Start) is set to TRUE value.

The blocking of the directional decision is decided in the decision logic of the function, using the binary parameter DIF87N_DirCheck_BPar_.

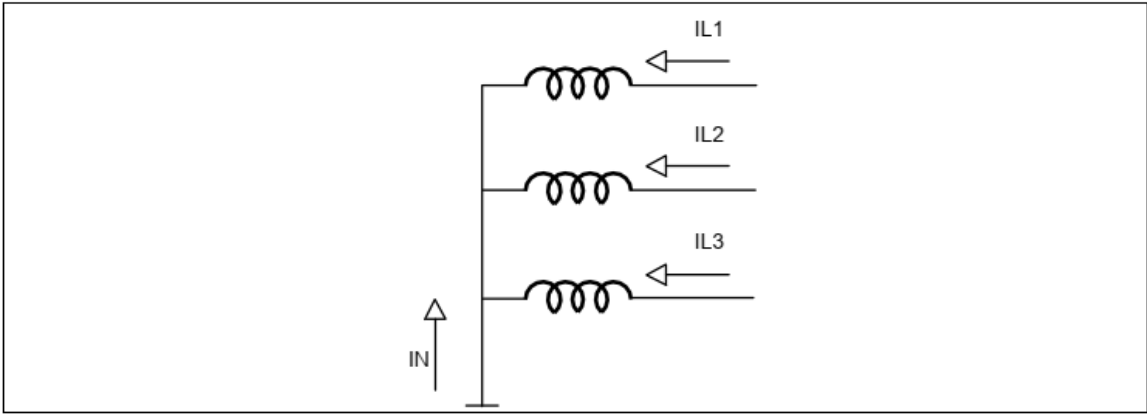


Figure 1-4 Positive directions for the directional decision

The **inputs** are the Fourier components of the calculated zero sequence current ($3I_{0Four}$) and that of the neutral current (I_{NFour}).

The **binary output status signal** of the directional decision is shown in Table 1-2.

| Binary output signals | Signal title | Explanation |
|-----------------------|-------------------|----------------------------------------------------------------------|
| DIF87N_StDir_Grl_ | Dir.element Start | Directional blocking signal of the zero-sequence directional element |

Table 1-2 The binary output status signals of the directional decision

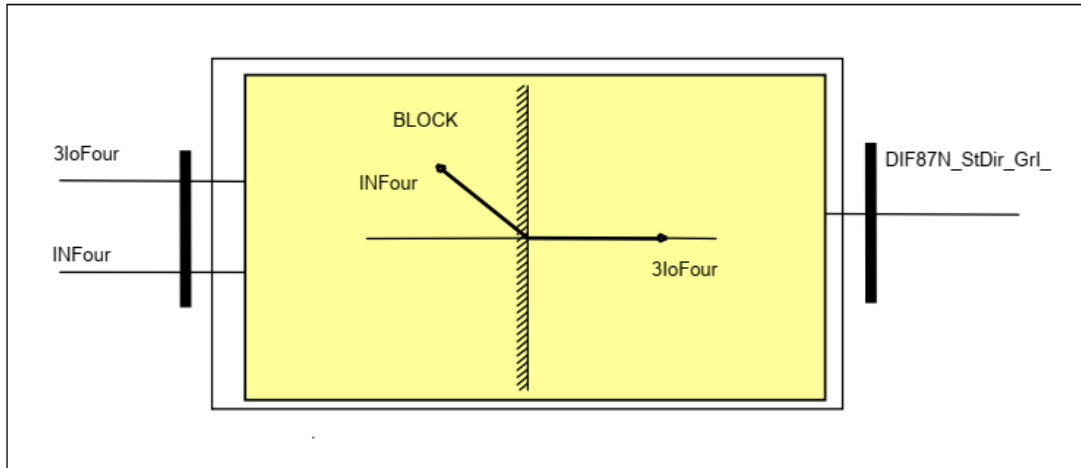


Figure 1-5 Principal scheme of the directional decision

3.1.17.5. The zero sequence differential characteristics (Differential characteristics)

This module performs the necessary calculations for the evaluation of the “percentage differential characteristics”, and decides if the differential current is above the characteristic curve of the zero sequence differential protection (restricted earth-fault protection) function. This curve is the function of the restraint current, which is the maximum of the phase currents and the current of the neutral point. The result of this calculation is processed in the decision logic.

The differential current is calculated using the following formula:

$$Diff\ Current = IL1Four + IL2Four + IL3Four + INFour$$

The restraint current is calculated using the following formula:

$$Bias\ Current = MAX(IL1Four, IL2Four, IL3Four, INFour)$$

Based on these values, the zero sequence differential protection characteristics are shown in *Figure 1-6*.

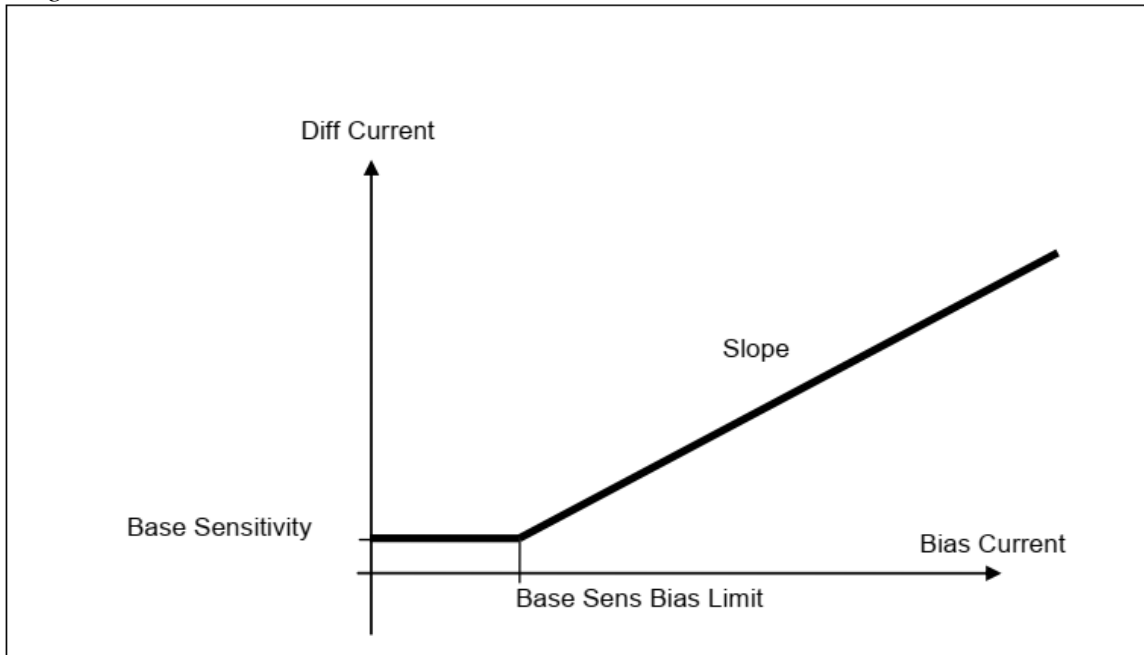


Figure 1-6 The zero sequence differential protection characteristics

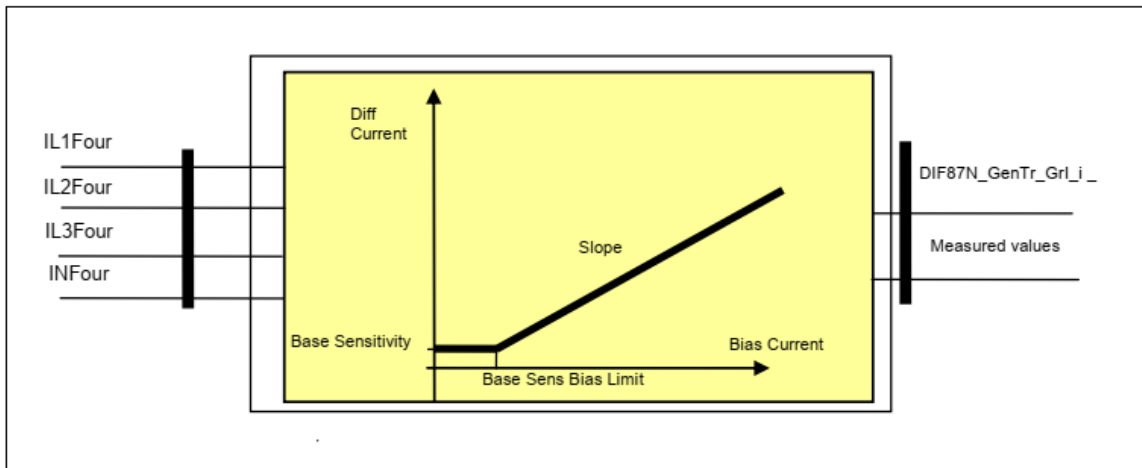
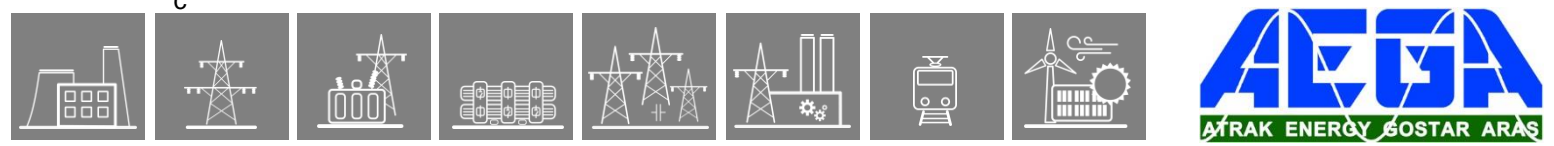


Figure 1-7 Principal scheme of the zero sequence differential protection



The **measured values** of the restricted earth-fault protection function are listed in Table 1-3.

| Measured value | Title | Dim. | Explanation |
|------------------|--------------|------|-------------------------------------|
| DIF87N_Id_OLM_ | Diff Current | In % | The calculated differential current |
| DIF87N_Bias_OLM_ | Bias Current | In % | The calculated restraint current |

Table 1-3 The measured analogue values of the zero sequence differential protection characteristics

The **binary output status signal** of the restricted earth-fault protection characteristics is shown in Table 1-4.

| Binary output signals | Signal title | Explanation |
|-----------------------|----------------|------------------------------------------------------------------|
| DIF87N_GenTr_GrI_i | General Trip_i | Internal general trip signal of the differential characteristics |

Table 1-4 The binary output status signals of the zero sequence differential protection characteristics

The parameters of the restricted earth-fault protection characteristics are explained in the following tables.

The integer parameters of the restricted earth-fault protection characteristics are listed in Table 1-5.

| Parameter name | Title | Unit | Min | Max | Step | Default |
|-----------------------------------------------------|----------------------|------|-----|-----|------|---------|
| Base sensitivity: | | | | | | |
| DIF87N_f1_IPar_ | Base Sensitivity | %* | 10 | 50 | 1 | 30 |
| Slope of the second section of the characteristics: | | | | | | |
| DIF87N_f2_IPar_ | Slope | %** | 50 | 100 | 1 | 70 |
| Break point of the characteristic line: | | | | | | |
| DIF87N_f2Brk_IPar_ | Base Sens Bias Limit | %* | 100 | 200 | 1 | 125 |

(* % related to the magnitude-compensated current (see Table 1-1)

** % related to the bias current)

Table 1-5 The integer parameters of the zero sequence differential protection characteristics

The binary input signal serves to increase the base sensitivity by 4 times. **The conditions of increasing are defined by the user, applying the graphic equation editor.**

| Binary input signal | Explanation |
|---------------------|-----------------------------------------------------------------------------------------------------|
| DIF87N_UnSens_GrO_ | Output status of a graphic equation defined by the user to increase the base sensitivity by 4 times |

Table 1-6 The binary input signal of the zero sequence differential protection characteristics

3.1.17.6. The decision logic (Decision logic)

The decision logic module combines the status signals, binary and enumerated parameters to generate the trip command of the function.

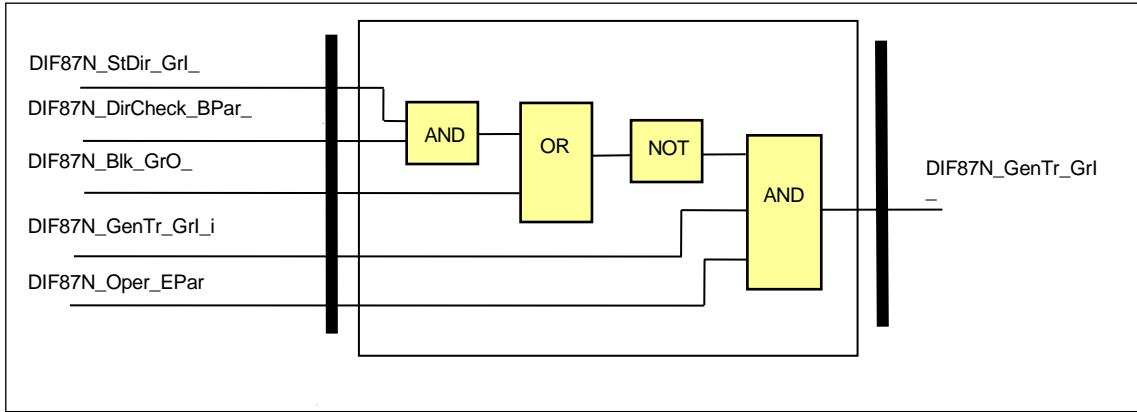


Figure 1-8 The logic scheme of the restricted earth-fault protection function

| Binary input signals | Signal title | Explanation |
|----------------------|-------------------|------------------------------------------------------------------------|
| DIF87N_GenTr_Grl_i | General Trip_i | Internal general trip signal of the differential characteristics |
| DIF87N_StDir_Grl_ | Dir.element Start | Directional blocking signal restricted earth-fault protection function |

Table 1-7 The binary input status signals of the zero sequence differential protection characteristics

The restricted earth-fault protection function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user applying the graphic equation editor.**

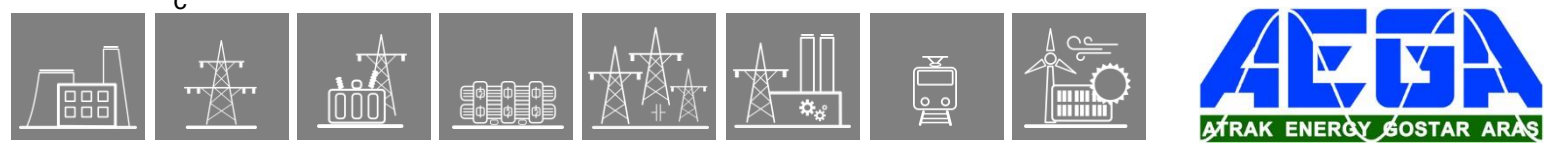
| Binary input signal | Explanation |
|---------------------|--------------------------------------------------------------------------------------------------------------------|
| DIF87N_Blk_GrO | Output status of a graphic equation defined by the user to disable the restricted earth-fault protection function. |

Table 1-8 The binary input signal of the restricted earth-fault protection function

The binary output signals of the restricted earth-fault protection function are listed in Table 1-9.

| Binary output signals | Signal title | Explanation |
|-----------------------|-------------------|----------------------------------------------------------------------------------|
| DIF87N_GenTr_Grl_ | General Trip | General trip signal of the zero sequence differential protection characteristics |
| DIF87N_StDir_Grl_ | Dir.element Start | Directional blocking signal of the restricted earth-fault protection function |

Table 1-9 The binary output status signals of the zero sequence differential protection characteristics



The enumerated parameter of the restricted earth-fault protection function is shown in Table 1-10:

| Parameter name | Title | Selection range | Default |
|-------------------------------------------------------------------------|-----------|-----------------|---------|
| Parameter to enable the zero sequence differential protection function: | | | |
| DIF87N_Oper_EPar_ | Operation | Off, On | On |

Table 1-10 The enumerated parameters of the restricted earth-fault protection function

The Boolean parameter of the restricted earth-fault protection function is shown in Table 1-11:

| Parameter name | Title | Default | Explanation |
|-----------------------|-------------------|---------|-----------------------------------------------------------------------------------------|
| DIF87N_DirCheck_BPar_ | Directional check | True | Enabling the directional checking of the measured and calculated zero sequence currents |

Table 1-11 The Boolean parameters of the restricted earth-fault protection function

The restricted earth-fault protection function generates a trip signal if the differential current as the function of the bias current is above the differential characteristic lines and the function is not blocked and the operation of the function is enabled by parameter setting.

Blocking can be caused by the directional decision if it is enabled by parameter setting and the angle of the currents is in the blocking area or the user has composed a blocking graphic equation, and the conditions result a TRUE value for the blocking.

3.1.17.7. Technical summary

3.1.17.7.1. Technical data

| Function | Value | Accuracy |
|--------------------------|--------------|----------|
| Operating characteristic | 1 breakpoint | |
| Reset ratio | 0,95 | |
| Characteristic accuracy | | <2% |
| Operate time | < 35 ms | |
| Reset time | < 25 ms | |

Table 1-12 Technical data of the restricted earth fault protection

3.1.17.7.2. The measured values

The **measured values** of the restricted earth-fault protection function are listed in Table 1-13.

| Measured value | Title | Dim. | Explanation |
|------------------|--------------|------|-------------------------------------|
| DIF87N_Id_OLM_ | Diff Current | In % | The calculated differential current |
| DIF87N_Bias_OLM_ | Bias Current | In % | The calculated restraint current |

Table 1-13 The measured analogue values of the restricted earth-fault protection function

The parameters of the restricted earth-fault protection function are explained in the following tables.

3.1.17.7.3. The parameters

The **enumerated parameter** of the restricted earth-fault protection function is shown in Table 1-14:

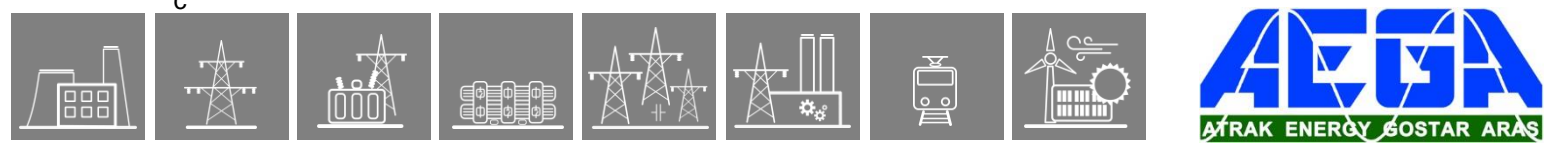
| Parameter name | Title | Selection range | Default |
|-------------------------------------------------------------------------|-----------|-----------------|---------|
| Parameter to enable the zero sequence differential protection function: | | | |
| DIF87N_Oper_EPar_ | Operation | Off, On | On |

Table 1-14 The enumerated parameters of the restricted earth-fault protection function

The **Boolean parameter** of the restricted earth-fault protection function is shown in Table 1-15:

| Parameter name | Title | Default | Explanation |
|-----------------------|-------------------|---------|-----------------------------------------------------------------------------------------|
| DIF87N_DirCheck_BPar_ | Directional check | True | Enabling the directional checking of the measured and calculated zero sequence currents |

Table 1-15 The Boolean parameters of the restricted earth-fault protection function



The integer parameters of the restricted earth-fault protection function are listed in Table 1-16.

| Parameter name | Title | Unit | Min | Max | Step | Default |
|-----------------------------------------------------|----------------------|------|-----|------|------|---------|
| Parameters for the current magnitude compensation: | | | | | | |
| DIF87N_TRPri_IPar_ | TR Primary Comp | % | 20 | 500 | 1 | 100 |
| DIF87N_TRNeut_IPar_ | TR Neutral | % | 100 | 1000 | 1 | 500 |
| Base sensitivity: | | | | | | |
| DIF87N_f1_IPar_ | Base Sensitivity | % | 10 | 50 | 1 | 30 |
| Slope of the second section of the characteristics: | | | | | | |
| DIF87N_f2_IPar_ | Slope | % | 50 | 100 | 1 | 70 |
| Break point of the characteristic line: | | | | | | |
| DIF87N_f2Brk_IPar_ | Base Sens Bias Limit | % | 100 | 200 | 1 | 125 |

Table 1-16 The integer parameters of the restricted earth-fault protection function

Floating-point parameters

The restricted earth-fault protection function has no floating-point parameters.

Timer parameters

The restricted earth-fault protection function has no timers.

3.1.17.7.4. The binary input status signals

The restricted earth-fault protection function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

The other binary input signal serves to increase the base sensitivity by 4 times. **The conditions of increasing the base sensitivity are defined by the user, applying the graphic equation editor.**

| Binary input signal | Explanation |
|---------------------|--------------------------------------------------------------------------------------------------------------------|
| DIF87N_BlK_GrO | Output status of a graphic equation defined by the user to disable the restricted earth-fault protection function. |
| DIF87N_UnSens_GrO_ | Output status of a graphic equation defined by the user to increase the base sensitivity by 4 times |

Table 1-17 The binary input signal of the restricted earth-fault protection function

3.1.17.7.5. Binary output status signals

The **binary output status signals** of the restricted earth-fault protection function are listed in Table 1-18.

| Binary output signals | Signal title | Explanation |
|-----------------------|--------------|-----------------------------------------------------------------------|
| DIF87N_GenTr_GrI_ | General Trip | General trip signal of the restricted earth-fault protection function |

Table 1-18 The binary output status signals of the restricted earth-fault protection function

3.1.17.7.6. The function block

The function block of the restricted earth fault protection function is shown in Figure 1-9. This block shows all binary input and output status signals that are applicable in the graphic equation editor.

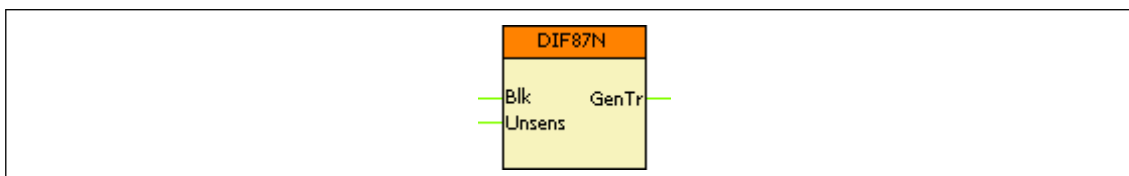


Figure 1-9 The function block of the restricted earth-fault protection function

3.1.17.8. Example for the calculation of settings of the zero sequence differential protection function

As an example, the transformer data:

$S_n = 25 \text{ MVA}$
 $U_1/U_2 = 120/22 \text{ kV/kV}$
 $Y(d)y_6$

Current transformers:

| | |
|-----|-----------|
| CT1 | 600/1 A/A |
| CT2 | 800/1 A/A |
| CTN | 250/1 A/A |

The selected base current is the primary rated current of the transformer: 120 A. If a lower current value is selected, the zero sequence differential protection becomes more sensitive.

REF on the secondary side:

| | | |
|---------------------------|---------------------------------|---------------------------|
| $I_{1np} = 120 \text{ A}$ | | |
| $I_{2np} = 656 \text{ A}$ | On the secondary side of the CT | $I_{2n} = 0.82 \text{ A}$ |
| $I_{Np} = 656 \text{ A}$ | On the secondary side of the CT | $I_N = 2.6 \text{ A}$ |

The setting parameters:

| Parameter name | Title | Setting value |
|---------------------|-----------------|---------------|
| DIF87N_TRPri_IPar_ | TR Primary Comp | 82% |
| DIF87N_TRNeut_IPar_ | TR Neutral | 260% |

The base sensitivity refers to the selected “base current” expressed in %, the slope is the ratio of the differential current and the bias current expressed in %.

3.1.17.9. Example for the application

For the application example consider an autotransformer equipped with tertiary, according to [Figure 1-1](#). The coils for the primary and secondary sides are auto-connected with solidly grounded neutral. The tertiary coils are delta connected, and applied also for power transmission.

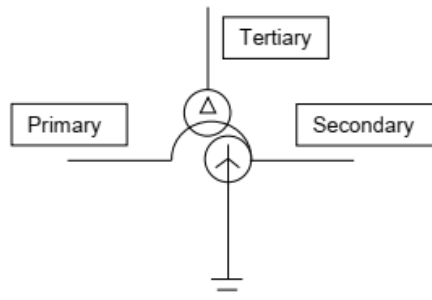


Figure 1-1 Autotransformer application

Example transformer data for the application:

Rated voltages: 220 kV / 132 kV / 11 kV

Rated power: 100 MVA / 100 MVA / 30 MVA

Calculated rated currents: 262 A / 437 A / 1575 A (5249 A)

NOTE: for the tertiary coil two currents are calculated, one is based on the coil rated power; this is 1575 A and one for the highest reference power (5249 A). This higher value is needed for balancing the differential protection function.

Current transformers installed for the application are shown in [Figure 1-2](#). The P1 points are arranged towards the transformer, except the CT in the grounding. For this CT the P2 point is toward the transformer.

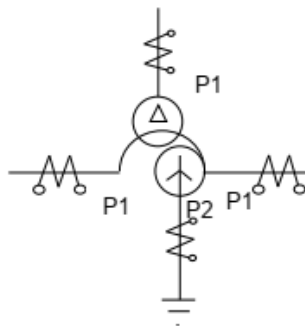


Figure 1-2 Current transformers, assigned to the differential protection and restricted earth-fault protection functions

Current transformer data:

Primary side 300 A / 1 A

Secondary side 500 A / 1 A

Tertiary side 2000 A / 1 A

Grounding 300 A / 1 A

Suppose that the transformer is to be protected by differential protection and restricted earth-fault protection.

The phase differential protection involves the primary, secondary and tertiary windings, for this function the current measured by the CT in the grounding is not applied. The zero sequence current is eliminated numerically using matrix transformation within the differential protection function. See *Figure 1-3*.

The restricted earth-fault protection is applied for the galvanic connected windings. This means the auto-connected coils for the primary and secondary sides. The tertiary side is excluded from the protected zone. See *Figure 1-3*.

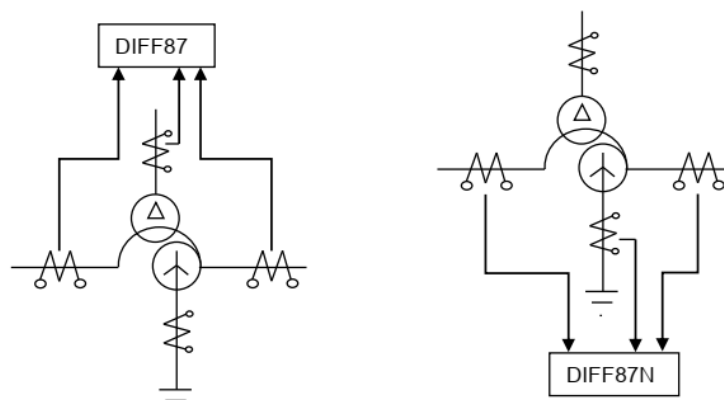


Figure 1-3 Differential protection and restricted restricted earth-fault protection application

The restricted earth-fault protection considers the coils as a node, bordered by current transformers: the three CT-s of the high voltage primary side, three CT-s of the secondary side and the CT in the grounding. Here the Kirchhoff's node-law is to be satisfied: the sum of these seven currents must result zero. In other cases, due to internal fault, a TRIP command is to be generated for the circuit breakers.

If in theory the summation is performed in three steps: first the sum of three primary side currents is calculated, resulting the residual component at the primary side, then the sum of the three secondary currents is calculated, resulting the residual component at the secondary side, finally these calculated residual currents and the residual current measured in the grounding CT is added. As it can be seen, the restricted earth-fault protection is basically a zero sequence differential protection for the galvanic connected coils, as a node.

For the realization of the differential protection and jointly the restricted earth-fault protection function, a Protecta made EuroProt+ device configuration is applied. This device realizes – among other protection, supervision and monitoring functions – also these functions.

The required connection diagram is shown in

Figure 1-4. The device contains three current input modules in positions “R”, “S” and “T”. Each current input module contains four CT inputs. The module in “T” is reserved for the primary three phase currents, and the fourth channel is the input for the CT in the grounding.

The module in “S” is reserved for the secondary three phase currents, and the fourth channel is not applied. Similarly, the module in “R” is reserved for the tertiary three phase currents, and the fourth channel is not applied.

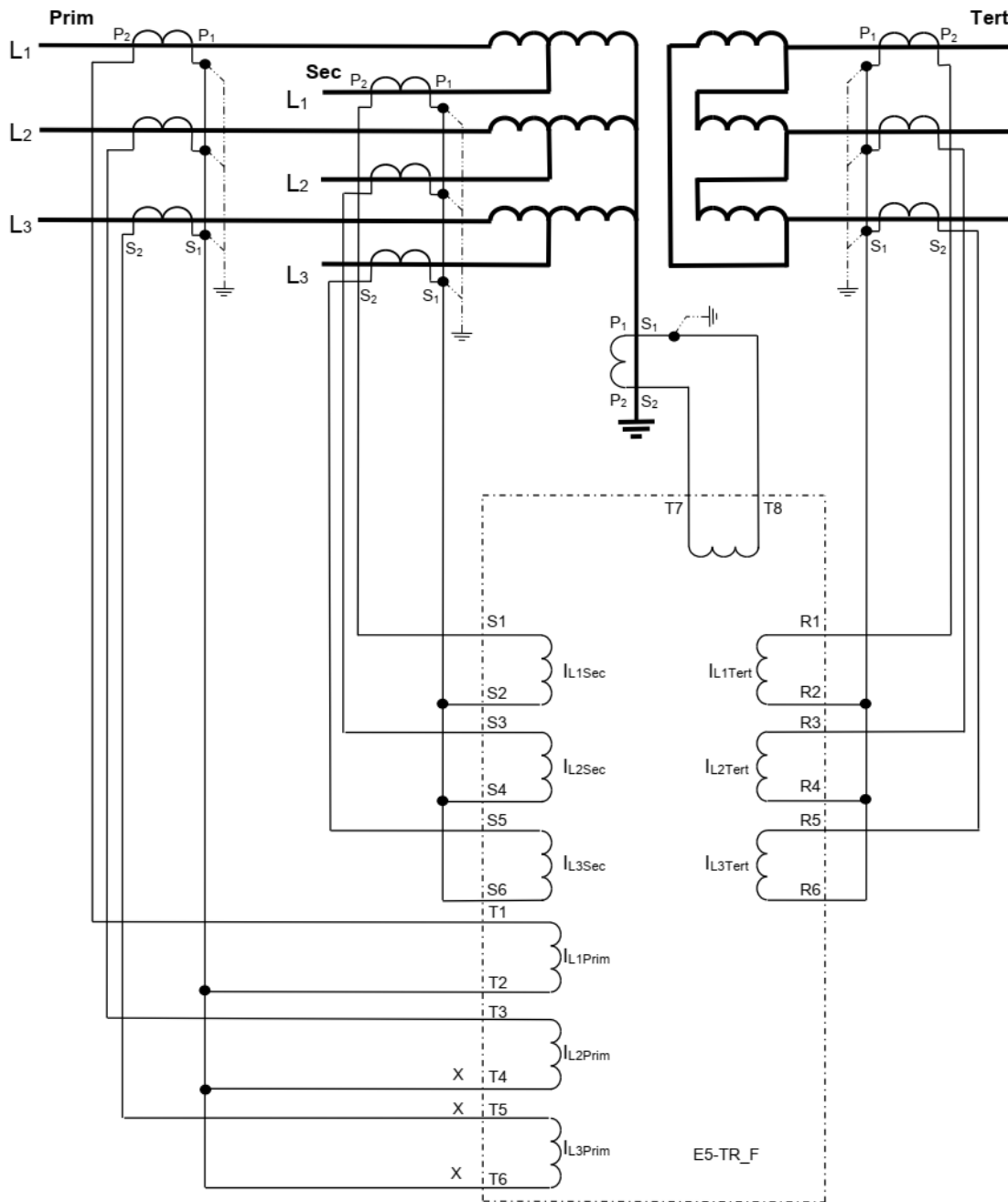
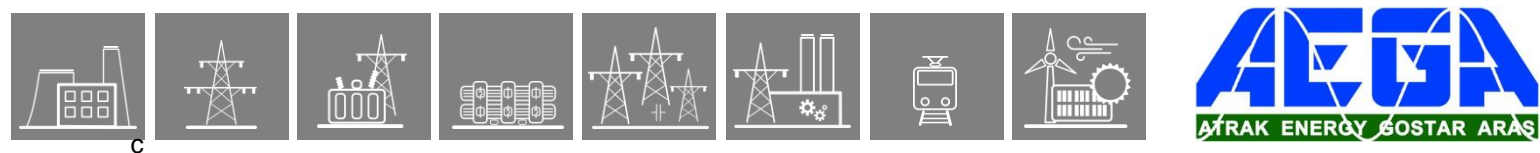


Figure 1-4 EuroProt+ connection diagram for differential protection and restricted earth-fault protection application

NOTE: In this diagram, as default, all CT P1 points are towards the protected object. Due to the reverse connection of the CT in the grounding, applied in the example, this direction is reverted by parameter setting.



In all three sides of the transformer, connect the CT in Y, with the neutral point at the transformer side, according to

Figure 1-4. The vector group compensation, required in Primary/Tertiary and in Secondary/Tertiary relationship is performed numerically within the differential protection function, together with magnitude compensation. Similarly the required zero sequence elimination is solved numerically. No interposing current transformers are required.

3.1.17.9.1. Setting the CT input function blocks

In the EuroProt+ devices the CT inputs are assigned to CT function blocks. They need parameter setting and also displaying functions are assigned to them. *Figure 2-1* shows the parameter screen, when there is Internet connection with the device. For details about this communication see the Protecta document “**Remote user interface description**” available in Protecta WEB site www.protecta.hu.

NOTE: the parameters can be set also using the local LCD touch-screen of the device, if no internet connection is available. For details about this communication see the Protecta document “**LCD touchscreen interface description**” available in Protecta WEB site www.protecta.hu.

The parameters of the current input function are explained in the following tables.

Enumerated parameters

| Parameter name | Title | Selection range | Default |
|------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|---------------------|---------|
| Rated secondary current of the first three input channels. 1A or 5A is selected by parameter setting, no hardware modification is needed. | | | |
| CT4_Ch13Nom_EPar_ | Rated Secondary I1-3 | 1A,5A | 1A |
| Rated secondary current of the fourth input channel. 1A or 5A (0.2A, 1A) is selected by parameter setting, no hardware modification is needed. | | | |
| CT4_Ch4Nom_EPar_ | Rated Secondary I4 | 1A,5A (0.2A, 1A) | 1A |
| Definition of the positive direction of the first three currents, given by location of the secondary star connection point | | | |
| CT4_Ch13Dir_EPar_ | Starpoint I1-3 | Line,Bus | Line |
| Definition of the positive direction of the fourth current, given as normal or inverted | | | |
| CT4_Ch4Dir_EPar_ | Direction I4 | Normal,Inverted | Normal |

Table 2-1 The enumerated parameters of the current input function

Floating point parameters

| Parameter name | Title | Dim. | Min | Max | Default |
|-------------------------------------|--------------------|------|-----|------|---------|
| Rated primary current of channel1-3 | | | | | |
| CT4_Pr113_FPar_ | Rated Primary I1-3 | A | 100 | 4000 | 1000 |
| Rated primary current of channel4 | | | | | |
| CT4_Pr114_FPar_ | Rated Primary I4 | A | 100 | 4000 | 1000 |

Table 2-2 The floating point parameters of the current input function

NOTE: The rated primary current of the channels is not needed for the current input function block itself. These values are passed on to the subsequent function blocks.

[-] CT4 module Prim.

| | Device value (Default_set_1) | New value | |
|----------------------|---------------------------------------|------------------------------------------------------------------------|---|
| Rated Secondary I1-3 | <input type="text" value="1A"/> | <input type="text" value="1A"/> <input type="button" value="v"/> | |
| Rated Secondary I4 | <input type="text" value="1A"/> | <input type="text" value="1A"/> <input type="button" value="v"/> | |
| Starpoint I1-3 | <input type="text" value="Line"/> | <input type="text" value="Line"/> <input type="button" value="v"/> | |
| Direction I4 | <input type="text" value="Inverted"/> | <input type="text" value="Inverted"/> <input type="button" value="v"/> | |
| Rated Primary I1-3 | <input type="text" value="300"/> | <input type="text" value="300"/> | A |
| Rated Primary I4 | <input type="text" value="300"/> | <input type="text" value="300"/> | A |

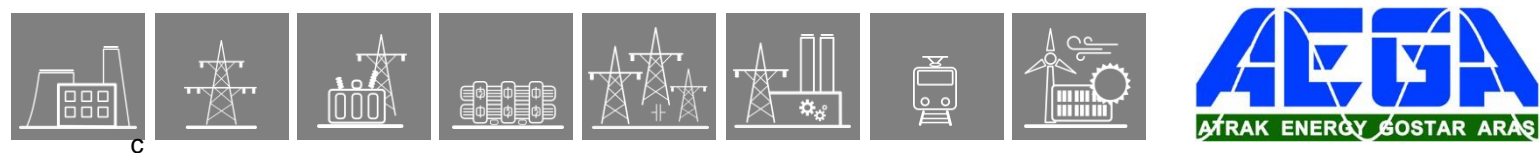
[-] CT4 module Sec.

| | Device value (Default_set_1) | New value | |
|----------------------|-------------------------------------|----------------------------------------------------------------------|---|
| Rated Secondary I1-3 | <input type="text" value="1A"/> | <input type="text" value="1A"/> <input type="button" value="v"/> | |
| Rated Secondary I4 | <input type="text" value="1A"/> | <input type="text" value="1A"/> <input type="button" value="v"/> | |
| Starpoint I1-3 | <input type="text" value="Line"/> | <input type="text" value="Line"/> <input type="button" value="v"/> | |
| Direction I4 | <input type="text" value="Normal"/> | <input type="text" value="Normal"/> <input type="button" value="v"/> | |
| Rated Primary I1-3 | <input type="text" value="500"/> | <input type="text" value="500"/> | A |
| Rated Primary I4 | <input type="text" value="300"/> | <input type="text" value="300"/> | A |

[-] CT4 module Tert.

| | Device value (Default_set_1) | New value | |
|----------------------|-------------------------------------|----------------------------------------------------------------------|---|
| Rated Secondary I1-3 | <input type="text" value="1A"/> | <input type="text" value="1A"/> <input type="button" value="v"/> | |
| Rated Secondary I4 | <input type="text" value="1A"/> | <input type="text" value="1A"/> <input type="button" value="v"/> | |
| Starpoint I1-3 | <input type="text" value="Line"/> | <input type="text" value="Line"/> <input type="button" value="v"/> | |
| Direction I4 | <input type="text" value="Normal"/> | <input type="text" value="Normal"/> <input type="button" value="v"/> | |
| Rated Primary I1-3 | <input type="text" value="2000"/> | <input type="text" value="2000"/> | A |
| Rated Primary I4 | <input type="text" value="300"/> | <input type="text" value="300"/> | A |

Figure 2-1 EuroProt+ parameter screen for the CT input modules



Using the information given in this example above, the following setting values are assigned:

Primary side and grounding CT:

| | | |
|----------------------|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Rated Secondary I1-3 | 1A | Selected, according to the CT applied at the primary side. |
| Rated Secondary I4 | 1A | Selected, according to the CT applied in the grounding. |
| Starpoint I1-3 | Line | “Line” in this case means “Toward protected object = Transformer” |
| Direction I4 | Inverted | In this application all P1 points of the CT-s are on the transformer side, except the CT in the grounding, which has P2 point at the transformer side. This is the reason why the positive direction is “Inverted” to fulfill the Kirchhoff’s node law. |
| Rated Primary I1-3 | 300 | Setting, according to the CT applied at the primary side. This parameter is used for scaling the displayed values only |
| Rated Primary I4 | 300 | Setting, according to the CT applied in the grounding. This parameter is used for scaling the displayed values only |

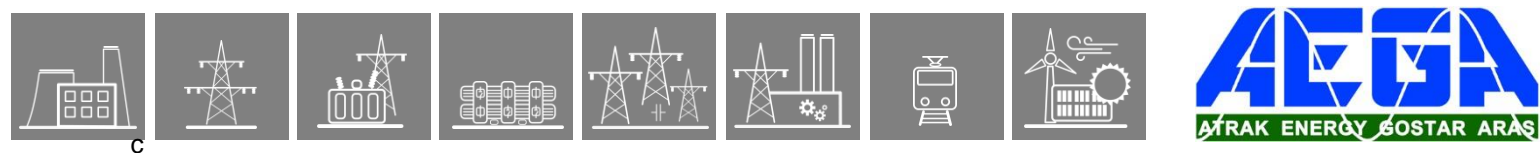
Secondary side:

| | | |
|----------------------|------|--------------------------------------------------------------------------------------------------------------------------|
| Rated Secondary I1-3 | 1A | Selected, according to the CT applied at the secondary side. |
| Rated Secondary I4 | | Not applied, the value is not considered. |
| Starpoint I1-3 | Line | “Line” in this case means “Toward protected object = Transformer” |
| Direction I4 | | Not applied, the value is not considered. |
| Rated Primary I1-3 | 500 | Setting, according to the CT applied at the secondary side. This parameter is used for scaling the displayed values only |
| Rated Primary I4 | | Not applied, the value is not considered. |

Tertiary side:

| | | |
|----------------------|------|-------------------------------------------------------------------------------------------------------------------------|
| Rated Secondary I1-3 | 1A | Selected, according to the CT applied at the tertiary side. |
| Rated Secondary I4 | | Not applied, the value is not considered. |
| Starpoint I1-3 | Line | “Line” in this case means “Toward protected object = Transformer” |
| Direction I4 | | Not applied, the value is not considered. |
| Rated Primary I1-3 | 2000 | Setting, according to the CT applied at the tertiary side. This parameter is used for scaling the displayed values only |
| Rated Primary I4 | | Not applied, the value is not considered. |

Table 2-3 Summary of the CT parameter setting



3.1.17.10. Setting the differential protection function

The parameters of the differential protection function are explained in the following tables.

Enumerated parameters for the differential protection function:

| Parameter name | Title | Selection range | Default |
|----------------------------------------------------------------------------------------------|-----------------|---------------------------------------------------------------------------------------------|---------|
| Parameter to enable the differential protection function: | | | |
| DIF87_Op_EPar_ | Operation | Off, On | On |
| Parameter to select connection group of the transformer coils in primary-secondary relation: | | | |
| DIF87_VGrSec_EPar_ | Pri-Sec VGroup* | Dy1,Dy5,Dy7,Dy11,Dd0,Dd6,Dz0,Dz2,Dz4,Dz6,Dz8,Dz10,Yy0,Yy6,Yd1,Yd5,Yd7,Yd11,Yz1,Yz5,Yz7,Yz11 | Dd0 |
| Parameter to select connection group of the transformer coils in primary-tertiary relation: | | | |
| DIF87_VGrTer_EPar_ | Pri-Ter VGroup* | Dy1,Dy5,Dy7,Dy11,Dd0,Dd6,Dz0,Dz2,Dz4,Dz6,Dz8,Dz10,Yy0,Yy6,Yd1,Yd5,Yd7,Yd11,Yz1,Yz5,Yz7,Yz11 | Dd0 |

Table 3-1 The enumerated parameters of the differential protection function

* If the connection of the primary winding in primary-secondary and primary tertiary relation is selected in contradiction then the protection function is automatically disabled, and the function generates a warning signal.

Boolean parameter for the differential protection function:

| Parameter name | Title | Default | Explanation |
|------------------|----------------------|---------|-------------|
| DIF87_0Seq_BPar_ | Zero Seq Elimination | True | |

Table 3-2 The Boolean parameter of the differential protection function

Integer parameters

| Parameter name | Title | Unit | Min | Max | Step | Default |
|-----------------------------------------------------|----------------------|------|-----|------|------|---------|
| Parameters for the current magnitude compensation: | | | | | | |
| DIF87_TRPr_IPar_ | TR Primary Comp | % | 20 | 500 | 1 | 100 |
| DIF87_TRSec_IPar_ | TR Secondary Comp | % | 20 | 500 | 1 | 100 |
| DIF87_TRTer_IPar_ | TR Tertiary Comp | % | 20 | 200 | 1 | 100 |
| Parameter of the second harmonic restraint: | | | | | | |
| DIF87_2HRat_IPar_ | 2nd Harm Ratio | % | 5 | 50 | 1 | 15 |
| Parameter of the fifth harmonic restraint: | | | | | | |
| DIF87_5HRat_IPar_ | 5th Harm Ratio | % | 5 | 50 | 1 | 25 |
| Parameters of the percentage characteristic curve: | | | | | | |
| Base sensitivity: | | | | | | |
| DIF87_f1_IPar_ | Base Sensitivity | % | 10 | 50 | 1 | 20 |
| Slope of the second section of the characteristics: | | | | | | |
| DIF87_f2_IPar_ | 1st Slope | % | 10 | 50 | 1 | 20 |
| Bias limit of the first slope: | | | | | | |
| DIF87_f3_IPar_ | 1st Slope Bias Limit | % | 200 | 2000 | 1 | 200 |
| Unrestrained differential protection current level: | | | | | | |
| DIF87_HCurr_IPar_ | UnRst Diff Current | % | 800 | 2500 | 1 | 800 |

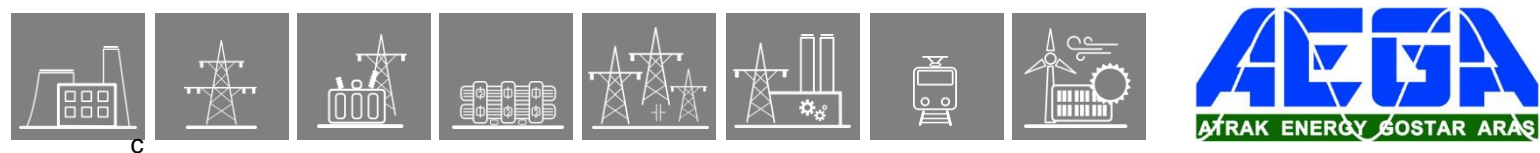
Table 3-3 The integer parameters of the differential protection function

[-] Differential 3w

| | Device value (Default_set_1) | New value | |
|----------------------|---------------------------------|--------------------------|---|
| Operation | On | On | ▼ |
| Pri-Sec VGroup | Yy0 | Yy0 | ▼ |
| Pri-Ter VGroup | Yd11 | Yd11 | ▼ |
| ZeroSeq Elimination | <input type="checkbox"/> | <input type="checkbox"/> | |
| TR Primary Comp | 87 | 87 | % |
| TR Secondary Comp | 87 | 87 | % |
| TR Tertial Comp | 262 | 262 | % |
| 2nd Harm Ratio | 15 | 15 | % |
| 5th Harm Ratio | 25 | 25 | % |
| Base Sensitivity | 50 | 50 | % |
| 1st Slope | 50 | 50 | % |
| 1st Slope Bias Limit | 400 | 400 | % |
| UnRst Diff Current | 800 | 800 | % |

Figure 3-1 EuroProt+ parameter screen for the differential protection function

These parameters need basic considerations some of them need also calculation. This is explained in the table below:



| | | |
|----------------------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Operation | On | Set this parameter to “On” for enabling the function. NOTE: In tests, when other protection functions are tested. Switch this parameter to “Off” to prevent false test results |
| Pri-Sec VGroup | Yy0 | This setting is selected according to the protected object. For autotransformers select always Yy0. NOTE: see explanation in paragraph 3.1. |
| Pri-Ter VGroup | Yd11 | This setting is selected according to the protected object. (Example) NOTE: see explanation in paragraph 3.1 |
| Zero Seq Elimination | False | Not checked. This parameter is needed only if there is isolated (Not grounded) side of the transformer and there is and additional neutral grounding transformer within the protected zone. As this additional neutral grounding transformer is not supposed to be present, the checkbox can remain unchecked. This is described in paragraph |
| TR Primary Comp | 87 | This value needs calculation. This is described in paragraph 3.2 |
| TR Secondary Comp | 87 | This value needs calculation. This is described in paragraph 3.2 |
| TR Tertiary Comp | 262 | This value needs calculation. This is described in paragraph 3.2 |
| 2nd Harm Ratio | 15 | This value needs some considerations. These are described in paragraph 3.3 |
| 5nd Harm Ratio | 25 | This value needs some considerations. These are described in paragraph 3.3 |
| Base Sensitivity | 50 | Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 3.4 |
| 1st Slope | 50 | Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 3.4 |
| 1st Slope Bias Limit | 400 | Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 3.4 |
| UnRst Diff Current | 800 | Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 3.4 |

Table 3-4 Summary of the differential protection parameter setting

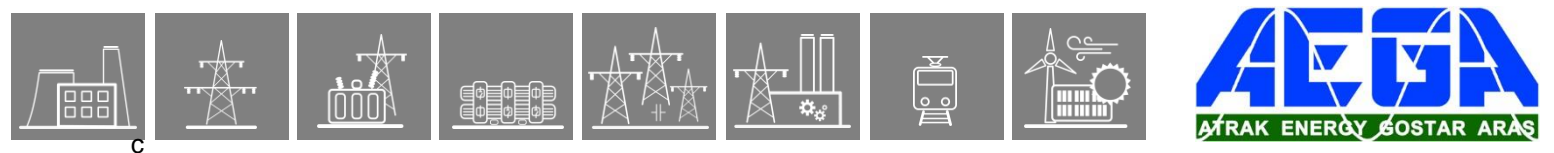
3.1.17.10.1. Vector shift compensation

The Protecta EuroProt+ configurations perform numerical vector shift compensation. The secondary wires of the current transformers are connected in Y, and the three phase currents secondary values are input directly into the current inputs of the device. No interposing CT-s are required.

The principle of the vector shift compensation is the numerical realization of the old principle: on Y side of the transformer apply delta connected secondary, on delta side of the transformer apply Y connected secondary. The advantage of this method is that the zero sequence current elimination is “automatic”.

The numerical solution is matrix multiplication: on Y side a phase shifting matrix is applied, e.g. for Yd11 transformation it is:

$$\begin{bmatrix} I_{1Rshift} \\ I_{1Sshift} \\ I_{1Tshift} \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} I_{1r} \\ I_{1s} \\ I_{1t} \end{bmatrix}$$



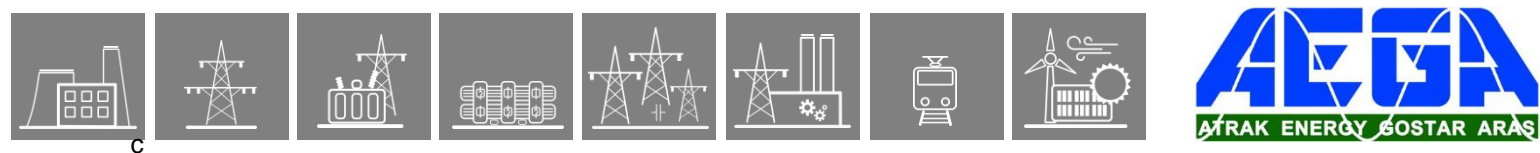
On delta side of the transformer phase shift is not applied, the realization is the unit matrix.

$$\begin{bmatrix} I2Rshift \\ I2Sshift \\ I2Tshift \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$$

This means that the reference vector is the “r = L1” phase current of the delta side. The Y side currents are transformed to this reference for comparison.

The details are described in the document “Differential protection function block description”, available in Protecta WEB site www.protecta.hu.

The related parameter setting is easy: consider the clock notation of the transformer. In the example above it is YNyn0d11. The software requires setting for the primary-secondary relationship: it is YNyn0, and the setting for the primary tertiary relationship: it is Ynd11. Then the vector shift compensation is performed automatically.



3.1.17.10.2. Calculation of the amplitude compensation for the differential protection function

The basic principle is that in case of power transfer at rated current the currents to be compared should be the same, 100%. This means that in case of any external faults there will be no current difference, the differential function is balanced and stable.

For a two winding transformer, usually the rated current of the transformer is considered to be the base current, considered to be 100%. The ratio of the secondary and primary rated currents is the turn's ratio of the transformer.

For the setting calculation, calculate the ratio of the transformer rated current and the CT rated primary current. These values expressed in % are the parameter values to be set for parameters „TR Primary Comp” and “TR Secondary Comp”.

For a three winding transformer in the example the rated power of the winding is not the same (100MVA, 100 MVA and 30 MVA), consequently the ratio of rated currents for the windings do not match the turn's ratio of the coils. In this case the usual procedure is to consider the rated current of the primary side, and transform this current both for the secondary and to the tertiary side. These calculated currents should be related to the rated currents of the CT-s. These values expressed in % are the parameter values to be set for parameters „TR Primary Comp”, “TR Secondary Comp” and “TR Tertiary Comp”.

In the example:

The rated primary current is 262 A, see the transformer data above. This is the reference current.

This current is transformed to the secondary is 437 A.

This current is transformed to the tertiary is 5249 A. (Here the rated current would be 1575 A, this value is not considered!) The calculation of the setting values is as follows

$$\begin{aligned} \text{„TR Primary Comp"} &= 100 * 262 \text{ A} / 300 \text{ A} = 87\% \\ \text{„TR Secondary Comp"} &= 100 * 437 \text{ A} / 500 \text{ A} = 87\% \\ \text{„TR Tertiary Comp"} &= 100 * 5249 \text{ A} / 2000 \text{ A} = 262\% \end{aligned}$$

Using this setting, the reference current on the secondary side is displayed by the differential protection function as 100%.

3.1.17.10.3. Considerations, related to the harmonic restraint

When a transformer is energized then due to the asymmetric saturation of the iron core a high “inrush current” can flow from one side into the transformer. This is a pure differential current. To prevent unwanted operation of the differential protection the special waveform of the inrush current is identified. The principle is the detection of the second harmonic content, which is present in the inrush current, but its value can be neglected in any fault current. For the differential current, the second harmonic component in the evaluation is related to the value of the base harmonic. This is the parameter „2nd Harm Ratio”. If this ration gets higher due to inrush current, the trip command is blocked.

When a transformer is overexcited then the iron core is saturated symmetrically, resulting high current peaks, distorting both the positive and the negative sinusoidal current shape. In this current shape the fifth harmonic is characteristic. To prevent mal-operation, this component of the differential current is analyzed and compared to the base harmonic. If the ratio is high, then the differential current is caused by the over-excitation, the trip command is blocked. If however the fifth harmonic content is low, then the high differential current, which is a fault current, results trip command. The ratio is the parameter „5th Harm Ratio”.

If no results of detailed harmonic analysis are available, apply the factory setting, which can be corrected later. The proposed setting values are:

$$\text{„2nd Harm Ratio”} = 15 \%$$

and

$$\text{„5th Harm Ratio”} = 25 \%$$

3.1.17.10.4. Considerations, related to the differential characteristic for the differential protection function

The differential characteristic is shown in *Figure 3-2*. If the calculated (I_{diff} , I_{bias}) operating point is above the characteristic, then the differential protection operates.

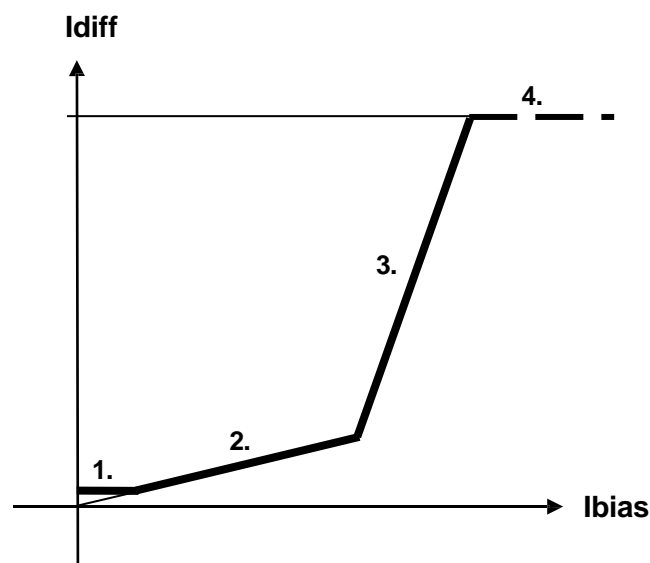
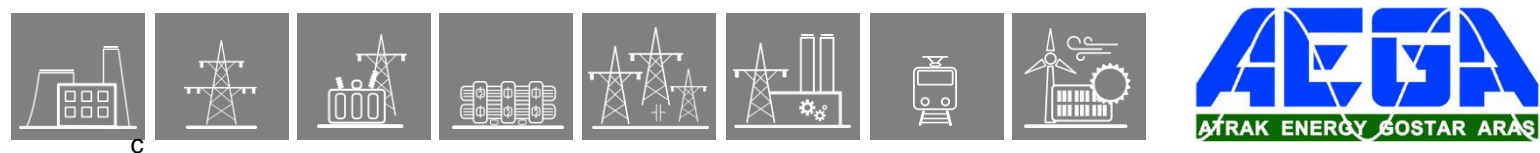


Figure 3-2 The differential characteristic

This characteristic has four sections; each of them is a straight line. The parameters define the position of these lines on the I_{diff} - I_{bias} plane.

The first parameter is “Base Sensitivity”, it defines the minimum differential current for the operation. Its role is to prevent mal-operation in case of current noises and measuring errors for small currents. In this example the selected setting value is the less sensitive selection:



„Base Sensitivity” = 50 %,

This value can be tested easily: inject three phase symmetrical currents from one side only and increase its value. The operation is expected if this current gets above 50% of the reference current. (In this example it is $0.5 \cdot 0.87A$. NOTE: for asymmetrical fault current this value changes due to the matrix transformation.)

The second section of the characteristic is a line through the origin of the I_{diff} - I_{bias} plane. The slope of this line serves to compensate the not correct matching of the CT-s, e.g. due to the different tap-changer positions and the CT errors. Due to these causes the error current increases if the current flowing through the transformer increases. The parameter is “1st Slope”. The mathematical expression of the second section of the characteristic is:

$$I_{diff} = \frac{1stSlope}{100} * I_{bias}$$

The steps for getting the parameter value are as follows:

- Calculate the error in percent, due to not correct matching (To be calculated for all three voltage levels):

$$x\% = \left(1 - \left| \frac{I1 \cdot required_matching}{I1 \cdot matching} \right| \right) * 100$$

- The unbalance of the differential protection at top or bottom position of the tap changer in percent, related to the value of 0 position ($r_{max}\%$):

$$x\% = |r_{max}\%|$$

Select the biggest value of the calculated x% values above. The setting value is advised to be above this value.

Example: suppose the voltage control range to be +18%/–12 %, and the reference position for current balancing is the 0 position, then the parameter value with 1,5x safety is:

$$\text{„1st Slope”} = 1,5 \cdot 18 = 27 \rightarrow 30 \%$$

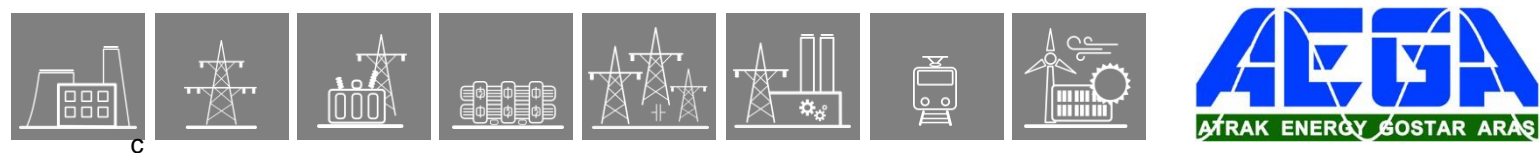
Another choice for calculation is the selection the mid-position of the tap-changer. This is in this example as follows: The full position range is $18 + 12 = 30 \%$, The half value is 15% , accordingly the mid-position is $+3 \%$. With his the voltage ratio of the transformer to be considered is to be increased by $118 / 115$, and the balancing of the current is to be determined for this voltage. In this case only $\pm 15 \%$ tap position range can be considered, and the value of this parameter is decreased to:

$$\text{„1st Slope”} = 1,5 \cdot 15 = 22,5 \rightarrow 25 \%$$

The slope of the third section of the characteristic is higher. This is to compensate the increased CT error, due to the CT saturation at higher currents. This higher sloe is a factory setting: 200%. The parameter “1st Slope Bias Limit” defines the intersection point of section 2 and 3.

This parameter value is influenced by the highest fault current in the protected object and the applied current transformer saturation point related to the rated value. If the current transformer is less over-dimensioned then select the parameter vale for “1st Slope Bias Limit” low. The usual consideration is: for relatively high currents select 200 %, for low fault currents select 1000 %.

The fourth section of the characteristic is the unrestrained section. The related parameter is “UnRst Diff Current”. This parameter serves unrestrained fast operation if the high magnitude of the fault current indicates internal fault. The calculation determines the maximal external fault current, and the setting value should be above this current.



3.1.17.10.5. Considerations for zero sequence elimination

In solidly grounded high voltage networks, in case of external earth faults, the Y-delta transformers revert zero sequence current, which is present on the Y side only. No zero sequence current can flow on the delta side. When comparing the currents in the differential protection, this could cause unwanted operation.

The differential protection function in the Protecta EuroProt+ devices eliminates the Y side zero sequence current by matrix transformation (simulating the old type delta connected CT secondary behavior). This elimination is automatic, no additional solution is needed.

In several cases, however, there is additional neutral grounding transformer on the delta side for the transformer within the protected zone. Between the neutral point of this additional transformer an arc suppression Petersen coil, or a grounding resistor is connected. The Petersen coil minimizes the earth-fault current to some Amperes, the resistor limits the earth-fault current to 100 A (in some cases to 200 A).

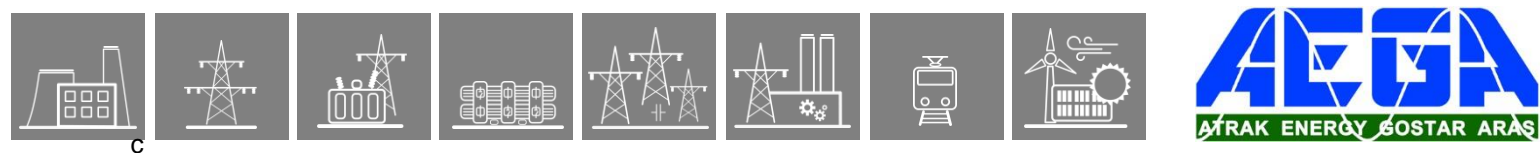
If the neutral grounding transformer is not in the protected zone, it is outside the current transformers, then set:

„ZeroSeq Elimination” = „False” (Not checked)

In some cases, however, the neutral grounding transformer is closely connected to the main transformer's delta side terminals, it is in the protected zone. The advantage of this arrangement is that the energizing the transformer immediately solves the neutral grounding problems.

In case of external earth-fault the zero sequence current of the neutral grounding transformer is detected by the delta side current transformers. The zero sequence elimination is needed. In this case set

„ZeroSeq Elimination” = „True” (Checked)



3.1.17.11. Setting the restricted earth-fault protection function

The restricted earth-fault protection function is basically a zero sequence (residual) differential protection (DIF87N), applied for the galvanic interconnected coils.

The parameters of the restricted earth-fault protection function are explained in the following tables.

Enumerated parameter for the restricted earth-fault protection function:

| Parameter name | Title | Selection range | Default |
|-----------------------------------------------------------|-----------|-----------------|---------|
| Parameter to enable the differential protection function: | | | |
| DIF87N_Op_EPar_ | Operation | Off, On | On |

Table 4-1 The enumerated parameter of the restricted earth-fault protection function

Boolean parameter for the differential protection function:

| Parameter name | Title | Default | Explanation |
|-----------------------|-------------------|---------|-------------|
| DIF87N_DirCheck_BPar_ | Directional check | True | |

Table 4-2 The Boolean parameter of the restricted earth-fault protection function

Integer parameters

| Parameter name | Title | Unit | Min | Max | Step | Default |
|-----------------------------------------------------|-----------------------------|------|-----|------|------|---------|
| Parameters for the current magnitude compensation: | | | | | | |
| DIF87N_TRPri_IPar_ | TR Primary Comp | % | 4 | 500 | 1 | 100 |
| DIF87N_TRSec_IPar_ | TR Secondary Comp | % | 4 | 500 | 1 | 100 |
| DIF87N_TRNeut_IPar_ | TR Neutral Comp | % | 4 | 1000 | 1 | 500 |
| Parameters of the percentage characteristic curve: | | | | | | |
| Base sensitivity: | | | | | | |
| DIF87N_f1_IPar_ | Base Sensitivity | % | 10 | 50 | 1 | 20 |
| Slope of the second section of the characteristics: | | | | | | |
| DIF87N_f2_IPar_ | Slope | % | 50 | 100 | 1 | 70 |
| Bias limit of the first slope: | | | | | | |
| DIF87N_f2Brk_IPar_ | Base Sensitivity Bias Limit | % | 100 | 200 | 1 | 125 |

Table 4-3 The integer parameters of the restricted earth-fault protection function

[-] Restricted EF

| | Device value (Default_set_1) | New value |
|----------------------|----------------------------------|--------------------------------------------------------------------------|
| Operation | <input type="text" value="On"/> | <input type="text" value="On"/> ▼ |
| Directional check | <input type="checkbox"/> | <input type="checkbox"/> |
| TR Primary Comp | <input type="text" value="15"/> | <input type="text" value="15"/> % |
| TR Secondary Comp | <input type="text" value="9"/> | <input type="text" value="9"/> % |
| TR Neutral Comp | <input type="text" value="15"/> | <input type="text" value="15"/> % |
| Base Sensitivity | <input type="text" value="50"/> | <input type="text" value="50"/> % |
| Slope | <input type="text" value="50"/> | <input type="text" value="50"/> % |
| Base Sens Bias Limit | <input type="text" value="125"/> | <input type="text" value="125"/> % |

Figure 4-1 EuroProt+ parameter screen for the restricted earth-fault protection function

These parameters need basic considerations some of them need also calculation. This is explained in the table below:

| | | |
|----------------------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Operation | On | Set this parameter to “On” for enabling the function. NOTE: In tests, when other protection functions are tested, switch this parameter to “Off” to prevent false test results |
| Directional check | False | Not checked. This parameter is needed to increase the security of the function in case of low level external faults. This is described in paragraph 4.3 |
| TR Primary Comp | 15 | This value needs calculation. This is described in paragraph 4.1 |
| TR Secondary Comp | 9 | This value needs calculation. This is described in paragraph 4.1 |
| TR Neutral Comp | 15 | This value needs calculation. This is described in paragraph 4.1 |
| Base Sensitivity | 50 | Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 4.2 |
| 1st Slope | 50 | Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 4.2 |
| 1st Slope Bias Limit | 125 | Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 4.2 |

Table 4-4 Summary of the CT parameter setting

3.1.17.11.1. Calculation of the amplitude compensation for the restricted earth-fault protection function

The basic principle is that in case of any external faults there will be no current difference, the zero sequence differential function is balanced and stable.

The setting of the restricted earth-fault protection function is independent of the setting of the differential protection function.

Here the same current is freely selected as the base current for the whole, galvanic connected coil system. The choice of the current is free. For more sensitive protection select a relatively low value. In the example the following value is selected:

$$I_{Base} = 44 \text{ A}$$

This is a primary value, which is transformed by the current transformers to the secondary side. For the setting, it is related to the rated primary currents of the current transformers:

$$\begin{aligned} \text{„TR Primary Comp”} &= 100 \cdot 44 \text{ A} / 300 \text{ A} = 15\% \\ \text{„TR Secondary Comp”} &= 100 \cdot 44 \text{ A} / 500 \text{ A} = 9\% \\ \text{„TR Neutral Comp”} &= 100 \cdot 44 \text{ A} / 300 \text{ A} = 15\% \end{aligned}$$

In the restricted earth-fault protection these values are used for amplitude matching the secondary currents

3.1.17.11.2. Considerations, related to the differential characteristic for the restricted earth-fault protection function

The differential characteristic is shown in *Figure 4-2*. If the calculated (I_{bias}, I_{diff}) operating point is above the characteristic, then the differential protection operates.

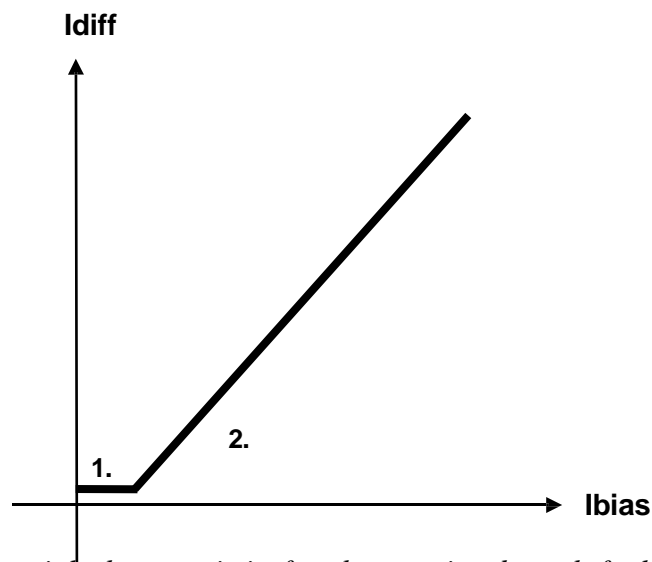


Figure 4-2 The differential characteristic for the restricted earth-fault protection function

This characteristic has two sections; each of them is a straight line. The parameters define the position of these lines on the I_{diff} - I_{bias} plane.

The parameters are expressed in percent, the basis is the “IBase” selected current. The first parameter is “Base Sensitivity”, it defines the minimum differential current for the operation. Its role is to prevent mal-operation in case of current noises and measuring errors for small currents. In this example the selected setting value is the less sensitive selection:

$$\text{„Base Sensitivity”} = 50 \%,$$

NOTE: The percent value is related to the “IBase” selected current. In the example the restricted earth-fault protection summarizes the secondary currents of seven current transformers. It is advised to avoid too sensitive setting, due to the accumulated errors of several CT-s. Similarly select not too low current for “IBase” base current for the reference and for the calculation.

This value can be tested easily: inject a single residual current e.g. into the grounding CT input and increase its value. The operation is expected if this current gets above 50% of the reference current. (In this example it is $0.5 \cdot 44A / 300A \cdot 1A = 73.3 \text{ mA}$.)

The slope of the second section of the characteristic intends to compensate the not correct matching of the CT-s, e.g. due to the CT errors. Consider that the error current increases if the zero sequence current flowing through the transformer increases. In the example the selected setting value is:

$$\text{„1st Slope”} = 50 \%,$$

NOTE: The percent value is related to the IBias current.

The third parameter defines the intersection point of the two characteristic lines. Do not select this point too high, because near to the intersection point it leaves too much area, where error currents can intersect the characteristic.

In the example the selected setting value is:

$$\text{„1st Slope Bias Limit”} = 125 \%.$$

NOTE: The percent value is related to the “IBase” selected current.

3.1.17.11.3. Considerations, related to the directional check

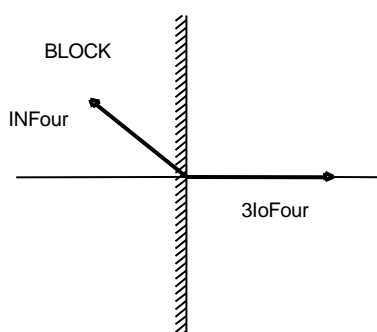
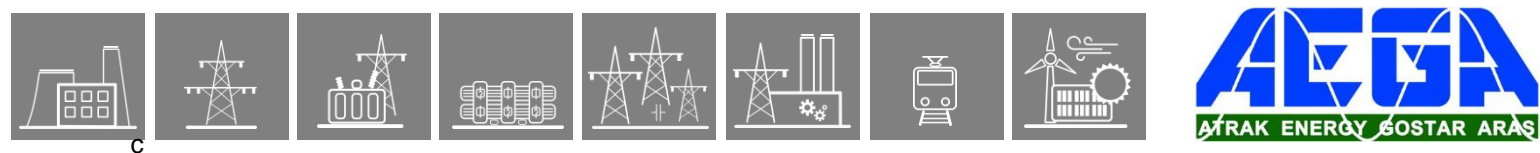


Figure 4-3 Principle of the directional check

In the directional check the vector position of the residual current measured in the grounding (INFour) and that of the vectorial sum of all other currents (3IoFour) is compared.

Figure 4-3 shows a vector position which blocks the operation of the restricted earth fault protection, if the Boolean parameter “Directional check” is True (Checked). If the checkbox is not checked then the directionality is not considered. This parameter is needed to increase the security of the function in case of low level external faults



3.1.17.12. Testing instructions

3.1.17.12.1. Testing the differential protection

When testing a function, it is advised to disable all other functions to avoid trip commands generated by the other functions.

The applied test set supports the tests with 2*3 currents. With this test set the differential protection can be tested in three steps: Primary/Secondary, Primary/Tertiary and Secondary/Tertiary relationship. In all cases the currents of the not tested side is supposed to be zero.

This paragraph shows the tests in Pimary/Secondary relationship.

The basic parameters are documented by the test set, as it is shown in

Test Object - Differential Parameters

Protected Object:

Protected Object: Transformer
Vector Group: YY0D11

| Winding/Leg Name: | Primary | Secondary | Tertiary |
|-----------------------------|------------|------------|-----------|
| Voltage: | 220,00 kV | 132,00 kV | 11,00 kV |
| Power: | 100,00 MVA | 100,00 MVA | 30,00 MVA |
| Starpoint Grounding: | Yes | Yes | No |
| Delta-connected CT: | No | No | No |

CT:

| Winding/Leg Name: | Primary | Secondary | Tertiary |
|-----------------------------|-----------------|-----------------|-----------------|
| CT Current Prim: | 300,00 A | 500,00 A | 2000,00 A |
| CT Current Sec: | 1,00 A | 1,00 A | 1,00 A |
| CT Grounding: | tow. Prot. Obj. | tow. Prot. Obj. | tow. Prot. Obj. |
| Gnd CT Prim Current: | 200,00 A | 800,00 A | 800,00 A |
| Gnd CT Sec Current: | 1,00 A | 1,00 A | 1,00 A |
| Gnd CT Grounding: | n/a | n/a | n/a |

Figure 5-1 Basic test parameters

The setting values of the function correspond to the values described above.

Please consider that the differential protection function is the cooperation of three “measuring elements”. Each measuring element gets the magnitude- and phase-compensated currents. NOTE that in case of asymmetric fault the input current values are modified due to the matrix phase-shift compensation as compared to the injected fault currents, if the fault is supposed to be on the Y side of the transformer.

In the characteristic tests please consider that the Idiff differential current in the differential protection function is the vectorial sum of all nine phase-compensated and magnitude compensated currents in three groups, related to the three “measuring elements”. The Ibias current is the sum of the absolute values of three currents in the measuring elements divided by 2.

The simplest test is a three phase injection test for testing the accuracy of the differential characteristic.

Test Results for Fault Location L1-L2-L3 at Reference Side Primary

| Ibias | Idiff Nominal | Idiff Actual | Dev (rel) | Dev (abs) | Check Test | State | Result |
|----------|---------------|--------------|-----------|------------|------------|--------|--------|
| 0,50 In | 0,500 In | 0,497 In | -0,62 % | -0,0031 In | | Tested | Passed |
| 1,00 In | 0,500 In | 0,505 In | 1,00 % | 0,0050 In | | Tested | Passed |
| 1,50 In | 0,750 In | 0,747 In | -0,38 % | -0,0028 In | | Tested | Passed |
| 2,00 In | 1,000 In | 0,997 In | -0,34 % | -0,0034 In | | Tested | Passed |
| 2,50 In | 1,250 In | 1,246 In | -0,32 % | -0,0040 In | | Tested | Passed |
| 3,00 In | 1,500 In | 1,495 In | -0,31 % | -0,0046 In | | Tested | Passed |
| 4,00 In | 2,000 In | 1,991 In | -0,43 % | -0,0087 In | | Tested | Passed |
| 5,00 In | 4,000 In | 3,948 In | -1,31 % | -0,0523 In | | Tested | Passed |
| 6,00 In | 6,000 In | 5,954 In | -0,77 % | -0,0463 In | | Tested | Passed |
| 7,00 In | 8,000 In | 7,966 In | -0,43 % | -0,0342 In | | Tested | Passed |
| 8,00 In | 8,000 In | 7,972 In | -0,35 % | -0,0281 In | | Tested | Passed |
| 9,00 In | 8,000 In | 7,972 In | -0,35 % | -0,0281 In | | Tested | Passed |
| 10,00 In | 8,000 In | 7,966 In | -0,43 % | -0,0344 In | | Tested | Passed |

Operating Characteristic Diagram

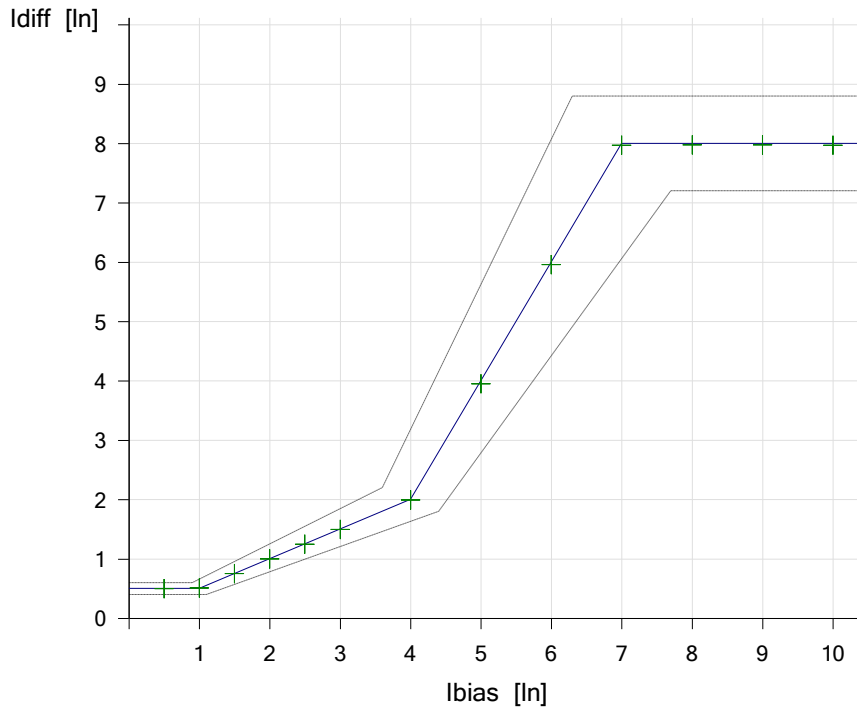


Figure 5-2 Result of three phase fault test, the fault is at the secondary side, supplied from the primary side

NOTE that the measured points match the original characteristic.

For asymmetric fault tests the expected characteristic is modified to cover the current modification of the vector shift compensation.

Test Results for Fault Location L2-L3 at Reference Side Primary

| Ibias | Idiff Nominal | Idiff Actual | Dev (rel) | Dev (abs) | Check Test | State | Result |
|----------|---------------|--------------|-----------|------------|------------|--------|--------|
| 0,50 In | 0,433 In | 0,430 In | -0,72 % | -0,0031 In | | Tested | Passed |
| 1,00 In | 0,495 In | 0,498 In | 0,54 % | 0,0027 In | | Tested | Passed |
| 1,50 In | 0,745 In | 0,742 In | -0,40 % | -0,0030 In | | Tested | Passed |
| 2,00 In | 0,995 In | 0,991 In | -0,37 % | -0,0036 In | | Tested | Passed |
| 2,50 In | 1,245 In | 1,241 In | -0,34 % | -0,0043 In | | Tested | Passed |
| 3,00 In | 1,495 In | 1,490 In | -0,33 % | -0,0049 In | | Tested | Passed |
| 4,00 In | 1,995 In | 1,992 In | -0,16 % | -0,0031 In | | Tested | Passed |
| 5,00 In | 2,495 In | 2,491 In | -0,15 % | -0,0037 In | | Tested | Passed |
| 6,00 In | 2,995 In | 2,991 In | -0,15 % | -0,0044 In | | Tested | Passed |
| 7,00 In | 3,600 In | 3,586 In | -0,41 % | -0,0146 In | | Tested | Passed |
| 8,00 In | 5,606 In | 5,626 In | 0,35 % | 0,0197 In | | Tested | Passed |
| 9,00 In | 6,930 In | 6,903 In | -0,39 % | -0,0274 In | | Tested | Passed |
| 10,00 In | 6,930 In | 6,900 In | -0,43 % | -0,0298 In | | Tested | Passed |

Operating Characteristic Diagram

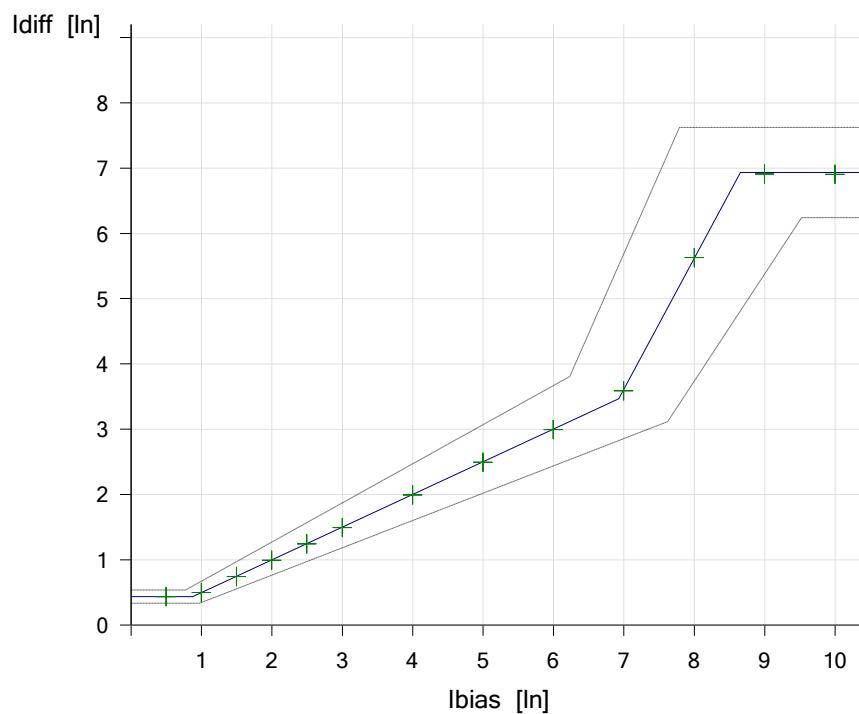


Figure 5-3 Result of double phase fault test, the fault is at the secondary side, supplied from the primary side

NOTE The matrix vector shift compensation decreases the compared current by SQRT3. Consequently the detected knee points of the characteristic are shifted to increased current values. (The setting values of the differential protection function are the same as those applied in three-phase fault test.)

Similarly, in case of single phase faults, the expected characteristic is modified. (The setting values of the differential protection function are the same as those applied in three-phase fault test.) This is shown in [Figure 5-4](#).

Operating Characteristic Diagram

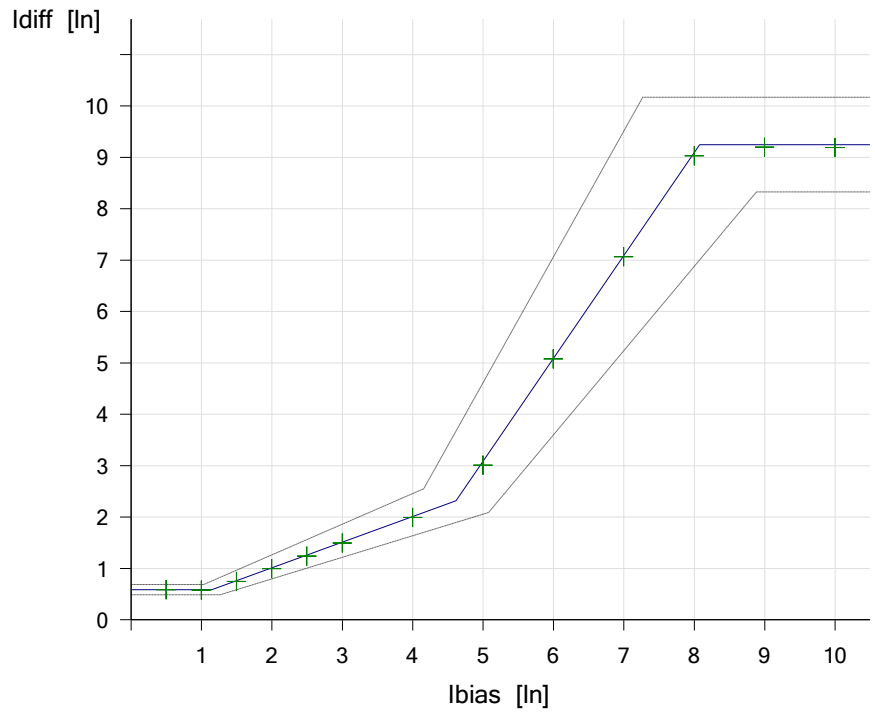
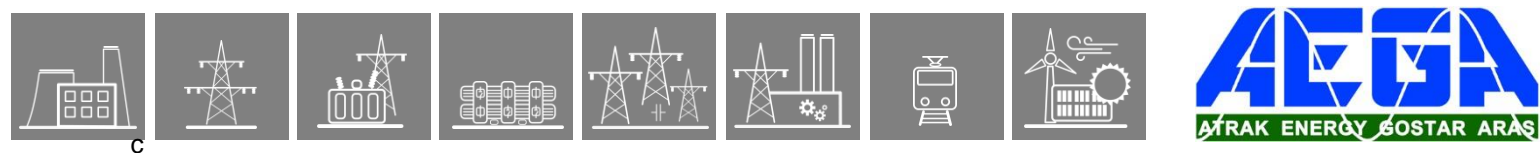


Figure 5-4 Result of single phase fault test, the fault is at the secondary side, supplied from the primary side



3.1.17.12.2. Testing the restricted earth-fault protection

When testing a function, it is advised to disable all other functions to avoid trip commands generated by the other functions.

The applied test set supports the tests with 2*3 currents. With this test set the restricted earth-fault protection can be tested in two steps: Primary/Neutral, and Secondary/Neutral relationship. In all cases the currents of the not tested sides (Secondary or Primary respectively) is supposed to be zero. Note that the Tertiary side is not involved in the restricted earth-fault protection.

In the characteristic tests please consider that the Idiff differential current in the restricted earth-fault protection function is the vectorial sum of six phase currents plus the neutral current. The I_{bias} current is the maximum of these seven currents.

3.1.17.12.2.1. Characteristic accuracy tests

This paragraph shows the tests in Primary/Neutral relationship. Three-phase current are injected in the Primary side and the sum of the other three current set is injected in the Neutral.

Test Results for Fault Location L1-E at Reference Side Primary

| I _{bias} | I _{diff} Nominal | I _{diff} Actual | Dev (rel) | Dev (abs) | Check Test | State | Result |
|-------------------|---------------------------|--------------------------|-----------|------------|------------|--------|--------|
| 0,50 In | 0,500 In | 0,503 In | 0,63 % | 0,0031 In | | Tested | Passed |
| 1,00 In | 0,500 In | 0,447 In | -10,62 % | -0,0531 In | | Tested | Passed |
| 1,50 In | 0,625 In | 0,612 In | -2,17 % | -0,0136 In | | Tested | Passed |
| 2,00 In | 0,875 In | 0,838 In | -4,29 % | -0,0375 In | | Tested | Passed |
| 4,00 In | 1,876 In | 1,880 In | 0,20 % | 0,0037 In | | Tested | Passed |
| 6,00 In | 2,877 In | 2,791 In | -2,97 % | -0,0855 In | | Tested | Passed |
| 8,00 In | 3,877 In | 3,798 In | -2,05 % | -0,0796 In | | Tested | Passed |
| 10,00 In | 4,878 In | 4,838 In | -0,82 % | -0,0401 In | | Tested | Passed |
| 12,00 In | 5,878 In | 5,848 In | -0,52 % | -0,0304 In | | Tested | Passed |
| 14,00 In | 6,879 In | 6,811 In | -0,99 % | -0,0681 In | | Tested | Passed |
| 16,00 In | 7,880 In | 7,802 In | -0,98 % | -0,0775 In | | Tested | Passed |
| 18,00 In | 8,880 In | 8,748 In | -1,49 % | -0,1320 In | | Tested | Passed |
| 20,00 In | 9,881 In | 9,885 In | 0,04 % | 0,0043 In | | Tested | Passed |

Operating Characteristic Diagram

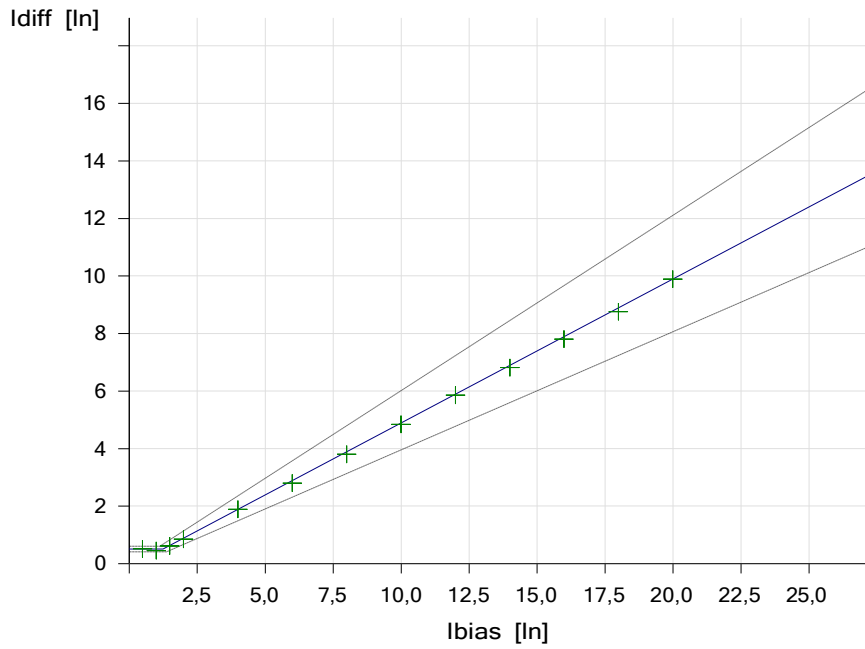


Figure 5-5 Result of characteristic accuracy test of the restricted earth-fault protection

3.1.17.13. Single shot fault simulation

In this test an external earth-fault is supposed at the secondary side with 1500A primary current. The primary current distribution is shown in Figure 5-6.

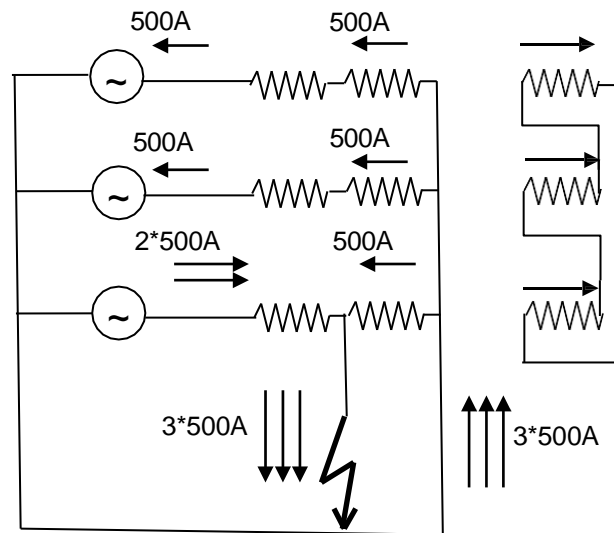


Figure 5-6 Primary current distribution

The currents are transformed to the device side by the current transformers:

$$I_{\text{primary L1}} = 2 \cdot 500 \text{ A} \cdot 1/300 = 3.33 \text{ A}$$

$$I_{\text{primary L2}} = I_{\text{primary L3}} = 500 \text{ A} \cdot 1/300 = 1.66 \text{ A}$$

$$I_{\text{secondary L1}} = 3 \cdot 500 \text{ A} \cdot 1/500 = 3 \text{ A}$$

$$I_{\text{neutral}} = 3 \cdot 500 \text{ A} \cdot 1/300 = 3.33 \text{ A}$$

These currents are drawn in [Figure 5-7](#). Note that the Kirchhoff's node law is satisfied with primary currents only. The secondary currents are transformed with CT with different ratios. (This deviation is compensated by the current matching parameters of the restricted earth-fault protection function.)

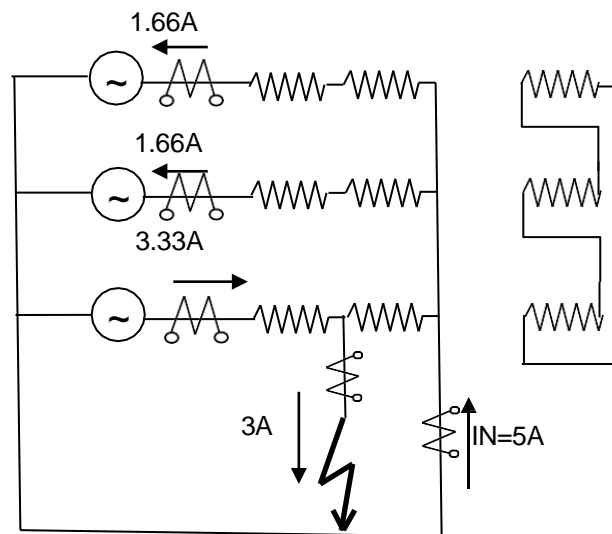


Figure 5-7 Secondary current distribution

NOTE. The current in the neutral point is measured with a CT of reverse polarity. This is not indicated in the figure.

[Figure 5-8](#) below shows the measured (secondary) currents of the CT modules. The first module shows the three currents of the primary side and the current in the grounding CT. The second module measures the single fault current of the secondary side. (The currents of the tertiary side are all zero.)



Figure 5-8 Measured currents of the CT modules

Figure 5-9 shows the displayed values by the restricted earth-fault protection function. The differential current value is small (not zero due to the not accurate current injection). The high bias (restraint) current prevents operation, i.e. the “General Trip” box is not checked in the figure. The behavior is correct.

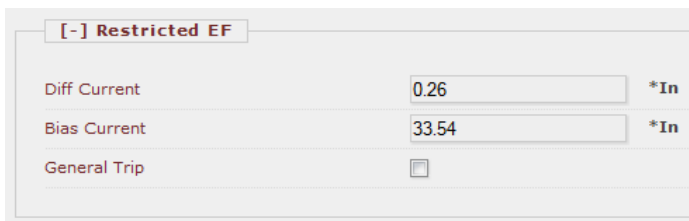


Figure 5-9 On-line display of the restricted earth-fault function with correct CT connection

If for example the grounding CT is reversed connected, then the function generates the trip command, due to the false high differential current (i.e. the “General Trip” box is checked in the figure). The behavior is correct.

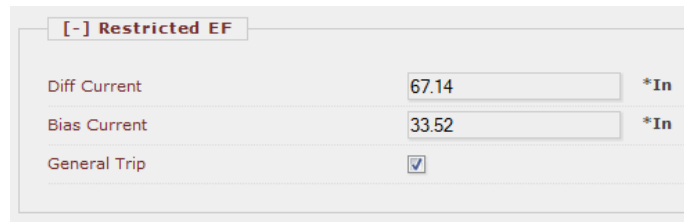


Figure 5-10 On-line display of the restricted earth-fault function with reverse CT connection in the grounding

3.1.17.13.1.1. Checking the directional blocking

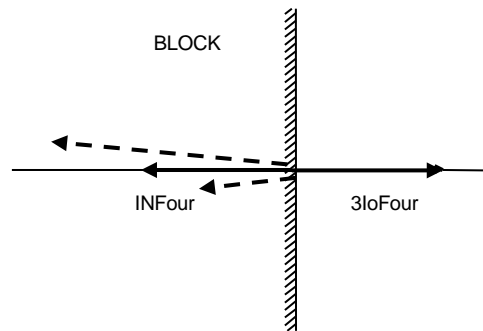


Figure 5-11 Checking the directional blocking

For checking the directional blocking, consider [Figure 5-11](#). For external fault the restricted earth-fault is balanced, the function does not generate the trip command. In this state the “3IoFour” vector, which is the sum of the currents of all phase current transformers has the same magnitude as “INFour” (solid vector on the figure), but the direction is opposite.

Now suppose that due to any measuring errors this balance is not fulfilled for external fault, and suppose that “INFour” is different in magnitude and/or phase angle. This is illustrated with dotted vectors. It is obvious that the difference of the solid “INFour” vector and the dotted version is the “Idiff” differential current, detected by the restricted earth-fault protection function. If this “Idiff” error current is large enough, the function generates the trip command.

For the test consider a balanced state, as shown in [Figure 5-7](#). Here the “INFour” current corresponds to $I_N=5A$. Increase /decrease the magnitude and/or phase angle of this vector to generate sufficient “Idiff” current for the operation of the restricted earth-fault protection function, if the Boolean parameter “Directional check” is FALSE (not checked).

NOTE: Remember that the “Ibias” is the maximum of any applied phase currents or the I_N neutral current. Considering this, for the trip command, the (I_{Bias}, I_{diff}) point must be above the characteristic.

Now change the parameter “Directional check” to TRUE (checked). In this state no trip command is generated if the phase angle between “3IoFour” and “INFour” is out of the range -90° to $+90^\circ$, this is the left side of [Figure 5-11](#). (An internal fault supposes that the phase angle between these vectors is in the range -90° to $+90^\circ$, this is the right side of [Figure 5-11](#).)

3.1.18. Differential protection function

3.1.18.1. Operation principle

The differential protection function provides main protection for transformers, generators or large motors, but it can be applied for overhead lines and cables of solidly grounded networks or for protection of any combination of the mentioned protected objects.

The version DIF87T3 can be applied to protect three-winding transformers. The simpler version DIF87T2 does not process analogue inputs from the tertiary side. This document is the description of the three-winding transformer version, but it hints necessary changes in application with two sides only.

3.1.18.1.1. Structure of the differential protection algorithm

The figure below shows the structure of the differential protection (DIF87T3) algorithm.

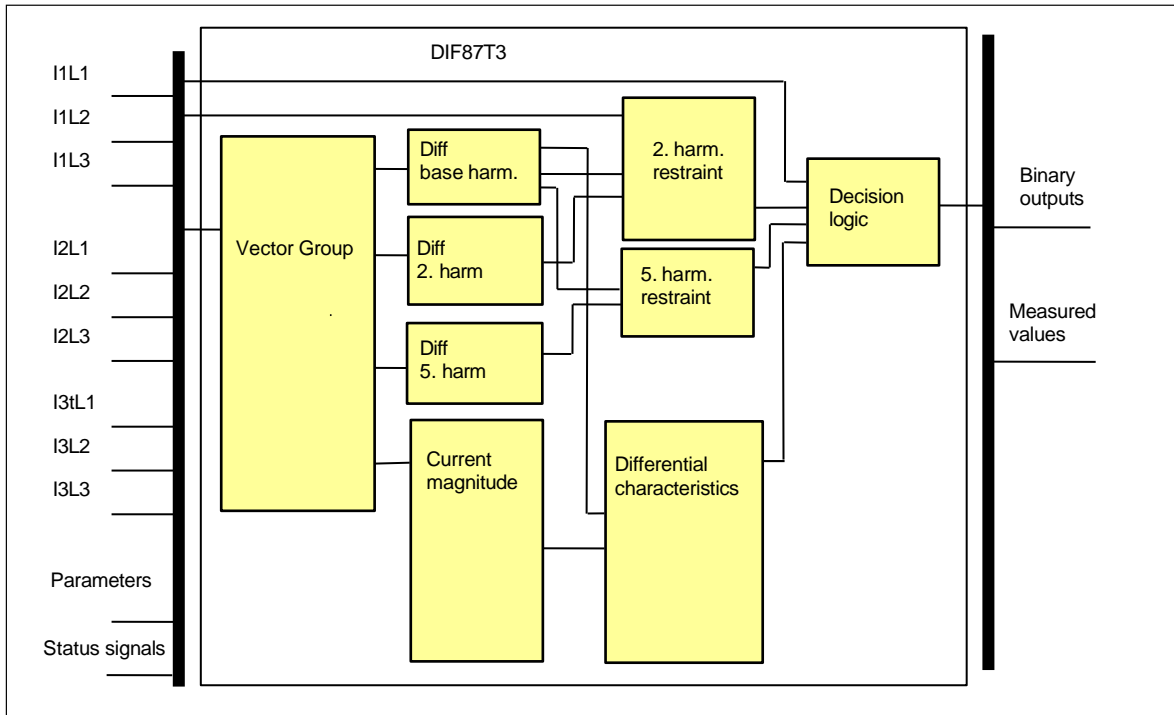


Figure 1-1 Structure of the differential protection algorithm

The **inputs** are

- the sampled values of three primary phase currents,
- the sampled values of three secondary phase currents,
- the sampled values of three tertiary phase currents (in DIF87T3 version only),
- parameters
- status signal.

The **outputs** are

- the binary output status signals,
- the measured values for displaying.



The **software modules** of the differential protection function:

Vector group

This module compensates the phase shift and turn's ratio of the transformer. The results of this calculation are the "sampled values" of the phase-shifted phase currents for all three (two) sides of the transformer and those of the three differential currents.

Diff base harm.

This module calculates the basic Fourier components of the three differential currents. These results are needed for the high-speed differential current decision and for the second and fifth harmonic restraint calculation.

Diff 2. harm.

This module calculates the second harmonic Fourier components of the three differential currents. These results are needed for the second harmonic restraint decision.

Diff 5. harm.

This module calculates the fifth harmonic Fourier components of the three differential currents. These results are needed for the fifth harmonic restraint decision.

2. harm. restraint

The differential current can be high in case of transformer energizing, due to the current distortion caused by the transformer iron core asymmetric saturation. In this case the second harmonic content of the differential current is applied in this module to disable the operation of the differential protection function.

The differential current can be high in case of external faults, due to the current distortion caused by saturated CT on the faulty side. Additional usage of the second harmonic restraint in these cases can help to disable the operation of the differential protection function.

The result of this calculation is needed for the decision logic.

5. harm. restraint

The differential current can be high in case of over-excitation of the transformer, due to the current distortion caused by the transformer iron core symmetric saturation. In this case the fifth harmonic content of the differential current is applied in this module to disable the operation of the differential protection function. The result of this calculation is needed for the decision logic.

Current magnitude

This module calculates the magnitude of the phase-shifted phase currents and that of the differential currents. The result of this calculation is needed for the differential characteristic evaluation.

Differential characteristics

This module performs the necessary calculations for the evaluation of the "percentage differential characteristics". The result of this calculation is needed for the decision logic.

Decision logic

The decision logic module decides if the differential current of the individual phases is above the characteristic curve of the differential protection function. This curve is the function of the restraint current, which is calculated based on the magnitude of the phase-shifted phase currents. This module calculates the second and fifth harmonic ratio of the differential current, relative to the basic harmonic content. The result can restrain the operation of the differential protection function. The high-speed overcurrent protection function based on the differential currents is performed in this module too.

The following description explains the details of the individual components.

3.1.18.1.2. Turn’s ratio matching and vector shift compensation (Vector group)

The three-phase power transformers transform the primary current to the secondary side according to the turn’s ratio and the vector group of the transformers. The Y (star) D (delta) or Z (zig-zag) connection of the three phase coils on the primary and on the secondary side causes vector shift of the currents. The conventional electromechanical or static electronic devices of the differential protection compensate the vector shift with appropriate connection of the current transformer coils. The numerical differential protection function applies matrix transformation to the directly measured currents of one side of the transformer to match them with the currents of the other side(s).

In the transformer differential protection of Protecta the software module „Vector_group” calculates the matrix transformation and the turn’s ratio matching. Here the target of the matrix transformation is the delta (D) side.

3.1.18.1.2.1. Turn’s ratio matching

In the transformer, the magnitude of the current is transformed according to the turn’s ratio (and the vector group) of the transformers. In practical terms this transformation is expressed as the voltage ratio(s). For the calculation, the rated voltages of the transformation is to be declared: “Un Primary”, “Un Secondary” and in case of transformer with three voltage levels also “Un Tertiary”.

The differential protection function needs also a reference current. The specific points of the differential characteristic are expressed as percent of this reference current. This value is calculated internally, based on the rated power of the transformer. It is usual that for transformers with three voltage levels – where the rated power for all three sides can be different – the value for the primary side is to be set as a parameter. NOTE: when selecting other values, the scaling of the differential characteristic also changes.

The summary of the parameters needed for turn’s ratio matching are summarized in [Table 1-1](#).

Floating point parameters

Table 1-1 The floating-point parameters for the turn’s ratio compensation

| PARAMETER NAME | TITLE | DIM. | MIN | MAX | DEFAULT |
|-------------------------------------------------------------------|--------------|------|------|---------|---------|
| Rated power (primary side) of the transformer | | | | | |
| DIF87_Sn_FPar_ | Sn | MVA | 1.00 | 1000.00 | 125.00 |
| Rated voltages Un1, Un2 (and Un3 if tertiary side also available) | | | | | |
| DIF87_UTRPri_FPar_ | Un Primary | kV | 1.00 | 1000.00 | 132.00 |
| DIF87_UTRSec_FPar_ | Un Secondary | kV | 1.00 | 1000.00 | 22.00 |
| DIF87_UTRTer_FPar_ | Un Tertiary | kV | 1.00 | 1000.00 | 11.50 |

Based on these parameters, the reference current for the high voltage primary side of the transformer is calculated with the well-known formula:

$$I_{reference_1} = \frac{S_n}{\sqrt{3} Un1}$$

- Where:
- $I_{reference_1}$ is the reference current for the high voltage primary side of the transformer,
 - S_n is the rated power of the primary side of the transformer,
 - $Un1$ is the rated voltage of the primary side of the transformer.

This reference current can be transformed to the secondary or to the tertiary sides of the transformer for the reference values of other sides. For the relay, these reference values are transmitted by the current transformers, according to the CT turn’s ratios. This information is set in the CT modules of the device as parameter values.



3.1.18.1.2.2. Principle of transformation to the D side

The conventional electromechanical or static electronic devices of the differential protection compensate the vector shift with appropriate connection of the current transformer coils. The principle is that the Y connected current transformers on the delta side of the transformer do not shift the currents flowing out of the transformer. The delta connected current transformers on the Y side of the transformer however result a phase shift. This means that the Y side currents are shifted according to the vector group of the transformer to match the delta side currents.

Additionally, the delta connection of the currents transformers eliminates the zero sequence current component flowing on the grounded Y side of the transformer. As on the delta side no zero-sequence current can be detected, this compensation is unavoidable for the correct operation of the differential protection.

If a phase-to-ground fault occurs at the Y side of the transformer, then zero sequence current flows on the grounded Y side, but on the delta side no out-flowing zero sequence current can be detected. Without elimination of the zero-sequence current component the differential protection generates a trip command in case of external ground fault. If the connection group of the current transformers on the Y side is delta however, then no zero sequence current flows out of the group. So the problem of zero sequence current elimination in case of external ground fault is automatically solved.

The special problem of zero sequence current on the delta side, with the provided solution, is discussed in paragraph [1.1.5](#).

3.1.18.1.2.3. Mathematical modeling of the current transformer's vector group connection

The numerical differential protection function applies numerical matrix transformation for modeling the delta connection of the current transformers. In the practice it means cyclical subtraction of the phase currents.

In the vector shift compensation, the sampled $L1$, $L2$, $L3$ currents of the primary side ($I1L1$, $I1L2$, $I1L3$) and those of the secondary and tertiary side ($I2L1$, $I2L2$, $I2L3$) and ($I3L1$, $I3L2$, $I3L3$) are transformed to ($I1L1shift$, $I1L2shift$, $I1L3shift$) ($I2L1shift$, $I2L2shift$, $I2L3shift$) and ($I3L1shift$, $I3L2shift$, $I3L3shift$) values of the sides respectively, using matrix transformation. The method of transformation is defined by the Pri-Sec VGroup and Pri-Ter VGroup parameters, identifying the transformer vector group connection.

3.1.18.1.2.4. The matrix equations

In the Vector group compensation software module, the transformation matrices of [Table 1-2](#) are applied. The Matrix ID can start with character

- U for **U**nit matrix;
- P for **P**hase shifting matrix;
- Z for **Z**ero sequence eliminating matrix.

The number in the Matrix ID indicates the phase shift in clock notation. (e.g. P11 matrix is a phase shifting matrix to 11 o'clock from 0 o'clock, i.e. 30 degrees anti-clockwise.)

Table 1-2 Vector shift compensation matrices

| Matrix ID | Matrix |
|-----------|---------------------------------------------------------------------------------------------|
| U0 | $\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$ |
| U6 | $\begin{bmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{bmatrix}$ |
| P11 | $\frac{1}{\sqrt{3}} * \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix}$ |
| P5 | $\frac{1}{\sqrt{3}} * \begin{bmatrix} -1 & 1 & 0 \\ 0 & -1 & 1 \\ 1 & 0 & -1 \end{bmatrix}$ |
| P1 | $\frac{1}{\sqrt{3}} * \begin{bmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix}$ |
| P7 | $\frac{1}{\sqrt{3}} * \begin{bmatrix} -1 & 0 & 1 \\ 1 & -1 & 0 \\ 0 & 1 & -1 \end{bmatrix}$ |
| Z0 | $\frac{1}{3} * \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix}$ |
| Z6 | $\frac{1}{3} * \begin{bmatrix} -2 & 1 & 1 \\ 1 & -2 & 1 \\ 1 & 1 & -2 \end{bmatrix}$ |
| Z4 | $\frac{1}{3} * \begin{bmatrix} -1 & 2 & -1 \\ -1 & -1 & 2 \\ 2 & -1 & -1 \end{bmatrix}$ |
| Z10 | $\frac{1}{3} * \begin{bmatrix} 1 & -2 & 1 \\ 1 & 1 & -2 \\ -2 & 1 & -1 \end{bmatrix}$ |
| Z8 | $\frac{1}{3} * \begin{bmatrix} -1 & -1 & 2 \\ 2 & -1 & -1 \\ -1 & 2 & -1 \end{bmatrix}$ |
| Z2 | $\frac{1}{3} * \begin{bmatrix} 1 & 1 & -2 \\ -2 & 1 & 1 \\ 1 & -2 & 1 \end{bmatrix}$ |
| U4 | $\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix}$ |
| U10 | $\begin{bmatrix} 0 & -1 & 0 \\ 0 & 0 & -1 \\ -1 & 0 & 0 \end{bmatrix}$ |

Application of the matrix transformation for two winding transformers

The primary winding of a power transformer can be “Y” or “D” (Delta) connected.

If the primary is “Y” connected then the secondary can be configured to “y”, “d” or “z”. The possible combinations are shown in [Table 1-3](#).



Table 1-3 Vector shift compensation matrices for two winding transformers of primary “Y” connection

| Primary | Y |
|-----------|------------------|
| Secondary | Transformation |
| y0 | P1 P1 |
| y6 | P1 P7 |
| d1 | P1 U0 P1 Z0 |
| d5 | P11 U6 P11 Z6 |
| d7 | P1 U6 P1 Z6 |
| d11 | P11 U0 P11 Z0 |
| z1 | P1 Z0 |
| z5 | P11 Z6 |
| z7 | P1 Z6 |
| z11 | P11 Z0 |

As an example: In the differential protection of a YNd11 type transformer, the primary phase currents are transformed to match the secondary currents using the P11 matrix. The secondary currents are transformed using the U0 unit matrix (resulting no modification in the secondary currents). However, if there is a neutral grounding transformer in the protected zone on the secondary side of the transformer then the zero sequence current needs elimination. For this purpose, the Z0 matrix is applied. The choice depends on parameter setting “Zero Seq Elimination”, according to the application.

In the YNd11 transformer of the example, the primary “Y” side currents are transformed with matrix multiplication:

$$\begin{bmatrix} I1L1Shift \\ I1L2Shift \\ I1L3Shift \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix} * \begin{bmatrix} I1L1 \\ I1L2 \\ I1L3 \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} I1L1 - I1L2 \\ I1L2 - I1L3 \\ I1L3 - I1L1 \end{bmatrix}$$

NOTE: This transformation means also that the phase currents are transformed to the values of a “measuring element”. Accordingly, on the Y side of the transformer these values do not mean “phase currents” in the original sense.

In the YNd11 transformer of the example, the secondary “d” side currents are transformed with matrix multiplication *supposing no neutral grounding transformer in the protected zone:

$$\begin{bmatrix} I2L1Shift \\ I2L2Shift \\ I2L3Shift \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} I2L1 \\ I2L2 \\ I2L3 \end{bmatrix} = \begin{bmatrix} I2L1 \\ I2L2 \\ I2L3 \end{bmatrix}$$

NOTE: This means that the delta side currents are unchanged, and the Y side currents are phase shifted to match the secondary currents. At the same time, the zero sequence current components are automatically eliminated from the transformed currents.



If the primary is “D” connected then the secondary can be configured to “y”, “d” or “z”. The possible combinations are shown in [Table 1-4](#).

Table 1-4 Vector shift compensation matrices for transformers of primary “D” connection

| Primary | D |
|-----------|----------------|
| Secondary | Transformation |
| y1 | U0 P11 |
| y5 | U0 P7 |
| y7 | U0 P5 |
| y11 | U0 P1 |
| d0 | U0 U0 |
| d6 | U0 U6 |
| z0 | U0 Z0 |
| z2 | U0 Z10 |

Application of the matrix transformation for three winding transformers

The primary winding of a power transformer can be “Y” or “D” (Delta) connected.

If the primary is “Y” connected then the secondary and/or the tertiary can be configured to “y”, “d” or “z”. The possible combinations are shown in [Table 1-5](#).

Table 1-5 Vector shift compensation matrices for tree winding transformers of primary “Y” connection

| Secondary | y0 | y6 | d1 | d5 | d7 | d11 |
|-----------|------------|-----------|------------|------------|-----------|------------|
| y0 | P1 P1 P1 | P1 P1 P7 | P1 P1 U0 | P11 P11 U6 | P1 P1 U6 | P11 P11 U0 |
| y6 | P1 P7 P1 | P1 P7 P7 | P1 P7 U0 | P11 P5 U6 | P1 P7 U6 | P11 P5 U0 |
| d1 | P1 U0 P1 | P1 U0 P7 | P1 U0 U0 | P11 U10 U6 | P1 U0 U6 | P11 U10 U0 |
| d5 | P11 U6 P11 | P11 U6 P5 | P11 U6 U10 | P11 U6 U6 | P11 U6 U4 | P11 U6 U0 |
| d7 | P1 U6 P1 | P1 U 6 P7 | P1 U6 U0 | P11 U4 U6 | P1 U6 U6 | P11 U4 U0 |
| d11 | P11 U0 P11 | P11 U0 P5 | P11 U0 U10 | P11 U0 U6 | P11 U0 U4 | P11 U0 U0 |
| z1 | P1 Z0 P1 | P1 Z0 P7 | P1 Z0 U0 | P11 Z1 0U6 | P1 Z0 U6 | P11 Z10 U0 |
| z5 | P11 Z6 P11 | P11 Z6 P5 | P11 Z6 U10 | P11 Z6 U6 | P11 Z6 U4 | P11 Z6 U0 |
| z7 | P1 Z6 P1 | P1 Z6 P7 | P1 Z6 U0 | P11 Z4 U6 | P1 Z6 U6 | P11 Z4 U0 |
| z11 | P11 Z0 P11 | P11 Z0 P5 | P11 Z0 U10 | P11 Z0 U6 | P11 Z0 U4 | P11 Z0 U0 |

| Secondary | z1 | z5 | z7 | z11 |
|-----------|------------|------------|-----------|------------|
| y0 | P1 P1 Z0 | P11 P11 Z6 | P1 P1 Z6 | P11 P11 Z0 |
| y6 | P1 P7 Z0 | P11 P5 Z6 | P1 P7 Z6 | P11 P5 Z0 |
| d1 | P1 U0 Z0 | P11 U10 Z6 | P1 U0Z 6 | P11 U10 Z0 |
| d5 | P11 U6 Z10 | P11 U6 Z6 | P11 U6 Z4 | P11 U6 Z0 |
| d7 | P1 U6 Z0 | P11 U4 Z6 | P1U6 Z6 | P11 U4 Z0 |
| d11 | P11 U0 Z10 | P11 U0 Z6 | P11 U0 Z4 | P11 U0 Z0 |
| z1 | P1 Z0 Z0 | P11 Z10 Z6 | P1 Z 0Z6 | P11 Z10 Z0 |
| z5 | P11 Z6 Z10 | P11 Z6 Z6 | P11 Z6 Z4 | P11 Z6 Z0 |
| z7 | P1 Z6 Z0 | P11 Z4 Z6 | P1 Z6 Z6 | P11 Z4 Z0 |
| z11 | P11 Z0 Z10 | P11 Z0 Z6 | P11Z0 Z4 | P11 Z0 Z0 |

NOTE: If the secondary and/or tertiary is “d” and there *is* a neutral grounding transformer in the protected zone then Z matrix should be applied instead of U (controlled by the parameter “Zero Seq Elimination”), using the same clock rotation.



If the primary is “D” connected then the secondary and/or the tertiary can be configured to “y”, “d” or “z”. The possible combinations are shown in [Table 1-3](#).

Table 1-6 Vector shift compensation matrices for tree winding transformers of primary “D” connection

| Primary D | | | | | | |
|-----------|------------|-----------|-----------|-----------|-----------|-----------|
| Secondary | Tertiary | | | | | |
| | y1 | y5 | y7 | y11 | d0 | d6 |
| y1 | U0 P11 P11 | U0 P11 P7 | U0 P11 P5 | U0 P11 P1 | U0 P11 U0 | U0 P11 U6 |
| y5 | U0 P7 P11 | U0 P7 P7 | U0 P7 P5 | U0 P7 P1 | U0 P7 U0 | U0 P7 U6 |
| y7 | U0 P5 P11 | U0 P5 P7 | U0 P5 P5 | U0 P5 P1 | U0 P5 U0 | U0 P5 U6 |
| y11 | U0 P1 P11 | U0 P1 P7 | U0 P1 P5 | U0 P1 P1 | U0 P1 U0 | U0 P1 U6 |
| d0 | U0 U0 P11 | U0 U0 P7 | U0 U0 P5 | U0 U0 P1 | U0 U0 U0 | U0 U0 U6 |
| d6 | U0 U6 P11 | U0 U6 P7 | U0 U6 P5 | U0 U6 P1 | U0 U6 U0 | U0 U6 U6 |
| z0 | U0 Z0 P11 | U0 Z0 P7 | U0 Z0 P5 | U0 Z0 P1 | U0 Z0 U0 | U0 Z0 U6 |
| z2 | U0 Z10 P11 | U0 Z10 P7 | U0 Z10 P5 | U0 Z10 P1 | U0 Z10 U0 | U0 Z10 U6 |
| z4 | U0 Z8 P11 | U0 Z8 P7 | U0 Z8 P5 | U0 Z8 P1 | U0 Z8 U0 | U0 Z8 U6 |
| z6 | U0 Z6 P11 | U0 Z6 P7 | U0 Z6 P5 | U0 Z6 P1 | U0 Z6 U0 | U0 Z6 U6 |
| z8 | U0 Z4 P11 | U0 Z4 P7 | U0 Z4 P5 | U0 Z4 P1 | U0 Z4 U0 | U0 Z4 U6 |
| z10 | U0 Z2 P11 | U0 Z2 P7 | U0 Z2 P5 | U0 Z2 P1 | U0 Z2 U0 | U0 Z2 U6 |

| Primary D | | | | | | |
|-----------|-----------|------------|-----------|-----------|-----------|-----------|
| Secondary | Tertiary | | | | | |
| | z0 | z2 | z4 | z6 | z8 | z10 |
| y1 | U0 P11 Z0 | U0 P11 Z10 | U0 P11 Z8 | U0 P11 Z6 | U0 P11 Z4 | U0 P11 Z2 |
| y5 | U0 P7 Z0 | U0 P7 Z10 | U0 P7 Z8 | U0 P7 Z6 | U0 P7 Z4 | U0 P7 Z2 |
| y7 | U0 P5 Z0 | U0 P5 Z10 | U0 P5 Z8 | U0 P5 Z6 | U0 P5 Z4 | U0 P5 Z2 |
| y11 | U0 P1 Z0 | U0 P1 Z10 | U0 P1 Z8 | U0 P1 Z6 | U0 P1 Z4 | U0 P1 Z2 |
| d0 | U0 U0 Z0 | U0 U0 Z10 | U0 U0 Z8 | U0 U0 Z6 | U0 U0 Z4 | U0 U0 Z2 |
| d6 | U0 U6 Z0 | U0 U6 Z10 | U0 U6 Z8 | U0 U6 Z6 | U0 U6 Z4 | U0 U6 Z2 |
| z0 | U0 Z0 Z0 | U0 Z0 Z10 | U0 Z0 Z8 | U0 Z0 Z6 | U0 Z0 Z4 | U0 Z0 Z2 |
| z2 | U0 Z10 Z0 | U0 Z10 Z10 | U0 Z10 Z8 | U0 Z10 Z6 | U0 Z10 Z4 | U0 Z10 Z2 |
| z4 | U0 Z8 Z0 | U0 Z8 Z10 | U0 Z8 Z8 | U0 Z8 Z6 | U0 Z8 Z4 | U0 Z8 Z2 |
| z6 | U0 Z6 Z0 | U0 Z6 Z10 | U0 Z6 Z8 | U0 Z6 Z6 | U0 Z6 Z4 | U0 Z6 Z2 |
| z8 | U0 Z4 Z0 | U0 Z4 Z10 | U0 Z4 Z8 | U0 Z4 Z6 | U0 Z4 Z4 | U0 Z4 Z2 |
| z10 | U0 Z2 Z0 | U0 Z2 Z10 | U0 Z2 Z8 | U0 Z2 Z6 | U0 Z2 Z4 | U0 Z2 Z2 |

The differential currents are calculated using the (*I...shift*) values and the rated currents *I_reference_1*, *I_reference_2* (and *I_reference_3* if this is applicable). These currents are calculated internally, using the rated power and rated voltages, as given by parameters. (The positive direction of the currents is flowing IN on both sides.)

$$\begin{aligned}
 \begin{bmatrix} IdL1 \\ IdL2 \\ IdL3 \end{bmatrix} &= \begin{bmatrix} I1L1shift' \\ I1L2shift' \\ I1L3shift' \end{bmatrix} + \begin{bmatrix} I2L1shift' \\ I2L2shift' \\ I2L3shift' \end{bmatrix} = \\
 &= \frac{1}{I_reference_1} \begin{bmatrix} I1L1shift \\ I1L2shift \\ I1L3shift \end{bmatrix} + \frac{1}{I_reference_2} \begin{bmatrix} I2L1shift \\ I2L2shift \\ I2L3shift \end{bmatrix}
 \end{aligned}$$

This means that the differential currents (and also the phase shifted currents marked with character ‘ are “per unit currents”, and the reference values are the calculated reference currents. The current measuring software modules process these momentary values of the differential currents, and calculate values, which are proportional to the RMS values.



3.1.18.1.2.5. Operation with the zero-sequence current in case of phase-to-ground fault on the delta side

On the secondary side of a high voltage/medium voltage transformer which is connected in delta on the medium voltage side, an additional neutral grounding transformer is applied. Between the neutral point of this grounding transformer and the ground, either a grounding resistor is connected to limit the single phase to ground fault currents below 100 A (in some cases 200 A), or here a Petersen coil is applied which limits the single phase fault currents to a small value of some Amps.

In these cases, there are two locations for the currents transformers on the delta side to supply the differential protection. In one case the neutral grounding transformer is located inside the protected zone of the differential protection (*in Figure 3-7 and Figure 3-8 of the Appendix* it is the location "Z"), in the other case the neutral grounding transformer is outside the protected zone (*in Figure 3-7 and Figure 3-8 of the Appendix* this is the application of the current transformers on location „Y”).

If the neutral grounding transformer is in the protected zone, then the current distribution depends on the location of the supplying generator, as it is shown *in Figure 3-7 and Figure 3-8 of the Appendix*. In these cases, for correct operation of the differential protection (if the operating characteristic lines are set to be sensitive) the subtraction of the zero sequence current is needed. This additional transformation „replaces” the measuring location to the point („Y”), where no zero sequence current can flow, so these transformed currents do not include the zero sequence current of the neutral grounding transformer.

3.1.18.1.2.6. The principal scheme of the vector group compensation

Figure 1-2 shows the principal scheme of the vector shift compensation.

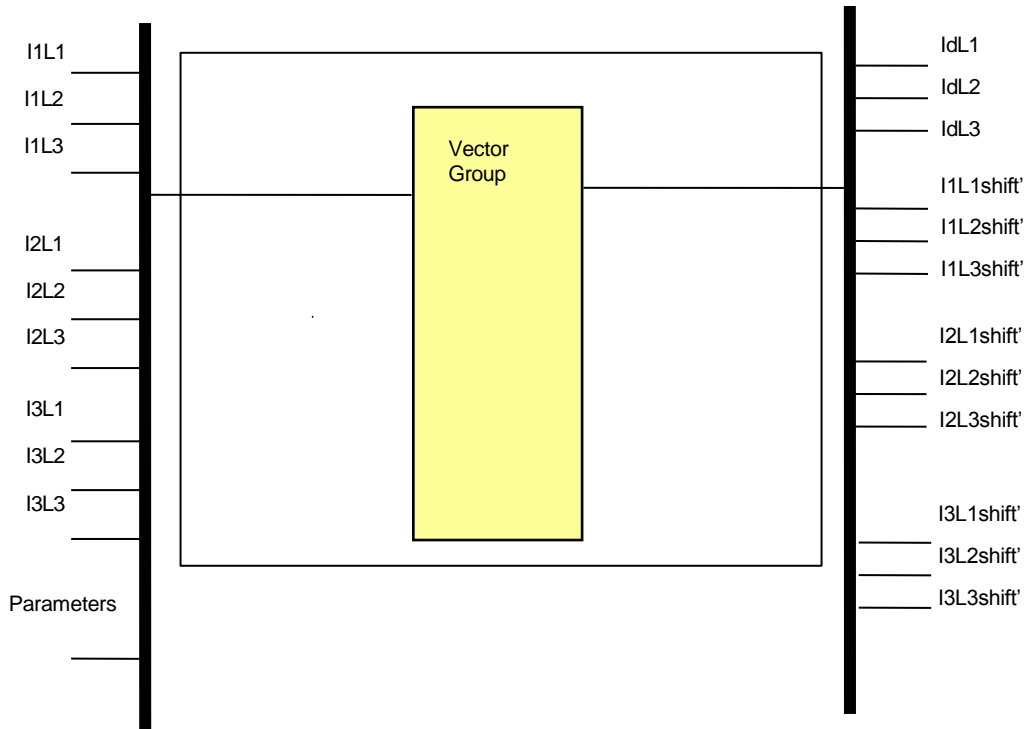


Figure 1-2 Principal scheme of the vector shift compensation.

The **inputs** are the sampled values of:

- The three phase currents of the primary side (I1L1, I1L2, I1L3)
- The three phase currents of the secondary side (I2L1, I2L2, I2L3)
- The three phase currents of the tertiary side (I3L1, I3L2, I3L3 in DIF87T3 version only)
- Parameters for vector shift and turn's ratio compensation.

Enumerated parameters for the vector shift compensation:

Table 1-7 Enumerated parameters for the vector shift compensation

| Parameter name | Title | Selection range | Default |
|----------------------------------------------------------------------------------------------|-----------------|---------------------------------------------------------------------------------------------|---------|
| Parameter to select connection group of the transformer coils in primary-secondary relation: | | | |
| DIF87_VGrSec_EPar_ | Pri-Sec VGroup* | Dy1,Dy5,Dy7,Dy11,Dd0,Dd6,Dz0,Dz2,Dz4,Dz6,Dz8,Dz10,Yy0,Yy6,Yd1,Yd5,Yd7,Yd11,Yz1,Yz5,Yz7,Yz11 | Dd0 |
| Parameter to select connection group of the transformer coils in primary-tertiary relation: | | | |
| DIF87_VGrTer_EPar_ | Pri-Ter VGroup* | Dy1,Dy5,Dy7,Dy11,Dd0,Dd6,Dz0,Dz2,Dz4,Dz6,Dz8,Dz10,Yy0,Yy6,Yd1,Yd5,Yd7,Yd11,Yz1,Yz5,Yz7,Yz11 | Dd0 |

* If the connection of the primary winding in primary-secondary and primary tertiary relation is selected in contradiction then the protection function is automatically disabled, and the function generates a warning signal.

Boolean parameter for the vector shift compensation:

Table 1-8 The Boolean parameter for the vector shift compensation

| Parameter name | Title | Default | Explanation |
|------------------|----------------------|---------|-----------------------------------|
| DIF87_0Seq_BPar_ | Zero Seq Elimination | True | See Chapter 1.1.5 |



The **outputs** are the “sampled values” of the phase-shifted currents:

- The differential currents after phase-shift $\left[\begin{array}{c} IdL1 \\ IdL2 \\ IdL3 \end{array} \right]$
- The primary currents after phase-shift $\left[\begin{array}{c} I1L1shift \\ I1L2shift \\ I1L3shift \end{array} \right]$
- The secondary currents after phase-shift $\left[\begin{array}{c} I2L1shift \\ I2L2shift \\ I2L3shift \end{array} \right]$
- The tertiary currents after phase-shift (in DIF87T3 version only) $\left[\begin{array}{c} I3L1shift \\ I3L2shift \\ I3L3shift \end{array} \right]$



3.1.18.1.3. Harmonic analysis of the differential currents (Diff basic harm.), (Diff 2. harm.), (Diff 5. harm.)

3.1.18.1.3.1. The principle of calculation

The differential current can be high in case of transformer energizing, due to the current distortion caused by the transformer iron core asymmetric saturation. In this case the second harmonic content of the differential current is applied to disable the operation of the differential protection function.

The differential current can also be high in case of external faults, due to the current distortion caused by saturated CT on the faulty side. Additional usage of the second harmonic restraint in these cases disables the operation of the differential protection function.

The differential current can be high in case of over-excitation of the transformer, due to the current distortion caused by the transformer iron core symmetric saturation. In this case the fifth harmonic content of the differential current is applied to disable the operation of the differential protection function.

The harmonic analysis block of modules consists of three individual software modules.

Diff base harm.

This module calculates the basic Fourier components of the three differential currents. These results are needed for the high-speed differential current decision and for the second and fifth harmonic restraint calculation.

Diff 2. harm.

This module calculates the second harmonic Fourier components of the three differential currents. These results are needed for the second harmonic restraint decision.

Diff 5. harm.

This module calculates the fifth harmonic Fourier components of the three differential currents. These results are needed for the fifth harmonic restraint decision.

3.1.18.1.3.2. The principal scheme of the harmonic analysis

Figure 1-3 shows the structure of the harmonic analysis.

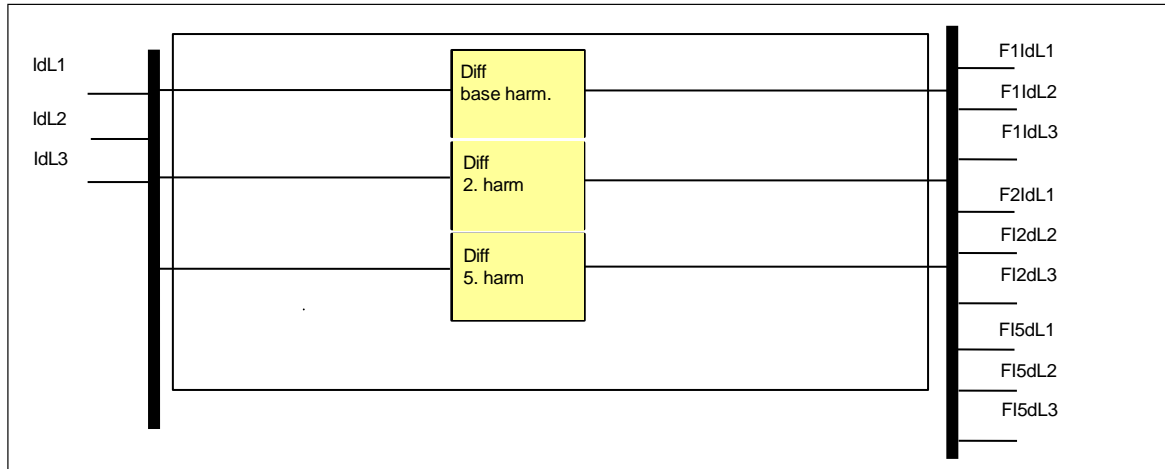


Figure 1-3 Principal scheme of the harmonic analysis.

The **inputs** are the “sampled values” of the differential currents, based on the phase-shifted currents:

- The differential currents after phase-shift
- $$\begin{bmatrix} IdL1 \\ IdL2 \\ IdL3 \end{bmatrix}$$

The **outputs** are the basic, the second and the fifth harmonic Fourier components of the differential currents (also as p.u. of the reference current):

- The basic harmonic Fourier components of the differential currents
- $$\begin{bmatrix} F1dL1 \\ F1dL2 \\ F1dL3 \end{bmatrix}$$
- The second harmonic Fourier components of the differential currents
- $$\begin{bmatrix} F2dL1 \\ F2dL2 \\ F2dL3 \end{bmatrix}$$
- The fifth harmonic Fourier components of the differential currents
- $$\begin{bmatrix} F5dL1 \\ F5dL2 \\ F5dL3 \end{bmatrix}$$

These values are processed by the software modules 2. harmonic restraint and 5. harmonic restraint



3.1.18.1.4. The harmonic restraint decision (2. harmonic restraint) and (5. harmonic restraint)

3.1.18.1.4.1. The principle of the restraint decision

The differential current can be high in case of transformer energizing, due to the current distortion caused by the transformer iron core asymmetric saturation. In this case the second harmonic content of the differential current is applied to disable the operation of the differential protection function.

The differential current can be high in case of external faults, due to the current distortion caused by saturated CT on the faulty side. Additional usage of the second harmonic restraint in these cases can help to disable the operation of the differential protection function.

The differential current can be high in case of over-excitation of the transformer as well, due to the current distortion caused by the transformer iron core symmetric saturation. In this case the fifth harmonic content of the differential current is applied to disable the operation of the differential protection function.

The harmonic analysis block of modules consists of two sub-blocks, one for the second harmonic decision and one for the fifth harmonic decision. Each sub-block includes three individual software modules for the phases.

The software modules evaluate the harmonic content relative to the basic harmonic component of the differential currents, and compare the result with the parameter values, set for the second and fifth harmonic. If the content is high, then the assigned status signal is set to “true” value. If the duration of the active status is at least 25 ms (or 20.83 ms on a 60 Hz system), then resetting of the status signal is delayed by additional 15 ms (12.5 ms on a 60 Hz system).

Depending on the dedicated Boolean parameter setting “Cross Blocking”, there are two modes of operation:

- If the “Cross Blocking” parameter is FALSE (not checked) then the three “measuring elements” operate individually. The internal output signal of the “measuring element” is blocked only if the own differential current contains harmonics (second and/or fifth) above the setting level, indicating inrush current or over-excitation. Other measuring element may generate trip requirement.
- If the “Cross Blocking” parameter is TRUE (checked) then the three blocking any of the “measuring elements” by harmonics (second and/or fifth) above the setting level blocks also the internal output signal of all three “measuring elements”. The function does not generate trip requirement.

The duration of the cross blocking is set by a dedicated parameter “Cross Blocking Limit”. This is the maximum duration of cross-blocking; after timeout, the cross-blocking resets even if there are high values of harmonics in another “measuring element(s)”. Note that the “measuring element(s)” with high values of harmonics will keep on self-blocking.

3.1.18.1.4.2. The principal scheme of the harmonic restraint decision

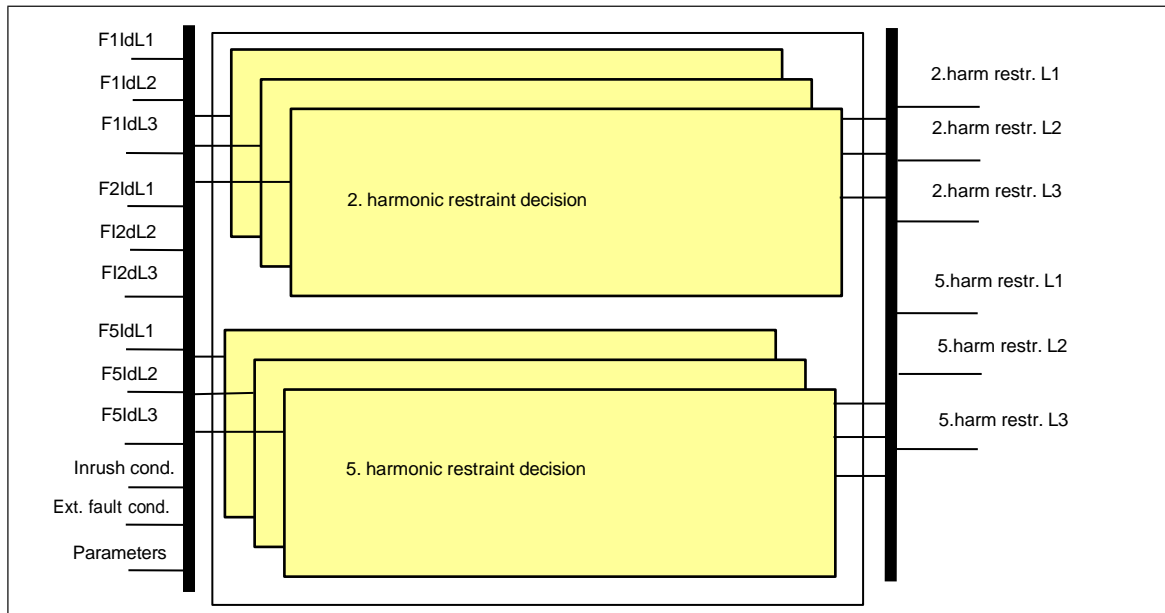


Figure 1-4 Principal scheme of the harmonic restraint decision

The **inputs** are the following:

- The basic harmonic Fourier components of the differential currents

$$\begin{bmatrix} F1dL1 \\ F1dL2 \\ F1dL3 \end{bmatrix}$$

- The second harmonic Fourier components of the differential currents

$$\begin{bmatrix} F2dL1 \\ F2dL2 \\ F2dL3 \end{bmatrix}$$

- The fifth harmonic Fourier components of the differential currents

$$\begin{bmatrix} F5dL1 \\ F5dL2 \\ F5dL3 \end{bmatrix}$$

- Inrush condition detection for 2nd harmonic decision
- External fault condition detection for 2nd harmonic decision
- Parameter settings for harmonic detection

The outputs of the modules are the status signals for each phase and for second and fifth harmonics separately, indicating the restraint status caused by high harmonic contents.



Binary output status signals of the harmonic restraint decision function are listed in [Table 1-9](#).

Table 1-9 The binary output status signals of the harmonic restraint decision function

| Binary output signals | Signal title | Explanation |
|-----------------------------------|------------------|--------------------------------------------------------------------------------------------------------------------------|
| Second harmonic restraint signals | | |
| DIF87_2HBIkL1_Grl_ | 2.harm Restr. L1 | High second harmonic content detected in the differential current in phase L1 |
| DIF87_2HBIkL2_Grl_ | 2.harm Restr. L2 | High second harmonic content detected in the differential current in phase L2 |
| DIF87_2HBIkL3_Grl_ | 2.harm Restr. L3 | High second harmonic content detected in the differential current in phase L3 |
| DIF87_InrushL1_Grl_ | Inrush. L1 | Restraint in phase L1 caused by high second harmonic content in the differential current during inrush or external fault |
| DIF87_InrushL2_Grl_ | Inrush L2 | Restraint in phase L2 caused by high second harmonic content in the differential current during inrush or external fault |
| DIF87_InrushL3_Grl_ | Inrush L3 | Restraint in phase L3 caused by high second harmonic content in the differential current during inrush or external fault |
| DIF87_Inrush_Grl_ | Inrush. | Restraint caused by high second harmonic content in any of the differential currents during inrush or external fault |
| Fifth harmonic restraint signals | | |
| DIF87_5HBIkL1_Grl_ | 5.harm Restr. L1 | Restraint in phase L1 caused by high fifth harmonic content in the differential current |
| DIF87_5HBIkL2_Grl_ | 5.harm Restr. L2 | Restraint in phase L2 caused by high fifth harmonic content in the differential current |
| DIF87_5HBIkL3_Grl_ | 5.harm Restr. L3 | Restraint in phase L3 caused by high fifth harmonic content in the differential current |
| DIF87_5HBIk_Grl_ | 5.Harm Restr. | Restraint caused by high fifth harmonic content in any of the differential currents |

Integer parameters of the harmonic restraint decision function are listed in [Table 1-10](#).

Table 1-10 The integer parameters of the harmonic restraint decision function

| Parameter name | Title | Unit | Min | Max | Step | Default |
|---------------------------------------------|----------------|------|-----|-----|------|---------|
| Parameter of the second harmonic restraint: | | | | | | |
| DIF87_2HRat_IPar_ | 2nd Harm Ratio | % | 5 | 50 | 1 | 15 |
| Parameter of the fifth harmonic restraint: | | | | | | |
| DIF87_5HRat_IPar_ | 5th Harm Ratio | % | 5 | 50 | 1 | 25 |

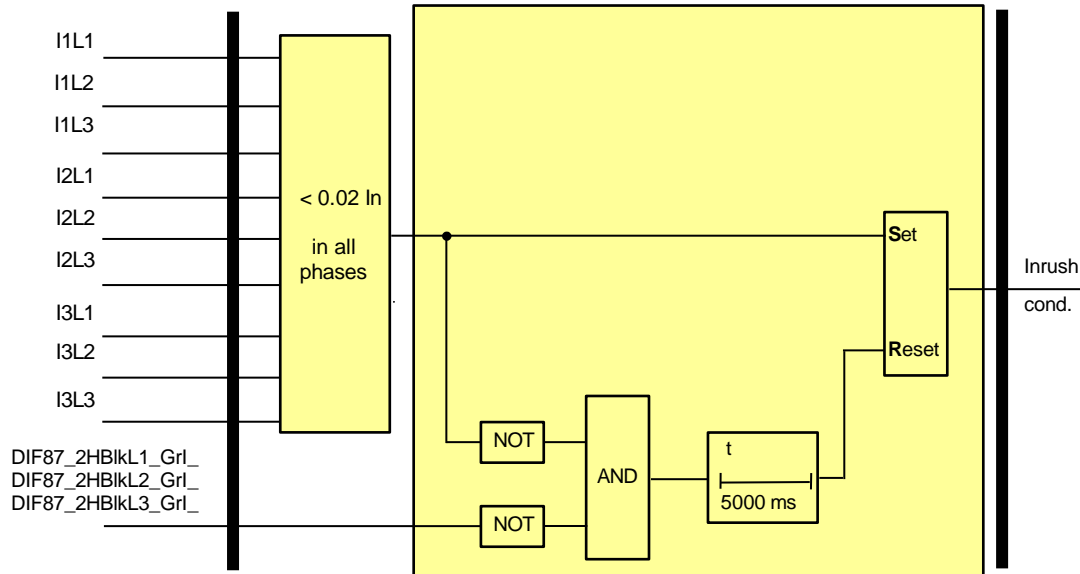
(% related to the 1st harmonic of the differential current)

3.1.18.1.4.2.1. Inrush condition for 2nd harmonic block

For blocking the differential protection function during inrush, the second harmonic restraint is evaluated if the transformer is detected to be either off or recently switched on. The **Inrush condition** signal indicates this state.

The inrush condition deactivates after a *5 seconds delay (or 4.167 seconds on a 60 Hz system)* if the following two conditions are fulfilled:

- any of the phase currents exceed 2%,
- there are no 2nd harmonics detected, see [Figure 1-7](#) and the figure below:



**the value is connected to the cycle time of 50 Hz. For 60 Hz applications it becomes lower: 4166.67 ms*

Figure 1-5 Logic scheme of the inrush condition

3.1.18.1.4.2.2. External fault condition for 2nd harmonic block

The second harmonic restraint is also evaluated for disabling the differential protection function during external faults with CT saturation. The **Ext. fault condition** signal indicates this state. This signal activates when the shifted and compensated currents between the two sides have at least an angle difference of **75 degrees**.

For valid angle measurement, it is required that the involved sides' shifted currents' magnitude is larger than **10%** (of the reference current, which is the transformer rated current).

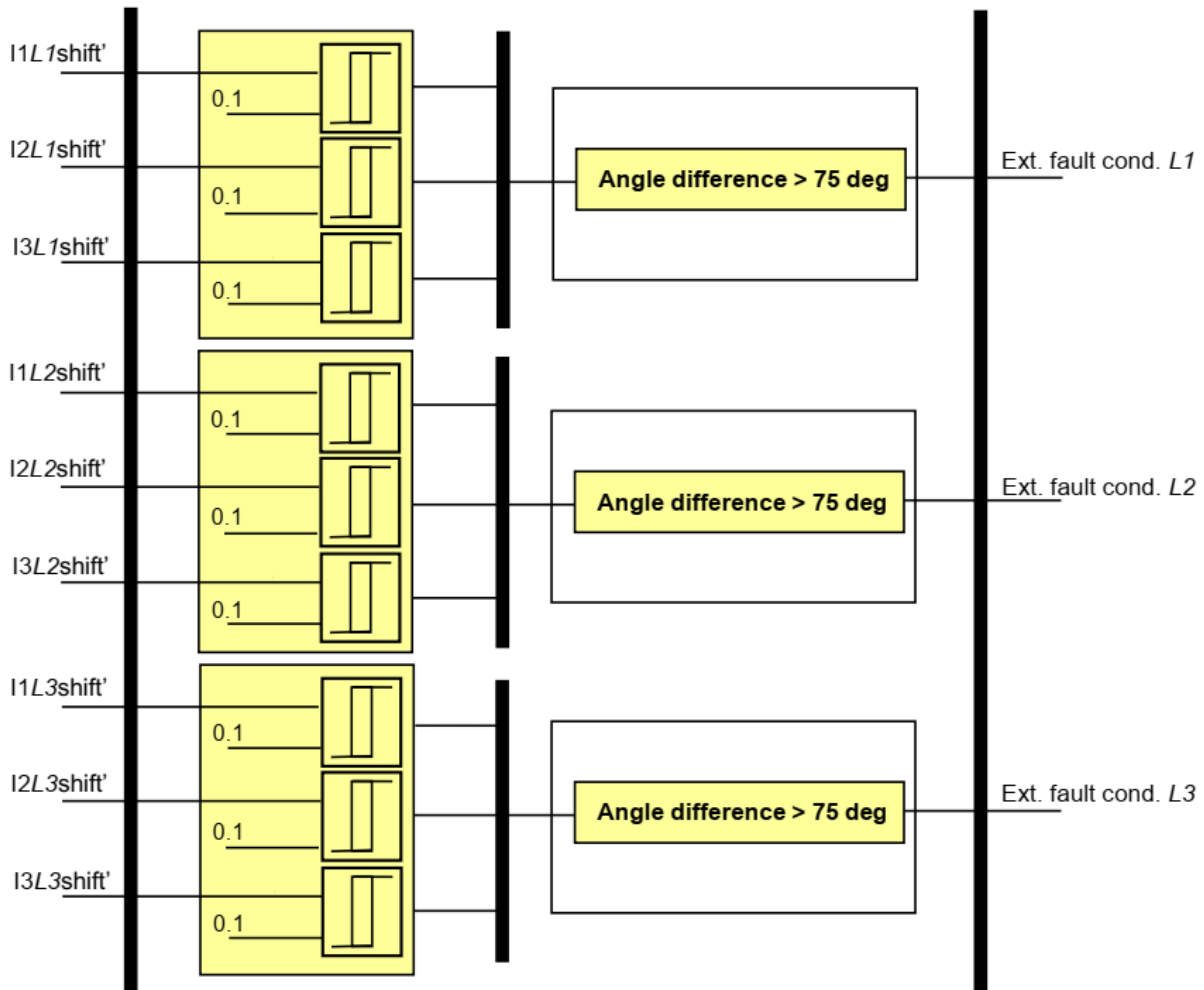
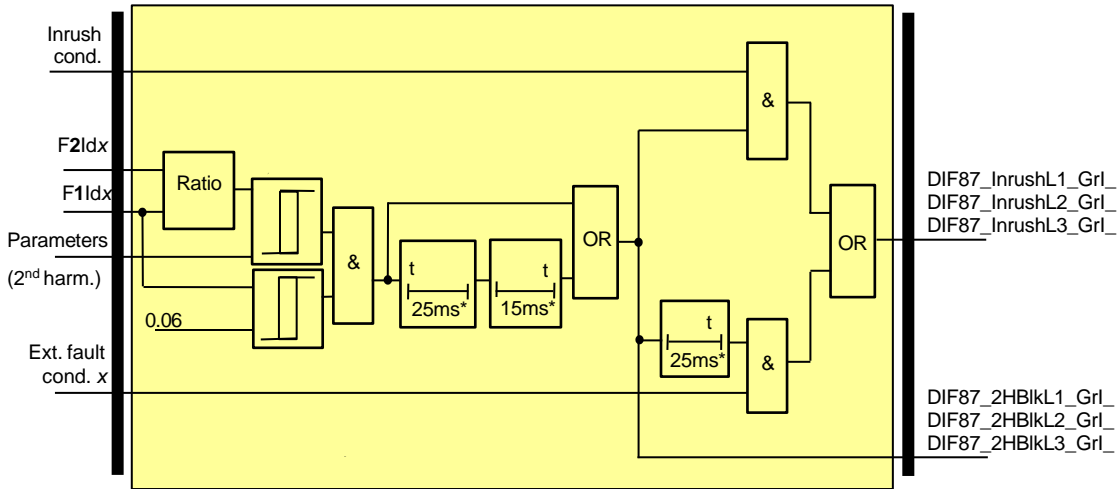


Figure 1-6 Logic scheme of the external fault condition

3.1.18.1.4.2.3. 2nd harmonic blocking scheme

The 2nd harmonic restraint function follows the logic below:



*the values are connected to the cycle time of 50 Hz. For 60 Hz applications these become lower: 20.83 ms and 12.5 ms

Figure 1-7 Logic scheme of the 2nd harmonic decision based on inrush or external fault

The logic scheme is repeated for the **second** harmonic restraint decision for all three phases ("measuring elements") separately (x=L1, L2, L3).

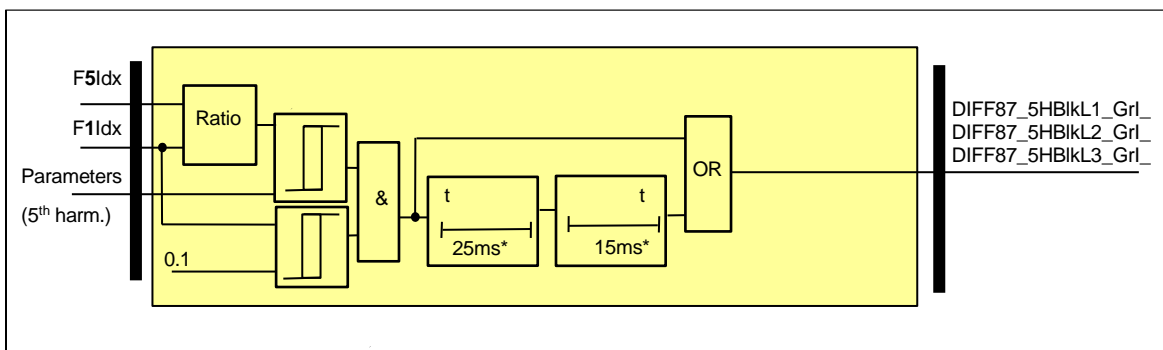
First the ratio of the harmonic and the base harmonic is calculated, and this ratio is compared to the parameter setting (second and fifth separately). In case of high ratio value, the restraint signal is generated immediately, and at the same time a timer is started. If the 25 ms (or 20.83 ms on a 60 Hz system) delay is over, and during the running time the high ratio was continuous, then a drop-off timer is started, which extends the duration of the restraint signal.

The restraint signal is generated if either the inrush condition or the external fault condition is active.

The decisions of the phases are connected in OR gate to result harmonic restraint status signal: DIF87_Inrush_Gr_ (Inrush). Note that the signal includes both cases where the 2nd harmonics are evaluated.

3.1.18.1.4.2.4. 5th harmonic blocking scheme

The 5th harmonic restraint function follows the logic below:



*the values are connected to the cycle time of 50 Hz. For 60 Hz applications these become lower: 20.83 ms and 12.5 ms

Figure 1-8 Logic scheme of the 5th harmonic restraint decision

The logic for the fifth harmonic restraint decision is like the second harmonic one with the difference that there are no further conditions other than the minimum differential current.

3.1.18.1.4.2.5. Cross blocking logic

Depending on the dedicated Boolean parameter setting “Cross Blocking”, there are two modes of operation:

- If the “Cross Blocking” parameter is FALSE (not checked) then the three “measuring elements” operate individually. The internal output signal of the “measuring element” is blocked only if the own differential current contains harmonics (second and/or fifth) above the setting level, indicating inrush current or over-excitation. Other measuring element may generate trip requirement.
- If the “Cross Blocking” parameter is TRUE (checked) then the three blocking any of the “measuring elements” by harmonics (second and/or fifth) above the setting level blocks also the internal output signal of all three “measuring elements”. The function does not generate trip requirement.

The duration of the cross blocking is set by a dedicated parameter “Cross Blocking Limit”. This is the maximum duration of cross-blocking; after timeout, the cross-blocking resets even if there are high values of harmonics in another “measuring element(s)”. Note that the “measuring element(s)” with high values of harmonics will keep on self-blocking.

Boolean parameter of the harmonic restraint decision function is shown in [Table 1-11](#):

Table 1-11 The Boolean parameter of the harmonic restraint decision function

| Parameter name | Title | Default | Explanation |
|-------------------------|----------------|---------|-----------------------------------------------------------------------------------------------------------|
| Harmonic cross blocking | | | |
| DIF87_Cross_BPar_ | Cross Blocking | True | The True setting enables cross-blocking for the maximum duration defined by the dedicated timer parameter |

Timer parameter of the harmonic restraint decision function is shown in [Table 1-12](#).

Table 1-12 The timer parameter of the harmonic restraint decision function

| Parameter name | Title | Unit | Min | Max | Step | Default |
|----------------------------------------------------|----------------------|------|-----|-------|------|---------|
| Duration of the cross-blocking (if it is enabled): | | | | | | |
| DIF87_CrossLimit_TPar_ | Cross Blocking Limit | ms | 100 | 60000 | 1 | 5000 |

3.1.18.1.5. The current magnitude calculation (Current magnitude)

3.1.18.1.5.1. The principle of the current magnitude calculation

The module, which evaluates the differential characteristics, compares the magnitude of the differential currents and those of the restraint currents. For this calculation the current magnitudes are needed. These magnitudes are calculated in this module.

3.1.18.1.5.2. The principal scheme of the current magnitude calculation

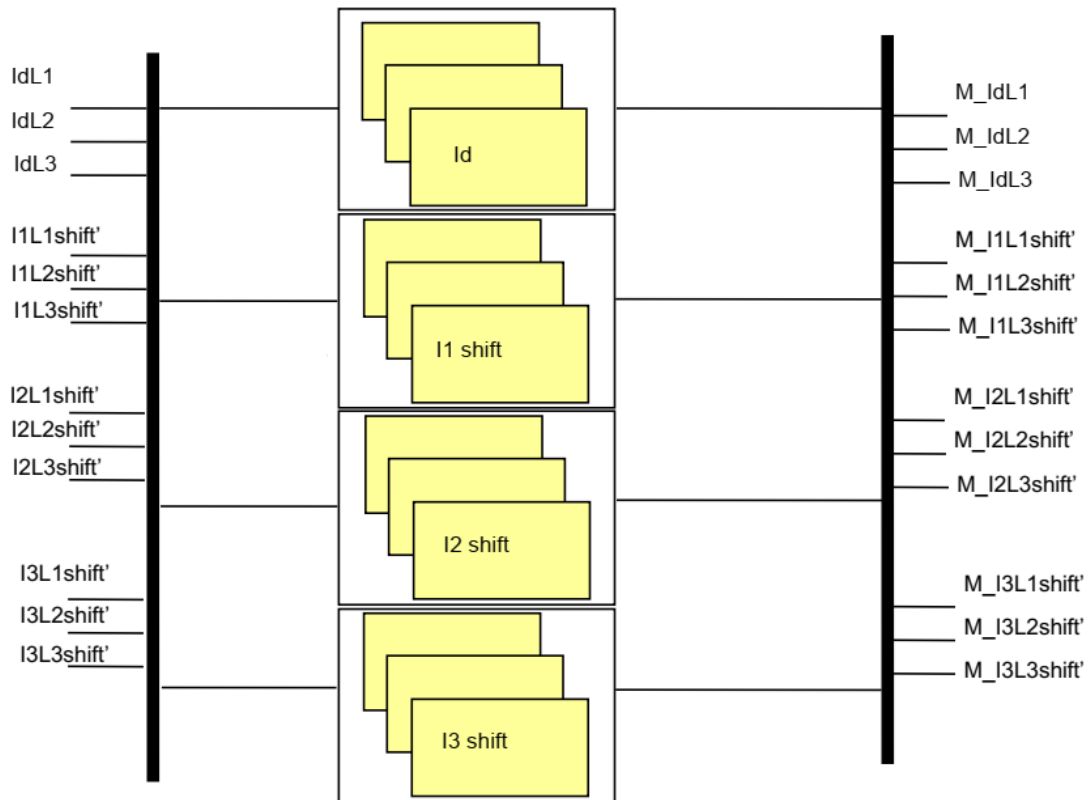


Figure 1-9 Principal scheme of the current magnitude calculation

The **inputs** are the “sampled values” of the phase-shifted currents:

- The differential currents after phase-shift $\begin{bmatrix} IdL1 \\ IdL2 \\ IdL3 \end{bmatrix}$
- The primary currents after phase-shift $\begin{bmatrix} I1L1shift' \\ I1L2shift' \\ I1L3shift' \end{bmatrix}$



- The secondary currents after phase-shift

$$\begin{bmatrix} I2L1shift \\ I2L2shift \\ I2L3shift \end{bmatrix}$$

- [The tertiary currents after phase-shift (in DIF87T3 version only)

$$\begin{bmatrix} I3L1shift \\ I3L2shift \\ I3L3shift \end{bmatrix}$$

The **outputs** are the magnitude of the calculated currents

- The magnitudes of the differential currents after phase-shift

$$\begin{bmatrix} M_IdL1 \\ M_IdL2 \\ M_IdL3 \end{bmatrix}$$

- The magnitudes of the primary currents after phase-shift

$$\begin{bmatrix} M_I1L1shift \\ M_I1L2shift \\ M_I1L3shift \end{bmatrix}$$

- The magnitudes of the secondary currents after phase-shift

$$\begin{bmatrix} M_I2L1shift \\ M_I2L2shift \\ M_I2L3shift \end{bmatrix}$$

- The magnitudes of the tertiary currents after phase-shift
(in DIF87T3 version only)

$$\begin{bmatrix} M_I3L1shift \\ M_I3L2shift \\ M_I3L3shift \end{bmatrix}$$

3.1.18.1.6. The evaluation of the differential characteristics (differential characteristics)

3.1.18.1.6.1. The principle of the differential characteristics

This module evaluates the differential characteristics. It compares the magnitude of the differential currents and those of the restraint currents. The restraint (bias) currents are calculated using the following formulas:

$$M_{IbiasL1} = \frac{M_{I1L1shift} + M_{I2L1shift} + M_{I3L1shift}}{2}$$

$$M_{IbiasL2} = \frac{M_{I1L2shift} + M_{I2L2shift} + M_{I3L2shift}}{2}$$

$$M_{IbiasL3} = \frac{M_{I1L3shift} + M_{I2L3shift} + M_{I3L3shift}}{2}$$

Based on these values (denoted generally as “Ibias”) and the values of the differential current magnitudes (denoted generally as “Idiff”) the differential protection characteristics are shown on Figure 1-10.

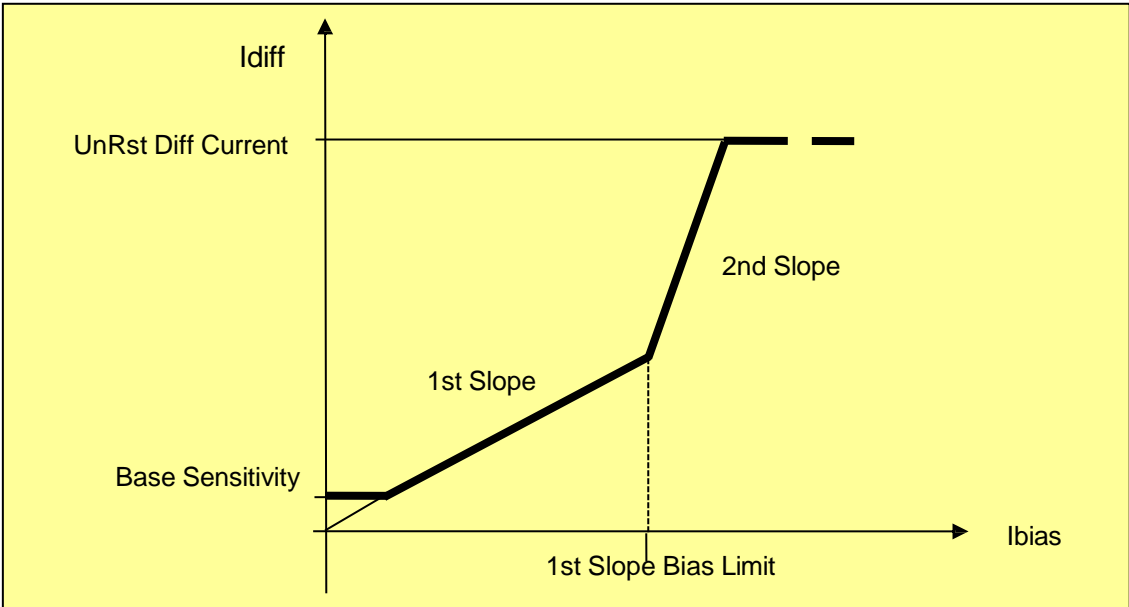


Figure 1-10 The differential protection characteristics

Additionally separate status-signals are set to “true” value if the differential currents in the individual phases are above the limit, set by parameter (see “Unrestrained differential function”).



Integer parameters

Table 1-13 The integer parameters of the differential protection characteristics

| Parameter name | Title | Unit | Min | Max | Step | Default |
|-------------------------------------------------------|---------------------------|------|-----|------|------|---------|
| Base sensitivity: | | | | | | |
| DIF87_f1_IPar_ | Base Sensitivity | %* | 10 | 50 | 1 | 20 |
| Slope of the second section of the characteristics: | | | | | | |
| DIF87_f2_IPar_ | 1st Slope | %** | 10 | 50 | 1 | 20 |
| Position of the third section of the characteristics: | | | | | | |
| DIF87_f3_IPar_ | 1st Slope Bias Limit | %* | 200 | 2000 | 1 | 200 |
| Slope of the third section of the characteristics: | | | | | | |
| DIF87_Slope2_IPar_ | 2nd Slope | %** | 30 | 200 | 1 | 200 |
| Unrestrained differential protection current level: | | | | | | |
| DIF87_HCurr_IPar_ | Unrestrained Diff Current | %* | 800 | 2500 | 1 | 800 |
| * % related to the reference current | | | | | | |
| ** % related to the bias current | | | | | | |

Table 1-14 The binary output status signals of the differential protection characteristics

| Binary output signals | Signal title | Explanation |
|------------------------------|--------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Differential characteristics | | |
| DIF87_L1St_Grl_i | Start L1 | This internal status is true if the differential current in measuring element L1 at the restraint current is above the characteristic lines |
| DIF87_L2St_Grl_i | Start L2 | This internal status is true if the differential current in measuring element L2 at the restraint current is above the characteristic lines |
| DIF87_L3St_Grl_i | Start L3 | This internal status is true if the differential current in measuring element L3 at the restraint current is above the characteristic lines |

3.1.18.1.6.2. The unrestrained differential function

If the calculated differential current is very high then the differential characteristic is not considered anymore, because separate status-signals for the phases are set to “true” value if the differential currents in the individual phases are above the limit, defined by parameter setting.

The decisions of the phases are connected in OR gate to result the general start status signal.

Integer parameter of the unrestrained differential function is shown in [Table 1-15](#).

Table 1-15 The integer parameter of the unrestrained differential protection characteristics

| Parameter name | Title | Unit | Min | Max | Step | Default |
|---------------------------------------------------|--------------------|------|-----|------|------|---------|
| High-speed differential protection current level: | | | | | | |
| DIF87_HCurr_IPar_ | UnRst Diff Current | %* | 800 | 2500 | 1 | 800 |
| * % related to the reference current | | | | | | |

Table 1-16 The binary output status signals of the unrestrained differential protection characteristics

| Binary output signals | Signal title | Explanation |
|-----------------------|-------------------|--------------------------------------------------------------------------------------------------------------------|
| Unrestrained decision | | |
| DIF87_UnRL1St_Grl_i | Start L1 unrestr. | This internal status is true if the differential current in measuring element L1 is above the high current setting |
| DIF87_UnRL2St_Grl_i | Start L2 unrestr. | This internal status is true if the differential current in measuring element L2 is above the high current setting |
| DIF87_UnRL3St_Grl_i | Start L3 unrestr. | This internal status is true if the differential current in measuring element L3 is above the high current setting |

3.1.18.1.6.3. The principal scheme of the evaluation of differential characteristics

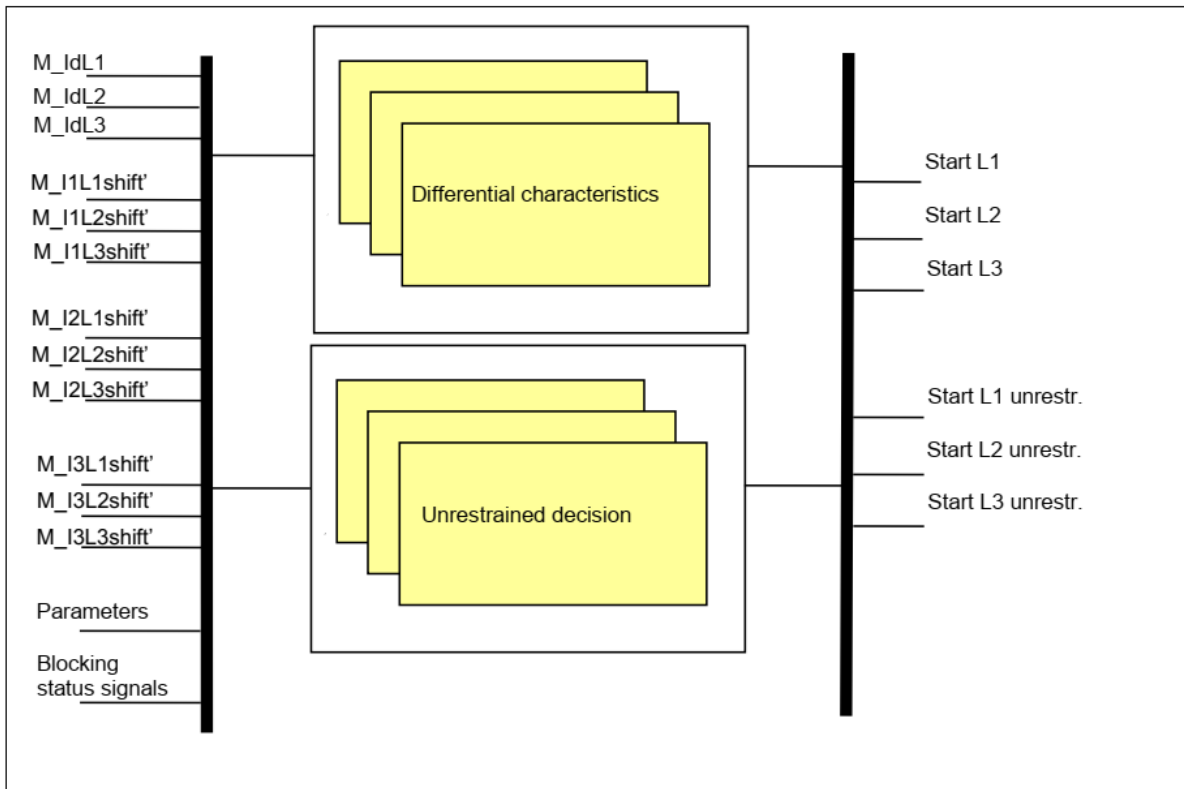


Figure 1-11 The Scheme of evaluation of differential protection characteristics.

The **inputs** are the magnitude of the calculated currents:

- The magnitudes of the differential currents after phase-shift $\begin{bmatrix} M_IdL1 \\ M_IdL2 \\ M_IdL3 \end{bmatrix}$
- The magnitudes of the primary currents after phase-shift $\begin{bmatrix} M_I1L1shift' \\ M_I1L2shift' \\ M_I1L3shift' \end{bmatrix}$



- The magnitudes of the secondary currents after phase-shift

$$\begin{bmatrix} M_I2L1shift \\ M_I2L2shift \\ M_I2L3shift \end{bmatrix}$$
 - The magnitudes of the tertiary currents after phase-shift

$$\begin{bmatrix} M_I3L1shift \\ M_I3L2shift \\ M_I3L3shift \end{bmatrix}$$
- (in DIF87T3 version only)

Table 1-17 The binary output status signals of the restrained and unrestrained differential protection characteristics

| Binary output signals | Signal title | Explanation |
|------------------------------|-------------------|------------------------------------------------------------------------------------------------------------------------------------|
| Differential characteristics | | |
| DIF87_L1St_Grl_ | Start L1 | This status is true if the differential current in measuring element L1 at the restraint current is above the characteristic lines |
| DIF87_L2St_Grl_ | Start L2 | This status is true if the differential current in measuring element L2 at the restraint current is above the characteristic lines |
| DIF87_L3St_Grl_ | Start L3 | This status is true if the differential current in measuring element L3 at the restraint current is above the characteristic lines |
| Unrestrained decision | | |
| DIF87_UnRL1St_Grl_ | Start L1 unrestr. | This status is true if the differential current in measuring element L1 is above the high current setting |
| DIF87_UnRL2St_Grl_ | Start L2 unrestr. | This status is true if the differential current in p measuring element L2 is above the high current setting |
| DIF87_UnRL3St_Grl_ | Start L3 unrestr. | This status is true if the differential current in measuring element L3 is above the high current setting |

3.1.18.1.7. The decision logic (Decision logic)

3.1.18.1.7.1. The principle of the decision logic

The decision logic combines the following binary signals:

- Start signals of the differential characteristic module
- Unrestrained start signals of the differential characteristic module
- Harmonic restraint signals of the 2. harmonic restraint decision
- Harmonic restraint signals of the 5. harmonic restraint decision
- Disabling status signal defined by the user, using graphic equation editor DIF87_Blk_GrO_

3.1.18.1.7.2. The principal scheme of the decision logic

The inputs are the calculated status signals of the Differential characteristics and Unrestrained differential modules, those of the 2.harmonic restraint and 5.harmonic restraint modules and binary input parameters.



Table 1-18 The binary input status signals of the decision logic

| Binary input signals | Signal title | Explanation |
|-----------------------------------|-------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Differential characteristics | | |
| DIF87_L1St_GrI_i | Start L1 | This internal status is true if the differential current in measuring element L1 at the restraint current is above the characteristic lines |
| DIF87_L2St_GrI_i | Start L2 | This internal status is true if the differential current in measuring element L2 at the restraint current is above the characteristic lines |
| DIF87_L3St_GrI_i | Start L3 | This internal status is true if the differential current in measuring element L3 at the restraint current is above the characteristic lines |
| Unrestrained decision | | |
| DIF87_UnRL1St_GrI_i | Start L1 unrestr. | This internal status is true if the differential current in measuring element L1 is above the high current setting |
| DIF87_UnRL2St_GrI_i | Start L2 unrestr. | This internal status is true if the differential current in measuring element L2 is above the high current setting |
| DIF87_UnRL3St_GrI_i | Start L3 unrestr. | This internal status is true if the differential current in measuring element L3 is above the high current setting |
| Second harmonic restraint signals | | |
| DIF87_InrushL1_GrI_ | Inrush L1 | Restraint in measuring element L1 caused by high second harmonic content in the differential current while either condition (inrush or external fault) is active |
| DIF87_InrushL2_GrI_ | Inrush L2 | Restraint in measuring element L2 caused by high second harmonic content in the differential current while either condition (inrush or external fault) is active |
| DIF87_InrushL3_GrI_ | Inrush L3 | Restraint in measuring element L3 caused by high second harmonic content in the differential current while either condition (inrush or external fault) is active |
| Fifth harmonic restraint signals | | |
| DIF87_5HBiKL1_GrI_ | 5.Harm Restr. L1 | Restraint in measuring element L1 caused by high fifth harmonic content in the differential current |
| DIF87_5HBiKL2_GrI_ | 5.Harm Restr. L2 | Restraint in measuring element L2 caused by high fifth harmonic content in the differential current |
| DIF87_5HBiKL3_GrI_ | 5.Harm Restr. L3 | Restraint in measuring element L3 caused by high fifth harmonic content in the differential current |

Blocking input signal

The differential protection function has a binary input signal, which serves disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor for the signal DIF87_BlK_GrO.**

Table 1-19 The blocking input status signal of the decision logic

| Binary input signal | Explanation |
|---------------------|------------------------------------------------------------------------------------------------------------------------------------|
| DIF87_BlK_GrO_ | Output status of a graphic equation to disable the differential protection function. Only the measurements work and are displayed. |



Table 1-20 The binary output status signals of the differential protection characteristics

| Binary output signals | Signal title | Explanation |
|------------------------------|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Differential characteristics | | |
| DIF87_ L1St _Grl_ | Start L1 | This status is true if the differential current in measuring element L1 at the restraint current is above the characteristic lines and the function is not blocked |
| DIF87_ L2St _Grl_ | Start L2 | This status is true if the differential current in measuring element L2 at the restraint current is above the characteristic lines and the function is not blocked |
| DIF87_ L3St _Grl_ | Start L3 | This status is true if the differential current in measuring element L3 at the restraint current is above the characteristic lines and the function is not blocked |
| DIF87_ GenSt _Grl_ | GenStart | This status is true if the differential current in any measuring element at the restraint current is above the restrained characteristic lines and the function is not blocked |
| Unrestrained decision | | |
| DIF87_ UnrL1St _Grl_ | Start L1 - unrestrained | This status is true if the differential current in measuring element e L1 is above the high current setting and the function is not blocked |
| DIF87_ UnrL2St _Grl_ | Start L2 - unrestrained | This status is true if the differential current in measuring element L2 is above the high current setting and the function is not blocked |
| DIF87_ UnrL3St _Grl_ | Start L3 - unrestrained | This status is true if the differential current in measuring element L3 is above the high current setting and the function is not blocked |
| DIF87_ UnrGenSt _Grl_ | GenStart - unrestrained | This status is true if the differential current in any measuring elements is above the high current setting and the function is not blocked |
| Harmonic blocking | | |
| DIF87_ Inrush _Grl_ | Inrush | Restraint caused by high second harmonic content during inrush or external fault |
| DIF87_ 5HBik _Grl_ | 5.Harm Restr. | Restraint caused by high fifth harmonic content in any of the differential currents |

The **GenSt** and **UnrGenSt** signals are processed by the trip logic of the device in the so-called Fast Logic (Fast Equations). These can be checked with the EuroCAP software in the .epc configuration file of the device in the Software Configuration → Equations → Fast Logic.

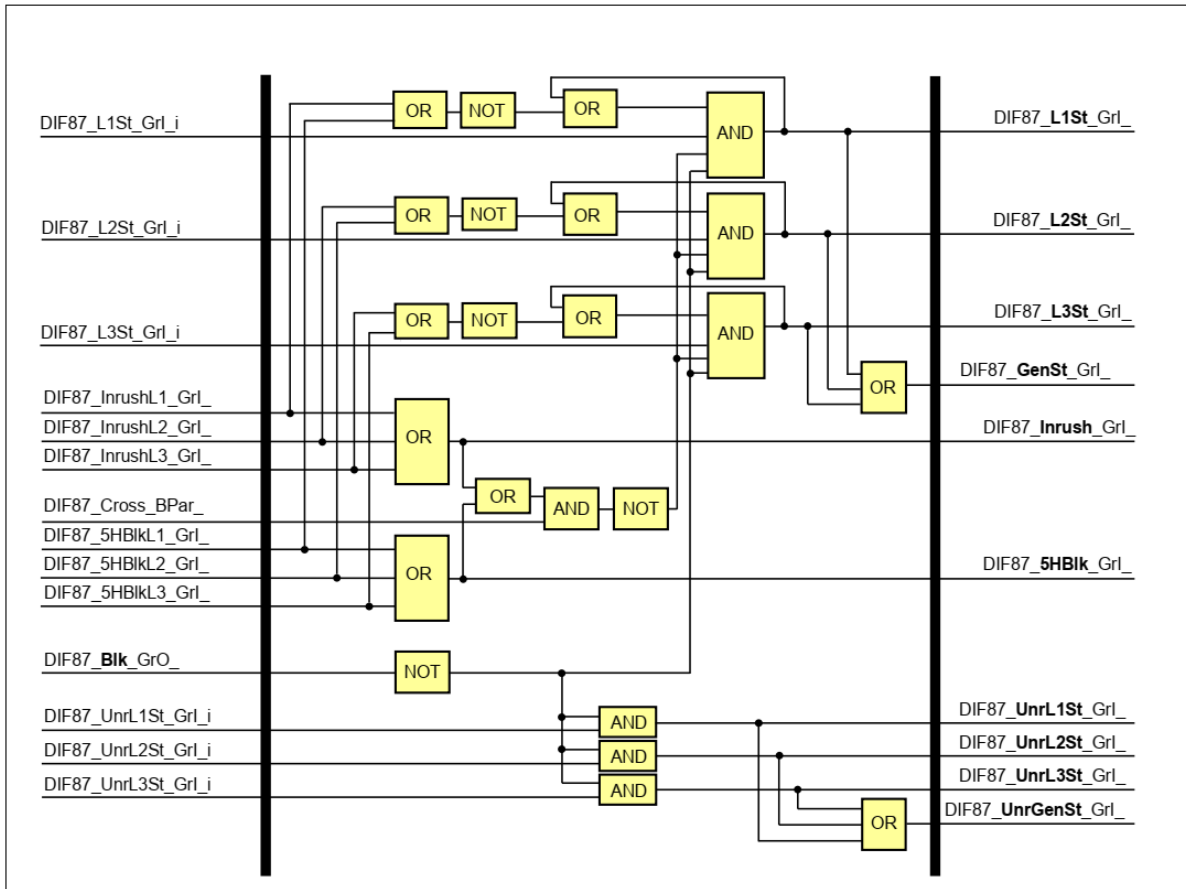


Figure 1-12 The decision logic schema of the differential protection function

3.1.18.1.7.3. Special measures for CT saturation during external faults

Basically, the 2nd slope of the differential characteristic is set to cover the errors caused by saturated CT, however, there are further methods implemented to stabilize the differential protection function even more in case of external faults (while keeping it sensitive for internal ones) with saturated CT. This chapter explains these two special functionalities and their conditions to activate.

- Adaptive characteristics**
 In case of external faults, the differential currents appear a little while after the CT has become saturated. In case of internal faults, these two events happen at the same time. Based on this principle, the differential protection function switches to a less sensitive characteristic if such sign of an external fault is detected.

The condition: the measured Bias current in any phase is above $1.25I_n$ for at least 3 milliseconds while the differential current is less than the set Base Sensitivity. This condition falls off if the Bias current drops below $0.8I_n$.

The characteristic: 1st slope 50% and 2nd slope 200%

- Usage of the 2nd harmonic restraint**
 The second harmonic restraint decision can be enabled if there is at least 75 degrees difference between the measured currents after vector shift compensation (indicating an external fault), see Chapter 1.3.

3.1.18.2. Differential protection function overview

The graphic appearance of the function blocks of the differential protection function for transformers of two or three voltage levels are shown on [Figure 2-1](#). These blocks show all binary input and output status signals, which are applicable in the graphic equation editor.

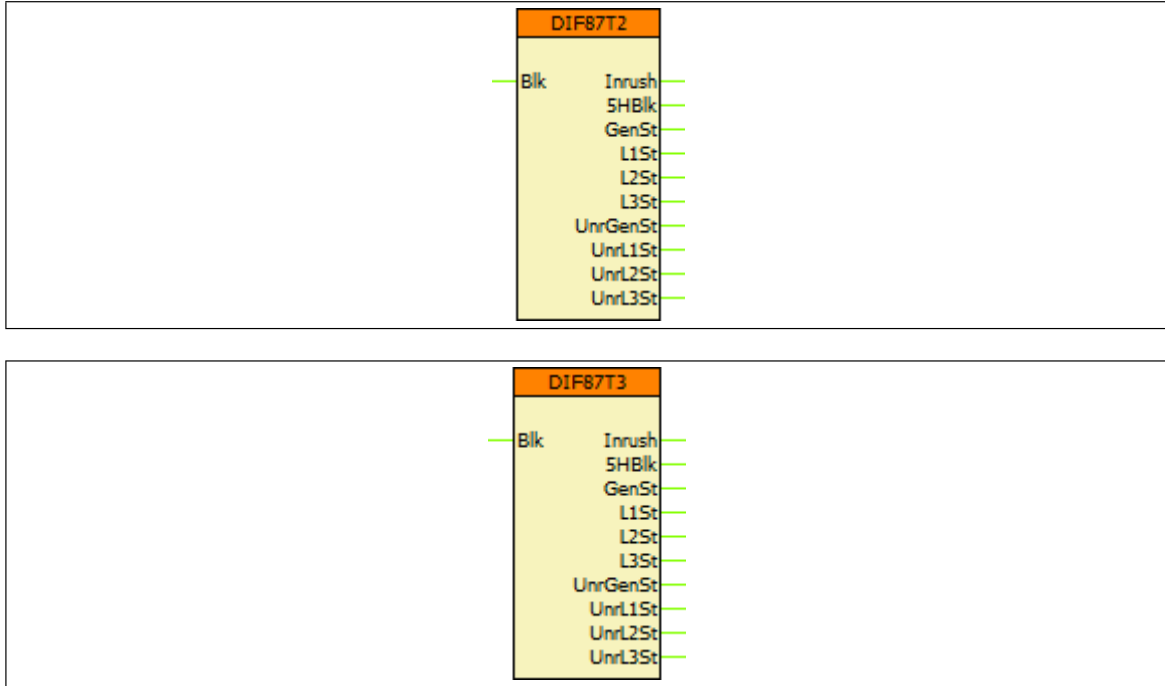


Figure 2-1 Graphic appearance of the function blocks of the differential protection function



3.1.18.2.1. Settings

3.1.18.2.1.1. Parameters

Table 2-1 Parameters of the differential protection function

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|--------------------------------------------------------|-----------|---------------------------------------------------------------------------------------------------------|------|---------|-----------------------------------------------------------------------------------------------------------------------------------------|
| Operation | - | Off, On | - | Off | Enabling the differential protection function |
| <i>Parameters related to the protected transformer</i> | | | | | |
| Pri-Sec VGroup | - | Dy1,Dy5,Dy7,Dy11, Dd0,Dd6,Dz0,Dz2, Dz4,Dz6,Dz8,Dz10, Yy0, Yy6, Yd1, Yd5, Yd7, Yd11, Yz1, Yz5, Yz7, Yz11 | - | Dd0 | Connection group of the transformer coils in primary-secondary relation |
| Pri-Ter VGroup* | - | Dy1,Dy5,Dy7,Dy11, Dd0,Dd6,Dz0,Dz2, Dz4,Dz6,Dz8,Dz10, Yy0, Yy6, Yd1, Yd5, Yd7, Yd11, Yz1, Yz5, Yz7, Yz11 | - | Dd0 | Connection group of the transformer coils in primary-tertiary relation |
| ZeroSeq Elimination | - | FALSE, TRUE | - | FALSE | Check this when a neutral grounding transformer is applied in the protected zone on the delta side (see Chapter 1.1.5) |
| Sn | MVA | 1.00 – 1000.00 | 0.01 | 125.00 | Rated apparent power of the transformer |
| Un Primary | kV | 1.00 – 1000.00 | 0.01 | 132.00 | Rated voltage of the transformer primary side |
| Un Secondary | kV | 1.00 – 1000.00 | 0.01 | 22.00 | Rated voltage of the transformer secondary side |
| Un Tertiary | kV | 1.00 – 1000.00 | 0.01 | 11.50 | Rated voltage of the transformer tertiary side |
| <i>Parameters related to the harmonic restraint</i> | | | | | |
| Cross Blocking | - | FALSE, TRUE | - | FALSE | When selected, the harmonic restraint blocks all phases instead of only the affected ones (see Chapter 1.3.2) |
| 2nd Harm Ratio | % (Idiff) | 5 – 50 | 1 | 15 | Second harmonic restraint ratio related to the <i>basic harmonic of the differential current</i> |
| 5th Harm Ratio | % (Idiff) | 5 – 50 | 1 | 15 | Fifth harmonic restraint ratio related to the <i>basic harmonic of the differential current</i> |
| Cross Blocking Limit | msec | 100 – 60000 | 1 | 5000 | After expiration the phases that still have high harmonic content will remain blocked, the others are released |

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|--------------------------------------------------------------|-----------|------------|------|---------|----------------------------------------------------------------------------------------------------------------------------------------|
| <i>Parameters related to the differential characteristic</i> | | | | | |
| Base Sensitivity | % (In) | 10 – 50 | 1 | 20 | Base sensitivity - 1st section of the characteristic curve related to the <i>nominal current of the transformer</i> |
| 1st Slope | % (Ibias) | 10 – 50 | 1 | 20 | 1st Slope - 2nd section of the characteristic curve related to the <i>bias current</i> |
| 1st Slope Bias Limit | % (In) | 200 – 2000 | 1 | 200 | Bias current limit of the 1st slope (2nd section) of the characteristic curve related to the <i>nominal current of the transformer</i> |
| 2nd Slope | % (Ibias) | 30 – 200 | 1 | 200 | 2nd Slope - 3rd section of the characteristic curve related to the <i>bias current</i> |
| Unrestrained Diff Current | % (In) | 800 – 2500 | 1 | 800 | Unrestrained differential current - 4th section of the characteristic curve related to the <i>nominal current of the transformer</i> |

* If the connection of the primary winding in primary-secondary and primary tertiary relation is selected in contradiction, then the protection function is automatically disabled, and the function (and the device itself) generates a warning signal.

3.1.18.2.1.2. Characteristics

The function uses a 2-slope characteristic with unrestrained section, see [Figure 2-2](#).

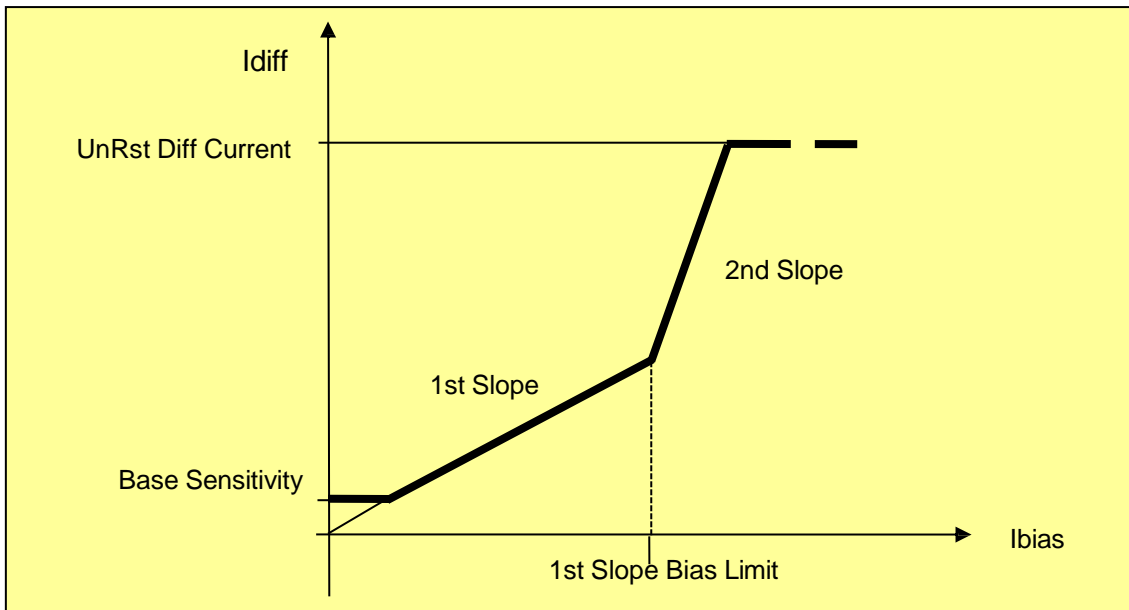


Figure 2-2 The differential protection characteristics



3.1.18.2.2. Function I/O

This section describes briefly the analogue and digital inputs and outputs of the function block.

3.1.18.2.2.1. Analogue inputs

The function uses the sampled values of the three phase currents of each side.

3.1.18.2.2.2. Analogue outputs (measurements)

The measured values of the differential protection function are listed in the table below.

Table 2-2 The measured analogue values of the differential protection function

| MEASURED VALUE | DIMENSION | EXPLANATION |
|-------------------------|-----------|-----------------------------------------------------------------------------------------------|
| Differential current L1 | In % | The calculated differential current in measuring element L1 (after vector group compensation) |
| Differential current L2 | In % | The calculated differential current in measuring element L2 (after vector group compensation) |
| Differential current L3 | In % | The calculated differential current in measuring element L3 (after vector group compensation) |
| Bias current L1 | In % | The calculated restraint current in measuring element L1 (after vector group compensation) |
| Bias current L2 | In % | The calculated restraint current in measuring element L2 (after vector group compensation) |
| Bias current L3 | In % | The calculated restraint current in measuring element L3 (after vector group compensation) |

Remark: The evaluated basic harmonic values of the measured input phase currents (without vector group compensation) help the commissioning of the differential protection function. These evaluations however are performed by an independent software measuring module, so this chapter excludes the description of these measurements.

3.1.18.2.2.3. Binary input signals (graphed output statuses)

The conditions of the inputs are defined by the user, applying the graphic equation editor (logic editor). The part written in **bold** is seen on the function block in the logic editor.

Table 2-3 The binary input signal of the differential protection function

| BINARY INPUT SIGNAL | EXPLANATION |
|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| DIF87_ Bik _GrO_ | Output status of a graphic equation defined by the user to disable the differential protection function. Only the measurements work and are displayed. |



3.1.18.2.2.4. Binary output signals (graphed input statuses)

The binary output status signals of the differential protection function. **Parts** written in **bold** are seen on the function block in the logic editor.

Table 2-4 The binary output status signals of the differential protection function

| BINARY OUTPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|-----------------------------------------------|-----------------------|----------------------------------------------------------------------------------------------------------------------|
| Harmonic blocking | | |
| DIF87_ Inrush _Grl_ | Inrush | Restraint caused by high second harmonic content in any of the differential currents during inrush or external fault |
| DIF87_ 5HBik _Grl_ | 5.Harm Restraint | Restraint caused by high fifth harmonic content in any of the differential currents |
| Restrained differential protection function | | |
| DIF87_ GenSt _Grl_ | General Start | General start of the restrained differential protection function |
| DIF87_ L1St _Grl_ | Start L1 | Start of the restrained differential protection function in measuring element L1 (after vector group compensation) |
| DIF87_ L2St _Grl_ | Start L2 | Start of the restrained differential protection function in measuring element L2 (after vector group compensation) |
| DIF87_ L3St _Grl_ | Start L3 | Start of the restrained differential protection function in measuring element L3 (after vector group compensation) |
| Unrestrained differential protection function | | |
| DIF87_ UnRGenSt _Grl_ | General Start unrestr | General start of the unrestrained differential protection function |
| DIF87_ UnRL1St _Grl_ | Start L1 unrestr. | Start of the unrestrained differential protection function in measuring element L1 (after vector group compensation) |
| DIF87_ UnRL2St _Grl_ | Start L2 unrestr. | Start of the unrestrained differential protection function in measuring element L2 (after vector group compensation) |
| DIF87_ UnRL3St _Grl_ | Start L3 unrestr. | Start of the unrestrained differential protection function in measuring element L3 (after vector group compensation) |



3.1.18.2.2.5. On-line data

Visible values on the on-line data page:

Table 2-5 On-line data of the differential protection function

| SIGNAL TITLE | DIMENSION | EXPLANATION |
|------------------------------|-----------|----------------------------------------------------------------------------------------------------------------------|
| Differential current L1 | In % | The calculated differential current in measuring element L1 (after vector group compensation) |
| Differential current L2 | In % | The calculated differential current in measuring element L2 (after vector group compensation) |
| Differential current L3 | In % | The calculated differential current in measuring element L3 (after vector group compensation) |
| Bias current L1 | In % | The calculated restraint current in measuring element L1 (after vector group compensation) |
| Bias current L2 | In % | The calculated restraint current in measuring element L2 (after vector group compensation) |
| Bias current L3 | In % | The calculated restraint current in measuring element L3 (after vector group compensation) |
| Inrush L1 | - | Restraint caused by high second harmonic content in L1 differential current during inrush or external fault |
| Inrush L2 | - | Restraint caused by high second harmonic content in L2 differential current during inrush or external fault |
| Inrush L3 | - | Restraint caused by high second harmonic content in L3 differential current during inrush or external fault |
| Inrush | - | Restraint caused by high second harmonic content in any of the differential currents during inrush or external fault |
| 5.Harm Restr. L1 | - | Restraint caused by high fifth harmonic content in L1 differential current |
| 5.Harm Restr. L2 | - | Restraint caused by high fifth harmonic content in L2 differential current |
| 5.Harm Restr. L3 | - | Restraint caused by high fifth harmonic content in L3 differential current |
| 5.Harm Restraint | - | Restraint caused by high fifth harmonic content in any of the differential currents |
| Start L1 | - | Start of the restrained differential protection function in measuring element L1 (after vector group compensation) |
| Start L2 | - | Start of the restrained differential protection function in measuring element L2 (after vector group compensation) |
| Start L3 | - | Start of the restrained differential protection function in measuring element L3 (after vector group compensation) |
| General Start | - | General start of the restrained differential protection function |
| Start L1 - unrestrained | - | Start of the unrestrained differential protection function in measuring element L1 (after vector group compensation) |
| Start L2 - unrestrained | - | Start of the unrestrained differential protection function in measuring element L2 (after vector group compensation) |
| Start L3 - unrestrained | - | Start of the unrestrained differential protection function in measuring element L3 (after vector group compensation) |
| General Start - unrestrained | - | General start of the unrestrained differential protection function |



3.1.18.2.2.6. Events

The following events are generated in the event list, as well as sent to SCADA according to the configuration.

Table 2-6 Events of the differential protection function

| EVENT | VALUE | EXPLANATION |
|------------------------------|---------|--------------------------------------------------------------------------------------------------------------------------|
| Inrush L1 | off, on | Restraint in phase L1 caused by high second harmonic content in the differential current during inrush or external fault |
| Inrush L2 | off, on | Restraint in phase L2 caused by high second harmonic content in the differential current during inrush or external fault |
| Inrush L3 | off, on | Restraint in phase L3 caused by high second harmonic content in the differential current during inrush or external fault |
| Start L1 | off, on | Start of the restrained differential protection function in measuring element L1 (after vector group compensation) |
| Start L2 | off, on | Start of the restrained differential protection function in measuring element L2 (after vector group compensation) |
| Start L3 | off, on | Start of the restrained differential protection function in measuring element L3 (after vector group compensation) |
| General Start | off, on | General start of the restrained part of the differential protection function |
| Start L1 – unrestrained | off, on | Start of the unrestrained differential protection function in measuring element L1 (after vector group compensation) |
| Start L2 – unrestrained | off, on | Start of the unrestrained differential protection function in measuring element L2 (after vector group compensation) |
| Start L3 – unrestrained | off, on | Start of the unrestrained differential protection function in measuring element L3 (after vector group compensation) |
| General Start – unrestrained | off, on | General start of the unrestrained part of the differential protection function |

3.1.18.2.3. Technical data and notes

Table 2-7 Technical data of the transformer differential protection

| FUNCTION | VALUE | ACCURACY |
|----------------------------|------------------|----------|
| Operating characteristic | 2 breakpoints | |
| Reset ratio | 0,9 | |
| Characteristic accuracy* | | <3% |
| Operate time, unrestrained | Typically 20 ms | <10 ms |
| Reset time, unrestrained | Typically <55 ms | |
| Operate time, restrained | Typically 30 ms* | <10 ms |
| Reset time, restrained | Typically <35 ms | |

*Bias current is above $0.2 I_n$; see Chapter 2.3.2 for more information

3.1.18.2.3.1. Notes for testing

There is an XRIO setting file available for the function. With that, only the parameters of the CT modules and the differential protection function should be entered along the type of the fault to be generated. By using this file, testing the operation characteristic will not need any further setting.

Normally in the EuroProt+ devices the trip contacts are assigned to the Trip Logic function block, and not to the protection function blocks. Because of this the testing personnel must make sure that the Trip Logic is switched on ('Operation' parameter is set to other than 'Off') before starting the testing, otherwise there will be no physical trip on the relay.

Notes for testing the operation characteristics:

- Direction settings in the CT4 module function are 'Line' and 'Bus'. However, in case of differential protection 'Line' means 'Towards protected object'. So if the two CTs' starpoints are towards protected object, their settings should be 'Line' for both. (with XRIO file this point is obsolete)
- Reference winding is the delta side (see Chapter 1.1.2). Reference current is the nominal current of the transformer (see Chapter 1.1.1). (with XRIO file this point is obsolete)
- When setting up the characteristics in the relay tester, and when checking the results, keep in mind that the currents are transformed to the delta side, which results in different behavior compared to the applications of other manufacturers. (with XRIO file this point is obsolete)
- The adaptive characteristics to external faults might cause different test results, as the characteristics will be different under certain circumstances (see Chapter 1.6.3). To avoid this, the pre-fault currents should not exceed $1 * I_n$.
If the pre-fault currents cannot be adjusted, then setting the *pre-fault time to zero* also solves the issue.

Notes for testing the harmonic restraint characteristic:

- When testing the **2nd harmonic** restraint, keep in mind that either of the two conditions (inrush or external fault, see Chapter 1.3) must be fulfilled to activate the restraint along with the condition of the differential current to be at least $0.1 I_n$.
- The **5th harmonic** restraint can be tested freely the condition of the differential current to be at least $0.1 I_n$.

3.1.18.2.3.2. CT sizing requirements

The CT sizing guidelines for internal and external faults (according to the IEC60255-187-1 standard) can be acquired on request from Protecta personnel on application@protecta.hu

3.1.18.2.3.3. Transformer and primary CT rated current ratios

When ordering a device with differential protection, it must be taken into consideration that the function's characteristics are based on the *transformer's rated current*. This means that the rated currents of the primary CTs shall be selected in a way that their secondary currents are reasonably high to be measured accurately on the protection device's CT modules.

The desirable value for the primary CTs' rated current would be close to that of the transformer's rated currents, so that their measurements stay accurate for the differential protection.

For example, let's take a transformer with the following data:

$$\begin{aligned} S_n &= 50 \text{ MVA} \\ U_{n1} &= 230 \text{ kV} \\ U_{n2} &= 11 \text{ kV} \end{aligned}$$

The reference currents (transformer rated currents) on the primary and secondary sides in this case are:

$$\begin{aligned} I_{reference1} &= \frac{S_n}{\sqrt{3} U_{n1}} \rightarrow I_{reference1} = 125.5 \text{ A} \\ I_{reference2} &= \frac{S_n}{\sqrt{3} U_{n2}} \rightarrow I_{reference2} = 1207.2 \text{ A} \end{aligned}$$

Staying at the example, if a CT with a rated current of *2000A* is installed on the *primary (1)* side, and another CT with *1500A* on the *secondary (2)* side, the matching ratios between the transformer's and the CT's rated currents would be the following:

$$\begin{aligned} TR_1 &= \frac{I_{TRn1}}{I_{CTn1}} \rightarrow TR_1 = \frac{125.5 \text{ A}}{2000 \text{ A}} = 0.06275 = 6.275\% \\ TR_2 &= \frac{I_{TRn2}}{I_{CTn2}} \rightarrow TR_2 = \frac{1207.2 \text{ A}}{3000 \text{ A}} = 0.4024 = 40.24\% \end{aligned}$$

The issue is on the primary side, where a rated current (100%) flowing on the transformer would represent only **6.275%** on the CT. In other words, if 6.275% current (62.75 mA on 1A rated secondary) is flowing on the primary side and no current on the secondary side, the differential protection function will show 100% differential current on its on-line data. With a base sensitivity setting of 20%, 12.55 mA current (1.255%) could already cause the function to operate.

3.1.18.2.3.3.1. Recommended CT/TR nominal current matching ratios

Because of the issue above, applying the function to different matching ratios might provide different accuracy results (the lower the ratio, the better the accuracy); this also depends on the function block settings, see the table below.

Table 2-8 Characteristic accuracy depending on the CT/TR matching ratio

| CHARACTERISTICS' PARAMETERS | | MATCHING RATIO (PRIMARY SIDE)* | | |
|-----------------------------|---------------|--------------------------------|------------|------------|
| BASE SENSITIVITY | 1ST SLOPE | 7 (14.29%) | 12 (8.33%) | 16 (6.25%) |
| 10% (minimum) | 10% (minimum) | 3% | 6% | 10% |
| 20% (default) | 20% (default) | 3% | 4% | 7% |
| 20% (default) | 30% | 3% | 3% | 5% |

*CT/TR ratio on the secondary side is constant (40%, see the example above)

The 3% accuracy shown in [Table 2-7](#) with the base sensitivity of 20% can be expected with a matching ratio of **7 or lower** (or higher than 14.29% if shown in TR/CT ratio instead).

If the 1st slope is at least 20% as well (default setting), the same accuracy can be reached until the ratio of **12**.

3.1.18.3. Appendix

3.1.18.3.1. Current distribution inside the Y/d transformers

For the explanation the following positive directions are applied:

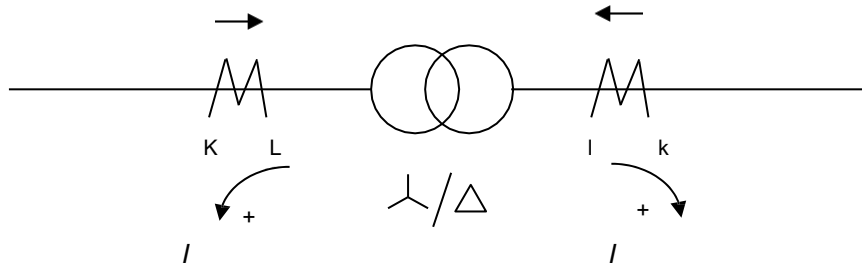


Figure 3-1 Positive directions.

3.1.18.3.1.1. Three-phase fault (or normal load state)

The figure below shows the current distribution inside the transformers in case of three-phase fault or at normal, symmetrical load state:

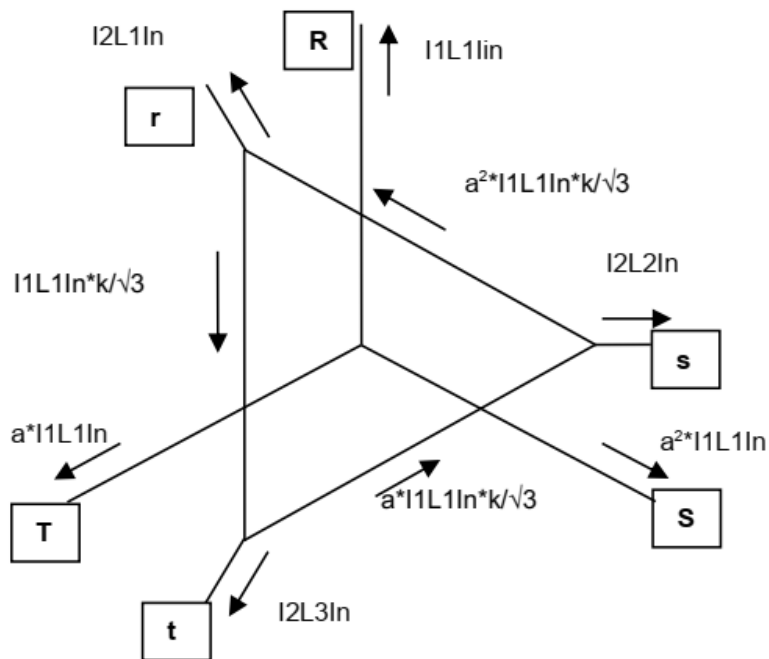


Figure 3-2 Currents in case of normal load (or three-phase fault)

On this figure k is the current ratio. The positive directions are supposed to be directed out of the transformer on both sides, as it is supposed by the differential protection. (If the directions suppose currents flowing through the transformer, then

$$I_{2L1} In = k \cdot I / \sqrt{3} \cdot (a^2 - 1)$$

This indicates that the connection group of this transformer is Yd11.

Here the primary currents form a symmetrical system:

$$\begin{bmatrix} I_{L1n} \\ I_{L2n} \\ I_{L3n} \end{bmatrix} = I \begin{bmatrix} 1 \\ a^2 \\ a \end{bmatrix}$$

The secondary currents can be seen on the figure (please consider the division factor $\sqrt{3}$ in the effective turn's ratio):

$$\begin{bmatrix} I_{2L1n} \\ I_{2L2n} \\ I_{2L3n} \end{bmatrix} = k * I \frac{1}{\sqrt{3}} \begin{bmatrix} (a^2 - 1) \\ (a - a^2) \\ (1 - a) \end{bmatrix}$$

3.1.18.3.1.2. Phase-to-phase fault on the Y side

Assume I current on the primary Y side between phases S ($\equiv L2$) and T ($\equiv L3$).

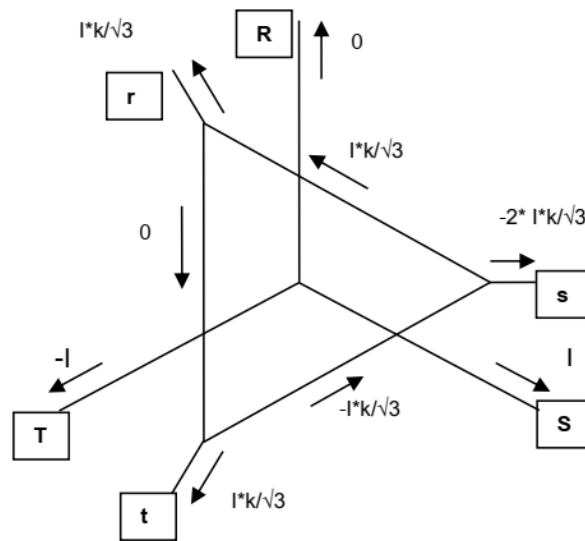


Figure 3-3 Currents inside the transformer at ST fault on the Y side

On this figure k is the current ratio.

The Y side currents are:

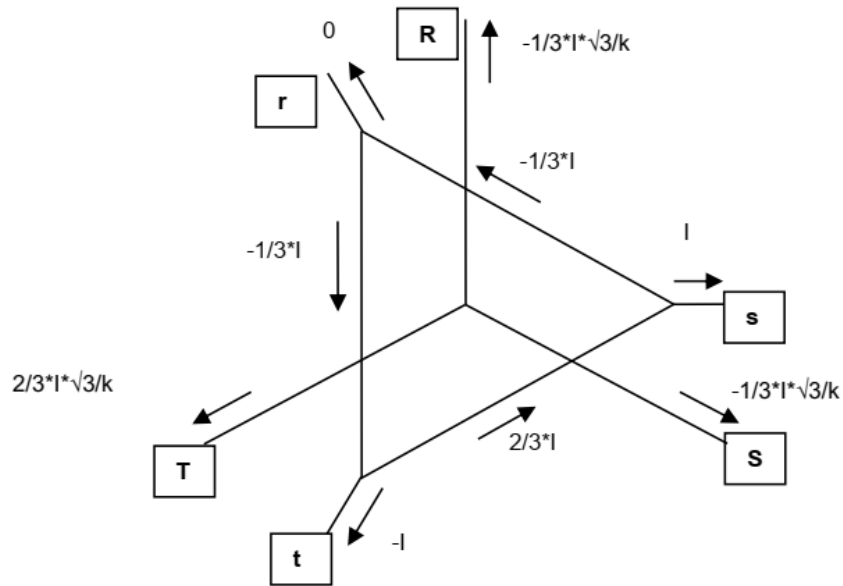
$$\begin{bmatrix} I_{L1n} \\ I_{L2n} \\ I_{L3n} \end{bmatrix} = I \begin{bmatrix} 0 \\ 1 \\ -1 \end{bmatrix}$$

The delta side currents can be seen on this figure:

$$\begin{bmatrix} I_{2L1n} \\ I_{2L2n} \\ I_{2L3n} \end{bmatrix} = k * \frac{1}{\sqrt{3}} * I \begin{bmatrix} 1 \\ -2 \\ 1 \end{bmatrix}$$

3.1.18.3.1.3. Phase-to-phase fault at the delta side

Assume I current on the secondary delta side between phases “s” ($\equiv L2$) and “t” ($\equiv L3$).



.Figure 3-4 Currents inside the transformer at “st” fault on the delta side

On this figure k is the current ratio.

The secondary currents are:

$$\begin{bmatrix} I_{2L1n} \\ I_{2L2n} \\ I_{2L3n} \end{bmatrix} = I \begin{bmatrix} 0 \\ 1 \\ -1 \end{bmatrix}$$

These are distributed in the delta supposing $2/3 : 1/3$ distribution factor. So the primary Y side currents can be seen on this figure:

$$\begin{bmatrix} I_{1L1n} \\ I_{1L2n} \\ I_{1L3n} \end{bmatrix} = \frac{1}{k} * \frac{\sqrt{3}}{3} * I \begin{bmatrix} -1 \\ -1 \\ 2 \end{bmatrix}$$

3.1.18.3.1.4. Single phase external fault at the Y side

- Assume I fault current in the phase R ($\equiv L1$) in case of solidly grounded neutral. No power supply is supposed at the delta side:

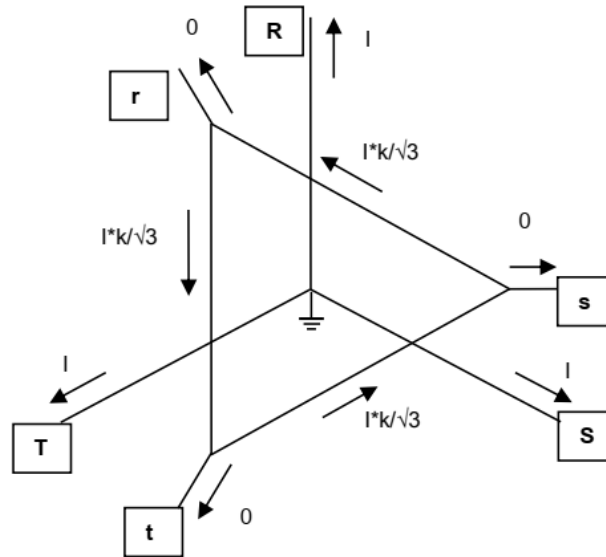


Figure 3-5 Currents inside the transformer at single phase fault at the Y side (Bauch effect)

On this figure k is the current ratio.

The primary Y side currents are:

$$\begin{bmatrix} I_{L1} \\ I_{L2} \\ I_{L3} \end{bmatrix} = I \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$$

On the delta side there are no currents flowing out of the transformer:

$$\begin{bmatrix} I_{2L1} \\ I_{2L2} \\ I_{2L3} \end{bmatrix} = I \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

- Assume I fault current at the Y side in phase R ($\equiv L1$) in case of solidly grounded neutral. Assume the power supply at the delta side:

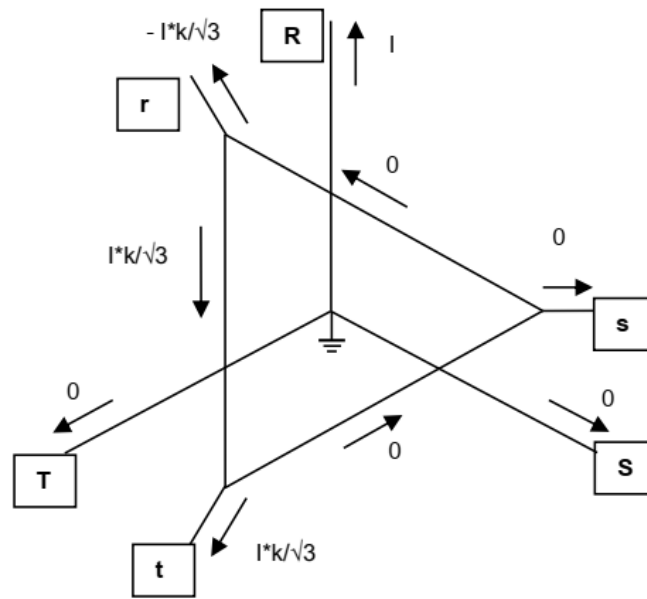


Figure 3-6 Currents inside the transformer at single phase fault at the Y side, supply at the delta side

On this figure k is the current ratio.

The primary Y side currents are:

$$\begin{bmatrix} I_{L1ln} \\ I_{L2ln} \\ I_{L3ln} \end{bmatrix} = I \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

The delta side currents can be seen on this figure:

$$\begin{bmatrix} I_{2L1ln} \\ I_{2L2ln} \\ I_{2L3ln} \end{bmatrix} = k * \frac{1}{\sqrt{3}} * I \begin{bmatrix} -1 \\ 0 \\ 1 \end{bmatrix}$$

3.1.18.3.1.5. Single phase fault at the delta side

The delta side is applied usually at medium voltage levels. If a high/medium voltage transformer with delta secondary is applied then for neutral grounding (Petersen or grounding resistance) a separate neutral grounding transformer is applied. The impedance between the neutral point and the ground suppresses the fault current below 100 A (perhaps 200 A), the Petersen coil allows only some Amperes.

At the delta side there are two locations for the current transformers, supplying the differential protection. In one case the neutral grounding transformer is within the protected zone (see figure below, current transformers at location „Z”). In the other possibility the neutral grounding transformer is excluded from the protected zone (see figure below, current transformers at location „Y”).

3.1.18.3.1.5.1. Power supply at the Y side

As the zero sequence current component of the delta side can influence the behavior of the differential protection (sensitive setting), this chapter analyses the current distribution in case of single phase to ground fault at the delta side.

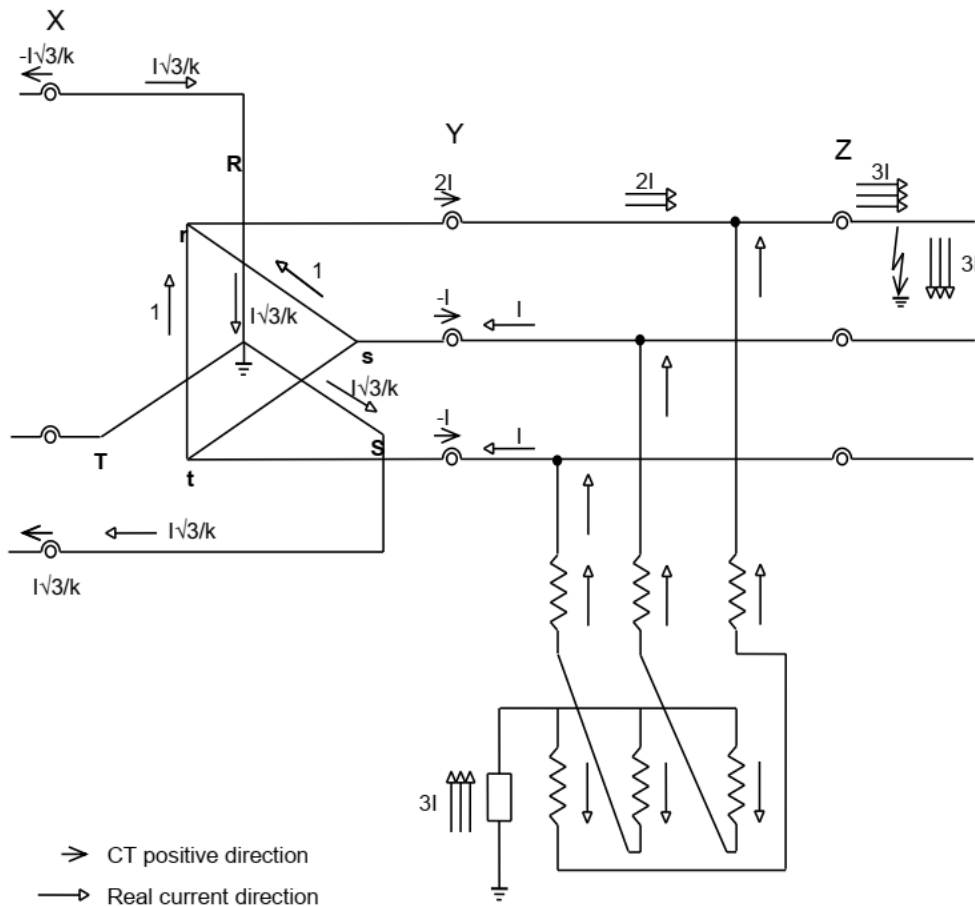


Figure 3-7 Current distribution at external single phase to ground fault, Y side power supply

For the current distribution an external „r” phase fault is assumed, and at the fault location the current is $I_r = 3I_0$. The arrows indicating the real currents can be constructed at this starting point.



Based on the figure above, with positive directions out of the transformer the currents in the CTs are:

On the Y side (location X in Fig. 2-7):

$$\begin{bmatrix} I_{1L1In} \\ I_{1L2In} \\ I_{1L3In} \end{bmatrix} = I\sqrt{3}/k \begin{bmatrix} -1 \\ 1 \\ 0 \end{bmatrix}$$

The delta side currents at the location „Y”:

$$\begin{bmatrix} I_{2L1In} \\ I_{2L2In} \\ I_{2L3In} \end{bmatrix} = I \begin{bmatrix} 2 \\ -1 \\ -1 \end{bmatrix}$$

If the current is measured at location „Z” then the node - which has to fulfill the Kirchhoff's node law – is extended by the neutral grounding transformer, but the current flowing between the neutral point and the ground is not measured and not added to the current summation. This current is the 3I₀ zero sequence component, which can be calculated as the sum of the phase currents. At location „Z” the zero sequence component has no other path to flow, but the neutral grounding transformer.

The delta side currents at the location „Z”:

$$\begin{bmatrix} I_{2L1In} \\ I_{2L2In} \\ I_{2L3In} \end{bmatrix} = I \begin{bmatrix} 3 \\ 0 \\ 0 \end{bmatrix}$$

In this case the zero sequence current is I. If the vector group compensation is for the delta side, then the transformation does not change this current, on the high voltage side however there is no zero sequence component. But anyhow the transformation would filter this component out.

In the practice this zero sequence current component is always below the rated current of the transformer, but in case of sensitive setting of the differential protection, or at mechanical application of a relay test set without any logic control this can result faulty operation of the differential protection in case of external fault.

To avoid this faulty operation there is a binary parameter in the differential protection, the effect of which is to subtract the zero sequence current component from the phase currents, if it is needed:

$$\begin{bmatrix} I_{2L1In} \\ I_{2L2In} \\ I_{2L3In} \end{bmatrix} = \begin{bmatrix} I_{2L1In}' - I_{20} \\ I_{2L2In}' - I_{20} \\ I_{2L3In}' - I_{20} \end{bmatrix} = I \begin{bmatrix} 3 \\ 0 \\ 0 \end{bmatrix} - I \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} = I \begin{bmatrix} 2 \\ -1 \\ -1 \end{bmatrix}$$

It means that based on the currents of the CT-s located at „Z” the current is calculated, which could be measured at location „Y”.

REMARK: This zero sequence current subtraction could be applied without any consequences in case of current transformers at location „Y” too, because in case of external faults, at this location no zero sequence current can be detected. In case of internal fault however this decreases the faulty phase current by 2/3. This could worsen the sensitivity of the differential protection in case high impedance internal faults. The application of the mentioned binary parameter can disable the subtraction of the zero sequence current in case of measurement at location „Y”.

3.1.18.3.1.5.2. Power supply at the delta side

If on a medium voltage network with neutral grounding transformer connects distributed generators, a possible state of operation can be that the transformer is disconnected at the high voltage Y side. On the Y side no current can flow, and if the differential protection measures the currents on the medium voltage side at location „Z” (Fig. 2-8) then in case of sensitive setting of the characteristic lines or at testing, the differential protection can generate a faulty trip command. The current distribution according to Fig. 2-8 is as follows:

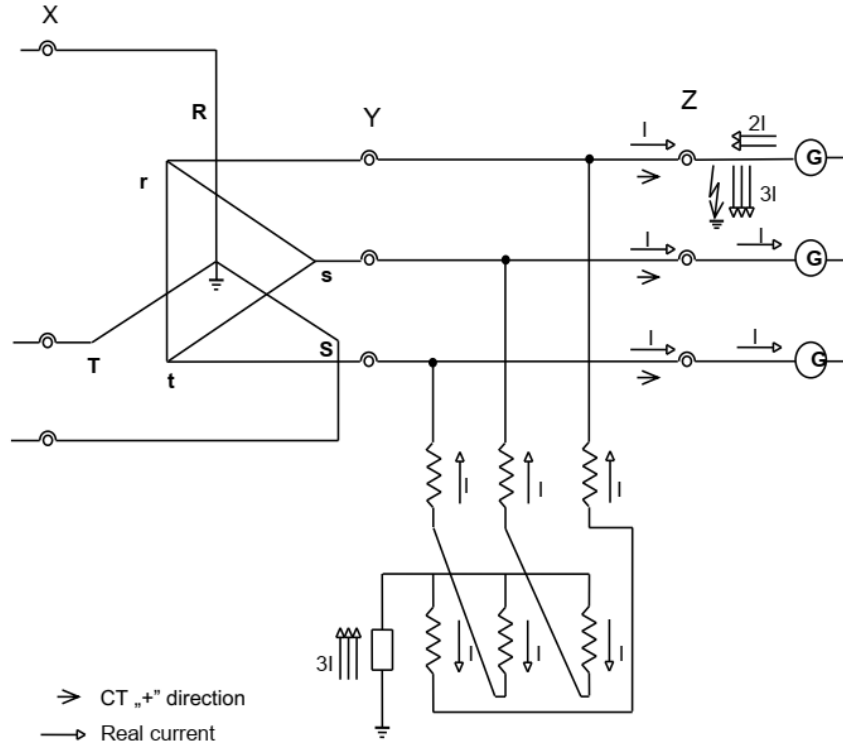


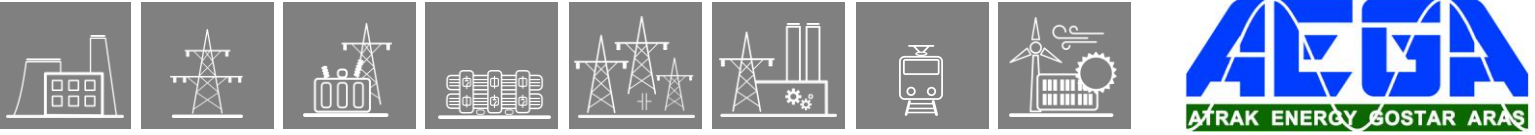
Figure 3-8 Current distribution in case of delta side single phase fault, supply at the delta side

In this case no current is detected at the point „X” (CB open):

$$\begin{bmatrix} I_{1L1In} \\ I_{1L2In} \\ I_{1L3In} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

The measured currents at „Z” can be seen in the figure:

$$\begin{bmatrix} I_{2L1In} \\ I_{2L2In} \\ I_{2L3In} \end{bmatrix} = I \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$$



To avoid mal-operation (trip) at external fault a binary parameter is applied, the effect of which is to subtract the zero sequence current at the delta side:

$$\begin{bmatrix} I_{2L1In} \\ I_{2L2In} \\ I_{2L3In} \end{bmatrix} = \begin{bmatrix} I_{2L1In'} - I_{20} \\ I_{2L2In'} - I_{20} \\ I_{2L3In'} - I_{20} \end{bmatrix} = I \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - I \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

It means that based on the currents of the CT-s located at „Z” the current is calculated, which could be measured at location „Y”.

With this transformation the unwanted trip is avoided.

3.1.18.4. Example for application

For the application example consider a transformer with three voltage levels, according to [Figure 1-1](#). The coils for the primary are connected Y with solidly grounded neutral. The secondary coils are delta connected, and the tertiary coils are also Y connected, but the neutral point is isolated. In this example it is supposed that no neutral grounding transformer is connected within the protected zone.

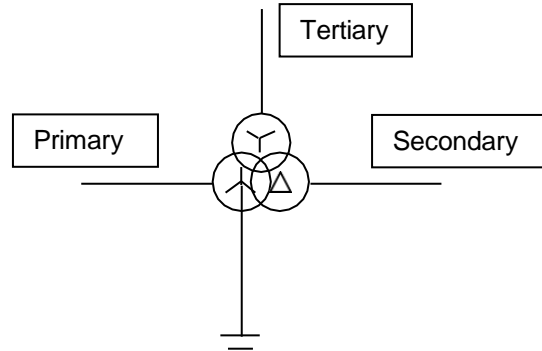


Figure 1-1 Application example

Example transformer data for the application:

| | |
|-------------------|--------------------------------------|
| Rated voltages: | $U1/U2/U3 = 120/36,75/22 \text{ kV}$ |
| Rated power: | $S_n = 40/30/20 \text{ MVA}$ |
| Connection group: | YNd11y6 |

Current transformers installed for the application are shown in [Figure 1-2](#). All P1 points are arranged towards the transformer.

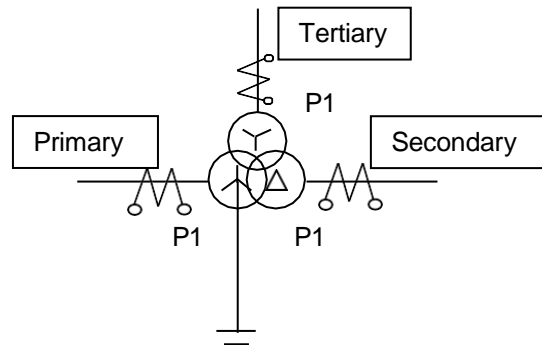


Figure 1-2 Current transformers, assigned to the differential protection function

Current transformer data:

| | |
|----------------|----------|
| Primary side | 1000/1 A |
| Secondary side | 500/1 A |
| Tertiary side | 600/1 A |

Suppose that the transformer is to be protected by differential protection.



The phase differential protection involves the primary, secondary and tertiary windings, for this function the current in the grounding is not applied. The zero sequence current is eliminated numerically using matrix transformation within the differential protection function. See *Figure 1-3*.

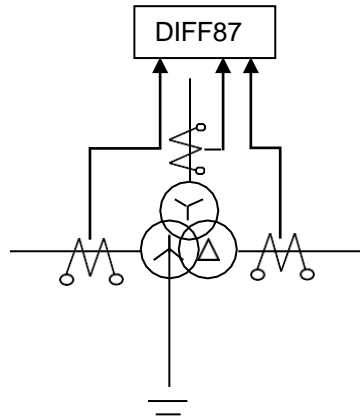


Figure 1-3 Differential protection application

The required connection diagram is shown in *Figure 1-4*. The device contains three current input modules in positions “R”, “S” and “T”. Each current input module contains four CT inputs. The module in “T” is assigned to the primary three phase currents, and the fourth channel is not applied. The module in “S” is reserved for the secondary three phase currents, and the fourth channel is not applied. Similarly, the module in “R” is reserved for the tertiary three phase currents, and the fourth channel is not applied.

Figure 1-4 Shows that the secondary coils of the current transformers are all connected to Y, and the common point is at the transformer side for all voltage levels of the transformer. No auxiliary current transformers are needed.

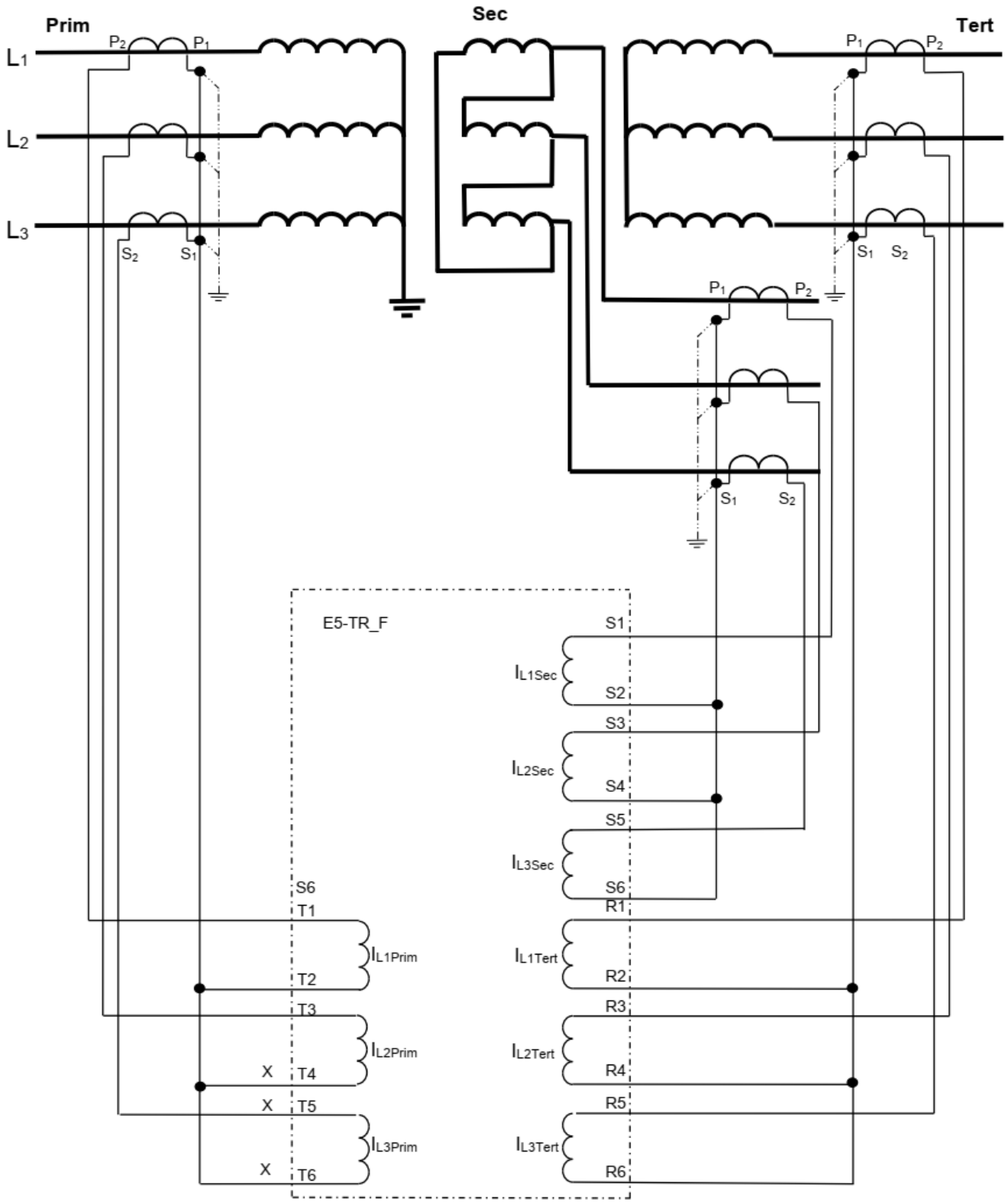


Figure 1-4 Connection diagram for the example

3.1.18.4.1. Setting the CT input function blocks

In the EuroProt+ devices the CT inputs are assigned to CT function blocks. They need parameter setting and also displaying functions are assigned to them. Parameters can be set in the parameter screen of a WEB browser, when there is Internet connection with the device. For details about this communication see the Protecta document “**Remote user interface description**” available in Protecta WEB site www.protecta.hu.

NOTE: the parameters can be set also using the local LCD touch-screen of the device, if no internet connection is available. For details about this communication see the Protecta document “**LCD touchscreen interface description**” available in Protecta WEB site www.protecta.hu.

The parameters of the current input function are explained in the following tables.

Enumerated parameters

| Parameter name | Title | Selection range | Default |
|------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|---------------------|---------|
| Rated secondary current of the first three input channels. 1A or 5A is selected by parameter setting, no hardware modification is needed. | | | |
| CT4_Ch13Nom_EPar_ | Rated Secondary I1-3 | 1A,5A | 1A |
| Rated secondary current of the fourth input channel. 1A or 5A (0.2A, 1A) is selected by parameter setting, no hardware modification is needed. | | | |
| CT4_Ch4Nom_EPar_ | Rated Secondary I4 | 1A,5A (0.2A, 1A) | 1A |
| Definition of the positive direction of the first three currents, given by location of the secondary star connection point | | | |
| CT4_Ch13Dir_EPar_ | Starpoint I1-3 | Line,Bus | Line |
| Definition of the positive direction of the fourth current, given as normal or inverted | | | |
| CT4_Ch4Dir_EPar_ | Direction I4 | Normal,Inverted | Normal |

Table 2-1 The enumerated parameters of the current input function

Floating point parameters

| Parameter name | Title | Dim. | Min | Max | Default |
|-------------------------------------|--------------------|------|-----|------|---------|
| Rated primary current of channel1-3 | | | | | |
| CT4_Pr113_FPar_ | Rated Primary I1-3 | A | 100 | 4000 | 1000 |
| Rated primary current of channel4 | | | | | |
| CT4_Pr114_FPar_ | Rated Primary I4 | A | 100 | 4000 | 1000 |

Table 2-2 The floating point parameters of the current input function

NOTE: The rated primary current of the channels is not needed for the current input function block itself. These values are passed on to the subsequent function blocks.



Using the information given in this example above, the following setting values are assigned:

Primary side and grounding CT:

| | | |
|----------------------|------|------------------------------------------------------------------------------------------------------------------------|
| Rated Secondary I1-3 | 1A | Selected, according to the CT applied at the primary side. |
| Rated Secondary I4 | 1A | Not applied, the value is not considered. |
| Starpoint I1-3 | Line | “Line” in this case means “Toward protected object = Transformer” |
| Direction I4 | | Not applied, the value is not considered. |
| Rated Primary I1-3 | 1000 | Setting, according to the CT applied at the primary side. This parameter is used for scaling the displayed values only |
| Rated Primary I4 | | Not applied, the value is not considered. |

Secondary side:

| | | |
|----------------------|------|--------------------------------------------------------------------------------------------------------------------------|
| Rated Secondary I1-3 | 1A | Selected, according to the CT applied at the secondary side. |
| Rated Secondary I4 | | Not applied, the value is not considered. |
| Starpoint I1-3 | Line | “Line” in this case means “Toward protected object = Transformer” |
| Direction I4 | | Not applied, the value is not considered. |
| Rated Primary I1-3 | 500 | Setting, according to the CT applied at the secondary side. This parameter is used for scaling the displayed values only |
| Rated Primary I4 | | Not applied, the value is not considered. |

Tertiary side:

| | | |
|----------------------|------|-------------------------------------------------------------------------------------------------------------------------|
| Rated Secondary I1-3 | 1A | Selected, according to the CT applied at the tertiary side. |
| Rated Secondary I4 | | Not applied, the value is not considered. |
| Starpoint I1-3 | Line | “Line” in this case means “Toward protected object = Transformer” |
| Direction I4 | | Not applied, the value is not considered. |
| Rated Primary I1-3 | 600 | Setting, according to the CT applied at the tertiary side. This parameter is used for scaling the displayed values only |
| Rated Primary I4 | | Not applied, the value is not considered. |

Table 2-3 Summary of the CT parameter setting

3.1.18.4.2. Parameter setting for the differential function

The parameters with the selected settings for the example application for the differential protection function are summarized in Table 3-1 below. Some parameters need basic considerations some of them need also calculation. This is explained in the paragraphs below:

| | | |
|----------------|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Operation | On | Set this parameter to “On” for enabling the function. NOTE: In tests, when other protection functions are tested. Switch this parameter to “Off” to prevent false test results. The details see in <u>paragraph 3.1</u> |
| Pri-Sec VGroup | Yy6 | This setting is selected according to the protected object. NOTE: see explanation in <u>paragraph 3.2</u> |
| Pri-Ter VGroup | Yd11 | This setting is selected according to the protected object. (Example) NOTE: see explanation in <u>paragraph 3.2</u> |

| | | |
|----------------------|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Zero Seq Elimination | False | Not checked. This parameter is needed only if there is isolated (Not grounded) side of the transformer and there is and additional neutral grounding transformer within the protected zone. As this additional neutral grounding transformer is not supposed to be present, the checkbox can remain unchecked. This is described in paragraph 3.6 |
| TR Primary Comp | 20 | This value needs calculation. This is described in paragraph 3.3 |
| TR Secondary Comp | 132 | This value needs calculation. This is described in paragraph 3.3 |
| TR Tertiary Comp | 184 | This value needs calculation. This is described in paragraph 3.3 |
| 2nd Harm Ratio | 15 | This value needs some considerations. These are described in paragraph 3.4 |
| 5nd Harm Ratio | 25 | This value needs some considerations. These are described in paragraph 3.4 |
| Base Sensitivity | 50 | Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 3.5 |
| 1st Slope | 50 | Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 3.5 |
| 1st Slope Bias Limit | 400 | Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 3.5 |
| UnRst Diff Current | 800 | Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 3.5 |

Table 3-1 Summary of the differential protection parameter setting

3.1.18.4.2.1. Enabling the differential protection function

The DIF87 differential protection function can be applied as main protection for transformers, generators, large motors and also for protection of lines or cables on solidly grounded networks, or any combination of the mentioned protected objects.

The version DIF87_3w can be applied to protect transformers with three voltage levels. The simpler version DIF87_2w is designed to protect two winding transformers.

The parameter for enabling the differential protection function is shown in table below:

| Parameter name | Title | Selection range | Default |
|-----------------------------------------------------------|-----------|-----------------|---------|
| Parameter to enable the differential protection function: | | | |
| DIF87_Op_EPar_ | Operation | Off, On | Off |

For enabling the function, set this Boolean parameter:

„Operation” = „On”

Additionally the differential protection function block has a binary input signal: „Blk”. In active state of this input signal the function is blocked. The conditions for blocking can be programmed using the graphic logic editor

3.1.18.4.2.2. Setting the vector compensation

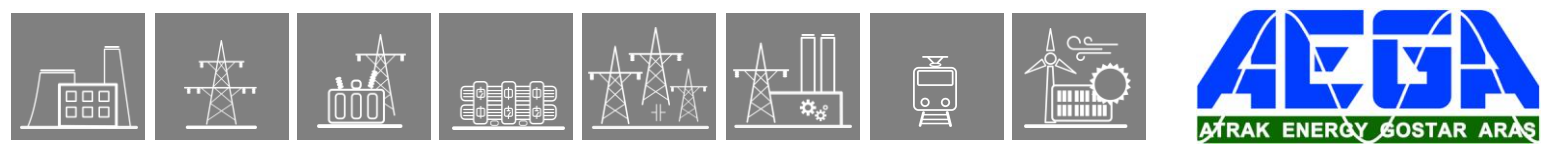
A three-phase transformer transforms the primary current to the secondary side according to the turn's ratio and the connection of the coils. The connection of the coils Y (star), D (delta) or Z (zig-zag) results phase shift of the current vectors. The numerical transformer differential protection function applies matrix transformation for the phase currents, according to the connection group to match them on all sides of the transformer.

The required matrix transformation is defined by correct selection of the transformer's connection group.

The transformer differential protection function in Protecta EuroProt+ devices transforms all currents to the delta side. This method is the numerical realization of the traditional principle: connect the secondary coils of the current transformers on the Y side of the transformer to delta, and apply y connection of the CT secondary coils on the delta side of the transformer. This transformation automatically eliminates also the problem caused by zero sequence current components.

Parameters for matching the vector group of the transformer are listed in the table below:

| Parameter name | Title | Selection range | Default |
|----------------------------------------------------------------------------------------------|-----------------|---------------------------------------------------------------------------------------------|---------|
| Parameter to select connection group of the transformer coils in primary-secondary relation: | | | |
| DIF87_VGrSec_EPar_ | Pri-Sec VGroup* | Dy1,Dy5,Dy7,Dy11,Dd0,Dd6,Dz0,Dz2,Dz4,Dz6,Dz8,Dz10,Yy0,Yy6,Yd1,Yd5,Yd7,Yd11,Yz1,Yz5,Yz7,Yz11 | Dd0 |
| Parameter to select connection group of the transformer coils in primary-secondary relation: | | | |
| DIF87_VGrTer_EPar_ | Pri-Ter VGroup* | Dy1,Dy5,Dy7,Dy11,Dd0,Dd6,Dz0,Dz2,Dz4,Dz6,Dz8,Dz10,Yy0,Yy6,Yd1,Yd5,Yd7,Yd11,Yz1,Yz5,Yz7,Yz11 | Dd0 |



* If the connection of the primary winding in primary-secondary and primary tertiary relation is selected in contradiction then the protection function is automatically disabled, and the function generates a warning signal.

The selection of these parameters is easy: select the real connection relationship of the protected transformer. For autotransformers select always Yy0.

If the protection function is applied to protect the unit of transformer-line or transformer-cable then the parameters should be selected as the connection group can be seen from the location of the protection. As an example: a transformer of Yd11 connection group is seen at the other side as a transformer Dy1.

3.1.18.4.2.3. Setting the magnitude matching

The basic principle is that in case of power transfer at rated current the currents to be compared should be the same, 100%. This means that in case of any external faults there will be no current difference, the differential function is balanced and stable.

For a two winding transformer, usually the rated current of the transformer is considered to be the base current, considered to be 100%. (NOTE: any other current value could also be selected for this reference current.) The ratio of the secondary and primary rated currents is the turn's ratio of the transformer. For the setting calculation, calculate the ratio of the transformer rated current and the CT rated primary current. These values expressed in % are the parameter values to be set for parameters „TR Primary Comp” and “TR Secondary Comp”.

For a three winding transformer in the example the rated power of the winding is not the same (40 MVA, 30 MVA and 20 MVA), consequently the ratio of rated currents for the windings do not match the turn's ratio of the coils. In this case the usual procedure is to consider the rated current of the primary side, and transform this current both for the secondary and to the tertiary side. These calculated currents should be related to the rated currents of the CT-s. These values expressed in % are the parameter values to be set for parameters „TR Primary Comp”, “TR Secondary Comp” and “TR Tertiary Comp”.

In the example:

The rated primary current is calculated from the transformer data above. This is the reference current.

$I_{1nprimary} = 192 \text{ A}$
 $I_{2nprimary} = 471 \text{ A}$ based on the turn's ratio it is: 627 A
 $I_{3nprimary} = 525 \text{ A}$ based on the turn's ratio it is: 1047 A

The calculation of the setting values is as follows

„TR Primary Comp”= $100 \cdot 192 \text{ A} / 1000 \text{ A} = 19.2\%$ It needs correction.
 „TR Secondary Comp”= $100 \cdot 627 \text{ A} / 500 \text{ A} = 125.4\%$ It needs correction, using the same factor
 „TR Tertiary Comp” = $100 \cdot 1047 \text{ A} / 600 \text{ A} = 174.5\%$ It needs correction, using the same factor

For the 120 kV side the setting of 19% is below the low limit of the parameter range. Select instead 20 %. Consequently the compensation values both for the secondary and tertiary sides should be multiplied by 20/19. Note this correction means only that not the rated current but a slightly different value is selected as the base current.

„TR Primary Comp”= 20 %
 „TR Secondary Comp”= $20/19 \cdot 125.4 \% = 132 \%$
 „TR Tertiary Comp” = $20/19 \cdot 174.5 \% = 184 \%$

3.1.18.4.2.4. Considerations, related to the harmonic restraint

When a transformer is energized then due to the asymmetric saturation of the iron core a high “inrush current” can flow from one side into the transformer. This is a pure differential current. To prevent unwanted operation of the differential protection the special waveform of the inrush current is identified. The principle is the detection of the second harmonic content, which is present in the inrush current, but its value can be neglected in any fault current. For the differential current, the second harmonic component in the evaluation is related to the value of the base harmonic. This is the parameter „2nd Harm Ratio”. If this ratio gets higher due to inrush current, the trip command is blocked.

When a transformer is overexcited then the iron core is saturated symmetrically, resulting high current peaks, distorting both the positive and the negative sinusoidal current shape. In this current shape the fifth harmonic is characteristic. To prevent mal-operation, this component of the differential current is analyzed and compared to the base harmonic. If the ratio is high, then the differential current is caused by the over-excitation, the trip command is blocked. If however the fifth harmonic content is low, then the high differential current, which is a fault current, results trip command. The ratio is the parameter „5th Harm Ratio”.

If no results of detailed harmonic analysis are available, apply the factory setting, which can be corrected later. The proposed setting values are:

and $\text{„2nd Harm Ratio”} = 15 \%$
 $\text{„5th Harm Ratio”} = 25 \%$

3.1.18.4.3. Considerations, related to the differential characteristic for the differential protection function

The differential characteristic is shown in *Figure 3-1*. If the calculated (I_{bias}, I_{diff}) operating point is above the characteristic, then the differential protection operates.

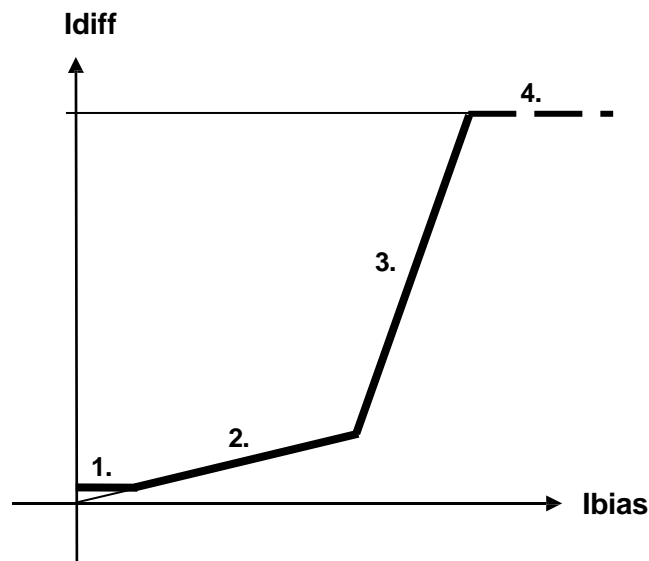
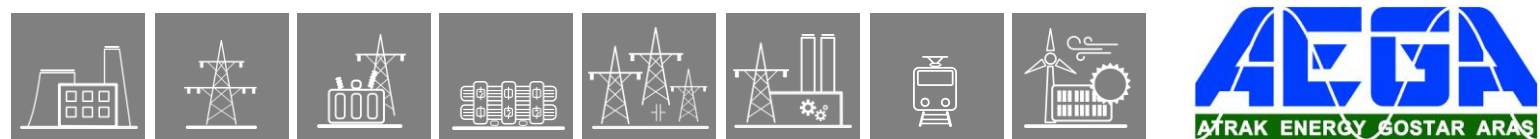


Figure 3-1 The differential characteristic

This characteristic has four sections; each of them is a straight line. The parameters define the position of these lines on the I_{diff} - I_{bias} plane.

The first parameter is “Base Sensitivity”. It defines the minimum differential current for the operation. Its role is to prevent mal-operation in case of current noises and measuring errors for small currents. In this example the selected setting value is the less sensitive selection:



„Base Sensitivity” = 50 %,

This value can be tested easily: inject three phase symmetrical currents from one side only and increase its value. The operation is expected if this current gets above 50% of the reference current. (In this example it is $0.5 \cdot 0.87A$. NOTE: for asymmetrical fault current this value changes due to the matrix transformation.)

The second section of the characteristic is a line through the origin of the I_{diff} - I_{bias} plane. The slope of this line serves to compensate the not correct matching of the CT-s, e.g. due to the different tap-changer positions and the CT errors. Due to these causes the error current increases if the current flowing through the transformer increases. The parameter is “1st Slope”. The mathematical expression of the second section of the characteristic is

$$I_{diff} = \frac{1stSlope}{100} * I_{bias}$$

. The steps for getting the parameter value are as follows:

- Calculate the error in percent, due to not correct matching (To be calculated for all three voltage levels):

$$x\% = \left(1 - \left| \frac{I_{\cdot} \cdot required_matching}{I_{\cdot} \cdot matching} \right| \right) * 100$$

- The unbalance of the differential protection at top or bottom position of the tap changer in percent, related to the value of 0 position ($r_{max}\%$):

$$x\% = |r_{max}\%|$$

Select the biggest value of the calculated $x\%$ values above. The setting value is advised to be above this value.

Example: suppose the voltage control range to be $+18\%/-12\%$, and the reference position for current balancing is the 0 position, then the parameter value with 1,5x safety is:

$$\text{„1st Slope”} = 1,5 \cdot 18 = 27 \rightarrow 30 \%$$

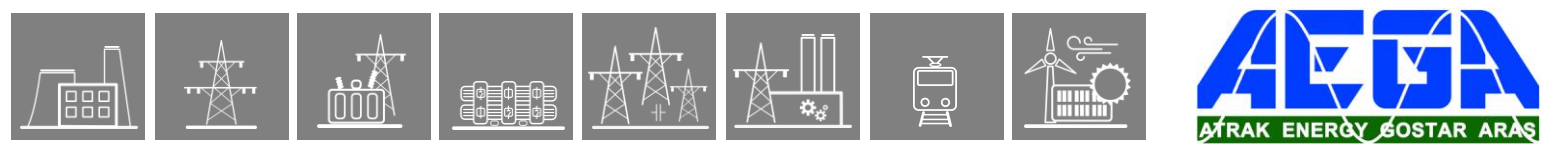
Another choice for calculation is the selection the mid-position of the tap-changer. This is in this example as follows: The full position range is $18 + 12 = 30\%$. The half value is 15% , accordingly the mid-position is $+3\%$. With this the voltage ratio of the transformer to be considered is to be increased by $118/115$, and the balancing of the current is to be determined for this voltage. In this case only $\pm 15\%$ tap position range can be considered, and the value of this parameter is decreased to:

$$\text{„1st Slope”} = 1,5 \cdot 15 = 22,5 \rightarrow 25 \%$$

The slope of the third section of the characteristic is higher. This is to compensate the increased CT error, due to the CT saturation at higher currents. This higher slope is a factory setting: 200%. The parameter “1st Slope Bias Limit” defines the intersection point of section 2 and 3.

This parameter value is influenced by the highest fault current in the protected object and the applied current transformer saturation point related to the rated value. If the current transformer is less over-dimensioned then select the parameter vale for “1st Slope Bias Limit” low. The usual consideration is: for relatively high currents select 200 %, for low fault currents select 1000 %.

The fourth section of the characteristic is the unrestrained section. The related parameter is “UnRst Diff Current”. This parameter serves unrestrained fast operation if the high magnitude of the fault current indicates internal fault. The calculation determines the maximal external fault current, and the setting value should be above this current.



3.1.18.4.4. Considerations for zero sequence elimination

In solidly grounded high voltage networks, in case of external earth faults, the Y-delta transformers supply zero sequence current, which is present on the Y side only. No zero sequence current can flow on the delta side. When comparing the currents in the differential protection, this could cause unwanted operation.

The differential protection function in the Protecta EuroProt+ devices eliminates the Y side zero sequence current by matrix transformation (simulating the old type delta connected CT secondary behavior). This elimination is automatic, no additional solution is needed.

In several cases, however, there is additional neutral grounding transformer on the delta side of the transformer within the protected zone. Between the neutral point of this additional transformer an arc suppression Petersen coil, or a grounding resistor is connected. The Petersen coil minimizes the earth-fault current to some Amperes, the resistor limits the earth-fault current to 100 A (in some cases to 200 A).

If the neutral grounding transformer is not in the protected zone, it is outside the current transformers, then set:

„ZeroSeq Elimination” = „False” (Not checked)

In some cases, however, the neutral grounding transformer is closely connected to the main transformer's delta side terminals; it is in the protected zone. The advantage of this arrangement is that the energizing the transformer immediately solves the neutral grounding problems.

In case of external earth-fault the zero sequence current of the neutral grounding transformer is detected by the delta side current transformers. The zero sequence elimination is needed. In this case set

„ZeroSeq Elimination” = „True” (Checked)

3.1.18.4.5. Application of the binary signals

The binary output status signals are usually applied in the graphic logic editor as input signals. The logic relationship can be programmed freely.

The available binary output status signals of the differential protection function are listed in the table below:

| Binary output signals | Signal title | Explanation |
|-----------------------------------------------|-----------------------|----------------------------------------------------------------------------------------------------------|
| Restrained differential protection function | | |
| DIF87_L1St_Grl_ | Start L1 | Start of the restrained differential protection function in phase L1 (after vector group compensation) |
| DIF87_L2St_Grl_ | Start L2 | Start of the restrained differential protection function in phase L2 (after vector group compensation) |
| DIF87_L3St_Grl_ | Start L3 | Start of the restrained differential protection function in phase L3 (after vector group compensation) |
| DIF87_GenSt_Grl | General Start | General start of the restrained differential protection function |
| Unrestrained differential protection function | | |
| DIF87_UnRL1St_Grl_ | Start L1 unrestr. | Start of the unrestrained differential protection function in phase L1 (after vector group compensation) |
| DIF87_UnRL2St_Grl_ | Start L2 unrestr. | Start of the unrestrained differential protection function in phase L2 (after vector group compensation) |
| DIF87_UnRL3St_Grl_ | Start L3 unrestr. | Start of the unrestrained differential protection function in phase L3 (after vector group compensation) |
| DIF87_UnRGenSt_Grl_ | General Start unrestr | General start of the unrestrained differential protection function |
| Harmonic blocking | | |
| DIF87_2HBlk_Grl | 2.Harm Restr. | Restraint caused by high second harmonic content in any of the differential currents |
| DIF87_5HBlk_Grl | 5.Harm Restr. | Restraint caused by high fifth harmonic content in any of the differential currents |

The differential protection function has a binary input signal, which serves disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

| Binary input signal | Explanation |
|---------------------|----------------------------------------------------------------------------------------------------------|
| DIF87_Blkc_GrO | Output status of a graphic equation defined by the user to disable the differential protection function. |

3.1.19. Inrush current detection function

3.1.19.1. Application

When an inductive element with an iron core (transformer, reactor, etc.) is energized, high current peak values can be detected. This is caused by the transient asymmetric saturation of the iron core as a nonlinear element in the power network. The sizing of the iron core is usually sufficient to keep the steady state magnetic flux values below the saturation point of the iron core, so the inrush transient slowly dies out. These current peaks depend also on random factors such as the phase angle at energizing. Depending on the shape of the magnetization curve of the iron core, the detected peaks can be several times above the rated current peaks. Additionally, in medium or high voltage networks, where losses and damping are low, the indicated high current values may be sustained at length. Figure 1-1 shows a typical example for the inrush current shapes of a three-phase transformer.

As a consequence, overcurrent relays, differential relays or distance relays may start, and because of the long duration of the high current peaks, they may generate an unwanted trip command.

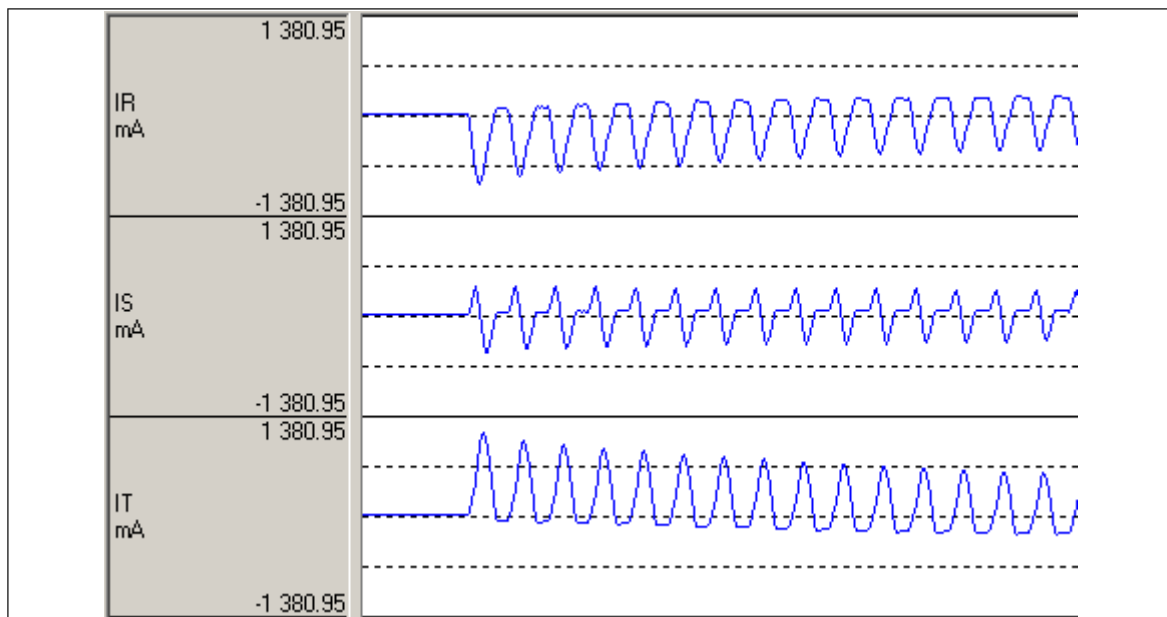
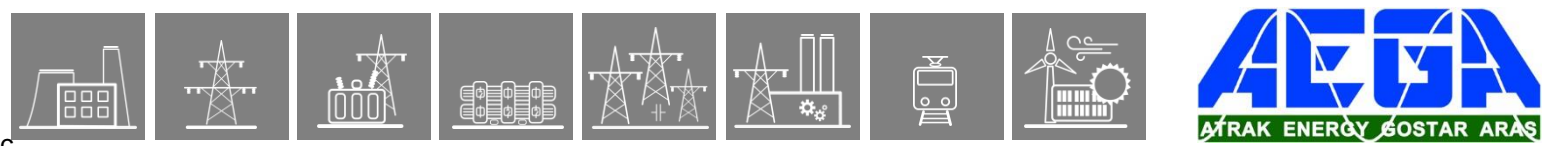


Figure 1-1 Example: A typical inrush current

The inrush current detection function can distinguish between high currents caused by overload or faults and the high currents during the inrush time.

Using the inrush detection binary signals, other protection functions can be blocked during the transient period so as to avoid the unwanted trip.

Some protection functions use these signals automatically, but a stand-alone inrush detection function block is also available for application at the user's discretion.



3.1.19.1.1. Mode of operation

The operating principle of the inrush current detection function is based on the special shape of the inrush current.

As Figure 1-1 shows, the typical inrush current in one or two phases is distorted and asymmetrical to the time axis: for example, in IT of the Figure above the positive peaks are high while no peaks can be detected in the negative domain.

The theory of the Fourier analysis states that even harmonic components (2nd, 4th etc.) are dominant in waves distorted as described above. The component with the highest value is the second one.

Typical overload and fault currents do not contain high even harmonic components.

The inrush current detection function processes the Fourier basic harmonic component and the second harmonic component of the three phase currents. If the ratio of the second harmonic and the base Fourier harmonic is above the setting value of the parameter 2nd Harm Ratio, an inrush detection signal is generated.

The signal is output only if the base harmonic component is above the level defined by the setting of the parameter IPh Base Sens. This prevents unwanted operation in the event that low currents contain relatively high error signals.

The function operates independently using all three phase currents individually, and additionally, a general inrush detection signal is generated if any of the phases detects inrush current.

The function can be disabled by the binary input INR2_**Blk**_GrO_. This signal is the result of logic equations graphically edited by the user.

The **inputs** of the inrush current detection function are

- the basic and second Fourier components of three phase currents,
- binary input,
- parameters.

The **output** signals of the inrush current detection function are

- inrush detection in phases L1, L2 or L3 individually,
- a general inrush detection signal.

3.1.19.2. Inrush current detection function overview

The function block of the inrush current detection function is shown in Figure 2-1. This block shows all binary input and output status signals that are applicable in the graphic equation editor.

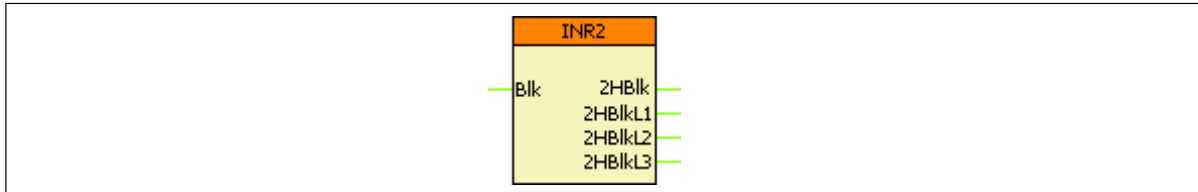


Figure 2-1 The function block of the inrush current detection function

3.1.19.2.1. Settings

3.1.19.2.1.1. Parameters

The available parameters are listed below in order of their appearance in the *parameters* menu. If the setting range of a parameter should be extended, contact Protecta Support.

Table 2-1 Parameters of the inrush current detection function

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|----------------------------|-----|----------|------|---------|------------------------------------------------------------------------------------|
| Operation | - | Off, On | - | Off | Enabling the function |
| 2 nd Harm Ratio | % | 5 – 50 | 1 | 15 | Ratio of the second harmonic Fourier component and the basic harmonic component. |
| IPh Base Sens | % | 20 – 100 | 1 | 30 | The function operates only if the base harmonic component is be above this setting |

3.1.19.2.2. Function I/O

This section briefly describes the analogue and digital inputs and outputs of the function block.

3.1.19.2.2.1. Analogue inputs

The basic and second Fourier components of three phase currents.

3.1.19.2.2.2. Binary input signals (graphed output statuses)

The conditions of the binary inputs are defined by the user, applying the graphic equation editor (*Logic Editor*). Parts written in **bold** are seen on the left side function block in the Logic editor.

Table 2-2 The binary input signal of the inrush current detection function

| BINARY INPUT SIGNAL | EXPLANATION |
|---------------------|--------------------------------|
| INR2_2HBik_GrO_ | Blocking input of the function |

3.1.19.2.2.3. Binary output signals (graphed input statuses)

These signals can be used in EuroCAP to assign to LED, user LCD object etc. Parts written in **bold** are seen on the right side of the function block in the *Logic Editor*.

Table 2-3 The binary output signals of the inrush current detection function

| BINARY OUTPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|----------------------|--------------|----------------------------------------------------|
| INR2_2HBik_GrI_ | Inrush | Inrush current detected in one of the three phases |
| INR2_2HBikL1_GrI_ | Inrush L1 | Inrush current detected in phase L1 |
| INR2_2HBikL2_GrI_ | Inrush L2 | Inrush current detected in phase L2 |
| INR2_2HBikL3_GrI_ | Inrush L3 | Inrush current detected in phase L3 |

3.1.19.2.2.4. Online data

Visible values on the *online data* page.

Table 2-4 Online displayed data of the inrush current detection function

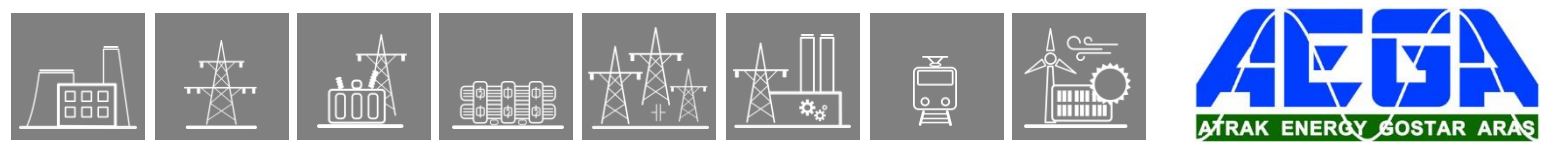
| SIGNAL TITLE | DIMENSION | EXPLANATION |
|--------------|-----------|----------------------------------------------------|
| Inrush L1 | - | Inrush current detected in phase L1 |
| Inrush L2 | - | Inrush current detected in phase L2 |
| Inrush L3 | - | Inrush current detected in phase L3 |
| Inrush | - | Inrush current detected in one of the three phases |

3.1.19.2.2.5. Events

The following events are generated in the event list, as well as sent to the SCADA according to the configuration.

Table 2-5 Generated events of the inrush current detection function

| EVENT | VALUE | EXPLANATION |
|---------------------------------|---------|----------------------------------------------------|
| 2 nd Harm. Restraint | off, on | Inrush current detected in one of the three phases |



3.1.19.2.3. Technical data

Table 2-6 Technical data of the inrush current detection function

| FUNCTION | VALUE | ACCURACY |
|------------------|---------------------|--------------------|
| Current accuracy | 20 – 2000% of I_n | $\pm 1\%$ of I_n |

3.1.19.2.4. Notes for testing

The differential protection function block (DIF87) has its own, built-in 2nd harmonic restraint feature which works independently from the function described here. For further information, see the Differential Protection Function description.

Keep in mind that there is a minimum requirement for the fundamental component of the current (% is the % of the CT nominal), and the function operates according to the 2nd harmonic content related to the fundamental component.

3.2. Control & supervision functions

3.2.1. Phase-Selective Trip Logic

3.2.1.1. Operation principle

The phase-selective trip logic function operates according to the functionality required by the IEC 61850 standard for the "Trip logic logical node".

3.2.1.1.1. Application

The phase-selective function is applied when one-phase trip commands might be required, mostly in distance protection applications.

The function receives the trip requirements of the protective functions implemented in the device and combines the binary signals and parameters to the outputs of the device.

The trip requirements are programmed by the user, using the graphic equation editor. The decision logic has the following aims:

- Define a minimal impulse duration even if the protection functions detect a very short time fault,
- In case of phase-to-phase faults, involve the third phase in the trip command,
- Fulfill the requirements of the automatic reclosing function to generate a three-phase trip command even in case of single-phase faults,
- In case of an evolving fault, during the evolving fault waiting time include all three phases into the trip command

3.2.1.1.2. The decision logic

The decision logic module combines the status signals and the enumerated parameter to generate the general trip command on the output module of the device.

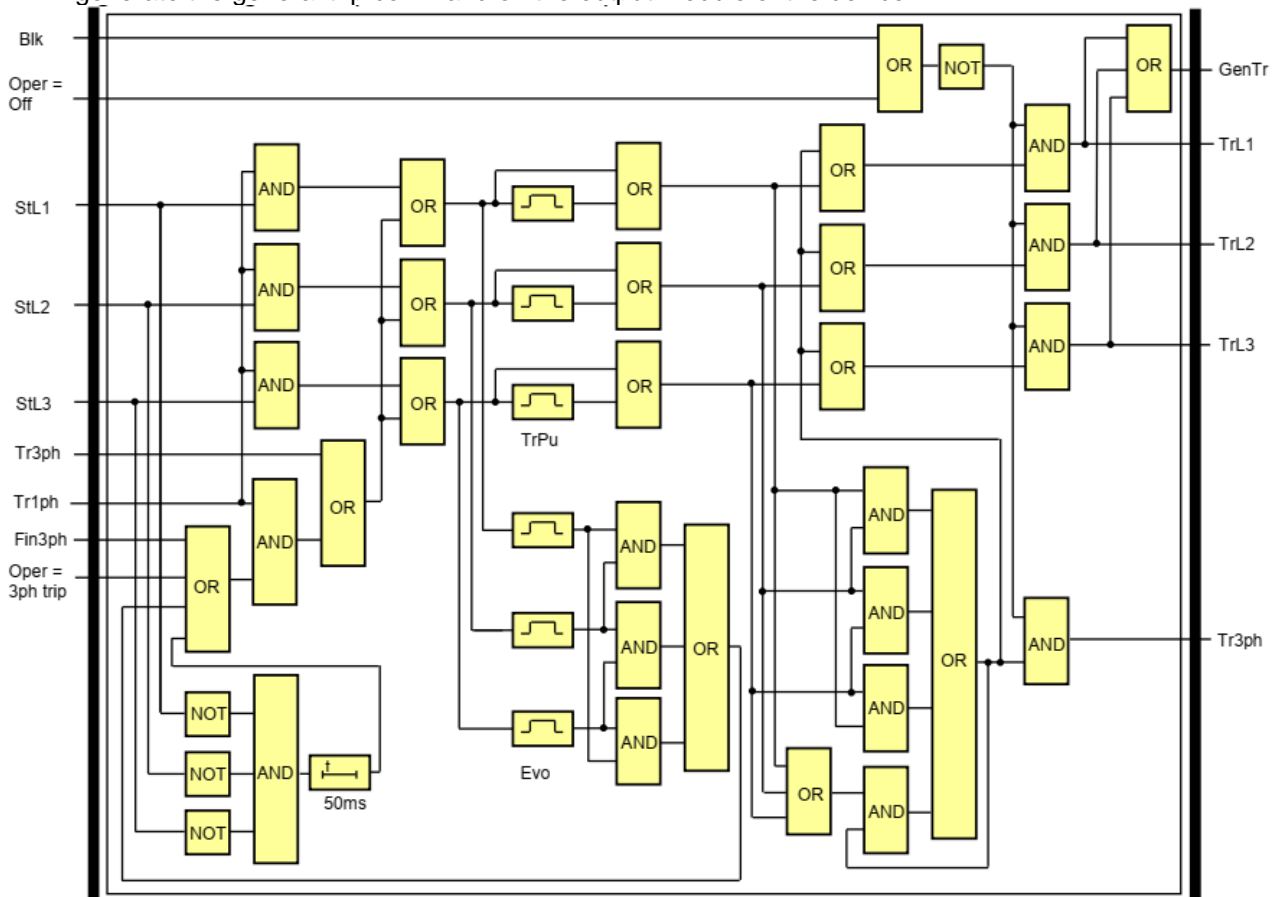


Figure 1-1 Logic scheme of the decision logic

3.2.1.2. PhSel. Trip logic function overview

The graphic appearance of the function block of the phase-selective trip logic function is shown in the figure below.

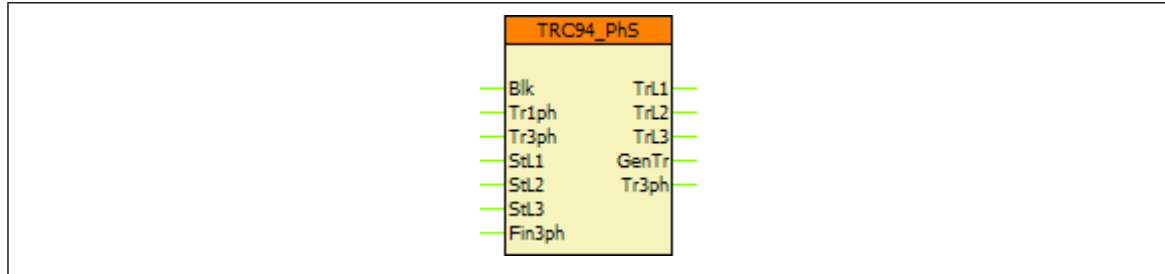


Figure 2-1 Graphic appearance of the function block of the phase-selective trip logic function

3.2.1.2.1. Settings

3.2.1.2.1.1. Parameters

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|---------------------|-----|-----------------------------|------|---------|-----------------------------------------|
| Operation | - | Off, 3ph trip, 1ph/3ph trip | - | Off | Selection of the operating mode |
| Min Pulse Duration | ms | 50 – 60000 | 1 | 150 | Minimum duration of the generated pulse |
| Evolving Fault Time | ms | 50 – 60000 | 1 | 1000 | Waiting time for evolving fault |

Table 2-1 Parameters of the phase-selective trip logic function

3.2.1.2.2. Function I/O

This section describes briefly the analogue and digital inputs and outputs of the function block.

3.2.1.2.2.1. Analogue inputs

This function does not have analogue inputs.

3.2.1.2.2.2. Analogue outputs (measurements)

This function does not have measurements.

3.2.1.2.2.3. Binary input signals (graphed output statuses)

The conditions of the inputs are defined by the user, applying the graphic equation editor (logic editor). The part written in **bold** is seen on the function block in the logic editor.

| BINARY INPUT SIGNAL | EXPLANATION |
|----------------------------|-------------------------------------------------------------|
| TRC94_ Blk _GrO_ | Blocking the outputs of the function |
| TRC94_ Tr1ph _GrO_ | Request for single-phase trip command |
| TRC94_ Tr3ph _GrO_ | Request for three-phase trip command |
| TRC94_ StL1 _GrO_ | Request for trip command in phase L1 |
| TRC94_ StL2 _GrO_ | Request for trip command in phase L2 |
| TRC94_ StL3 _GrO_ | Request for trip command in phase L3 |
| TRC94_ Fin3ph _GrO_ | Forcing three-phase trip even in case of single-phase fault |

Table 2-2 The binary input signals of the phase-selective trip logic function

3.2.1.2.2.4. Binary output signals (graphed input statuses)

The binary output status signals of the differential protection function. Parts written in **bold** are seen on the function block in the logic editor.

| BINARY OUTPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|----------------------|--------------|-----------------------------------------------------------------------|
| TRC94_TrL1_Grl_ | Trip L1 | Generated trip command for phase L1 |
| TRC94_TrL2_Grl_ | Trip L2 | Generated trip command for phase L2 |
| TRC94_TrL3_Grl_ | Trip L3 | Generated trip command for phase L3 |
| TRC94_GenTr_Grl_ | General Trip | Generated general trip command (active for 1ph and 3ph trips as well) |
| TRC94_Tr3ph_Grl_ | 3Ph Trip | Generated three-phase trip command |

Table 2-3 The binary output signal of the phase-selective trip logic function

3.2.1.2.2.5. On-line data

Visible values on the on-line data page:

| SIGNAL TITLE | DIMENSION | EXPLANATION |
|--------------|-----------|------------------------------------------|
| General Trip | - | Status of the General Trip binary output |
| Trip L1 | - | Status of the Trip L1 binary output |
| Trip L2 | - | Status of the Trip L2 binary output |
| Trip L3 | - | Status of the Trip L3 binary output |
| 3Ph Trip | - | Status of the 3Ph Trip binary output |

Table 2-4 On-line data of the phase-selective trip logic function

3.2.1.2.2.6. Events

The following events are generated in the event list, as well as sent to SCADA according to the configuration.

| EVENT | VALUE | EXPLANATION |
|--------------|---------|------------------------------------------|
| Trip L1 | off, on | Status of the Trip L1 binary output |
| Trip L2 | off, on | Status of the Trip L2 binary output |
| Trip L3 | off, on | Status of the Trip L3 binary output |
| General Trip | off, on | Status of the General Trip binary output |

Table 2-5 Event of the phase-selective trip logic function

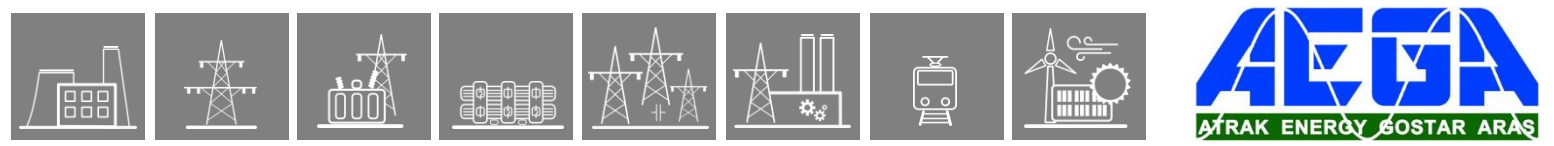
3.2.1.2.3. Technical data

| FUNCTION | VALUE | ACCURACY |
|------------|-------|----------|
| Pulse time | | < 3 ms |

Table 2-6 The technical data of the phase-selective trip logic function

3.2.1.2.3.1. Notes for testing

When using an EuroProt+ device with phase-selective trip logic, the first 3 trip contacts of the trip module are assigned to the corresponding Trip L1-L2-L3 outputs of the Trip Logic function block. These assignments can be checked in the configuration file of the device by using the EuroCAP tool (see the picture below, note that the actual configuration might be different from that of on the figure). It is possible to assign multiple contacts to one trip logic output (mainly when two trip circuits are used).



▼ E1-Line_F

- ▼ Hardware Configuration
 - Connector allocation
 - LED assignment
 - ▼ IO Signals
 - > Analogue Inputs
 - > Analogue Outputs
 - > Binary Inputs
 - > Binary Outputs
 - ▼ Trip definition
 - ▼ Assignment
 - > Communication
 - > Software Configuration
 - > Subscribed GOOSE assignment
 - > System

Trip definition / Assignment

Add

Insert

Remove

Modify

Move Up

Move Dn

| Ix | Name | Title | Defined by | Parameters | Type |
|----|-------------|---------|-------------------|----------------------------------|------------------|
| 0 | TripAssign1 | Trip L1 | RootFunctionBlock | TRC94_TripL1_TLO_TripContact_O02 | 4444 Trip assign |
| 1 | TripAssign2 | Trip L2 | RootFunctionBlock | TRC94_TripL2_TLO_TripContact_O04 | 4444 Trip assign |
| 2 | TripAssign3 | Trip L3 | RootFunctionBlock | TRC94_TripL3_TLO_TripContact_O06 | 4444 Trip assign |

Figure 2-2 Trip assignment in EuroCAP

During commissioning the testing personnel must make sure that, along with the protection functions under test, the corresponding Trip Logic(s) is (are) switched on ('Operation' parameter is set to other than 'Off') before starting the testing, otherwise there will be no actual trip signal given on the assigned trip contacts.

3.2.2. Circuit breaker wear monitoring function

If a circuit breaker interrupts a current, the electric arc between the contacts results some metal loss. If the metal loss due to the burning of the electric arc becomes substantial, the contacts must be replaced.

Manufacturers define the permitted number of short circuits by formulas such as:

$$\sum_{i=1}^n I_i^k = CycNum$$

where

n = number of short circuits

k = exponent, calculated by the algorithm, based on the parameters I = short-circuit current, kA (RMS)

CycNum = total value of weighted breaking currents.

Similar information is conveyed by the diagram below. This shows the number of permitted interruptions (logarithmic scaling) versus short-circuit current (logarithmic scaling) that the contacts in a circuit breaker can manage before the metal loss due to burning becomes so significant that the contacts must be replaced.

Number of interruptions

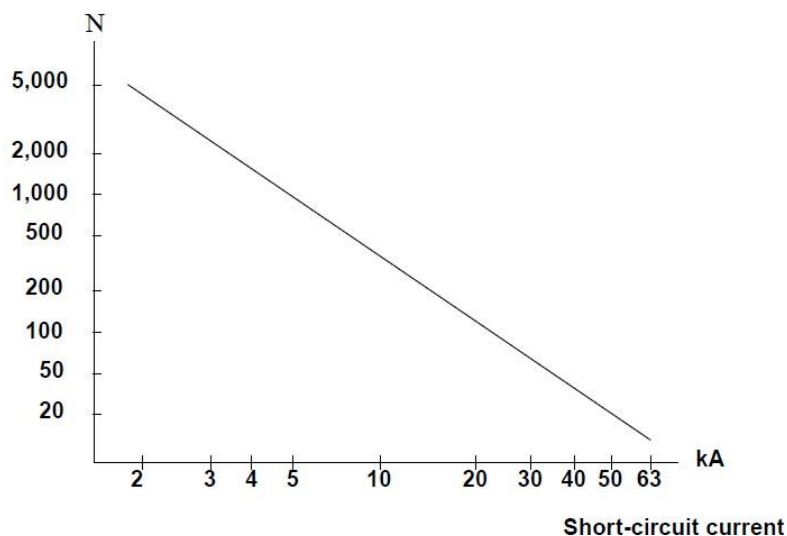
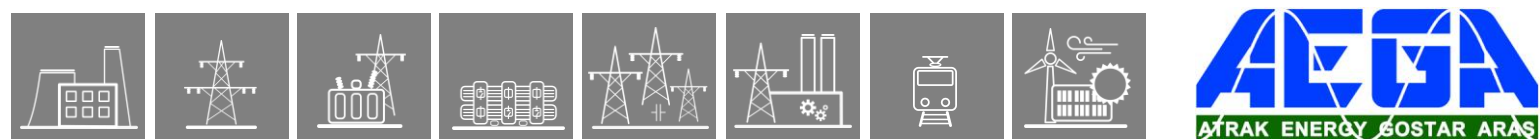


Figure 1-1 Example: Number of permitted interruptions as the function of the interrupted current

The straight line of the curve is defined by two points:

- The number of permitted interruptions of 1 kA current (CycNum - 1kA)
- The number of permitted interruptions of the rated breaking current of the circuit breaker (CycNum – I Rated Trip).

The circuit breaker wear monitoring function finds the maximum value of the phase currents of each interruption and calculates the wear caused by the operation performed. If the sum of the calculated wear reaches the limit, a warning signal is generated. This indicates the time of the required preventive maintenance of the circuit breaker.



3.2.2.1. Operation of the circuit breaker wear monitoring algorithm

The operating principle of the circuit breaker wear monitoring function is based on curves similar to the one shown in [Figure 1-1](#). With this figure, the manufacturer of the circuit breaker defines the permitted total number of current interruptions up to the subsequent preventive maintenance.

The straight line of the curve is defined by two points:

- The number of interruptions of 1 kA current, by parameter `CBWear_CycNumIn_IPar_` (`CycNum - 1kA`)
- The number of interruptions of the rated breaking current of the circuit breaker by parameter `CBWear_CycNumInTrip_IPar_` (`CycNum - I Rated Trip`). The rated breaking current of the circuit breaker is set by parameter `CBWear_InTrCB_FPar_` (`Rated Trip Current`)

The circuit breaker wear monitoring function processes the Fourier basic harmonic component of the three phase currents.

The circuit breaker wear monitoring function identifies the highest value of the phase currents at each interruption.

The procedure of monitoring starts at the receipt of a trip command on the dedicated input (`Trip`). For the start of this procedure, the circuit breaker also needs to be in closed state. This signal is received on the dedicated binary input (`CB Closed`).

The procedure of identifying the maximum phase current value terminates when the current falls below the minimum current defined by the parameter `CBWear_Imin_FPar_` (`Min Current`) AND the circuit breaker gets in open position. This signal is received on the dedicated binary input (`CB Open`).

The procedure also stops if the time elapsed since its start exceeds 1 s. In this case no CB wear is calculated.

Based on the characteristic defined above, the function calculates the wear caused by the operation performed. If the sum of the calculated wear reaches the limit defined by the parameter `CBWear_CycNumAlm_IPar_` (`CycNum - Alarm`), a warning signal is generated (`Alarm`). This indicates the advised time of the preventive maintenance of the circuit breaker.

The accumulated “wear” of the circuit breaker is stored on non-volatile memory; therefore, the value is not lost even if the power supply of the devices is switched off.

This information is displayed among the on-line data as “Actual wear”. This counter indicates how many 1 kA equivalent switches were performed since the last maintenance (reset).

When preventive maintenance is performed, the accumulated “wear” of the circuit breaker must be reset to 0 to start a new maintenance cycle. The circuit breaker wear monitoring function offers two ways of resetting:

- Binary True signal programmed to the “Reset” input of the function
- Performing a direct command via the Commands menu of the supervising WEB browser (for details, see the “Europrot+ manual”, “Remote user interface description” document). The Command window looks like [Figure 1-2](#).



Figure 1-2 The command window to reset the CB wear counter

The **inputs** of the circuit breaker wear monitoring function are

- the Fourier components of three phase currents,
- binary inputs,
- parameters.

The **output** of the circuit breaker wear monitoring function is

- the Alarm binary output status signal.

3.2.2.2. Technical summary

3.2.2.2.1. Technical data

| Function | Range | Accuracy |
|-----------------------------------------------------------|---------------------|--------------------|
| Current accuracy | 20 – 2000% of I_n | $\pm 1\%$ of I_n |
| Accuracy in tracking the theoretical wear characteristics | | 5% |

Table 1-1 Technical data of the circuit breaker wear monitoring

3.2.2.2.2. Summary of the parameters

The parameters of the circuit breaker wear monitoring function are explained in the following tables.

Enumerated parameter

| Parameter name | Title | Selection range | Default |
|-----------------------------------------------------|-----------|-----------------|---------|
| Disabling or enabling the operation of the function | | | |
| CBWear_Oper_EPar_ | Operation | Off,On | Off |

Table 1-2 The enumerated parameter of the circuit breaker wear monitoring function

Integer parameters

| Parameter name | Title | Unit | Min | Max | Step | Default |
|--------------------------------------------------------------------------------------------------------------------|-----------------------|------|-----|--------|------|---------|
| Permitted number of trip operation if the breaking current is 1kA | | | | | | |
| CBWear_CycNumIn_IPar_ | CycNum - 1kA | | 1 | 100000 | 1 | 50000 |
| Permitted number of trip operation if the breaking current is InTrip (See floating parameter "Rated Trip Current") | | | | | | |
| CBWear_CycNumInTrip_IPar_ | CycNum – I Rated Trip | | 1 | 100000 | 1 | 100 |
| Permitted level of the weighted sum of the breaking currents | | | | | | |
| CBWear_CycNumAlm_IPar_ | CycNum - Alarm | | 1 | 100000 | 1 | 50000 |

Table 1-3 The integer parameters of the circuit breaker wear monitoring function

Floating point parameters

| Parameter name | Title | Unit | Min | Max | Step | Default |
|--------------------------------------------------------------------------------------------------------|--------------------|------|------|------|------|---------|
| Rated breaking current of the circuit breaker | | | | | | |
| CBWear_InTrCB_FPar_ | Rated Trip Current | kA | 10 | 100 | 0.01 | 10 |
| Minimum level of the current below which the procedure to find the highest breaking current is stopped | | | | | | |
| CBWear_lmin_FPar_ | Min Current | kA | 0.10 | 0.50 | 0.01 | 0.10 |

Table 1-4 The floating-point parameters of the circuit breaker wear monitoring function

3.2.2.2.3. Binary output status signals

The **binary output status signals** of the circuit breaker wear monitoring function.

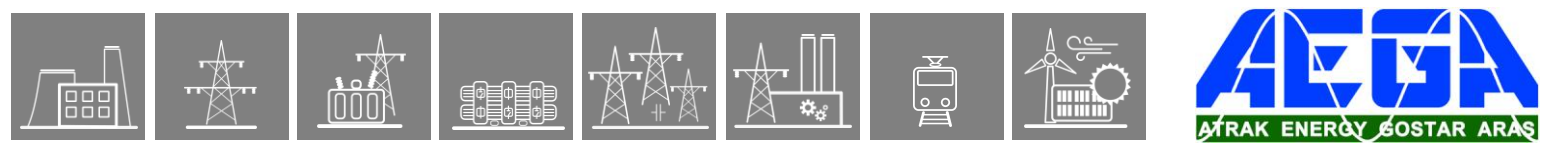
| Binary output signals | Signal title | Explanation |
|------------------------------------|--------------|-----------------------------------------------------------------------------------------------------|
| Alarm signal of the function block | | |
| CBWear_Alarm_GrI_ | Alarm | Alarm signal is generated if the weighted sum of the breaking currents is above the permitted level |

Table 1-5 The binary output status signal of the circuit breaker wear monitoring function

3.2.2.2.4. The binary input status signals

The **binary inputs** are signals influencing the operation of the circuit breaker wear monitoring function. These signals are the results of logic equations graphically edited by the user.

| Binary input signals | Signal title | Explanation |
|-------------------------------------|--------------|-----------------------------------------------------------------------------------------------------------------|
| Disabling the function | | |
| CBWear_BlK_GrO_ | Blk | The programmed True state of this input disables the operation of the function |
| Open state of the circuit breaker | | |
| CBWear_Open_GrO_ | Open | The open state of the circuit breaker is needed to stop the procedure to find the maximum breaking current |
| Closed state of the circuit breaker | | |
| CBWear_Closed_GrO_ | Closed | The closed state of the circuit breaker is needed to perform the procedure to find the maximum breaking current |



| | | |
|-------------------------------------|-------|---------------------------------------------------------------------------------------------------------------------|
| Trip command to the circuit breaker | | |
| CBWear_Trip_GrO_ | Trip | This signal starts the procedure to find the highest breaking current |
| Reset command | | |
| CBWear_Reset_GrO_ | Reset | If this input is programmed to logic True, at maintenance the weighted sum of the breaking currents can be set to 0 |

Table 1-6 The binary input signals of the circuit breaker wear monitoring function

3.2.2.2.5. The function block

The function block of the circuit breaker wear monitoring function is shown in [Figure 1-3](#). This block shows all binary input and output status signals that are applicable in the graphic equation editor.

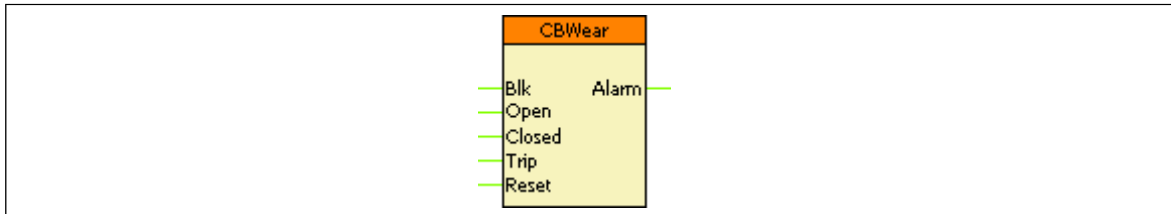
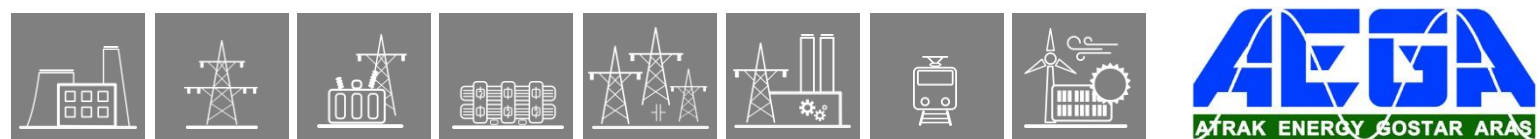


Figure 1-3 The function block of the circuit breaker wear monitoring function



3.2.3. Circuit breaker control function block

3.2.3.1. Application

The circuit breaker control block can be used to integrate the circuit breaker control of the EuroProt+ device into the station control system and to apply active scheme screens of the local LCD of the device.

3.2.3.1.1. Mode of operation

The circuit breaker control block receives remote commands from the SCADA system and local commands from the local LCD of the device, performs the prescribed checking and transmits the commands to the circuit breaker. It processes the status signals received from the circuit breaker and offers them to the status display of the local LCD and to the SCADA system.

Main features:

- Local (LCD of the device) and Remote (SCADA) operation modes can be enabled or disabled individually.
- The signals and commands of the synchro-check / synchro-switch function block can be integrated into the operation of the function block.
- Interlocking functions can be programmed by the user applying the inputs “EnaOff” and “EnaOn”, using the graphic equation editor.
- Programmed conditions can be used to temporarily disable the operation of the function block using the graphic equation editor.
- The function block supports the control models prescribed by the IEC 61850 standard.
- All necessary timing tasks are performed within the function block:
 - Time limitation to execute a command
 - Command pulse duration
 - Filtering the intermediate state of the circuit breaker
 - Checking the synchro-check and synchro-switch times
 - Controlling the individual steps of the manual commands
- Sending trip and close commands to the circuit breaker (to be combined with the trip commands of the protection functions and with the close command of the automatic reclosing function; the protection functions and the automatic reclosing function directly gives commands to the CB). The combination is made graphically using the graphic equation editor
- Operation counter
- Event reporting

3.2.3.2. Circuit Breaker control function overview

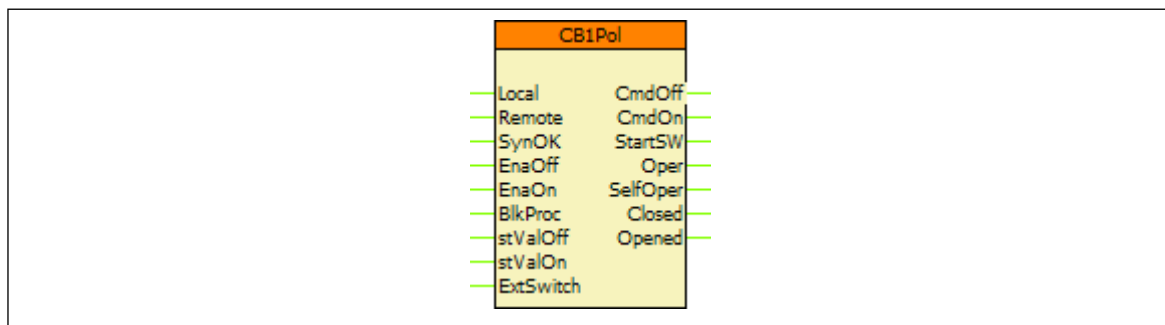


Figure 2-1 Graphic appearance of the function block of the circuit breaker control function

3.2.3.3. Settings

3.2.3.3.1. Parameters

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|-----------------------|-----|----------------------------------------------------|------|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ControlModel | - | Direct normal, Direct enhanced, SBO enhanced | - | Direct normal | The control model of the circuit breaker node according to the IEC 61850 standard |
| Forced Check | - | FALSE, TRUE | - | TRUE | If true, then the check function cannot be neglected by the check attribute defined by the IEC 61850 standard |
| Max Operating Time | ms | 10 – 1000 | 1 | 200 | When either enhanced control model is selected, the status of the CB must change within this time after the issued command. At timeout an invalid-position error will be generated for the client. |
| Pulse Duration | ms | 50 – 1000 | 1 | 300 | Duration of the generated On and Off impulse* |
| Max Intermediate Time | ms | 20 – 500 | 1 | 100 | Waiting time for status signals, at expiry the CB is reported to be in intermediate state |
| Max SynCheck Time | ms | 10 – 5000 | 1 | 1000 | Length of the time period to wait for the conditions of the synchronous state. After expiry of this time, the synchro-switch procedure is initiated (see synchro-check/ synchro-switch function block description) |
| Max SynSW Time** | ms | 0 – 60000 | 1 | 0 | Length of the time period to wait for the synchro-switch impulse (see synchro-check/ synchro-switch function block description). After this time the function resets, no switching is performed |
| SBO Timeout | ms | 1000 – 20000 | 1 | 5000 | Duration of the waiting time between object selection and command selection. At timeout no command is performed |

* If the input status signals (stValOff, stValOn) indicate the successful switching then the pulse is withdrawn, but the minimum duration is 100 ms (factory setting).

** If this parameter is set to 0, then the “StartSW” output is not activated

Table 2-1 Parameters of the circuit breaker control function

3.2.3.3.2. Function I/O

This section describes briefly the analogue and digital inputs and outputs of the function block.

3.2.3.3.2.1. Binary input signals (graphed output statuses)

The conditions of the inputs are defined by the user, applying the graphic equation editor (logic editor). The part written in **bold** is seen on the function block in the logic editor.

| BINARY INPUT SIGNAL | EXPLANATION |
|--------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CB1Pol_ Local _GrO_ | If this input is active, the circuit breaker can be controlled using the local LCD of the device. |
| CB1Pol_ Remote _GrO_ | If this input is active, the circuit breaker can be controlled via remote communication channels of the SCADA system or the device web page ('commands' menu) |
| CB1Pol_ SynOK _GrO_ | This input indicates if the synchronous state of the voltage vectors at both sides of the circuit breaker enables the closing command. This signal is usually generated by the synchro check/ synchro switch function. If this function is not available, set the input to logic true. |
| CB1Pol_ EnaOff _GrO_ | The active state of this input enables the opening of the circuit breaker. The state is usually generated by the <i>interlocking conditions defined graphically by the user</i> . |
| CB1Pol_ EnaOn _GrO_ | The active state of this input enables the closing of the circuit breaker. The state is usually generated by the <i>interlocking conditions defined graphically by the user</i> . |
| CB1Pol_ BlkProc _GrO_ | The active state of this input blocks the operation of the circuit breaker. The conditions are defined graphically by the user. |
| CB1Pol_ stValOff _GrO_ | Off (Opened) state of the circuit breaker. |
| CB1Pol_ stValOn _GrO_ | On (Closed) state of the circuit breaker. |
| CB1Pol_ ExtSwitch _GrO_ | This signal is considered only when evaluating unintended operation (see "SelfOper" output in Chapter 2.2.2). It indicates that an external command has been issued to the circuit breaker (e.g. trip request from other protection device or external on/off command is given). |

Table 2-2 The binary input signals of the circuit breaker control function

3.2.3.3.2.2. Binary output signals (graphed input statuses)

The binary output status signals of the differential protection function. Parts written in **bold** are seen on the function block in the logic editor.

| BINARY OUTPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|-------------------------------|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CB1Pol_ CmdOff _Grl_ | Off Command | Off command impulse, the duration of which is defined by the parameter "Pulse duration" |
| CB1Pol_ CmdOn _Grl_ | On Command | On command impulse, the duration of which is defined by the parameter "Pulse duration" |
| CB1Pol_ StartSW _Grl_ | Start Synchro-switch | If the synchro check/synchro switch function is applied and the synchronous state conditions are not valid for the time defined by the parameter "Max.SynChk time", then this output triggers the synchro switch function (see synchro-check/synchro-switch function block description). |
| CB1Pol_ Oper _Grl_ | Operation | An impulse with a duration of 150 ms at any operation of the circuit breaker |
| CB1Pol_ SelfOper _Grl_ | Unintended Operation | This output is logic true if the status of the circuit breaker has changed without detected command from the SCADA system or on the input "ExtSwitch" |
| CB1Pol_ Closed _Grl_ | Closed | The filtered status signal for closed state of the circuit breaker |
| CB1Pol_ Opened _Grl_ | Opened | The filtered status signal for opened state of the circuit breaker |

Table 2-3 The binary output signals of the circuit breaker control function

3.2.3.3.2.3. On-line data

Visible values on the on-line data page:

| SIGNAL TITLE | DIMENSION | EXPLANATION |
|----------------------|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| Status | - | State of the CB (see Chapter 2.2.6) |
| Off Command | - | Off command impulse, the duration of which is defined by the parameter "Pulse duration" |
| On Command | - | On command impulse, the duration of which is defined by the parameter "Pulse duration" |
| Operation | - | An impulse with a duration of 150 ms at any operation of the circuit breaker |
| Unintended Operation | - | This output is logic TRUE if the status of the circuit breaker has changed without detected command from the SCADA system or on the input "ExtSwitch" |
| Opened | - | The filtered status signal for opened state of the circuit breaker |
| Closed | - | The filtered status signal for closed state of the circuit breaker |
| Operation counter | - | Resettable* counter that increments every time the Operation (see above) output gets active |

*The operation counter can be reset on the device web page on-line menu.

Table 2-4 On-line data of the circuit breaker control function



3.2.3.3.2.4. Events

The following events are generated in the event list, as well as sent to SCADA according to the configuration.

| EVENT | VALUE | EXPLANATION |
|--------|-------------------------|---------------------------------------------------|
| Status | Intermediate,Off,On,Bad | CB state indication based on the received signals |

Table 2-5 Event of the circuit breaker control function

3.2.3.3.2.5. Commands

The following table contains the issuable commands of the function block. The name of the command channel is used while working in the EuroCAP configuration tool, whereas the title is seen by the user on the device web page.

| COMMAND CHANNEL | TITLE | RANGE | EXPLANATION |
|------------------|-----------|--------|-------------------------------------------------------------------------------------------|
| CB1Pol_Oper_Con_ | Operation | Off,On | Issue open (off) or close (on) command on the corresponding outputs of the function block |

Table 2-6 The command of the circuit breaker control function

3.2.3.3.2.6. Indication of the four states (Intermediate, On, Off, Bad)

To generate an active scheme on the local LCD, there is an internal status variable indicating the state of the circuit breaker. Different graphic symbols can be assigned to the values, the function block's events are generated also according to this status variable.

This integer status has four values based on the states of the **stValOn** and **stValOff** inputs of the function block.

| INTEGER STATUS | TITLE | STVALON STATE | STVALOFF STATE | VALUE | EXPLANATION |
|-------------------|--------|---------------|----------------|-----------------|----------------------------------------------------------------------------------------------------------------------|
| CB1Pol_stVal_ISt_ | Status | FALSE | FALSE | 0: Intermediate | Integer status signal for indicating the state of the CB according to the corresponding inputs of the function block |
| | | FALSE | TRUE | 1: Off | |
| | | TRUE | FALSE | 2: On | |
| | | TRUE | TRUE | 3: Bad | |

Table 2-7 State signals from the circuit breaker control function

3.2.3.3.3. Technical data

| FUNCTION | VALUE | ACCURACY |
|------------|-------|----------|
| Pulse time | | < 3 ms |

Table 2-8 The technical data of the circuit breaker control function

3.2.3.3.3.1. Notes for testing

If the commands get blocked from time to time during commissioning, it is advised to check how the conditions are fulfilled to issue commands on the function block. The following **three** conditions must be fulfilled at the same time:

- Local or Remote input is active appropriately
- The enabling input (EnaOff or EnaOn) of the issued command (off or on) is active
- (close/on command only) Synchro-check is OK (SynOK input is active)

If there are no conditions to be defined for any of these three (e.g. there is no synchro-check function present, so no valid signal can be provided to that input), the corresponding input can be connected to constant logical TRUE signal provided by the fixture output of the Common function block.

3.2.3.3.3.1.1. IEC 61850 commands

In several configurations the Interlocking and Control logical nodes may have the same prefix for CB and DC function blocks (**INTCILO#** and **SBwCSWI#** respectively where the '#' marks the instance number). This means that their instance number not necessarily corresponds to the actual function block:

- Example: if there are **2** DC and **1** CB function blocks in the same configuration where the former ones were added first, the instance number **#1** and **#2** will belong to the DC function blocks whereas number **#3** will belong to the CB function block even if it is the only CB control function in the device.
- Make sure to check which logical nodes belong to which function by checking the DOI description using the EuroCAP tool (right click the function block in the Logic editor)

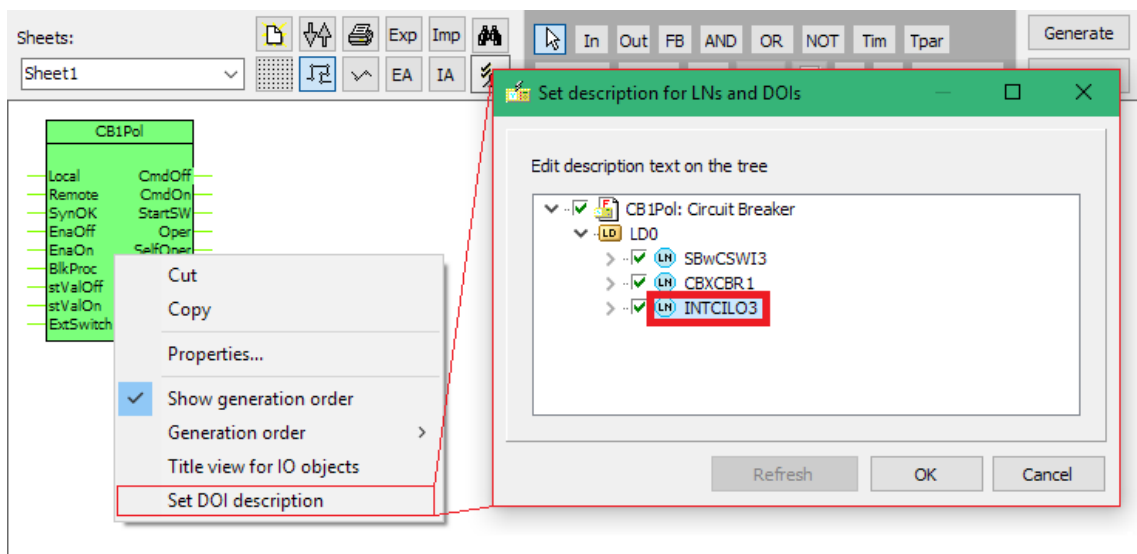
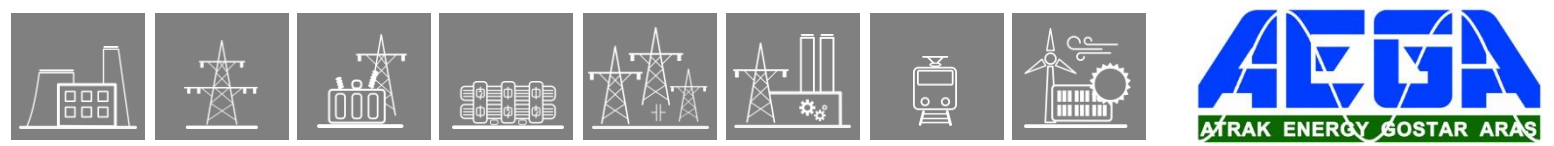


Figure 2-2 Checking the description of the Interlocking LN of the function block

In other cases, the two prefixes are given according to the type of the function block, so they are individual for each (i.e. **CBCILO#** and **CBCSW#** for circuit breaker and **DCCILO#** and **DCCSW#** for disconnector).



3.2.4. Disconnecter control function

3.2.4.1. Application

The disconnector control block can be used to integrate the disconnector control of the EuroProt+ device into the station control system and to apply active scheme screens of the local LCD of the device.

3.2.4.1.1. Mode of operation

The disconnector control block receives remote commands from the SCADA system and local commands from the local LCD of the device, performs the prescribed checking and transmits the commands to the disconnector. It processes the status signals received from the disconnector and offers them to the status display of the local LCD and to the SCADA system.

Main features:

- Local (LCD of the device) and Remote (SCADA) operation modes can be enabled or disabled individually.
- Interlocking functions can be programmed by the user applying the inputs “EnaOff” and “EnaOn”, using the graphic equation editor.
- Programmed conditions can be used to temporarily disable the operation of the function block using the graphic equation editor.
- The function block supports the control models prescribed by the IEC 61850 standard.
- All necessary timing tasks are performed within the function block:
 - Time limitation to execute a command
 - Command pulse duration
 - Filtering the intermediate state of the disconnector
 - Controlling the individual steps of the manual commands
- Sending open and close commands to the disconnector
- Operation counter
- Event reporting

3.2.4.2. Disconnecter control function overview

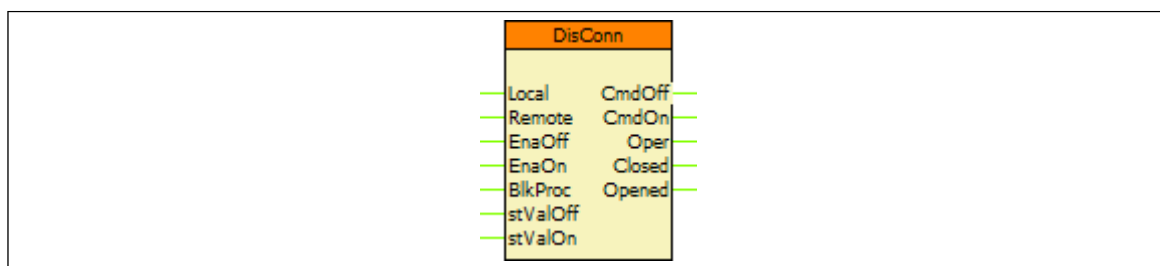


Figure 2-1 Graphic appearance of the function block of the disconnecter control function

3.2.4.2.1. Settings

3.2.4.2.1.1. Parameters

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|-----------------------|-----|-----------------------------------------------------------------------------|------|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Control Model | - | Direct normal, Direct enhanced, SBO enhanced | - | Direct normal | The control model of the disconnecter node according to the IEC 61850 standard |
| Type of Switch | - | N/A, Load Break, Disconnecter, Earthing Switch, HS Earthing Switch | - | Disconnecter | |
| Forced Check | - | FALSE, TRUE | - | TRUE | If true, then the check function cannot be neglected by the check attribute defined by the IEC 61850 standard |
| Max Operating Time | ms | 10 – 60000 | 1 | 10000 | When either enhanced control model is selected, the status of the DC must change within this time after the issued command. At timeout an invalid-position error will be generated for the client. |
| Pulse Duration | ms | 100 – 60000 | 1 | 1000 | Duration of the generated On and Off impulse* |
| Max Intermediate Time | ms | 20 – 60000 | 1 | 10000 | Waiting time for status signals, at expiry the DC is reported to be in intermediate state |
| SBO Timeout | ms | 1000 – 20000 | 1 | 5000 | Duration of the waiting time between object selection and command selection. At timeout no command is performed |

* If the input status signals (stValOff, stValOn) indicate the successful switching then the pulse is withdrawn, but the minimum duration is 1000 ms (factory setting).

Table 2-1 Parameters of the disconnecter control function

3.2.4.2.2. Function I/O

This section describes briefly the analogue and digital inputs and outputs of the function block.

3.2.4.2.2.1. Binary input signals (graphed output statuses)

The conditions of the inputs are defined by the user, applying the graphic equation editor (logic editor). The part written in **bold** is seen on the function block in the logic editor.

| BINARY INPUT SIGNAL | EXPLANATION |
|--------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| DisConn_ Local _GrO_ | If this input is active, the disconnector can be controlled using the local LCD of the device. |
| DisConn_ Remote _GrO_ | If this input is active, the disconnector can be controlled via remote communication channels of the SCADA system or the device web page ('commands' menu) |
| DisConn_ EnaOff _GrO_ | The active state of this input enables the opening of the disconnector. The state is usually generated by the <i>interlocking conditions defined graphically by the user</i> . |
| DisConn_ EnaOn _GrO_ | The active state of this input enables the closing of the disconnector. The state is usually generated by the <i>interlocking conditions defined graphically by the user</i> . |
| DisConn_ BlkProc _GrO_ | The active state of this input blocks the operation of the disconnector. The conditions are defined graphically by the user. |
| DisConn_ stValOff _GrO_ | Off (Opened) state of the disconnector. |
| DisConn_ stValOn _GrO_ | On (Closed) state of the disconnector. |

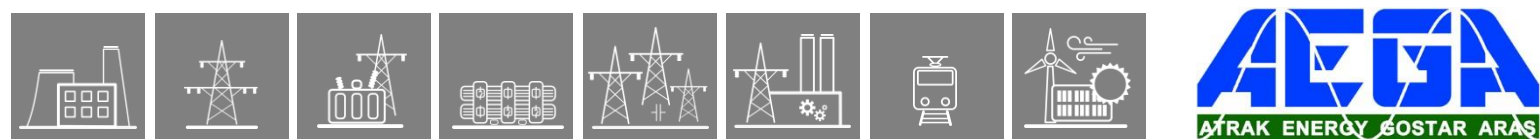
Table 2-2 The binary input signals of the disconnector control function

3.2.4.2.2.2. Binary output signals (graphed input statuses)

The binary output status signals of the differential protection function. Parts written in **bold** are seen on the function block in the logic editor.

| BINARY OUTPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|------------------------------|--------------|-----------------------------------------------------------------------------------------|
| DisConn_ CmdOff _Grl_ | Off Command | Off command impulse, the duration of which is defined by the parameter "Pulse duration" |
| DisConn_ CmdOn _Grl_ | On Command | On command impulse, the duration of which is defined by the parameter "Pulse duration" |
| DisConn_ Oper _Grl_ | Operation | An impulse with a duration of 150 ms at any operation of the disconnector |
| DisConn_ Closed _Grl_ | Closed | The filtered status signal for closed state of the disconnector |
| DisConn_ Opened _Grl_ | Opened | The filtered status signal for opened state of the disconnector |

Table 2-3 The binary output signals of the disconnector control function



3.2.4.2.2.3. On-line data

Visible values on the on-line data page:

| SIGNAL TITLE | DIMENSION | EXPLANATION |
|-------------------|-----------|---------------------------------------------------------------------------------------------|
| Status | - | State of the DC (see Chapter 2.2.6) |
| Off Command | - | Off command impulse, the duration of which is defined by the parameter "Pulse duration" |
| On Command | - | On command impulse, the duration of which is defined by the parameter "Pulse duration" |
| Operation | - | An impulse with a duration of 150 ms at any operation of the disconnecter |
| Opened | - | The filtered status signal for opened state of the disconnecter |
| Closed | - | The filtered status signal for closed state of the disconnecter |
| Operation counter | - | Resettable* counter that increments every time the Operation (see above) output gets active |

Table 2-4 On-line data of the disconnecter control function

*The operation counter can be reset on the device web page on-line menu.

3.2.4.2.2.4. Events

The following events are generated in the event list, as well as sent to SCADA according to the configuration.

| EVENT | VALUE | EXPLANATION |
|--------|-------------------------|----------------------------------------------------------|
| Status | Intermediate,Off,On,Bad | DC state indication based on the received status signals |

Table 2-5 Event of the disconnecter control function

3.2.4.2.2.5. Commands

The following table contains the issuable commands of the function block. The name of the command channel is used while working in the EuroCAP configuration tool, whereas the title is seen by the user on the device web page.

| COMMAND CHANNEL | TITLE | RANGE | EXPLANATION |
|-------------------|-----------|--------|-------------------------------------------------------------------------------------------|
| DisConn_Oper_Con_ | Operation | Off,On | Issue open (off) or close (on) command on the corresponding outputs of the function block |

Table 2-6 The command of the disconnecter control function

3.2.4.2.2.6. Indication of the four states (Intermediate, On, Off, Bad)

To generate an active scheme on the local LCD, there is an internal status variable indicating the state of the disconnecter. Different graphic symbols can be assigned to the values, the function block's events are generated also according to this status variable.

This integer status has four values based on the states of the **stValOn** and **stValOff** inputs of the function block.

| INTEGER STATUS | TITLE | STVALON STATE | STVALOFF STATE | VALUE | EXPLANATION |
|--------------------|--------|---------------|----------------|-----------------|----------------------------------------------------------------------------------------------------------------------|
| DisConn_stVal_ISt_ | Status | FALSE | FALSE | 0: Intermediate | Integer status signal for indicating the state of the DC according to the corresponding inputs of the function block |
| | | FALSE | TRUE | 1: Off | |
| | | TRUE | FALSE | 2: On | |
| | | TRUE | TRUE | 3: Bad | |

Table 2-7 State signals from the disconnecter control function

3.2.4.2.3. Technical data

| FUNCTION | VALUE | ACCURACY |
|--------------|-------|-------------------------------------|
| Operate time | | ±5% or ±15 ms, whichever is greater |

Table 2-8 The technical data of the disconnecter control function

3.2.4.2.3.1. Notes for testing

If the commands get blocked from time to time during commissioning, it is advised to check how the conditions are fulfilled to issue commands on the function block. The following **three** conditions must be fulfilled at the same time:

- Local or Remote input is active appropriately
- The enabling input (EnaOff or EnaOn) of the issued command (off or on) is active

If there are no conditions to be defined for any of these two (e.g. there is no difference made between local/remote control), the corresponding input can be connected to constant logical TRUE signal provided by the fixture output of the Common function block.

3.2.4.2.3.1.1. IEC 61850 commands

In several configurations the Interlocking and Control logical nodes may have the same prefix for DC and CB function blocks (**INTCILO#** and **SBwCSWI#** respectively where the '#' marks the instance number). This means that their instance number not necessarily corresponds to the actual function block:

- Example: if there are **1** CB and **1** DC function blocks in the same configuration where the former was added first, the instance number **#1** will belong to the CB function block whereas number **#2** will belong to the DC function block even if it is the only DC control function in the device.
- Make sure to check which logical nodes belong to which function by checking the DOI description using the EuroCAP tool (right click the function block in the Logic editor)

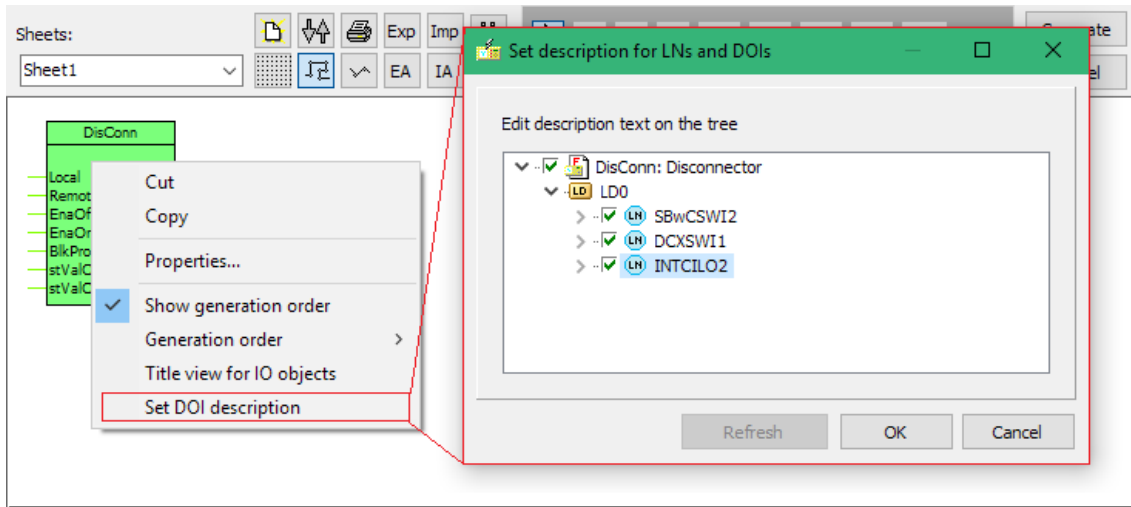


Figure 2-2 Checking the description of the Interlocking LN of the function block

In other cases, the two prefixes are given according to the type of the function block, so they are individual for each (i.e. **DCCILO#** and **DCCSW#** for disconnector and **CBCILO#** and **CBCSW#** for circuit breaker).

3.2.4.3. Example logic

A simple example can be seen below of how to insert the function block in the user logic using the EuroCAP Logic Editor:

- The Local/Remote state of the device is provided by the Common function block which is present in all configurations
- The connections to the BIn and BOut elements show the connections to the physical input and output contacts
- The highlighted signal leading to the EnaOff and EnaOn inputs is the realization of the interlocking logic. In this case the disconnecter can operate only if the circuit breaker is opened.

The opened state of the CB is now indicated by its filtered 'Opened' signal which is active only if the CB is open and there is no state error (or intermediate state) of it.

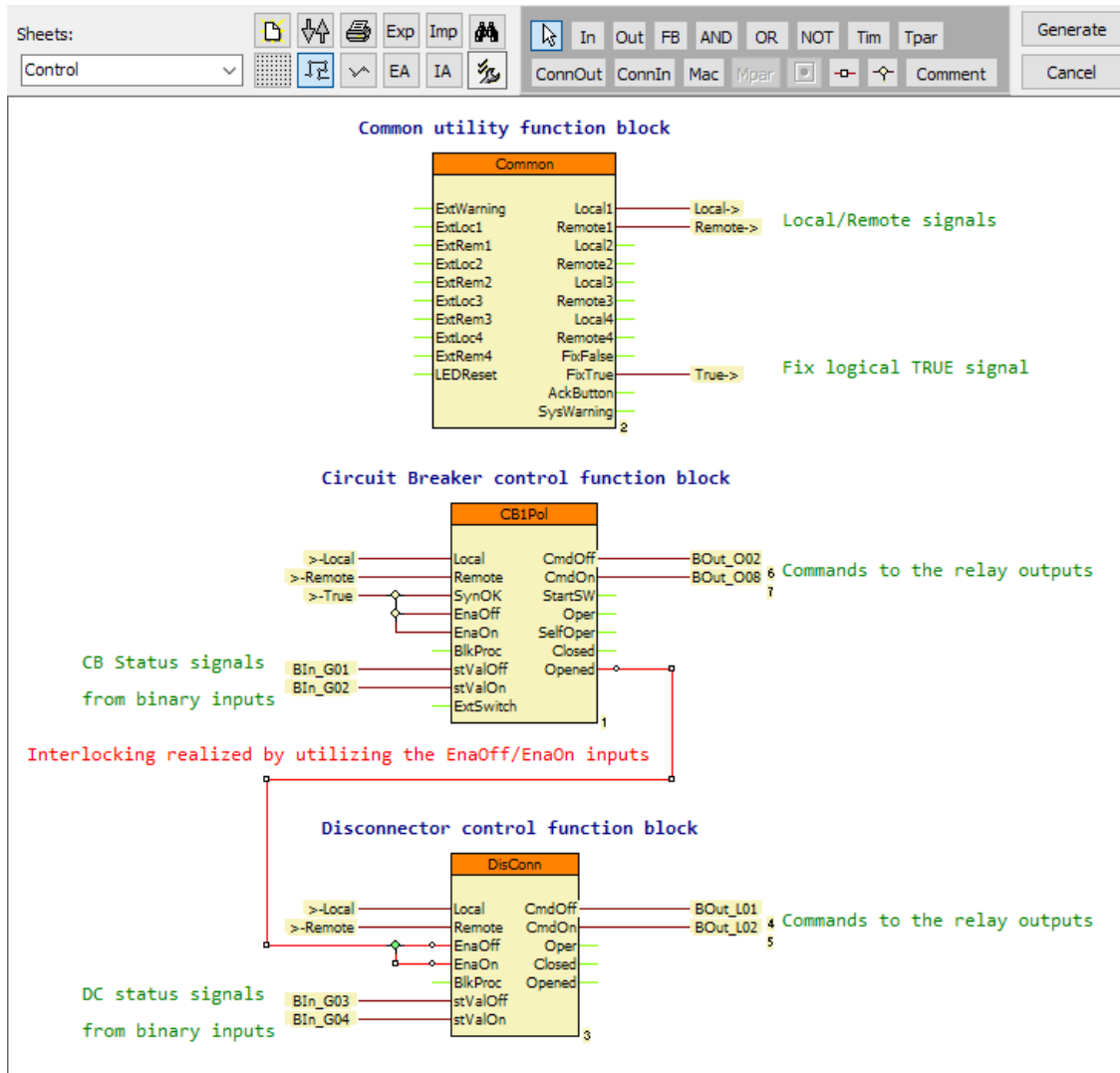


Figure 3-1 Inserting the disconnecter function block into the logic (example)



3.2.5. Ethernet Links function

3.2.5.1. Introduction

The EuroProt+ device constantly checks the statuses of its connections to the outside world (wherever possible). These statuses can be seen on the **status/log** page in the advanced menu on the web page of the device.

When further indications are needed or the signals of the statuses (such as events, logic signals for the user logic, LEDs etc.), the Ethernet Links function block makes these available for the user.

3.2.5.1.1. Ports

The function can check the following types of communication ports:

- Fiber Optic (MM – multi mode)
- Fiber Optic (SM – single mode)
- RJ45
- PRP/HSR
- EOB (Ethernet On Board on the front HMI of the device)

See the EuroProt+ Hardware Description (different document) for the list of the CPU modules that contain any of these ports.

3.2.5.2. Ethernet Links function overview

The graphic appearance of the function block is shown on [Figure 2-1](#). These blocks show all binary input and output status signals, which are applicable in the graphic equation editor.

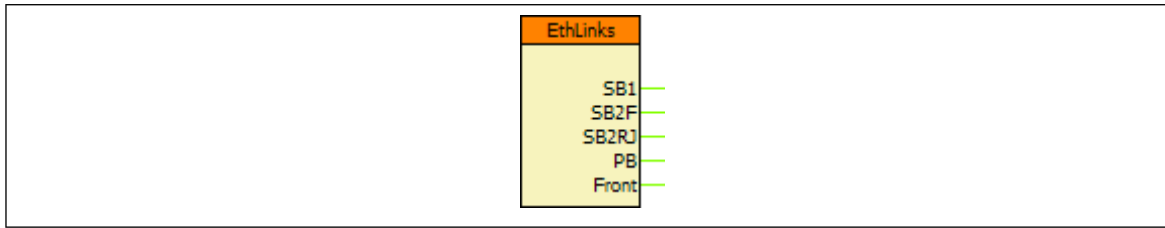


Figure 2-1 Graphic appearance of the function block of the ethernet links function

3.2.5.2.1. Settings

There are no settings for this function block.

3.2.5.2.2. Function I/O

This section describes briefly the analogue and digital inputs and outputs of the function block.

This function block owns only binary output signals.

3.2.5.2.2.1. Binary output signals (graphed input statuses)

The binary output status signals of the Ethernet Links function. **Parts written in bold** are seen on the function block in the logic editor.

| BINARY OUTPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|----------------------------|-------------------------|--------------------------------------------------------------------------------------------|
| EthLnk_ SB1 _Grl_ | Station Bus1 | Active if the first (upper) fiber optic port of the CPU module has an active connection. |
| EthLnk_ SB2F _Grl_ | Station Bus2 – Fiber | Active if the second (middle) fiber optic port of the CPU module has an active connection. |
| EthLnk_ SB2RJ _Grl_ | Station Bus2 –RJ4 | Active if the RJ45 port of the CPU module has an active connection. |
| EthLnk_ PB _Grl_ | Process Bus | Active if the third (lower) fiber optic port of the CPU module has an active connection |
| EthLnk_ Front _Grl_ | RJ45/EOB on front panel | Active if the front RJ45 port (or EOB) has an active connection |

Table 2-1 The binary output status signals of the ethernet links function

3.2.5.2.2.2. On-line data

Visible values on the on-line data page:

| SIGNAL TITLE | DIMENSION | EXPLANATION |
|-------------------------|-----------|--------------------------------------------------------------------------------------------|
| Station Bus1 | - | Active if the first (upper) fiber optic port of the CPU module has an active connection. |
| Station Bus2 – Fiber | - | Active if the second (middle) fiber optic port of the CPU module has an active connection. |
| Station Bus2 –RJ4 | - | Active if the RJ45 port of the CPU module has an active connection. |
| Process Bus | - | Active if the third (lower) fiber optic port of the CPU module has an active connection |
| RJ45/EOB on front panel | - | Active if the front RJ45 port (or EOB) has an active connection |

Table 2-2 The measured analogue values of the ethernet links function

3.2.5.2.2.3. Events

The following events are generated in the event list, as well as sent to SCADA according to the configuration.

| EVENT | VALUE | EXPLANATION |
|-------------------------|---------|--------------------------------------------------------------------------------------------|
| Station Bus1 | off, on | Active if the first (upper) fiber optic port of the CPU module has an active connection. |
| Station Bus2 – Fiber | off, on | Active if the second (middle) fiber optic port of the CPU module has an active connection. |
| Station Bus2 –RJ4 | off, on | Active if the RJ45 port of the CPU module has an active connection. |
| Process Bus | off, on | Active if the third (lower) fiber optic port of the CPU module has an active connection |
| RJ45/EOB on front panel | off, on | Active if the front RJ45 port (or EOB) has an active connection |

Table 2-3 Events of the ethernet links function

3.2.5.2.3. Technical data

There is no technical data to add.

3.2.6. Trip Circuit Supervision

3.2.6.1. Introduction

This document describes the applicable hardware and provides guidelines for usage in the device configuration.

3.2.6.1.1. Operation principle

The trip circuit supervision is utilized for checking the integrity of the circuit between the trip coil and the tripping output of the protection device.

This is realized by injecting a small DC current (around 1-5 mA) into the trip circuit. If the circuit is intact, the current flows, causing an active signal to the opto coupler input of the trip contact.

The state of the input is shown on the devices' binary input listing among the other binary inputs, and it can be handled like any other of them (it can be added to the user logic, etc.)

3.2.6.1.2. Applicable modules

The following modules contain trip outputs with trip circuit supervision. The information here is restricted to the trip circuit supervision only. For more details please refer to the EuroProt+ Hardware description from which these were extracted. Note that there are other modules without trip circuit supervision, those are not listed here.

Table 1-1 Modules with Trip Circuit Supervision

| MODULE TYPE | TRIP+4201 | TRIP+2101 | TRIP+2201 | PSTP+4201 | PSTP+2101 |
|---------------------------|---------------------|-----------|-----------|---------------------------------|-----------------------|
| CHANNEL NUMBER | 4 | 4 | 4 | 2 | 2 |
| RATED VOLTAGE | 24 V DC and 48 V DC | 110 V DC | 220 V DC | 24 V DC and 48 V DC and 60 V DC | 110 V DC and 220 V DC |
| THERMAL WITHSTAND VOLTAGE | 72 V DC | 150 V DC | 242 V DC | 72 V DC | 242 V DC |

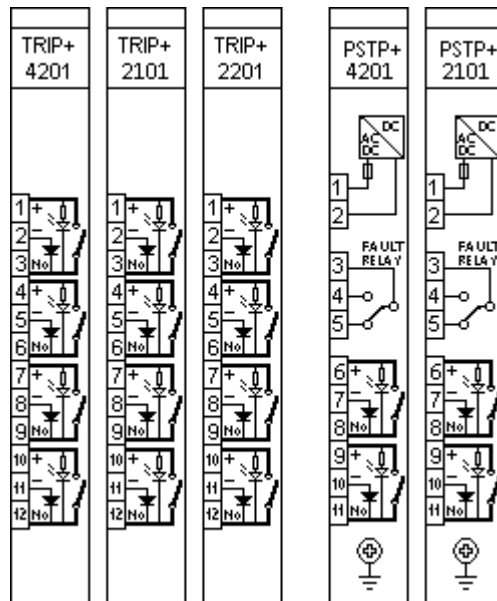


Figure 1-1 I/O arrangement of the modules with TCS

3.2.6.2. Hardware application

3.2.6.2.1. Wiring

The wiring of these modules can be 2-wire or 3-wire. The TCS – Trip Circuit Supervision function is active with both methods.



The voltage of the "No" contact is maximized at 15 V by a Zener-diode. Make sure that the voltage caused by the resistance of the circuit breaker and the injected current from the TRIP+ module does not reach 10 V. In case of PSTP+ modules, this voltage is 8 V (PSTP+/4201) and 13 V (PSTP+/2101).



Our TRIP+ modules are made to switch DC circuits. **Using reversed polarity or AC voltage can cause the damage of the internal circuits.**

3.2.6.2.1.1. 3-wire TRIP+ wiring methods

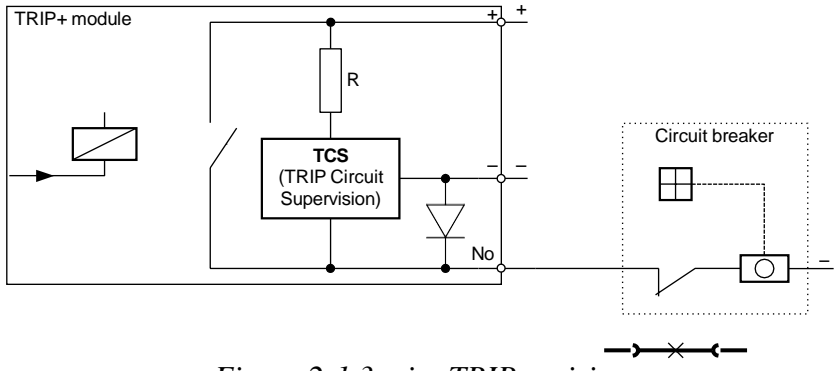


Figure 2-1 3-wire TRIP+ wiring

It is possible to use parallel connected TRIP+ modules. In this case the negative contacts must be common.

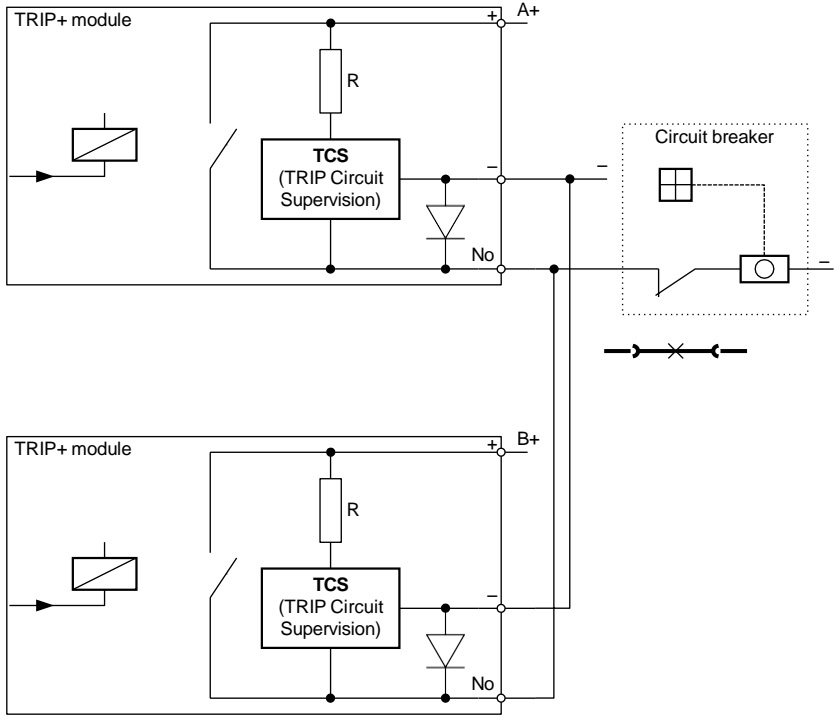


Figure 2-2 3-wire TRIP+ wiring using parallel connected TRIP+ modules

3.2.6.2.1.2. 2-wire TRIP+ wiring methods

If it is necessary, you can also wire the TRIP+ modules using only the “+” and the “No” contacts.

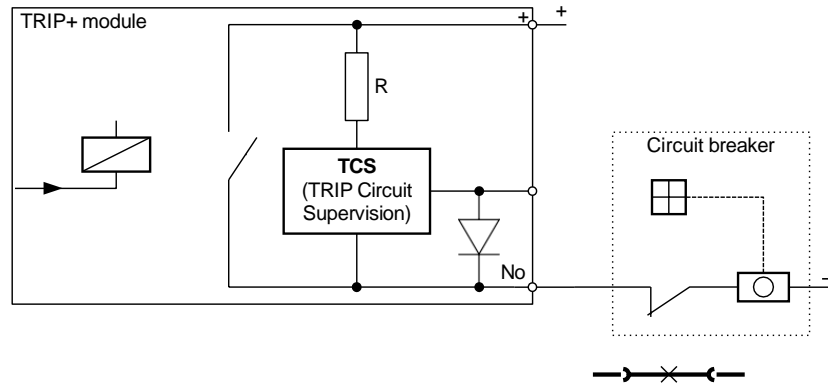


Figure 2-3 2-wire TRIP+ wiring

It is possible to use parallel connected TRIP+ modules.

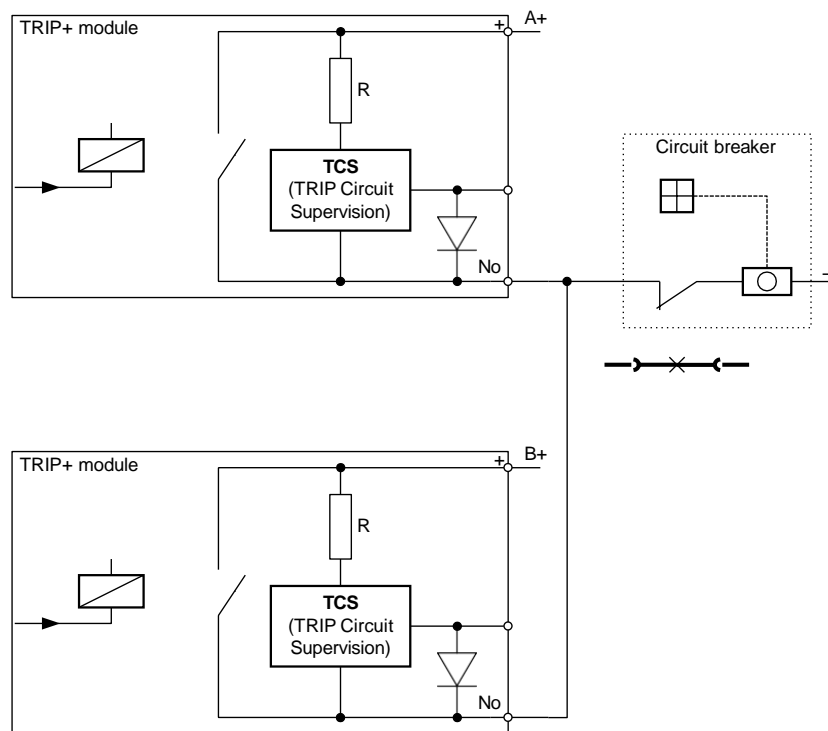


Figure 2-4 2-wire TRIP+ wiring using parallel connected TRIP+ modules

If the circuit breaker needs two-pole switching, TRIP+ modules can be connected series as you can see in [Figure 2-5](#).

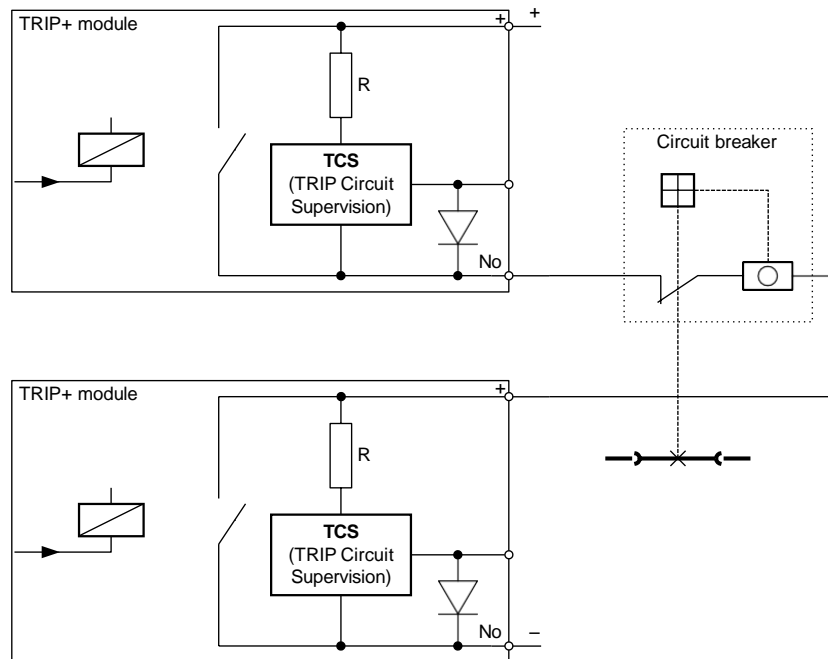


Figure 2-5 2-wire TRIP+ wiring using series connected TRIP+ modules

3.2.6.2.2. TCS signal handling

The Trip Circuit Supervision detects broken trip circuit if the current flowing through the trip coil is below 1 mA or (in case of 3-wire wirings) the voltage on it is above 8-10-13 V (depending on the module).

In Chapter [2.3](#) there are calculated maximum values for the resistance of the trip coil. If these values are exceeded, the TCS might consider the trip circuit broken even if it is intact.

To solve this, there are two ways:

- Using the 2-wire wiring method*:** leaving out/disconnecting the DC- part of the TRIP wiring may solve the issue.
Note that in this case the voltage is not maximized on 15 V, so **the used voltage (up to 220 Vdc) will appear on the “NO” pin**. Caution is advised when touching the wiring in this case.
- Usage of modules without TCS:** if the TCS is not a requirement (e.g. in backup protections), it can be simply left out by opting for the appropriate modules (such as PSTP+/2131 or TRIP+/21F1) while ordering.

**The inputs of some relay testers might sense the states of the Trip contacts active even if they are not. In such cases the “-“ pin must be wired in for the tests.*



3.2.6.2.3. Technical data

The following tables contain information according to the wiring connections described in Chapter 2.1.

Table 2-1 Technical data for the TRIP+ modules

| MODULE TYPE | TRIP+4201 | TRIP+2101 | TRIP+2201 | |
|-------------------------------------|--------------------------------------------|-------------------------------------------------------|--------------------------------------------------------|---------------------------|
| VALUE OF R RESISTOR ($\pm 10\%$) | 10 k Ω | 73 k Ω | 130 k Ω | |
| INJECTED CURRENT AT "NO" CONTACT | 2.4 mA @ 24 V DC 4.8 mA @ 48 V DC | 1.5 mA @ 110 V DC | 1.7 mA @ 220 V DC | |
| MAXIMUM RESISTANCE OF THE TRIP COIL | 3-WIRE WIRING (MAX. 10 V) | 11.8 k Ω @ 24 V DC 3.7 k Ω @ 48 V DC | 9.7 k Ω @ 110 V DC 8.4 k Ω @ 125 V DC | 8.1 k Ω @ 220 V DC |
| | 3-WIRE WIRING WITH IN PARALLEL (MAX. 10 V) | 5.9 k Ω @ 24 V DC 1.8 k Ω @ 48 V DC | 4.8 k Ω @ 110 V DC 4.2 k Ω @ 125 V DC | 4 k Ω @ 220 V DC |
| | 2-WIRE METHOD (1 mA MIN. CURRENT) | 14 k Ω @ 24 V DC 38 k Ω @ 48 V DC | 37 k Ω @ 110 V DC 52 k Ω @ 125 V DC | 90 k Ω @ 220 V DC |

The PSTP+ modules work based on current generator principle, so the calculations for these are based on the necessary minimum current and the allowed maximum voltage.

Table 2-2 Technical data for the PSTP+ modules

| MODULE TYPE | PSTP+4201 | PSTP+2101 | |
|-------------------------------------|-----------------------------------|-------------------------------------------------------------------------------|--------------------------------------------------------|
| INJECTED CURRENT AT "NO" CONTACT | 1.5 mA | 1.5 mA | |
| MAXIMUM RESISTANCE OF THE TRIP COIL | 3-WIRE WIRING (1 mA CURRENT) | 8 k Ω (max. 8 V) | 13 k Ω (max. 13 V) |
| | 3-WIRE WIRING IN PARALLEL | 4 k Ω (max. 8 V) | 6.5 k Ω (max. 13 V) |
| | 2-WIRE METHOD (1 mA MIN. CURRENT) | 24 k Ω @ 24 V DC 48 k Ω @ 48 V DC 60 k Ω @ 60 V DC | 110 k Ω @ 110 V DC 220 k Ω @ 220 V DC |

3.2.6.3. Software application

3.2.6.3.1. Binary inputs



The **TCS input is active if the trip circuit is intact**, so the logical '0' or FALSE signal of the input means that either the trip circuit is broken, or it connects to high resistance.

The TCS signals are shown the same way as other binary inputs are in the device: they can be seen in the **on-line data** menu on the local HMI or the device web page, and they can be utilized just like any other binary input when editing the device configuration with EuroCAP software.

The names/titles of the inputs follow the occupied slot of the TRIP module (if it is in Slot **N**, the TCS contact is named BIn_#N##).

3.2.6.3.2. The TCS macro

In most cases the trip circuit is tripped along with the circuit breaker as well. In situations like this the TCS input would signal a broken trip circuit (logical '0' or FALSE) unnecessarily. To avoid this, the status signals of the CB are to be used combined with the TCS input signal so that it will be evaluated only when the CB is closed.

The TCS macro incorporates this logic for two separate TCS inputs for one CB (see [Figure 3-2](#) for the two TCS inputs and the CB status signal inputs). The outputs are the failure signals for each connected TCS input.

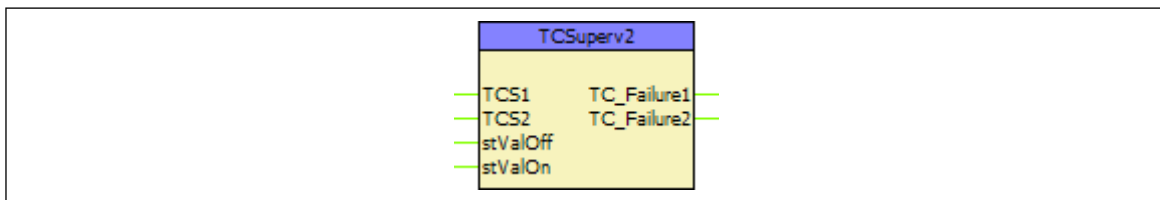


Figure 3-1 Graphic appearance of the Trip Circuit Supervision macro



The internal logic of the macro can be seen on [Figure 3-2](#) below. Both outputs have a fixed pick delay of 1000 ms. Note that **here the outputs are active if the trip circuit is broken**. For a CB with only 1 trip circuit it is enough to simply leave the **TCS2** input open (naturally in this case the TC_Failure2 output cannot be used).

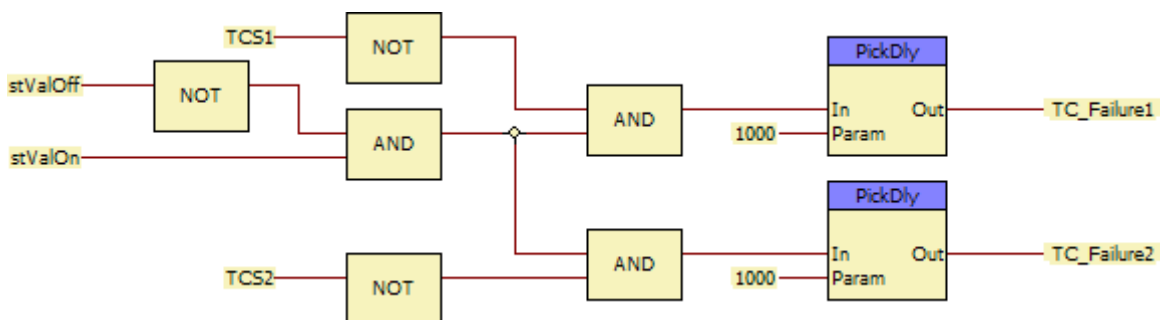


Figure 3-2 Internal logic of the Trip Circuit Supervision macro

3.2.6.3.2.1. Binary input signals

The following table explains the binary input signals of the macro.

Table 3-1 Binary input signals of the Trip Circuit Supervision macro

| BINARY INPUT SIGNAL | EXPLANATION |
|---------------------|------------------------------------------|
| TCS1 | Connect here the first TCS binary input |
| TCS2 | Connect here the second TCS binary input |
| stValOff | CB Off/Open signal |
| stValOn | CB On/Closed signal |

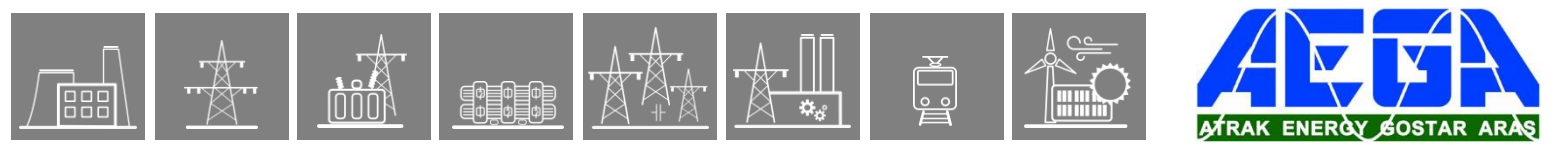
3.2.6.3.2.2. Binary output signals

The following table explains the binary output signals of the macro.

Table 3-2 Binary output signals of the Trip Circuit Supervision macro

| BINARY OUTPUT SIGNAL | EXPLANATION |
|----------------------|-------------------------------|
| TC_Failure1 | Failure on the first circuit |
| TC_Failure2 | Failure on the second circuit |

Note that these are the outputs of a macro, and not a function block, so they must be connected to a physical or a logical output (ConnOut, create status) to make them usable in other parts of the configuration. For further information please refer to the EuroCAP software description.



3.2.7. Dead Line Detection Function

3.2.7.1. Application

The “Dead Line Detection” (DLD) function generates a signal indicating the dead or live state of the line. Additional signals are generated to indicate if the phase voltages and phase currents are above the pre-defined limits.

3.2.7.1.1. Mode of Operation

The task of the “Dead Line Detection” (DLD) function is to decide the Dead line/Live line state.

Criteria of “Dead line” state: all three phase voltages are below the voltage setting value AND all three currents are below the current setting value.

Criteria of “Live line” state: all three phase voltages are above the voltage setting value.

3.2.7.1.2. Structure of the Algorithm

Figure 1-1 shows the structure of the dead line detection algorithm.

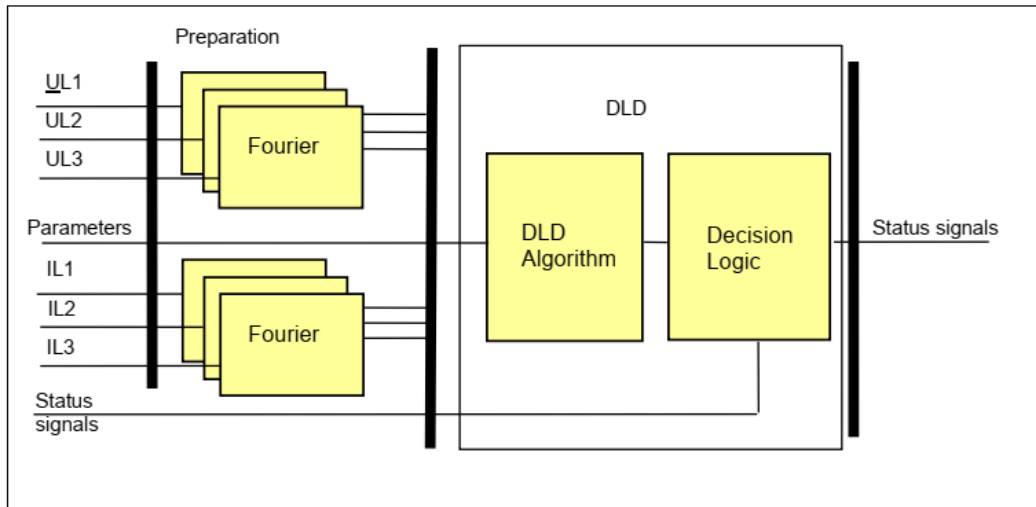


Figure 1-1 Structure of the dead line detection algorithm

For the preparation phase:

The **inputs** are

- the sampled values of the three phase voltages (UL1, UL2, UL3) and three phase currents (IL1, IL2, IL3),
- parameters.

The **outputs** are

- the fundamental Fourier components of the three phase voltages (UL1, UL2, UL3) and three phase currents (IL1, IL2, IL3).

For the DLD function:

The **inputs** are

- the fundamental Fourier components of the three phase voltages (UL1, UL2, UL3) and three phase currents (IL1, IL2, IL3),
- parameters,
- status signals.

The **software modules** of the dead line detection function are:

Fourier calculations

These modules calculate the basic Fourier components of the phase currents and phase voltages individually. These modules belong to the preparation phase.

Dead Line Detection

This module decides if the “Live line condition” (Line_OK) or the “DeadLine condition” is fulfilled.

Decision logic

The decision logic module combines the status signals to generate the outputs of the function.

The following description explains the details of the individual components.

3.2.7.1.3. The Fourier Calculation (Fourier)

These modules calculate the basic Fourier current components of the phase voltages and phase currents individually. These modules belong to the preparation phase.

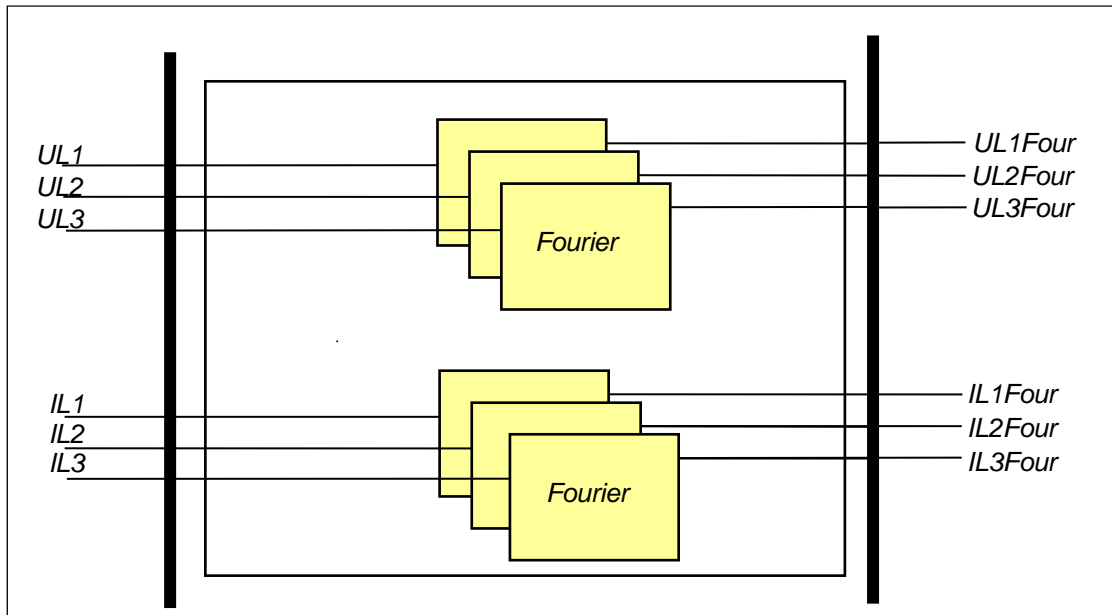


Figure 1-2 Principal scheme of the Fourier calculation

The **inputs** are the sampled values of:

- the three phase voltages (UL1, UL2, UL3)
- the three phase currents (IL1, IL2, IL3)

The **outputs** are:

- the basic Fourier components of the analyzed voltages (UL1Four, UL2Four, UL3Four),
- the basic Fourier components of the analyzed currents (IL1Four, IL2Four, IL3Four).

3.2.7.1.4. The Dead Line Detection Algorithm (Dead Line Detection)

This module decides if the “Live line condition” (Line_OK) or the “DeadLine condition” is fulfilled.

The **inputs** are

- the basic Fourier components of the phase voltages (UL1Four, UL2Four, UL3Four),
- the basic Fourier components of the phase currents (IL1Four, IL2Four, IL3Four),
- status signals,
- parameters.

The **outputs** are the internal status signals of the function. These indicate the “DeadLine condition” or the “Live line condition” (Line_OK) state.

Criteria of “Dead line” state: all three phase voltages are below the voltage setting value AND all three currents are below the current setting value.

Criteria of “Live line” state: all three phase voltages are above the voltage setting value.

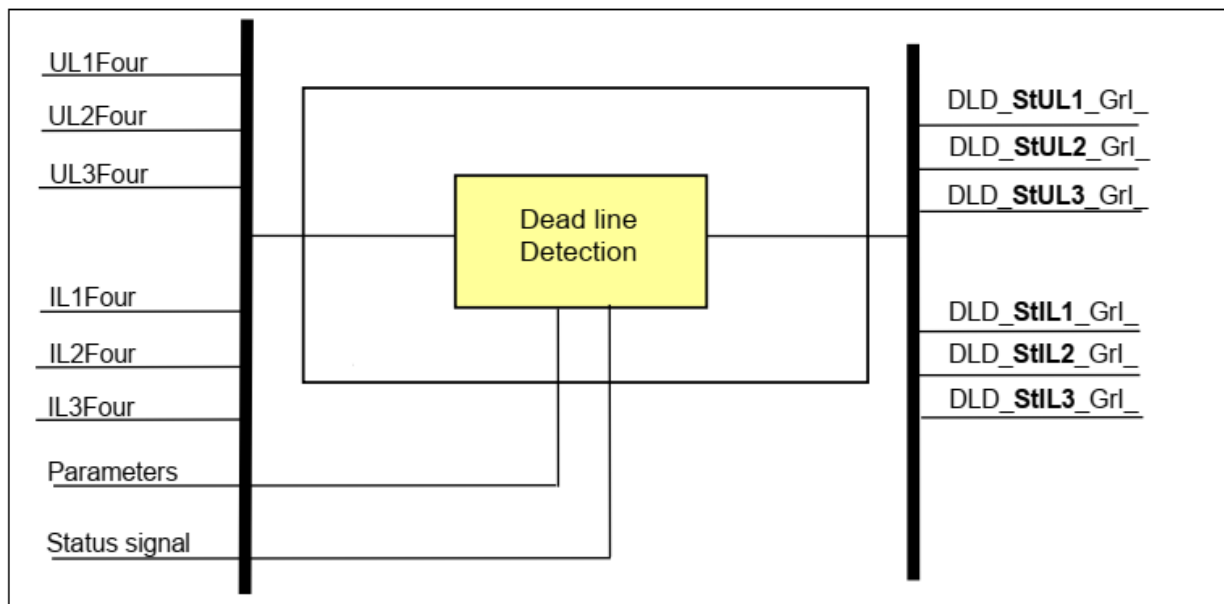


Figure 1-3 Principal scheme of the dead line detection function



Enumerated parameters

Table 1-1 The enumerated parameters of the dead line detection function

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|-----------|-----|---------|------|---------|-------------------------------------|
| Operation | - | Off, On | - | Off | Parameter for enabling the function |

Integer parameters

Table 1-2 The integer parameters of the dead line detection function

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|---------------------|-----|----------|------|---------|-------------------------------------------------|
| Min Operate Voltage | % | 10 – 100 | 1 | 60 | Voltage setting for “Dead line” state criteria. |
| Min Operate Current | % | 2 – 100 | 1 | 10 | Current setting for “Dead line” state criteria. |

Binary status signals

The dead line detection function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

Table 1-3 The binary input signal of the dead line detection function

| BINARY STATUS SIGNAL | SIGNAL TITLE | EXPLANATION |
|----------------------|--------------|------------------------------------|
| DLD_Blk_GrO_ | Block | Input used to disable the function |

The **binary output status signals** of the residual dead line detection function are listed in [Table 1-4](#).

Table 1-4 The binary output status signals of the dead line detection function

| BINARY OUTPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|----------------------|--------------|----------------------------------------------------|
| DLD_StUL1_GrI_ | Start UL1 | The voltage of phase L1 is above the setting limit |
| DLD_StUL2_GrI_ | Start UL2 | The voltage of phase L2 is above the setting limit |
| DLD_StUL3_GrI_ | Start UL3 | The voltage of phase L3 is above the setting limit |
| DLD_StIL1_GrI_ | Start IL1 | The current of phase L1 is above the setting limit |
| DLD_StIL2_GrI_ | Start IL2 | The current of phase L2 is above the setting limit |
| DLD_StIL3_GrI_ | Start IL3 | The current of phase L3 is above the setting limit |

3.2.7.1.5. The Decision Logic (Decision logic)

The decision logic module combines status signals, binary and enumerated parameters to generate the dead line or live line status signals.

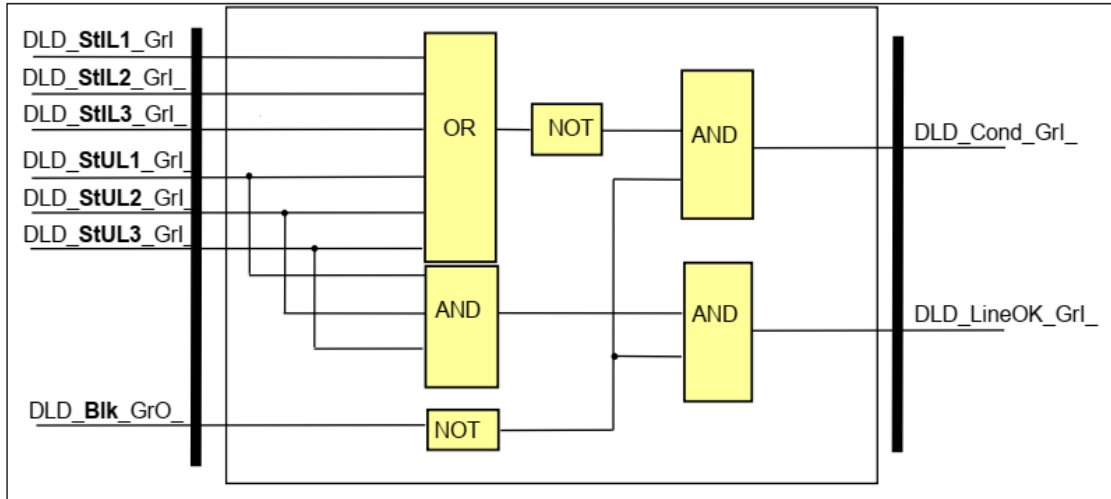


Figure 1-4 The logic scheme of the decision logic

Table 1-5 The binary input status signal of the decision logic

| BINARY INPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|---------------------|--------------|----------------------------------------------------|
| DLD_StUL1_Grl_ | Start UL1 | The voltage of phase L1 is above the setting limit |
| DLD_StUL2_Grl_ | Start UL2 | The voltage of phase L2 is above the setting limit |
| DLD_StUL3_Grl_ | Start UL3 | The voltage of phase L3 is above the setting limit |
| DLD_StIL1_Grl_ | Start IL1 | The current of phase L1 is above the setting limit |
| DLD_StIL2_Grl_ | Start IL2 | The current of phase L2 is above the setting limit |
| DLD_StIL3_Grl_ | Start IL3 | The current of phase L3 is above the setting limit |

Binary status signals

The function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

Table 1-6 The binary input signal of the dead line detection function

| BINARY STATUS SIGNAL | SIGNAL TITLE | EXPLANATION |
|----------------------|--------------|----------------------------------|
| DLD_Blk_GrO_ | Block | Input for disabling the function |

Table 1-7 The binary output status signals of the dead line detection function

| BINARY OUTPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|----------------------|--------------------|------------------------------------------------------------------|
| DLD_DeadLine_Grl_ | DeadLine condition | The requirements of "DeadLine condition" are fulfilled |
| DLD_LineOK_Grl_ | LineOK condition | The requirements of "Live line condition" (LineOK) are fulfilled |

3.2.7.2. DeadLine Detection Function Overview

The graphic appearance of the dead line detection function block is shown in [Figure 2-1](#). This block shows all binary input and output status signals that are applicable in the graphic equation editor.

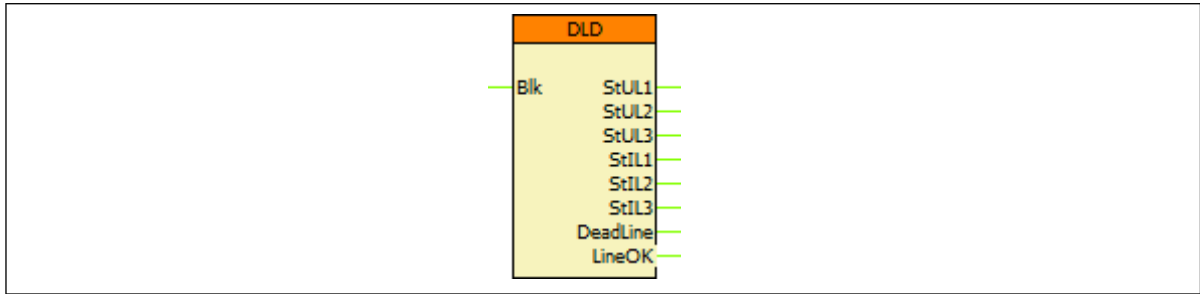


Figure 2-1 The function block of the residual instantaneous overcurrent protection

3.2.7.2.1. Settings

3.2.7.2.1.1. Parameters

The available parameters are listed below in order of their appearance in the *parameters* menu. If the setting range of a parameter should be extended, contact Protecta Support.

Table 2-1 Parameters of the dead line detection function

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|---------------------|-----|----------|------|---------|-------------------------------------------------|
| Operation | - | Off, On | - | Off | Parameter for enabling the function |
| Min Operate Voltage | % | 10 – 100 | 1 | 60 | Voltage setting for “Dead line” state criteria. |
| Min Operate Current | % | 2 – 100 | 1 | 10 | Current setting for “Dead line” state criteria. |

3.2.7.2.2. Function I/O

This section briefly describes the analogue and digital inputs and outputs of the function block.

3.2.7.2.2.1. Analogue inputs

The analog inputs are the sampled values of the three phase voltages and the three phase currents.

3.2.7.2.2.2. Binary input signals (graphed output statuses)

The conditions of the binary inputs are defined by the user, applying the graphic equation editor (*Logic Editor*). Parts written in **bold** are seen on the left side of the function block in the Logic editor.

Table 2-2 The binary input signals of the dead line detection function

| BINARY INPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|-----------------------|--------------|----------------------------------|
| DLD_ Blk _GrO_ | Block | Input for disabling the function |

3.2.7.2.2.3. Binary output signals (graphed input statuses)

These signals can be used in EuroCAP to assign to LED, user LCD object etc. Parts written in **bold** are seen on the right side of the function block in the *Logic Editor*.

Table 2-3 The binary output signals of the dead line detection function

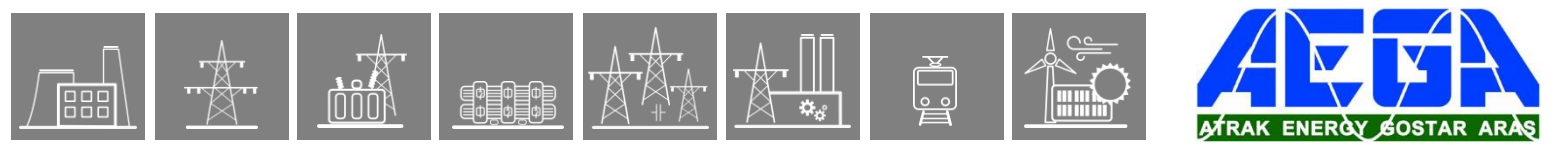
| BINARY OUTPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|----------------------------|--------------------|------------------------------------------------------------------|
| DLD_ StUL1 _GrI_ | Start UL1 | The voltage of phase L1 is above the setting limit |
| DLD_ StUL2 _GrI_ | Start UL2 | The voltage of phase L2 is above the setting limit |
| DLD_ StUL3 _GrI_ | Start UL3 | The voltage of phase L3 is above the setting limit |
| DLD_ StIL1 _GrI_ | Start IL1 | The current of phase L1 is above the setting limit |
| DLD_ StIL2 _GrI_ | Start IL2 | The current of phase L2 is above the setting limit |
| DLD_ StIL3 _GrI_ | Start IL3 | The current of phase L3 is above the setting limit |
| DLD_ DeadLine _GrI_ | DeadLine condition | The requirements of "DeadLine condition" are fulfilled |
| DLD_ LineOK _GrI_ | LineOK condition | The requirements of "Live line condition" (LineOK) are fulfilled |

3.2.7.2.2.4. Online data

The following values are visible in the *online data* page.

Table 2-4 Online data of the dead line detection function

| SIGNAL TITLE | DIMENSION | EXPLANATION |
|--------------------|-----------|---------------------------------------------------------|
| DeadLine condition | - | The requirements of "DeadLine condition" are fulfilled |
| LineOK condition | - | The requirements of "Live line condition" are fulfilled |



3.2.7.2.2.5. Events

There are no events generated for this function block.

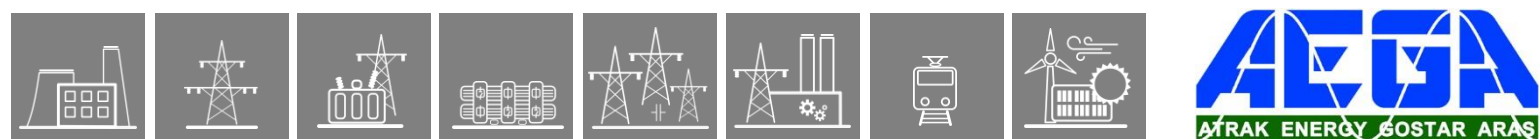
3.2.7.2.3. Technical Data

Table 2-5 Technical data of the dead line detection function

| FUNCTION | VALUE | ACCURACY |
|-----------------|---------|----------|
| Pick-up voltage | | 1% |
| Operation time | < 20 ms | |
| Reset ratio | 0.95 | |

3.2.7.2.4. Notes for Testing

This function does not generate events on its own. To create them, another function block, the GGIO16 custom event function block must be utilized, see its description for more information.



3.2.8. Voltage transformer supervision function

The voltage transformer supervision function generates a signal to indicate an error in the voltage transformer secondary circuit. This signal can serve, for example, as a warning, indicating disturbances in the measurement, or it can disable the operation of the distance protection function if appropriate measured voltage signals are not available for a distance decision.

The voltage transformer supervision function is designed to detect faulty asymmetrical states of the voltage transformer circuit caused, for example, by a broken conductor in the secondary circuit.

(Another method for detecting voltage disturbances is the supervision of the auxiliary contacts of the miniature circuit breakers in the voltage transformer secondary circuits. This function is not described here.)

The user has to generate graphic equations for the application of the signal of this voltage transformer supervision function.

This function is interconnected with the “dead line detection function”. Although the dead line detection function is described fully in a separate document, the explanation necessary to understand the operation of the VT supervision function is repeated also in this document.

3.2.8.1. Mode of operation

3.2.8.1.1. “Dead line detection” (DLD) function - modes of operation

The voltage transformer supervision function is based on the “Dead line detection” (DLD) function, the task of which is to decide the Dead line/Live line state.

Criteria of “Dead line” state: all three phase voltages are below the preset voltage value AND all three currents are below the preset current value.

Criteria of “Live line” state: all three phase voltages are above the preset voltage value.

The dead line detection function is described in a separate document.

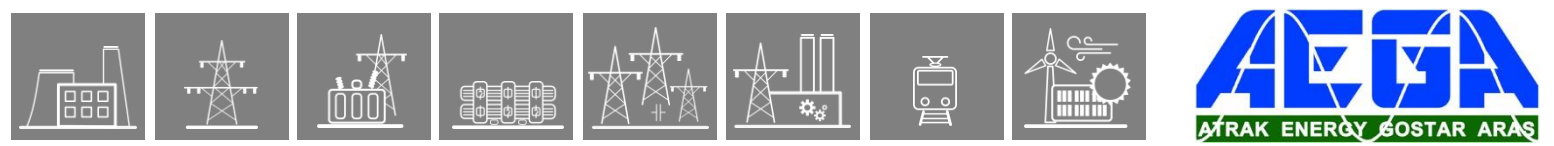
3.2.8.1.2. “Voltage transformer supervision” (VTS) function - modes of operation

The voltage transformer supervision function can be used in three different modes of application:

Zero sequence detection (for typical applications in systems with grounded neutral): “VT failure” signal is generated if the residual voltage ($3U_0$) is above the preset voltage value AND the residual current ($3I_0$) is below the preset current value.

Negative sequence detection (for typical applications in systems with isolated or resonant grounded (Petersen) neutral): “VT failure” signal is generated if the negative sequence voltage component (U_2) is above the preset voltage value AND the negative sequence current component (I_2) is below the preset current value.

Special application: “VT failure” signal is generated if the residual voltage ($3U_0$) is above the preset voltage value AND the residual current ($3I_0$) AND the negative sequence current component (I_2) are below the preset current values.



3.2.8.1.3. Activating the VTS function

The voltage transformer supervision function can be activated if “Live line” status is detected for at least 200 ms. This delay avoids mal-operation at line energizing if the poles of the circuit breaker make contact with a time delay. The function is set to be inactive if “Dead line” status is detected.

If the conditions specified by the selected mode of operation are fulfilled (for at least 4 milliseconds) then the voltage transformer supervision function is activated and the operation signal is generated. (When evaluating this time delay, the natural operating time of the applied Fourier algorithm must also be considered.)

NOTE: For the operation of the voltage transformer supervision function the “Dead line detection function” must be operable as well: it must be enabled by binary parameter setting, and its blocking signal may not be active.

3.2.8.1.4. Resetting the VTS function

If, in the active state, the conditions for operation are no longer fulfilled, the resetting of the function depends on the mode of operation of the primary circuit:

- If the “Live line” state is valid, then the function resets after approx. 200 ms of time delay. (When evaluating this time delay, the natural operating time of the applied Fourier algorithm must also be considered.)
- If the “Dead line” state is started and the “VTS Failure” signal has been continuous for at least 100 ms, then the “VTS failure” signal does not reset; it is generated continuously even when the line is in a disconnected state. Thus, the “VTS Failure” signal remains active at reclosing.
- If the “Dead line” state is started and the “VTS Failure” signal has not been continuous for at least 100 ms, then the “VTS failure” signal resets.

3.2.8.2. Structure of the voltage transformer supervision algorithm

Fig.1-1 shows the structure of the voltage transformer supervision (VTS) algorithm.

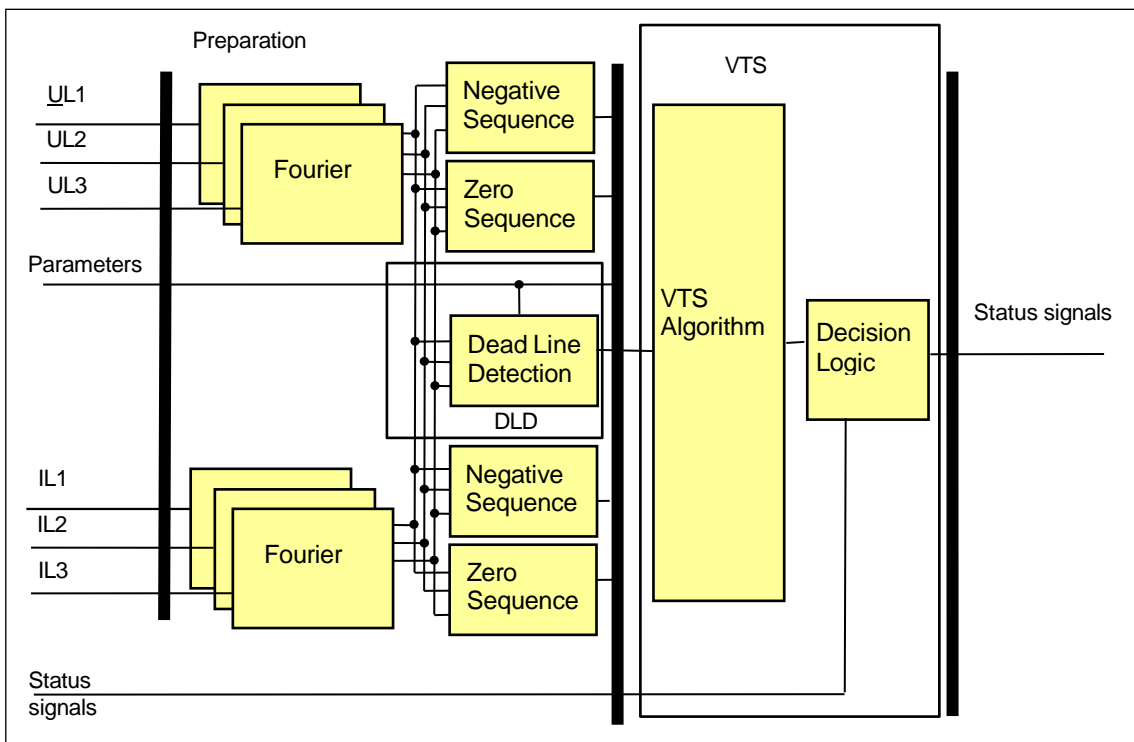


Figure 1-1 Structure of the voltage transformer supervision algorithm

For the preparation phase:

The **inputs** are

- the sampled values of the three phase voltages (UL1, UL2, UL3) and three phase currents (IL1, IL2, IL3),
- parameters.

The **outputs** are

- negative and zero sequence voltage and current components.
- signals indicating the “Live line” or “Dead line” condition.

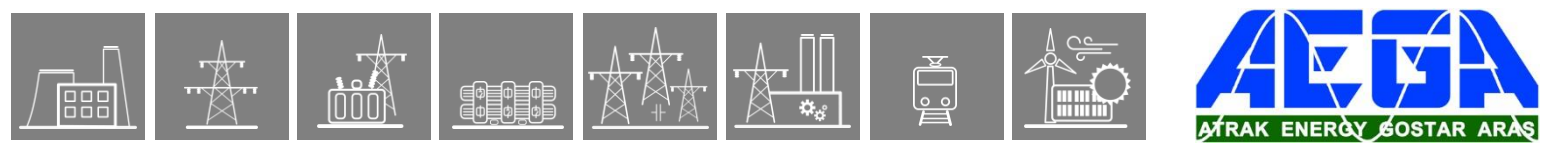
For the VTS function:

The **inputs** are

- negative and zero sequence voltage and current components.
- signals indicating the “Live line” or “Dead line” condition,
- parameters,
- status signals.

The **outputs** are

- the binary output status signal indicating a failure of the voltage transformer secondary circuit,
- signals indicating the “Live line” or “Dead line” condition.



The **software modules** of the voltage transformer supervision function and those of the preparation phase:

Fourier calculations

These modules calculate the basic Fourier current components of the phase voltages and currents. These modules belong to the preparation phase.

Negative sequence

This module calculates the basic Fourier current components of the negative sequence voltage and current, based on the Fourier components of the phase voltages and currents. This module belongs to the preparation phase.

Zero sequence

This module calculates the basic Fourier voltage and current components of the residual voltage ($3U_0$) and current ($3I_0$), based on the Fourier components of the phase voltages and currents. This module belongs to the preparation phase.

Dead Line Detection

This module decides if the "Line_OK condition" or the "DeadLine condition" is fulfilled. This module belongs to the preparation phase.

VTS algorithm

This module decides if the "VTS_FAIL" conditions are fulfilled according to the conditions specified for the selected mode.

Decision logic

The decision logic module combines the status signals to generate the trip command of the function.

The following description explains the details of the individual components.

3.2.8.3. The Fourier calculation (Fourier)

These modules calculate the basic Fourier current components of the phase voltages and phase currents individually. These modules belong to the preparation phase.

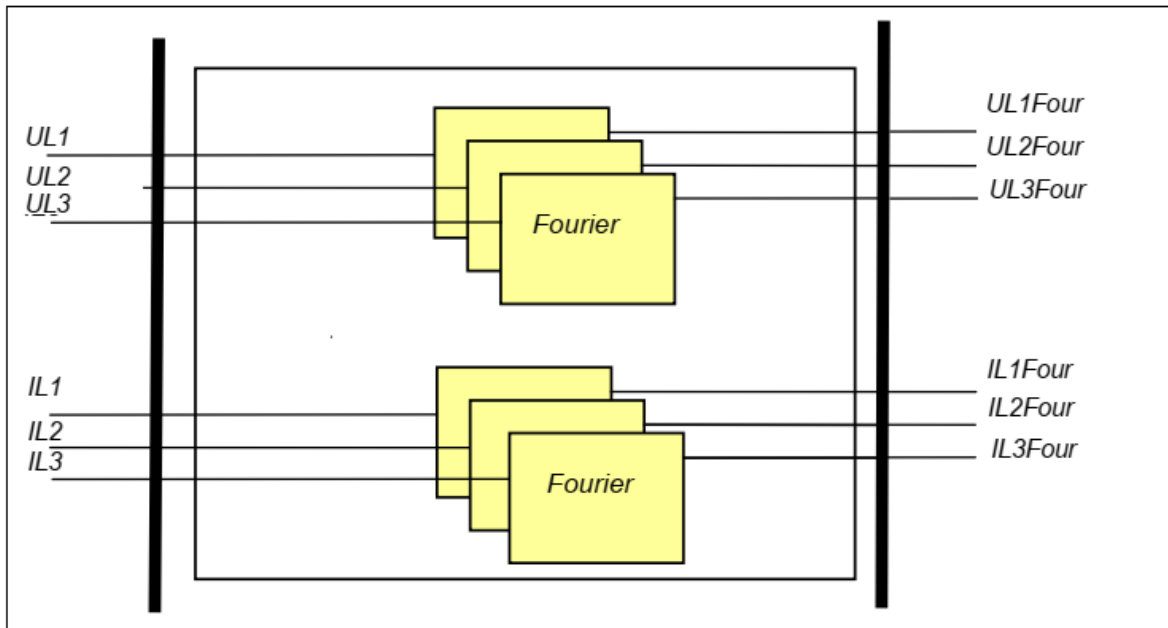


Figure 1-2 Principal scheme of the Fourier calculation

The **inputs** are the sampled values of:

- the three phase voltages (UL1, UL2, UL3)
- the three phase currents (IL1, IL2, IL3)

The **outputs** are

- the basic Fourier components of the analyzed voltages (UL1Four, UL2Four, UL3Four),
- the basic Fourier components of the analyzed currents (IL1Four, IL2Four, IL3Four).

3.2.8.4. The negative phase sequenc calculation (Negative sequence)

This module calculates the negative phase sequence components based on the Fourier components of the phase voltages and phase currents. These modules belong to the preparation phase.

The **inputs** are the basic Fourier components of the phase voltages and phase currents (UL1Four, UL2Four, UL3Four, IL1Four, IL2Four, IL3Four).

The **outputs** are

- the basic Fourier components of the negative sequence voltage component (UNegFour),
- the basic Fourier components of the negative sequence current component (INegFour).

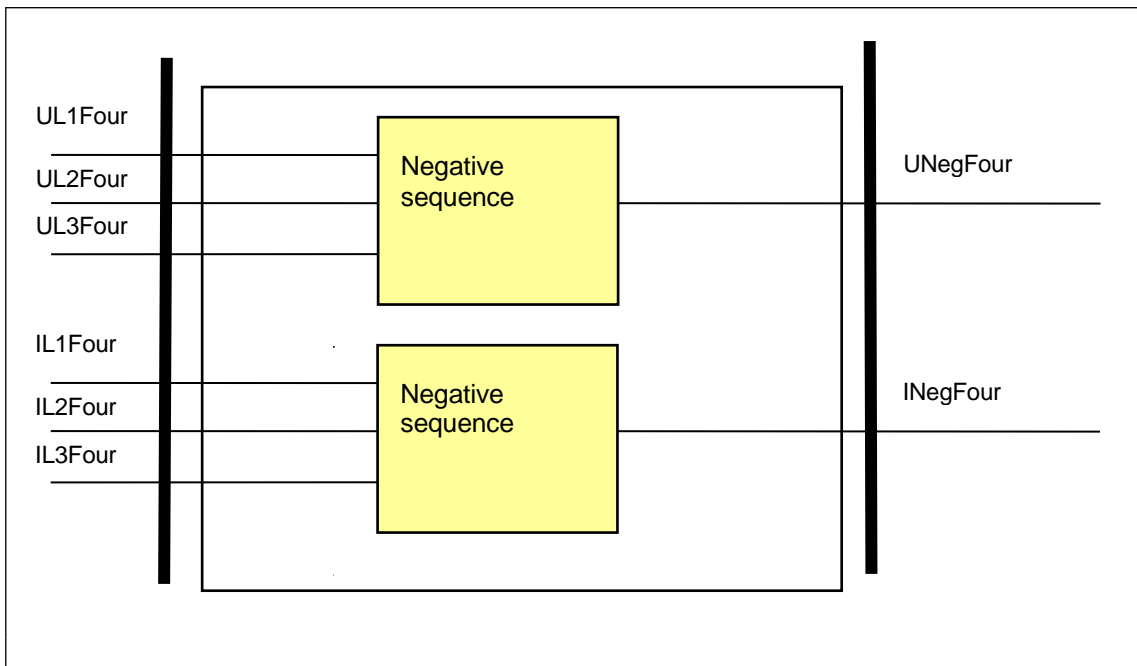


Figure 1-3 Schema of the negative sequence component calculation

3.2.8.5. The residual voltage and current calculation (Zero sequence)

This module calculates the residual voltage ($U_{ZerFour}$) and current ($I_{ZerFour}$) based on the Fourier components of the phase voltages and currents. These modules belong to the preparation phase.

The **inputs** are

- the basic Fourier components of the phase voltages ($UL1Four$, $UL2Four$, $UL3Four$),
- the basic Fourier components of the phase currents ($IL1Four$, $IL2Four$, $IL3Four$).

The **outputs** are

- the basic Fourier components of the residual voltage ($U_{ZerFour}$),
- the basic Fourier components of the residual current ($I_{ZerFour}$).

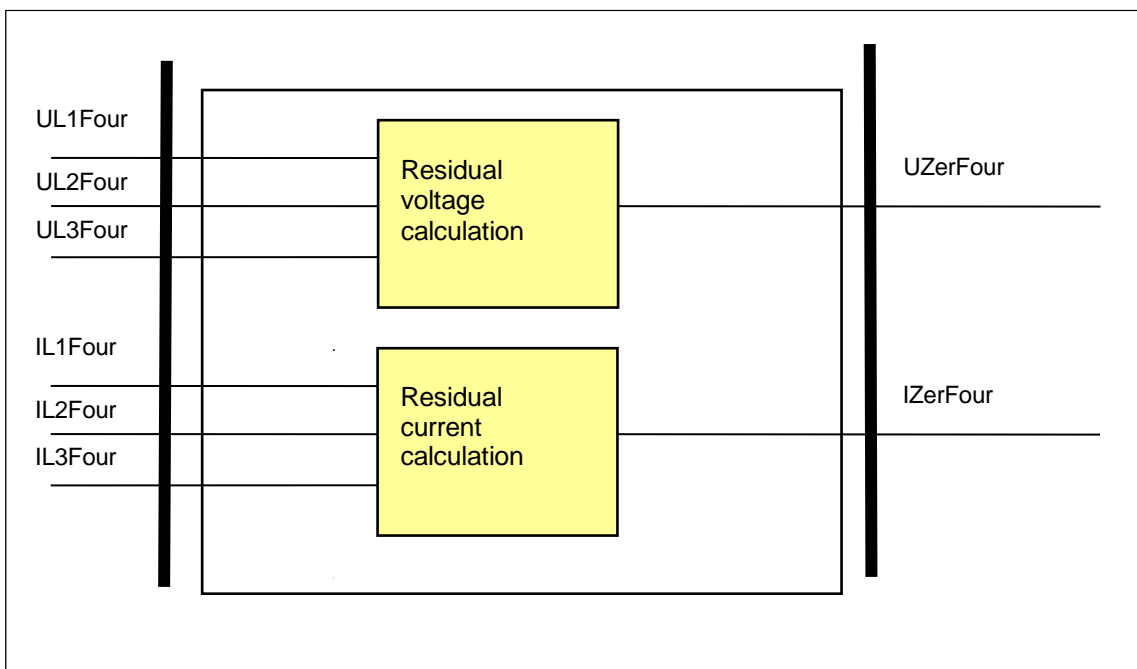


Figure 1-4 Schema of the residual voltage and current calculation

3.2.8.6. The dead line detection algorithm (Dead Line Detection)

This module decides if the “Line_OK condition” or the “DeadLine condition” is fulfilled. This module belongs to the preparation phase.

The **inputs** are

- the basic Fourier components of the phase voltages (UL1Four, UL2Four, UL3Four),
- the basic Fourier components of the phase currents (IL1Four, IL2Four, IL3Four),
- parameters.

The **outputs** are the internal status signals of the function. These indicate the “DeadLine condition state” or the “Line_OK conditions” state. This module belongs to the preparation phase.

Criteria of “Dead line” state: all three phase voltages are below the voltage setting value AND all three currents are below the current setting value.

Criteria of “Live line” state: all three phase voltages are above the voltage setting value.

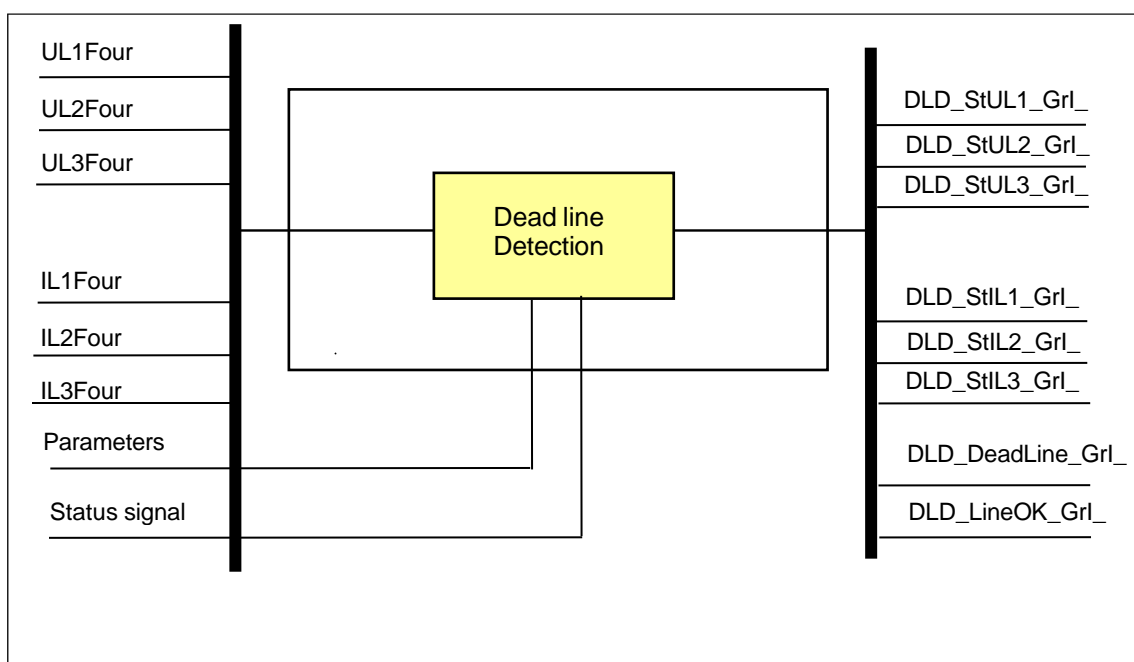


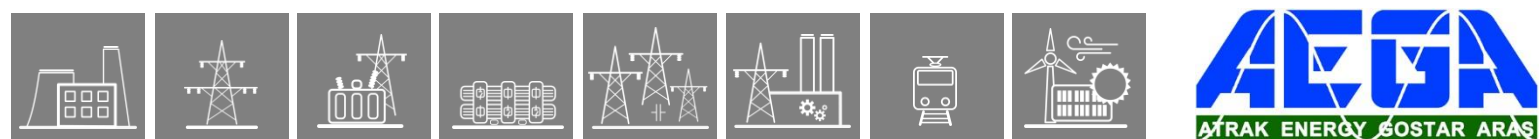
Figure 1-5 Principal scheme of the dead line detection function

The parameters of the dead line detection function are listed in [Table 1-1](#).

Integer parameters

| Parameter name | Title | Unit | Min | Max | Step | Default |
|--------------------------------------------------------|---------------------|------|-----|-----|------|---------|
| Integer parameters of the dead line detection function | | | | | | |
| DLD_ULev_IPar_ | Min Operate Voltage | % | 10 | 100 | 1 | 60 |
| DLD_ILev_IPar_ | Min Operate Current | % | 2 | 100 | 1 | 10 |

Table 1-1 The integer parameters of the dead line detection function



Binary status signals

The dead line detection function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

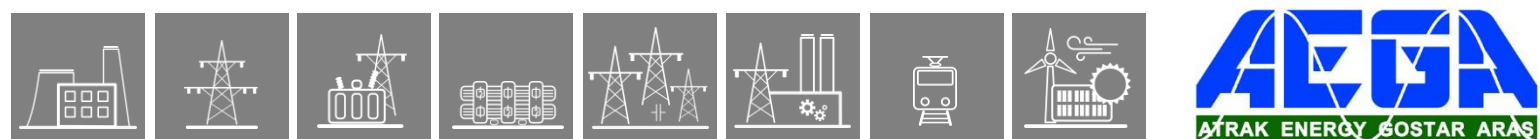
| Binary status signal | Explanation |
|----------------------|------------------------------------------------------------------------------------------------------|
| DLD_Blk_GrO_ | Output status of a graphic equation defined by the user to disable the dead line detection function. |

Table 1-2 The binary input signal of the dead line detection function

The **binary output status signals** of the dead line detection function are listed in [Table 1-3](#).

| Binary output signals | Signal title | Explanation |
|-----------------------|--------------------|-------------------------------------------------------------|
| DLD_StUL1_GrI_ | Start UL1 | The voltage of phase L1 is above the preset parameter value |
| DLD_StUL2_GrI_ | Start UL2 | The voltage of phase L2 is above the preset parameter value |
| DLD_StUL3_GrI_ | Start UL3 | The voltage of phase L3 is above the preset parameter value |
| DLD_StIL1_GrI_ | Start IL1 | The current of phase L1 is above the preset parameter value |
| DLD_StIL2_GrI_ | Start IL2 | The current of phase L2 is above the preset parameter value |
| DLD_StIL3_GrI_ | Start IL3 | The current of phase L3 is above the preset parameter value |
| DLD_DeadLine_GrI_ | DeadLine condition | The criteria for dead line condition are fulfilled |
| DLD_LineOK_GrI_ | LineOK condition | The criteria for line OK condition are fulfilled |

Table 1-3 The binary output status signals of the dead line detection function



3.2.8.7. Voltage transformer supervision (VTS algorithm)

The voltage transformer supervision function can be used in three different modes of operation:

Zero sequence detection (for typical applications in systems with grounded neutral): “VT failure” signal is generated if the residual voltage ($3U_0$) is above the preset voltage value AND the residual current ($3I_0$) is below the preset current value.

Negative sequence detection (for typical applications in systems with isolated or resonant grounded (Petersen) neutral): “VT failure” signal is generated if the negative sequence voltage component (U_2) is above the preset voltage value AND the negative sequence current component (I_2) is below the preset current value.

Special application: “VT failure” signal is generated if the residual voltage ($3U_0$) is above the preset voltage value AND the residual current ($3I_0$) AND the negative sequence current component (I_2) are below the preset current values.

The task of this module is to detect if the conditions of the “VTS FAIL” state are fulfilled, according to the conditions defined for the selected mode of operation.

The **inputs** are

- the basic Fourier components of the residual voltage ($UZerFour$) and current ($IZerFour$),
- the negative sequence components of the voltage ($UNegFour$) and current ($INegFour$),
- binary signals from the dead line detection function,
- parameters.

NOTE: For the operation of the voltage transformer supervision function the “Dead line detection function” must be operable as well: it must be enabled by binary parameter setting, and its blocking signal may not be active.

The **output** is the internal status signal of the function. This internal signal indicates if the “VTS_FAIL_int” condition is fulfilled.

| Binary output signals | Signal title | Explanation |
|-----------------------|--------------|---------------------------------------------------------------------------------------------------------------------|
| VTS_FAIL_int | VTS_FAIL_int | Internal status signal indicating the fulfillment of conditions. This status signal is not available for the users. |

Table 1-4 The binary internal status signals of the voltage transformer supervision algorithm

The parameters of the voltage transformer supervision algorithm are listed in [Table 1-5](#) and in [Table 1-6](#).

Enumerated parameter

| Parameter name | Title | Selection range | Default |
|------------------------------|-----------|-------------------------------------------|---------------|
| Parameter for type selection | | | |
| VTS_Oper_EPar_ | Operation | Off, Zero sequence, Neg sequence, Special | Zero sequence |

Table 1-5 The enumerated parameters of the voltage transformer supervision function

Integer parameters

| Parameter name | Title | Unit | Min | Max | Step | Default |
|--------------------------------------------------------------------------------------|------------|------|-----|-----|------|---------|
| Starting voltage and current parameter for residual and negative sequence detection: | | | | | | |
| VTS_Uo_IPar_ | Start URes | % | 5 | 50 | 1 | 30 |
| VTS_Io_IPar_ | Start IRes | % | 10 | 50 | 1 | 10 |
| VTS_Uneg_IPar_ | Start UNeg | % | 5 | 50 | 1 | 10 |
| VTS_Ineg_IPar_ | Start INeg | % | 10 | 50 | 1 | 10 |

Table 1-6 The integer parameters of the voltage transformer supervision algorithm

3.2.8.8. The decision logic (Decision logic)

The decision logic module combines the status signals, binary and enumerated parameters to generate the trip command of the function.

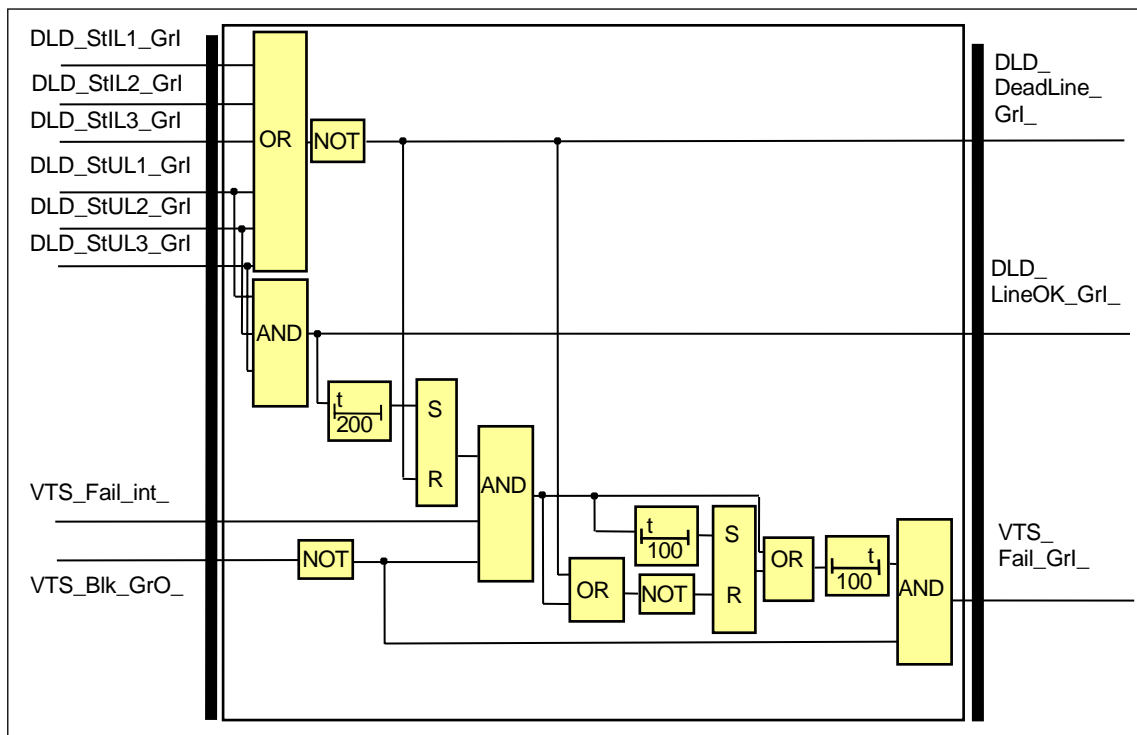


Figure 1-6 The logic scheme of the decision logic

| Binary input signals | Signal title | Explanation |
|----------------------|--------------|---------------------------------------------------------------------------------------------------------------------|
| DLD_StUL1_Grl_ | Start UL1 | The voltage of phase L1 is above the preset parameter value |
| DLD_StUL2_Grl_ | Start UL2 | The voltage of phase L2 is above the preset parameter value |
| DLD_StUL3_Grl_ | Start UL3 | The voltage of phase L3 is above the preset parameter value |
| DLD_StIL1_Grl_ | Start IL1 | The current of phase L1 is above the preset parameter value |
| DLD_StIL2_Grl_ | Start IL2 | The current of phase L2 is above the preset parameter value |
| DLD_StIL3_Grl_ | Start IL3 | The current of phase L3 is above the preset parameter value |
| VTS_FAIL_int | VTS_FAIL_int | Internal status signal indicating the fulfillment of conditions. This status signal is not available for the users. |

Table 1-7 The binary input signals of the decision logic

Binary status signals

The voltage transformer supervision function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

| Binary status signal | Explanation |
|----------------------|------------------------------------------------------------------------------------------------------------------|
| VTS_BlK_GrO_ | Output status of a graphic equation defined by the user to disable the voltage transformer supervision function. |

Table 1-8 The binary input signal of the decision logic

| Binary output signals | Signal title | Explanation |
|-----------------------|--------------------|--------------------------------------------------------|
| DLD_DeadLine_Grl_ | DeadLine condition | The requirements of “DeadLine condition” are fulfilled |
| DLD_LineOK_Grl_ | LineOK condition | The requirements of “LineOK condition” are fulfilled |
| VTS_Fail_Grl | VT Failure | Failure status signal of the VTS function |

Table 1-9 The binary output status signals of the decision logic

3.2.8.9. Technical summary

3.2.8.9.1. Technical data

| Function | Value | Accuracy |
|-------------------------------------------------------------|-------|------------|
| Pick-up voltage I ₀ =0A I ₂ =0A | | <1% <1% |
| Operation time | <20ms | |
| Reset ratio | 0.95 | |

Table 1-10 Technical data of the voltage transformer supervision function

3.2.8.9.2. The parameters

Integer parameters

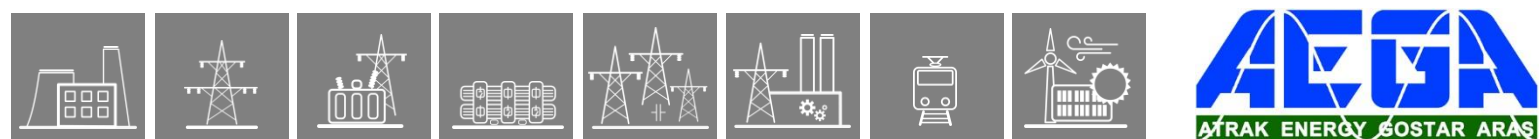
| Parameter name | Title | Unit | Min | Max | Step | Default |
|--------------------------------------------------------------------------------------|---------------------|------|-----|-----|------|---------|
| Integer parameters of the dead line detection function | | | | | | |
| DLD_ULev_IPar_ | Min Operate Voltage | % | 10 | 100 | 1 | 60 |
| DLD_ILev_IPar_ | Min Operate Current | % | 2 | 100 | 1 | 10 |
| Starting voltage and current parameter for residual and negative sequence detection: | | | | | | |
| VTS_Uo_IPar_ | Start URes | % | 5 | 50 | 1 | 30 |
| VTS_Io_IPar_ | Start IRes | % | 10 | 50 | 1 | 10 |
| VTS_Uneg_IPar_ | Start UNeg | % | 5 | 50 | 1 | 10 |
| VTS_Ineg_IPar_ | Start INeg | % | 10 | 50 | 1 | 10 |

Table 1-11 The integer parameters of the voltage transformer supervision function

Enumerated parameter

| Parameter name | Title | Selection range | Default |
|------------------------------|-----------|--------------------------------------------|---------------|
| Parameter for type selection | | | |
| VTS_Oper_EPar_ | Operation | Off, Zero sequence, Neg. sequence, Special | Zero sequence |

Table 1-12 The enumerated parameter of the voltage transformer supervision function



3.2.8.9.3. The binary input status signals

Binary status signals

The voltage transformer supervision function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

| Binary status signal | Explanation |
|----------------------|------------------------------------------------------------------------------------------------------------------|
| VTS_BlK_GrO_ | Output status of a graphic equation defined by the user to disable the voltage transformer supervision function. |

Table 1-13 The binary input signal of the voltage transformer supervision function

3.2.8.9.4. Binary output status signals

The **binary output status signals** of the voltage transformer supervision function are listed in Table 1-14.

| Binary output signals | Signal title | Explanation |
|-----------------------|--------------------|-----------------------------------------------------------------------------------------|
| DLD function | | |
| DLD_StUL1_Grl_ | Start UL1 | The voltage of phase L1 is above the preset parameter value, signal of the DLD function |
| DLD_StUL2_Grl_ | Start UL2 | The voltage of phase L2 is above the preset parameter value, signal of the DLD function |
| DLD_StUL3_Grl_ | Start UL3 | The voltage of phase L3 is above the preset parameter value, signal of the DLD function |
| DLD_StIL1_Grl_ | Start IL1 | The current of phase L1 is above the preset parameter value, signal of the DLD function |
| DLD_StIL2_Grl_ | Start IL2 | The current of phase L2 is above the preset parameter value, signal of the DLD function |
| DLD_StIL3_Grl_ | Start IL3 | The current of phase L3 is above the preset parameter value, signal of the DLD function |
| DLD_DeadLine_Grl_ | DeadLine condition | The requirements of "DeadLine condition" are fulfilled, signal of the DLD function |
| DLD_LineOK_Grl_ | LineOK condition | The requirements of "LineOK condition" are fulfilled, signal of the DLD function |
| VTS function | | |
| VTS_Fail_Grl | VT Failure | Failure status signal of the VTS function |

Table 1-14 The binary output signals of the voltage transformer supervision function

3.2.8.9.5. The function block

The function block of the dead line detection and voltage transformer supervision function is shown in Figure 1-7. This block shows all binary input and output status signals that are applicable in the graphic equation editor.

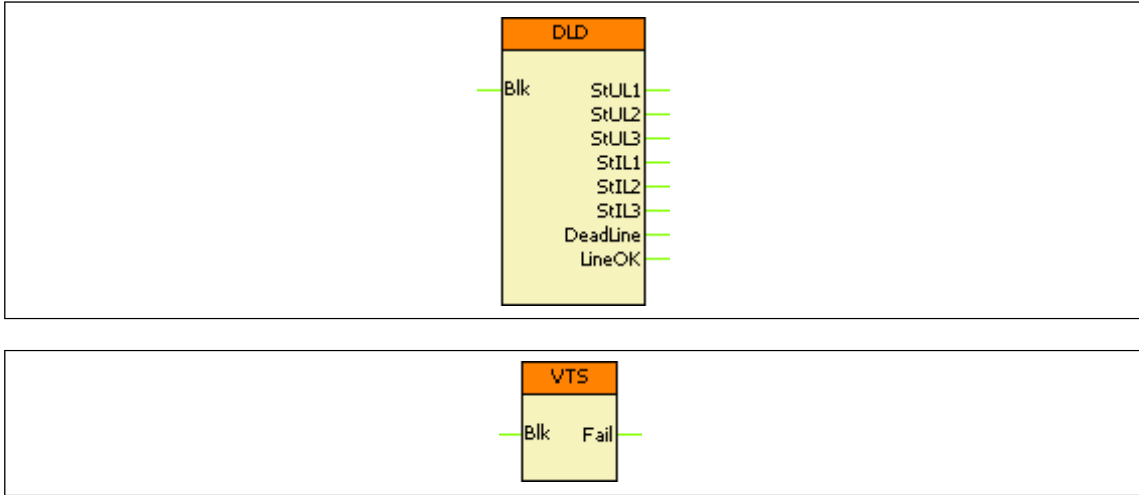


Figure 1-7 The function block of the dead line detection and voltage transformer supervision function

3.2.9. Current unbalance function

3.2.9.1. Application

The current unbalance protection function can be applied to detect unexpected asymmetry in current measurement.

3.2.9.1.1. Mode of operation

The applied method selects maximum and minimum phase currents (RMS values of the fundamental Fourier components). If the difference between them is above the setting limit, the function generates a start signal. It is a necessary precondition of start signal generation that the maximum of the currents be above 10 % of the rated current and below 150% of the rated current.

The function can be disabled by parameter setting, and by an input signal programmed by the user with the graphic programming tool.

The trip command is generated after the defined time delay if trip command is enabled by parameter setting.

3.2.9.1.2. Operation principles

Figure 1-1 shows the structure of the current unbalance protection algorithm.

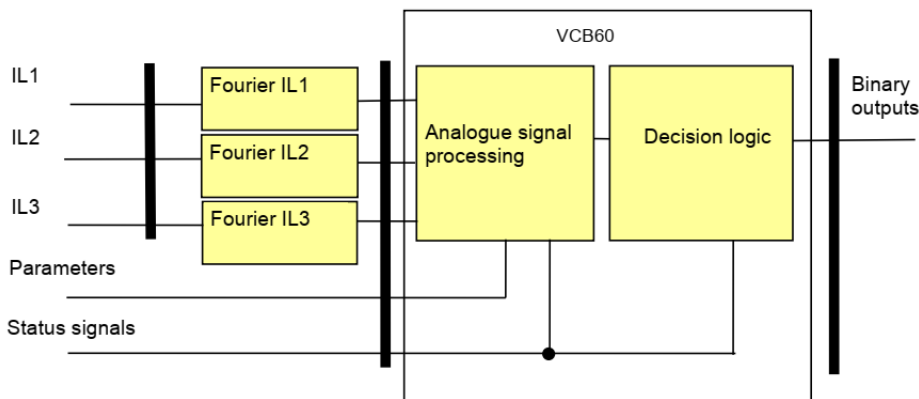


Figure 1-1 Structure of the current unbalance protection algorithm

The **inputs** of the preparatory phase are

- the three phase currents,

The **outputs** of the preparatory phase are

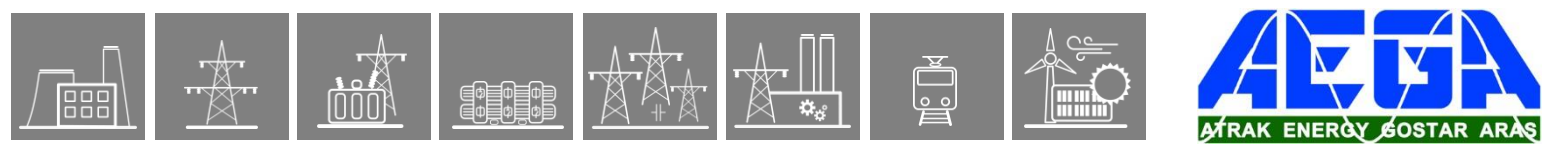
- the RMS values of the fundamental Fourier component of three phase currents.

The **inputs** of the current unbalance function are

- the RMS values of the fundamental Fourier component of three phase currents,
- parameters,
- status signals.

The **outputs** are

- the binary output status signals.



The **software modules** of the current unbalance function:

Fourier calculations

These modules calculate the RMS values of the basic Fourier current components of the phase currents individually (not part of the VCB60 function).

Analogue signal processing

This module processes the RMS values of the Fourier components of the phase currents to prepare the signals for the decision.

Decision logic

The decision logic module combines the status signals to generate the starting signal and the trip command of the function.

The following description explains the details of the individual components.

3.2.9.1.3. The Fourier calculation (Fourier)

These modules calculate the RMS values of the fundamental Fourier components of the phase currents individually. They are not part of the VCB60 function; they belong to the preparatory phase.

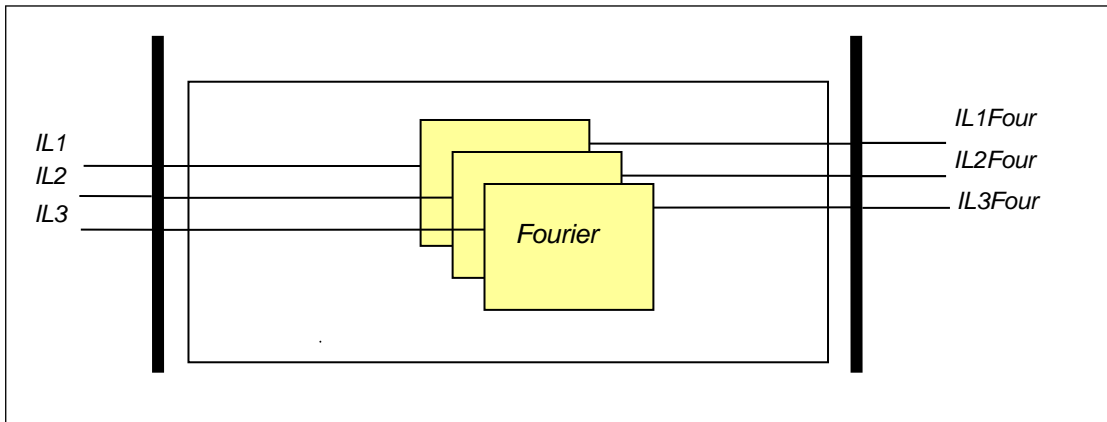


Figure 1-2 Principal scheme of the Fourier calculation

The **inputs** are the sampled values of the three phase currents (IL1, IL2, IL3)

The **outputs** are the RMS values of the fundamental Fourier components of the phase currents (IL1Four, IL2Four, IL3Four).

3.2.9.1.4. The Analogue signal processing

This module processes the Fourier components of the phase currents to prepare the signals for the decision.

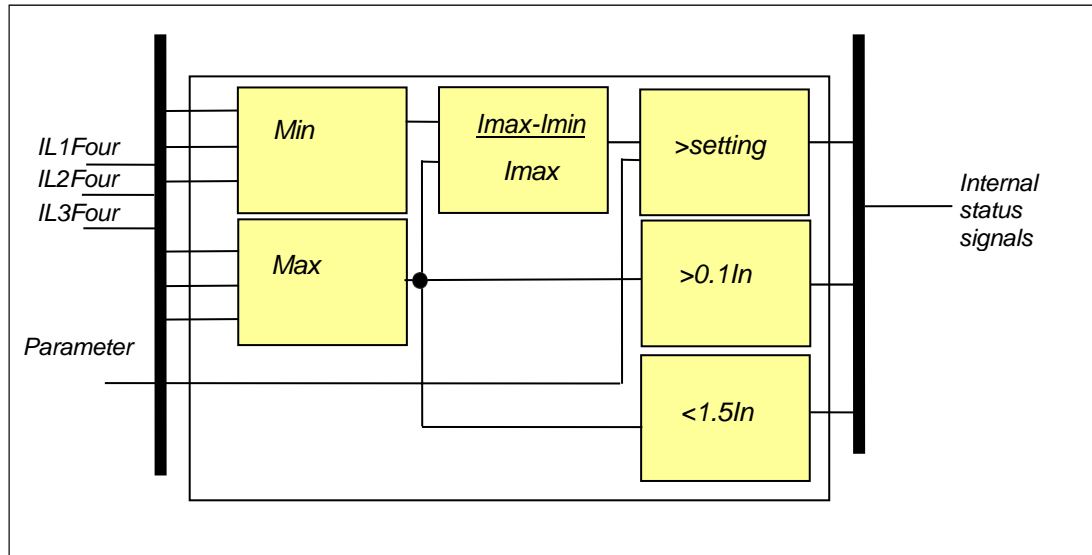


Figure 1-3 Principal scheme of the analogue signal processing

The **inputs** are the fundamental Fourier components of the analyzed currents (IL1Four, IL2Four, IL3Four)

The **outputs** are internal binary signals:

- $\Delta I >$ The difference between the maximum and minimum of the RMS values of the fundamental Fourier components of the phase currents as a percentage of the maximum of these values is above the limit defined by the preset parameter "Start current";
- $I_{max} > 0.1 I_n$ The maximum of the RMS values of the fundamental Fourier components of the phase currents is sufficient for evaluation;
- $I_{max} < 1.5 I_n$ The maximum of the RMS values of the fundamental Fourier components of the phase currents is not considered as a fault current.

3.2.9.1.5. The decision logic (Decision logic)

The decision logic module combines the status signals, binary and enumerated parameters to generate the trip command of the function.

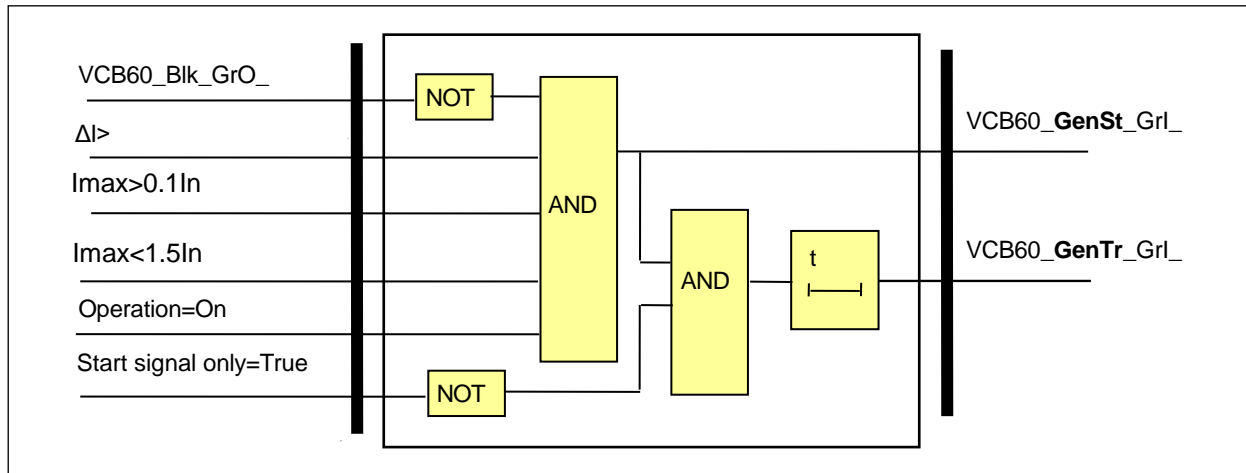


Figure 1-4 The logic scheme of the current unbalance function

The **inputs** are internal binary signals:

- $\Delta I >$ the difference between the maximum and minimum of the RMS values of the fundamental Fourier components of the phase currents as a percentage of the maximum of these values is above the limit defined by parameter setting "Start Current Diff";
- $I_{max} > 0.1 I_n$ the maximum of the RMS values of the fundamental Fourier components of the phase currents is sufficient for evaluation;
- $I_{max} < 1.5 I_n$ the maximum of the RMS values of the fundamental Fourier components of the phase currents is not considered as a fault current.

3.2.9.2. Current unbalance protection function overview

The graphic appearance of the function block of the current unbalance protection function is shown below. The block shows all binary input and output status signals which are applicable in the graphic equation editor.

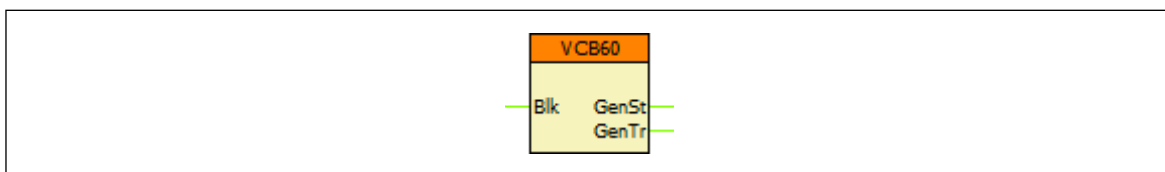
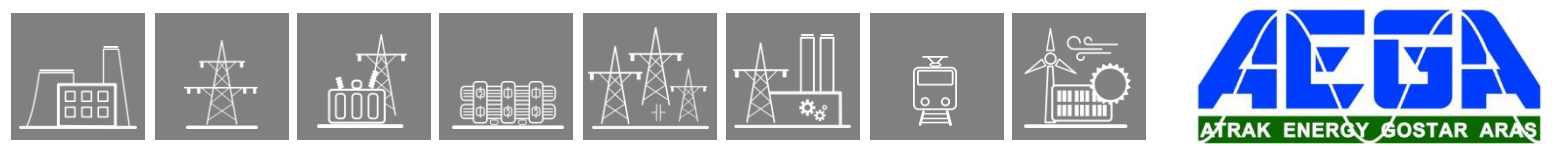


Figure 2-1 Graphic appearance of the function block of the current unbalance protection function



3.2.9.2.1. Settings

3.2.9.2.1.1. Parameters

The available parameters are listed below in order of their appearance in the *parameters* menu. If the setting range of a parameter should be extended, contact Protecta Support.

Table 2-1 Parameters of the current unbalance protection function

| TITLE | DIM | RANGE | STEP | DEFAULT | EXPLANATION |
|-------------------|------|-------------|------|---------|---------------------------------------------------------------------------------|
| Operation | - | Off, On | - | Off | Enabling the function |
| Start Signal Only | - | FALSE, TRUE | - | FALSE | When checked, the function provides start signal only, and no trip signal. |
| Start Current | % | 10 – 90 | 1 | 50 | Phase difference current setting |
| Time Delay | msec | 100 – 60000 | 1 | 1000 | Time delay (including the algorithm time, see Chapter 2.4 for more explanation) |

3.2.9.2.2. Function I/O

This section describes briefly the analogue and digital inputs and outputs of the function block.

3.2.9.2.2.1. Analogue inputs

The function uses the sampled values of a current input. This is defined in the configuration.

3.2.9.2.2.2. Binary input signals (graphed output statuses)

The conditions of the binary inputs are defined by the user, applying the graphic equation editor (*Logic Editor*). Parts written in **bold** are seen on the left side function block in the Logic editor.

Table 2-2 The binary input signal of the current unbalance protection function

| BINARY OUTPUT SIGNAL | EXPLANATION |
|-------------------------|--------------------------------|
| VCB60_ Blk _GrO_ | Blocking input of the function |

3.2.9.2.2.3. Binary output signals (graphed input statuses)

These signals can be used in EuroCAP to assign to LED, user LCD object etc. Parts written in **bold** are seen on the right side of the function block in the *Logic Editor*.

Table 2-3 The binary output signals of the current unbalance protection function

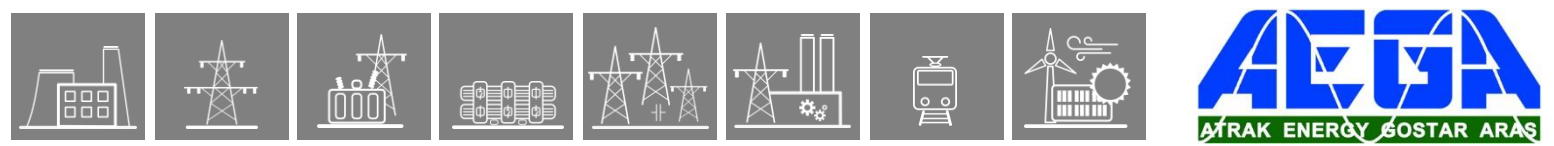
| BINARY OUTPUT SIGNAL | SIGNAL TITLE | EXPLANATION |
|---------------------------|---------------|--------------------------------------|
| VCB60_ GenSt _Grl_ | General Start | General start signal of the function |
| VCB60_ GenTr _Grl_ | General Trip | General trip command of the function |

3.2.9.2.2.4. Online data

Visible values on the *online data* page.

Table 2-4 Online displayed data of the current unbalance protection function

| SIGNAL TITLE | DIMENSION | EXPLANATION |
|---------------|-----------|--------------------------------------|
| General Start | - | General start signal of the function |
| General Trip | - | General trip command of the function |



3.2.9.2.2.5. Events

The following events are generated in the event list, as well as sent to the SCADA according to the configuration.

Table 2-5 Generated events of the current unbalance protection function

| EVENT | VALUE | EXPLANATION |
|---------------|---------|--------------------------------------|
| General Start | off, on | General start of the function |
| General Trip | off, on | General trip command of the function |

3.2.9.2.3. Technical data

Table 2-6 Technical data of the current unbalance protection function

| FUNCTION | VALUE | ACCURACY |
|---------------------------------|-------|----------|
| Pick-up starting accuracy at In | | < 2 % |
| Reset ratio | 0,95 | |
| Operate time | 70 ms | |

3.2.9.2.4. Notes for testing

Normally in the EuroProt+ devices the trip contacts are assigned to the Trip Logic function block, and not to the protection function blocks. Because of this, the testing personnel must make sure that the Trip Logic is switched on ('Operation' parameter is set to other than 'Off') before starting the tests, otherwise there will be no physical trip on the relay.

Note that the time delay parameter incorporates the algorithm time as well, so the time delay **does not mean the time difference between the appearance of the start and trip signals** of the function. In other words: it is not the delay between the detection of the fault and the trip that follows it. This should be taken into consideration when checking the disturbance records.

Instead the time delay parameter defines the elapsed time from the appearance of the faulty state to the trip. Because of this, while testing, the delay measurement should start *from the moment of the fault injection* until the trip signal.

3.2.10. Earth-fault phase selection function

The protection functions, based on residual current and/or voltage measurement can detect the earth-fault on the network, they can however not select the faulty phase. The simple function, described in this document measures the three phase voltages. After starting by any kind of residual protection functions, this software module evaluates the phase voltages. The one below the threshold level indicates the faulty phase.

3.2.10.1. Operation of the earth-fault phase selection function

The operation of the function is started by any kind of residual protection functions. Usually the trip command, generated by this functions is configured to the start input (EF_Trip). If it is not configured in the factory, the user can define it or can edit it, using the graphic logic editor.

The operation of the function can be blocked by an active signal connected to the dedicated binary input (VTS). Usually the error signal of the voltage transformer supervision function is assigned to this input. If it is not configured in the factory, the user can define it, using the graphic logic editor.

The function gets the calculated Fourier basic harmonics of the three phase voltages (UL1Four, UL2Four, UL3Four). The Fourier calculation is not part of this function, it belongs to the preparatory phase, and these calculated values may be applied by other functions configured in the device.

There are three embedded, simplified undervoltage functions (TUV27 L1, TUV27 L2 and TUV27 L3), which compare the Fourier magnitude values with the voltage parameter (Start Voltage). If any of the voltages is below this threshold value, the phase-selective outputs indicate the faulty phase.

3.2.10.2. Structure of the earth-fault phase selection algorithm

Figure 1-1 shows the structure of the phase selection algorithm.

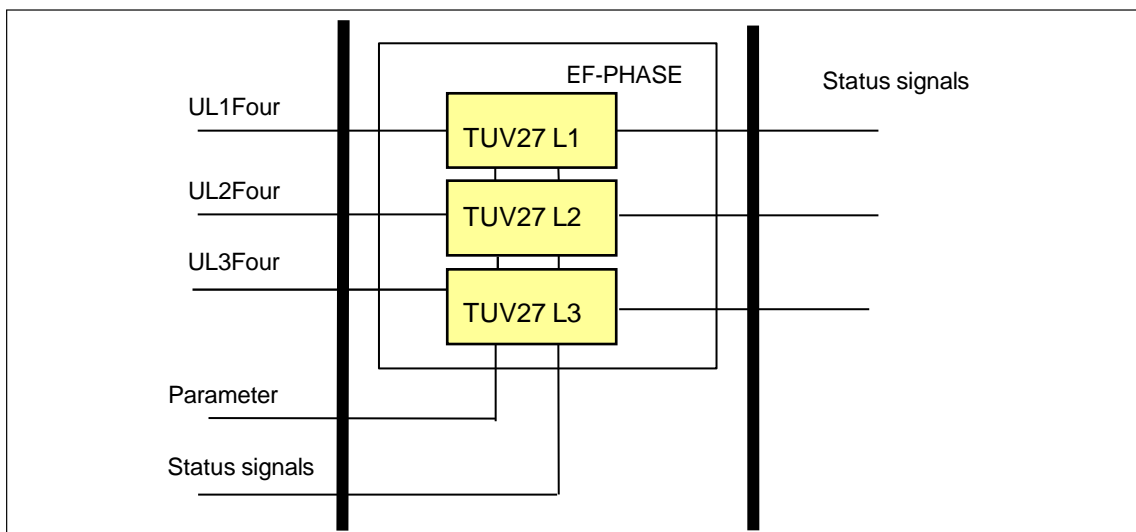
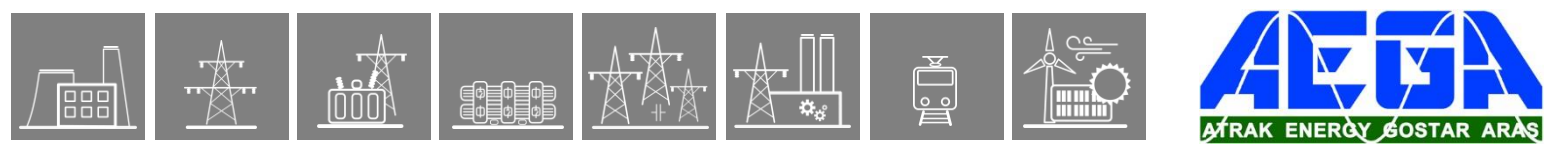


Figure 1-1 Structure of the earth-fault phase selection algorithm



The **inputs** are

- the RMS value of the fundamental Fourier component of the phase voltages,
- parameters,
- status signals.

The **outputs** are

- the binary output status signals.

3.2.10.3. Parameter of the earth-fault phase selection function

The function has a single parameter to define the starting voltage in %, below which the phase is evaluated as the faulty phase.

Integer parameter

| Parameter name | Title | Unit | Min | Max | Step | Default |
|-----------------------------|---------------|------|-----|-----|------|---------|
| Starting voltage parameter: | | | | | | |
| TUV27_StVol_IPar_ | Start Voltage | % | 5 | 57 | 1 | 45 |

Table 1-1 The integer parameters of the earth-fault phase selection function

Note: the function is a simplified undervoltage function. All other parameters are hidden, the user cannot modify the values of these parameters.

3.2.10.4. Output status signals of the earth-fault phase selection function

The **binary output status signals** of the earth-fault phase selection function are listed in Table 1-2.

| Binary output signals | Signal title | Explanation |
|-----------------------|--------------|--------------------------------------|
| TUV27_StL1_Grl_ | Start L1 | Starting of the function in phase L1 |
| TUV27_StL2_Grl_ | Start L2 | Starting of the function in phase L2 |
| TUV27_StL3_Grl_ | Start L3 | Starting of the function in phase L3 |

Table 1-2 The binary output status signals of the earth-fault phase selection function

3.2.10.5. Input status signals of the earth-fault phase selection function

Binary input signal

The residual overcurrent protection function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

| Binary output signals | Signal title | Explanation |
|-----------------------|--------------|-----------------------------------------------------------------------------|
| TUV27_EFTrip_GrO_ | EFTrip | Starting of the function, usually by the TRIP command of residual functions |
| TUV27_VTS_GrO_ | VTS | Blocking by voltage transformer supervision |

Table 1-3 The binary input signal of the earth-fault phase selection function

3.2.10.6. The function block of the earth-fault phase selection function

The function block of the earth-fault phase selection function is shown in Figure 1-2. This block shows all binary input and output status signals that are applicable in the graphic logic editor.

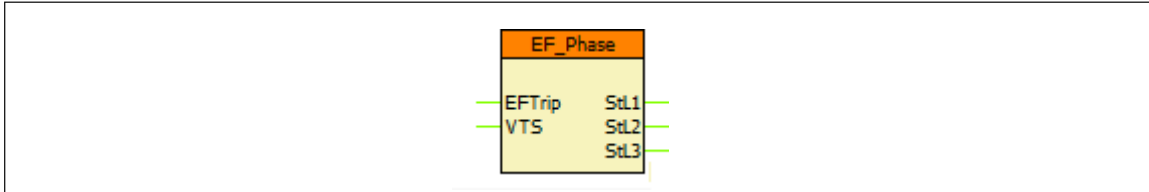


Figure 1-2 The function block of the earth-fault phase selection function

3.2.10.7. Technical data

| Function | Value | Accuracy |
|---------------------------|--------|-----------------------|
| Pick-up starting accuracy | | $< \pm 0,5 \%$ |
| Blocking voltage | 0 | |
| Reset ratio | 1.05 | |
| Reset time | | |
| U> → Un | 50 ms | |
| U> → 0 | 40 ms | |
| Operate time accuracy | 100 ms | $< \pm 20 \text{ ms}$ |

Table 1-4 Technical data of the undervoltage protection function

3.3. Measuring functions

The measured values can be checked on the touch-screen of the device in the “On-line functions” page, or using an Internet browser of a connected computer. The displayed values are secondary voltages and currents, except the block “Line measurement”. This specific block displays the measured values in primary units, using VT and CT primary value settings.

| Analog value | Explanation |
|------------------------------------------------|----------------------------------------------------------------------------------|
| VT4 module | |
| Voltage Ch – U1 | RMS value of the Fourier fundamental harmonic voltage component in phase L1 |
| Angle Ch – U1 | Phase angle of the Fourier fundamental harmonic voltage component in phase L1* |
| Voltage Ch – U2 | RMS value of the Fourier fundamental harmonic voltage component in phase L2 |
| Angle Ch – U2 | Phase angle of the Fourier fundamental harmonic voltage component in phase L2* |
| Voltage Ch – U3 | RMS value of the Fourier fundamental harmonic voltage component in phase L3 |
| Angle Ch – U3 | Phase angle of the Fourier fundamental harmonic voltage component in phase L3* |
| Voltage Ch – U4 | RMS value of the Fourier fundamental harmonic voltage component in Channel U4 |
| Angle Ch – U4 | Phase angle of the Fourier fundamental harmonic voltage component in Channel U4* |
| CT4 module | |
| Current Ch - I1 | RMS value of the Fourier fundamental harmonic current component in phase L1 |
| Angle Ch - I1 | Phase angle of the Fourier fundamental harmonic current component in phase L1* |
| Current Ch - I2 | RMS value of the Fourier fundamental harmonic current component in phase L2 |
| Angle Ch - I2 | Phase angle of the Fourier fundamental harmonic current component in phase L2* |
| Current Ch - I3 | RMS value of the Fourier fundamental harmonic current component in phase L3 |
| Angle Ch - I3 | Phase angle of the Fourier fundamental harmonic current component in phase L3* |
| Current Ch - I4 | RMS value of the Fourier fundamental harmonic current component in Channel I4 |
| Angle Ch - I4 | Phase angle of the Fourier fundamental harmonic current component in Channel I4* |
| Distance protection function (DIS21_HV) | |
| Fault location | Measured distance to fault |
| Fault react. | Measured reactance in the fault loop |
| L1N loop R | Resistive component value of impedance in L1-N loop |
| L1N loop X | Reactive component value of impedance in L1-N loop |
| L2N loop R | Resistive component value of impedance in L2-N loop |
| L2N loop X | Reactive component value of impedance in L2-N loop |
| L3N loop R | Resistive component value of impedance in L3-N loop |
| L3N loop X | Reactive component value of impedance in L3-N loop |
| L12 loop R | Resistive component value of impedance in L12 loop |
| L12 loop X | Reactive component value of impedance in L12 loop |
| L23 loop R | Resistive component value of impedance in L23 loop |
| L23 loop X | Reactive component value of impedance in L23 loop |
| L31 loop R | Resistive component value of impedance in L31 loop |
| L31 loop X | Reactive component value of impedance in L31 loop |

| <i>Synchrocheck function (SYN25)</i> | |
|--------------------------------------------------------------------------------------|---------------------------------------------------------------------|
| Voltage Diff | Voltage different value |
| Frequency Diff | Frequency different value |
| Angle Diff | Angle different value |
| <i>Line measurement (MXU_L) (here the displayed information means primary value)</i> | |
| Active Power – P | Three-phase active power |
| Reactive Power – Q | Three-phase reactive power |
| Apparent Power – S | Three-phase power based on true RMS voltage and current measurement |
| Current L1 | True RMS value of the current in phase L1 |
| Current L2 | True RMS value of the current in phase L2 |
| Current L3 | True RMS value of the current in phase L3 |
| Voltage L1 | True RMS value of the voltage in phase L1 |
| Voltage L2 | True RMS value of the voltage in phase L2 |
| Voltage L3 | True RMS value of the voltage in phase L3 |
| Voltage L12 | True RMS value of the voltage between phases L1 L2 |
| Voltage L23 | True RMS value of the voltage between phases L2 L3 |
| Voltage L31 | True RMS value of the voltage between phases L3 L1 |
| Frequency | Frequency |
| <i>Metering (MTR)</i> | |
| Forward MWh | Forward MWh |
| Backward MWh | Backward MWh |
| Forward MVarh | Forward MVarh |
| Backward MVarh | Backward MVarh |
| <i>Line thermal protection (TTR49L)</i> | |
| Calc. Temperature | Calculated line temperature |

* *The reference angle is the phase angle of “Voltage Ch - U1”*

Table 3-146 Measured analog values



3.3.1. Current input function

3.3.1.1. Application of the current input function

The application of the current inputs depends on the correct connection of the hardware terminals and also on the correct parameter setting for the CT4 function block. This guide describes examples, based on which any other combinations can be realized.

In the applications of the current transformer hardware module, the first three current inputs (terminals 1-2, 3-4, 5-6) receive the three phase currents (IL1, IL2, IL3), the fourth input (terminals 7-8) is reserved for zero sequence current, for the zero sequence current of the parallel line or for any additional currents. Accordingly, the first three inputs have common parameters while the fourth current input needs individual setting.

The CT4 function block is an independent module in the sense that:

- It has independent parameters to be set, associated to the current inputs,
- It delivers the sampled current values for protection, measurement function blocks and for disturbance recording and for on-line displaying,
- It provides parameters for the subsequent functions blocks for scaling the measured currents.
- It performs the basic calculations
 - Fourier basic harmonic magnitude and angle,
 - True RMS value.

3.3.1.1.1. Parameter setting

3.3.1.1.1.1. Summary of the parameters

The parameters of the current input function are explained in the following tables.

Enumerated parameters

| Parameter name | Title | Selection range | Default |
|------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|---------------------|---------|
| Rated secondary current of the first three input channels. 1A or 5A is selected by parameter setting, no hardware modification is needed. | | | |
| CT4_Ch13Nom_EPar_ | Rated Secondary I1-3 | 1A,5A | 1A |
| Rated secondary current of the fourth input channel. 1A or 5A (0.2A, 1A) is selected by parameter setting, no hardware modification is needed. | | | |
| CT4_Ch4Nom_EPar_ | Rated Secondary I4 | 1A,5A (0.2A, 1A) | 1A |
| Definition of the positive direction of the first three currents, given by location of the secondary star connection point | | | |
| CT4_Ch13Dir_EPar_ | Starpoint I1-3 | Line,Bus | Line |
| Definition of the positive direction of the fourth current, given as normal or inverted | | | |
| CT4_Ch4Dir_EPar_ | Direction I4 | Normal,Inverted | Normal |

Table 1-1 The enumerated parameters of the current input function

Floating point parameters

| Parameter name | Title | Dim. | Min | Max | Default |
|-------------------------------------|--------------------|------|-----|------|---------|
| Rated primary current of channel1-3 | | | | | |
| CT4_Pr113_FPar_ | Rated Primary I1-3 | A | 100 | 4000 | 1000 |
| Rated primary current of channel4 | | | | | |
| CT4_Pr14_FPar_ | Rated Primary I4 | A | 100 | 4000 | 1000 |

Table 1-2 The floating point parameters of the current input function



NOTE: The rated primary current of the channels is not needed for the current input function block itself. These values are passed on to the subsequent function blocks.

3.3.1.1.1.2. Setting the rated secondary current

The scaling of the currents (even hardware scaling) depends on parameter setting.

Rated Secondary I1-3 and Rated Secondary I4

Select the rated secondary current according to the nominal data of the main current transformer. The options to choose from are 1A or 5A (in special applications, 0.2A or 1A). This parameter influences the internal number format and, naturally, accuracy. (A small current is processed with finer resolution if 1A is selected.) The first parameter is common for the first three channels and the second one is applied for the fourth channel.

NOTE: when selecting from the available choice, no hardware modification is needed.

3.3.1.1.1.3. Setting the positive direction of the currents

The positive direction of the currents influences the correct operation of directionality (e.g. distance protection, directional overcurrent protection, power calculation, etc.) If needed, the currents can be inverted by setting parameters. This is equivalent to interchanging the two wires, connecting the currents to the inputs.

Starpoint I1-3 and Direction I4.

Starpoint I1-3 applies to each of the channels IL1, IL2 and IL3. The example of Figure 1-1 below shows the connection and the correct parameter setting for Starpoint I1-3=Line. The current L1 is connected to terminal No1 of the CT input, the current L2 to No3, and the current L3 to No5. The common point of the CT inputs is the connected No2-No4-No6. This point leads the residual current to the input No7. The connection point No8 is connected with the fourth wire to the star-point of the CTs. This application of the fourth channel is the "Normal" direction.

If the currents are connected not this way then change the parameter values accordingly.

3.3.1.1.1.4. Setting the rated primary current

These parameters are needed only to display the currents (and powers) in primary scale. The protection function apply secondary values, these parameters are not needed for protection functions.

Rated Primary I1-3 and Rated Primary I-4

Select the rated primary currents according to the nominal data of the main current transformers. The first parameter (Rated Primary I1-3) is common for the first three channels and the second (Rated Primary I-4) is for the fourth channel.

3.3.1.1.2. Application of the on-line measurements in commissioning

The **measured values** of the current input function block are listed and explained in the Table below.

| Measured value | Dim. | Explanation |
|-----------------|--------------|-------------------------------------------------------|
| Current Ch - I1 | A(secondary) | Fourier basic component of the current in channel IL1 |
| Angle Ch - I1 | degree | Vector position of the current in channel IL1 |
| Current Ch - I2 | A(secondary) | Fourier basic component of the current in channel IL2 |
| Angle Ch - I2 | degree | Vector position of the current in channel IL2 |
| Current Ch - I3 | A(secondary) | Fourier basic component of the current in channel IL3 |
| Angle Ch - I3 | degree | Vector position of the current in channel IL3 |
| Current Ch - I4 | A(secondary) | Fourier basic component of the current in channel IL4 |
| Angle Ch - I4 | degree | Vector position of the current in channel IL4 |

Table 1-3 The measured analogue values of the current input function

NOTE1: The scaling of the Fourier basic component is such that if pure sinusoid 1A RMS of the rated frequency is injected, the displayed value is 1A.

NOTE2: The reference of the vector position depends on the device configuration. If a voltage input module is included, then the reference vector (vector with angle 0 degree) is the vector calculated for the first voltage input channel of the first applied voltage input module. If no voltage input module is configured, then the reference vector (vector with angle 0 degree) is the vector calculated for the first current input channel of the first applied current input module. (The first input module is the one, located closer to the CPU module.)

3.3.1.1.3. Examples

When the vector position of the currents are relevant (e.g. distance protection, directional overcurrent protection, power measurement, etc.) then mind the correct connection of the instrument transformers and the related parameter setting. If the wires of the secondary cables are interchanged then change also the related parameter values.

3.3.1.1.3.1. Residual current measurement

Figure 1-1 shows a connection example with 3I₀ measurement. The star-point of the CT-s is towards the line, L1 is connected to terminal No1 of the CT input, L2 to No3, L3 to No5.

The common point of the CT inputs is the connected No2-No4-No6. This point leads the residual current to the input No7. The connection point No8 is connected with the fourth wire to the star-point of the CTs.

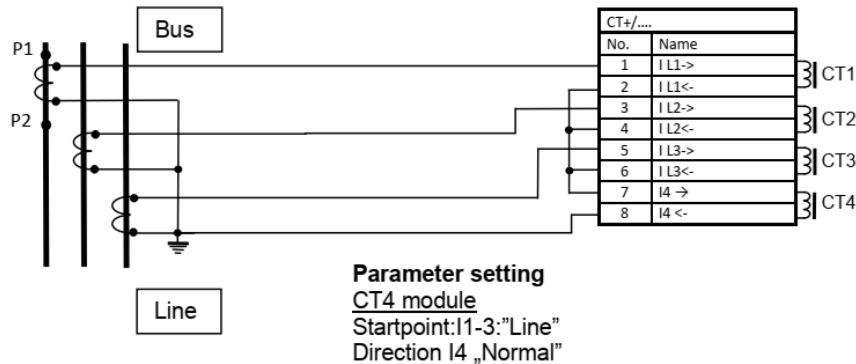


Figure 1-1 Example: CT connection with 3I₀ measurement

The related proposed parameter setting is the screen-shot of Figure 1-2. Parameter “Starpoint I1-3” is set to “Line”, indicating that the star-point is toward the protected object (line). The parameter “Direction I4” is set to “Normal”, indicating that the residual current flows in to terminal No7 and the star point of the primary current transformer is toward the protected object (line).

| | Device value (Default_set_1) | New value | | |
|----------------------|---------------------------------|-----------|---|------------------|
| Rated Secondary I1-3 | 1A | 1A | | |
| Rated Secondary I4 | 1A | 1A | | |
| Starpoint I1-3 | Line | Line | | |
| Direction I4 | Normal | Normal | | |
| Rated Primary I1-3 | 1000 | 1000 | A | (100 - 4000 / 1) |
| Rated Primary I4 | 1000 | 1000 | A | (100 - 4000 / 1) |

Figure 1-2 Example: Parameter setting, according to Figure 1-1

In case of normal operation of the network, the correct connection of the CT-s and the related parameter setting can be checked using the “On-line” measurements. Disconnect one phase of the protected line, e.g. L1. The expected result is shown in Figure 1-3. The current is missing in phase L1 (Current Ch-I1 = 0) and the measured 3I₀ value is the vector sum of the remaining I₂+I₃. (Value of “Current Ch - I4” with the related “Angle - I4”).

NOTE: If in this test, only the secondary current is disclosed using a short measuring cable, then the measured current in this phase is usually not zero, due to the current distribution between the low-impedance input and the impedance of the measuring cable. For correct result, additionally to the short-circuit, also the disconnection of this input is needed. In this example the reference vector is the vector of the first voltage channel (not shown in the screenshot).

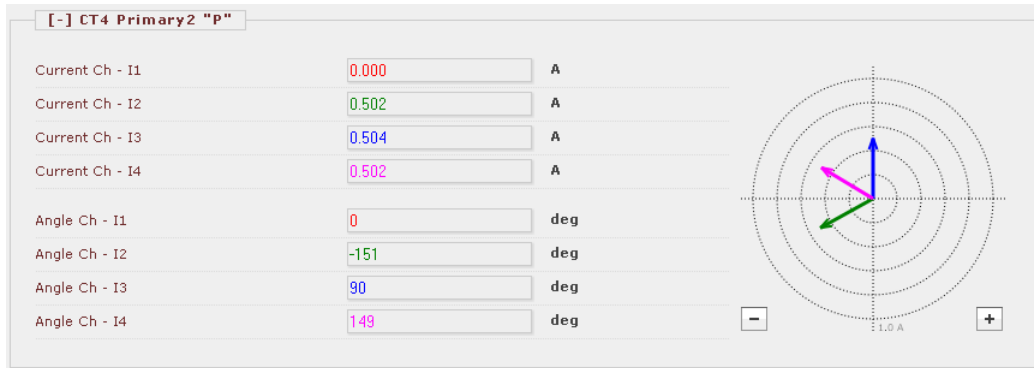


Figure 1-3 Example: Checking the current connection

3.3.1.1.3.2. Application of core-balanced CT

Figure 1-4 shows a connection example with 3I₀ measurement. The star-point of the CT-s is towards the line, L1 is connected to terminal No1 of the CT input, L2 to No3, L3 to No5. The common point of the CT inputs is the connected No2-No4-No6. The separately measured residual current is connected with the same polarity to terminals 7-8.

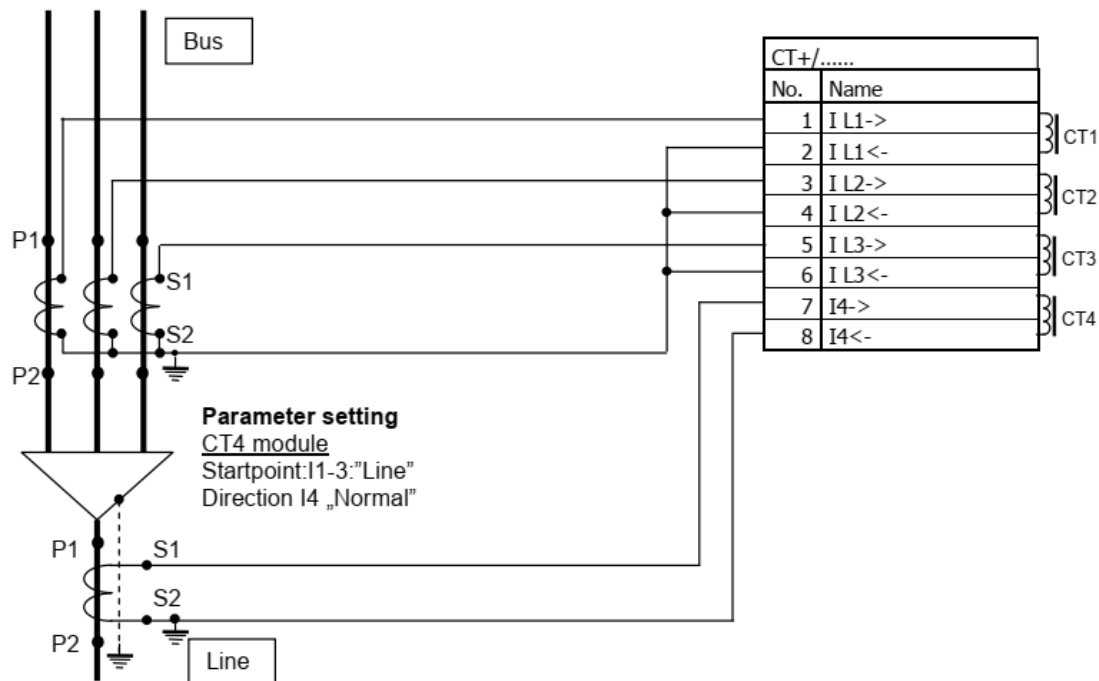


Figure 1-4 Example: CT connection with core-balance CT application

This figure also indicates the proposed parameter values for this connection. The checking is similar to that, shown in Figure 1-3.

3.3.2. AIC current input function

3.3.2.1. Application of the AIC current input function

If the factory configuration includes an AIC input hardware module, the AIC current input function block is automatically configured among the software function blocks. Separate current input function blocks are assigned to each AIC current input hardware module.

The AIC current input module accepts transducers current outputs. The AIC module has four channels, they can measure unipolar and bipolar current values in wide ranges. (See EuroProt+ hardware description document.) The transducer converts any physical quantity to DC current values.

The transmitters can be connected by wiring methods, shown in Figure 1–1, Figure 1–2 and Figure 1–3.

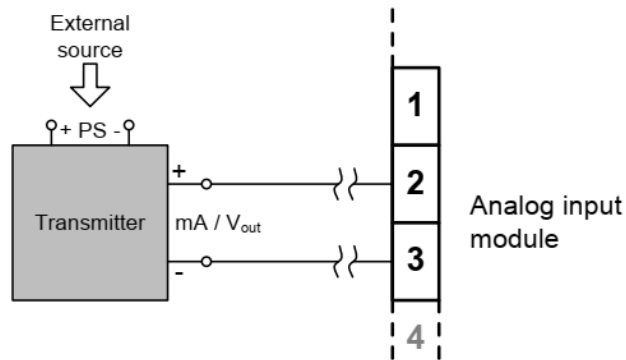


Figure 1–1 2-wire AIC wiring without 12 V excitation

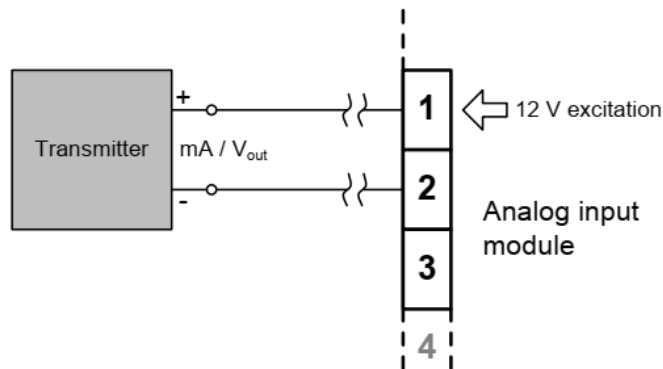


Figure 1–2 2-wire AIC wiring with 12 V excitation

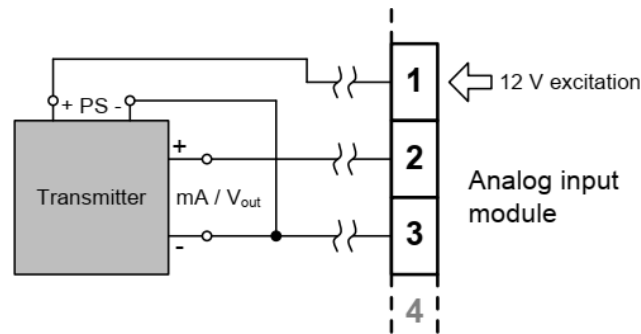


Figure 1–3 3-wire AIC wiring with 12 V excitation

The channels of the module are independent of each other. To each channel a dedicated measuring module is assigned. These measuring modules are described in a separate document: “**GGIOmA current measurement module function block description**”.

3.3.2.2. Technical summary

3.3.2.2.1. Technical data

The technical data of the AIC analog current input module are related to the hardware module. This is described in the document “**EuroProt+ Hardware description**, Chapter 11: analog input module”.

3.3.2.2.2. Summary of the parameters

The parameters of the AIC analog current input function are explained in the following table.

Enumerated parameters

| Parameter name | Title | Selection range | Default |
|-----------------------|-----------------|------------------|---------|
| Polarity of Channel 1 | | | |
| AIC_Ch1Dir_EPar_1 | Direction - Ch1 | Normal,Inverted* | Normal |
| Polarity of Channel 2 | | | |
| AIC_Ch2Dir_EPar_1 | Direction – Ch2 | Normal,Inverted* | Normal |
| Polarity of Channel 3 | | | |
| AIC_Ch3Dir_EPar_1 | Direction – Ch3 | Normal,Inverted* | Normal |
| Polarity of Channel 4 | | | |
| AIC_Ch4Dir_EPar_1 | Direction – Ch4 | Normal,Inverted* | Normal |

*Figures 1-1, 1-2 and 1-3 show “Normal” connection polarity

Table 1-1 The enumerated parameters of the current input function

NOTE: The function block has no input and output binary signals, the graphic logic editor does not show this function block.

3.3.3. Voltage input function

3.3.3.1. Application of the voltage input function

The application of the voltage inputs depends on the correct connection of the hardware terminals and also on the correct parameter setting for the VT4 function block. This guide describes examples, based on which any other combinations can be realized.

In the applications of the voltage transformer hardware module, the first three voltage inputs receive the three phase voltages (UL1, UL2, UL3), the fourth input is reserved for zero sequence voltage, for the busbar voltage if synchronized switching is applied or for any additional voltages. Accordingly, the first three inputs have common parameters while the fourth voltage input needs individual setting.

The VT4 function block is an independent module in the sense that:

- It has independent parameters to be set, associated to the voltage inputs,
- It delivers the sampled voltage values for protection, measurement function blocks and for disturbance recording,
- It provides parameters for the subsequent functions blocks for scaling the measured voltages.
- It performs the basic calculations
 - Fourier basic harmonic magnitude and angle,
 - True RMS value.

3.3.3.1.1. Parameter setting

3.3.3.1.1.1. Summary of the parameters

The parameters of the voltage input function are explained in the following tables.

Enumerated parameters

| Parameter name | Title | Selection range | Default |
|------------------------------------------------------------------------------------------------------------------------------------|-----------------|----------------------------|----------|
| Rated secondary voltage of the input channels. 100 V or 200V is selected by parameter setting, no hardware modification is needed. | | | |
| VT4_Type_EPar_ | Range | Type 100,Type 200 | Type 100 |
| Connection of the first three voltage inputs (main VT secondary) | | | |
| VT4_Ch13Nom_EPar_ | Connection U1-3 | Ph-N, Ph-Ph, Ph-N-Isolated | Ph-N |
| Selection of the fourth channel input: phase-to-neutral or phase-to-phase voltage | | | |
| VT4_Ch4Nom_EPar_ | Connection U4 | Ph-N,Ph-Ph | Ph-Ph |
| Definition of the positive direction of the first three input channels, given as normal or inverted | | | |
| VT4_Ch13Dir_EPar_ | Direction U1-3 | Normal,Inverted | Normal |
| Definition of the positive direction of the fourth voltage, given as normal or inverted | | | |
| VT4_Ch4Dir_EPar_ | Direction U4 | Normal,Inverted | Normal |

Table 1-1 The enumerated parameters of the voltage input function

Integer parameter

| Parameter name | Title | Unit | Min | Max | Step | Default |
|--------------------|---------------|------|-----|-----|------|---------|
| Voltage correction | | | | | | |
| VT4_CorrFact_IPar_ | VT correction | % | 100 | 115 | 1 | 100 |

Table 1-2 The integer parameter of the voltage input function



Floating point parameters

| Parameter name | Title | Dim. | Min | Max | Default |
|------------------------------------------|--------------------|------|-----|------|---------|
| Rated primary voltage of channel 1, 2, 3 | | | | | |
| VT4_PriU13_FPar | Rated Primary U1-3 | kV | 1 | 1000 | 100 |
| Rated primary voltage of channel 4 | | | | | |
| VT4_PriU4_FPar | Rated Primary U4 | kV | 1 | 1000 | 100 |

Table 1-3 The floating point parameters of the voltage input function

NOTE: The rated primary voltage of the channels is not needed for the voltage input function block itself. These values are passed on to the subsequent function blocks.

3.3.3.1.1.2. Setting the rated secondary voltage

The scaling of the voltage depends on parameter setting.

Range

There are basically two standard voltage transformer types: one with secondary rated voltage 100 V, the other with 200 V. Select the parameter value respectively: Type 100, Type 200. No hardware modification is needed. This parameter influences the internal number format and, naturally, accuracy. (A small voltage is processed with finer resolution if 100V is selected.)

VT correction

In some cases the rated secondary of the voltage transformers is not 100V but e.g. 110 V. This parameter is to correct this difference, if the rated secondary voltage of the main voltage transformer does not match the rated input of the device. As an example: if the rated secondary voltage of the main voltage transformer is 110V, then select Type 100 for the parameter "Range" and the required value to set here is 110%.

3.3.3.1.1.3. Setting the connection and the positive direction of the voltages

The connection and direction parameters of the first three VT secondary windings must be set to reflect actual physical connection of the main VTs.

Connection U1-3.

The selection can be: "Ph-N", "Ph-Ph" or "Ph-N-Isolated".

The *Ph-N* option is applied in solidly grounded networks, where the measured phase voltage is never above $1.5 \cdot U_n$. In this case the primary rated voltage of the VT must be the value of the rated PHASE-TO-NEUTRAL voltage.

The *Ph-N-Isolated* option is applied in compensated or isolated networks, where the measured phase voltage can be above $1.5 \cdot U_n$ even in normal operation. In this case the primary rated voltage of the VT must be the value of the rated PHASE-TO-PHASE voltage.

The *Ph-Ph* option is to be selected if phase-to-phase voltage is connected to the VT input of the device. Here, the primary rated voltage of the VT must be the value of the rated PHASE-TO-PHASE voltage. This option must not be selected if the distance protection function or directional overcurrent protection function is supplied from the VT input.



Connection U4

The fourth input is reserved for zero sequence voltage or for a voltage from the other side of the circuit breaker for synchronized switching. Accordingly, the connected voltage must be identified with parameter setting Connection U4. Here, phase-to-neutral or phase-to-phase voltage can be selected: “Ph-N”, “Ph-Ph”

Direction U1-3

If needed, the phase voltages can be inverted by setting the parameter Direction U1-3. This selection applies to each of the channels UL1, UL2 and UL3. The primary/secondary connection of the VT windings is generally star/star connected and the phase voltages signed with • are connected to the VT4 terminals 1-3-5. In this case the parameter setting is „Normal”. Select “Inverted” to the parameter Direction U1-3 in case of inverted connection of phase voltages.” (See also Figure 1-1 in setting example.)

Direction U4

This parameter applies to the channel UL4. If the voltage signed with • is connected to the VT4 terminal 7 the parameter setting is „Normal”. Select “Inverted” to the parameter Direction U4 in case of inverted connection of the voltage. This inversion may be needed in protection functions such as distance protection or for any functions with directional decision, or for checking the voltage vector positions.

Figure 1-1 shows an example with harmonized connection and parameter setting.

If the voltages are connected not this way then change the parameter values accordingly.

3.3.3.1.1.4. Setting the rated primary voltage

These parameters are needed only to display the voltages (and powers) in primary scale. The protection functions apply secondary values, these parameters are not needed for protection functions.

Rated Primary U1-3 and Rated Primary U-4

Select the rated primary voltages according to the nominal data of the main voltage transformers. The two parameters are: common for the first three channels and one for the fourth channel respectively.

3.3.3.1.2. Application of the on-line measurements in commissioning

The performed basic calculation results the Fourier basic harmonic magnitude and angle value of the voltages. These results are processed by subsequent protection function blocks and they are available for on-line displaying as well.

3.3.3.1.2.1. Summary of the on-line measurements

The **measured values** of the voltage input function block.

| Measured value | Dim. | Explanation |
|-----------------|--------------|-------------------------------------------------------|
| Voltage Ch - U1 | V(secondary) | Fourier basic component of the voltage in channel UL1 |
| Angle Ch - U1 | degree | Vector position of the voltage in channel UL1 |
| Voltage Ch - U2 | V(secondary) | Fourier basic component of the voltage in channel UL2 |
| Angle Ch - U2 | degree | Vector position of the voltage in channel UL2 |
| Voltage Ch - U3 | V(secondary) | Fourier basic component of the voltage in channel UL3 |
| Angle Ch - U3 | degree | Vector position of the voltage in channel UL3 |
| Voltage Ch - U4 | V(secondary) | Fourier basic component of the voltage in channel U4 |
| Angle Ch - U4 | degree | Vector position of the voltage in channel U4 |

Table 1-4 The measured analogue values of the voltage input function

NOTE1: The scaling of the Fourier basic component is such that if pure sinusoid 57V RMS of the rated frequency is injected, the displayed value is 57V.

NOTE2: The reference vector (vector with angle 0 degree) is the vector calculated for the first voltage input channel of the first applied voltage input module. (The first voltage input module is the one, configured closer to the CPU module.)

3.3.3.1.3. Examples

When the vector position of the voltages are relevant (e.g. distance protection, directional overcurrent protection, power measurement, synchrocheck, etc.) then mind the correct connection of the instrument transformers and the related parameter setting. If the wires of the secondary cables are interchanged then change also the related parameter values.

3.3.3.1.3.1. Phase voltage and residual voltage measurement

Figure 1-1 shows the phase voltage measurement and also the residual voltage measurement e.g. for residual directional overcurrent protection function. In this example the residual voltage is measured in open delta of the VT secondary coils. The network is supposed to be compensated. This figure also indicates the proposed parameter values.

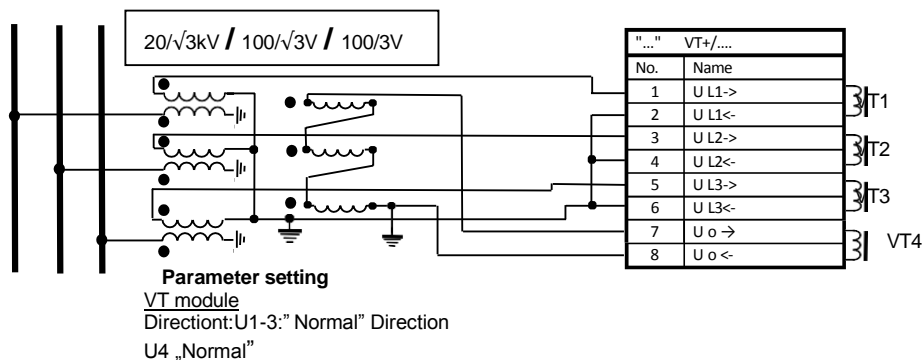


Figure 1-1 Example: Phase voltage and residual voltage measurement

| | | |
|--------------------|---------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Range | Type 100 | The type indicates the rated secondary voltage of the VT. This can be 100 V (in this example) or 200V |
| Connection U1-3 | Ph-N-Isolated | This indicates that the VT primary is connected between the conductor and the ground (in this example in compensated network). This could be Ph-N or Ph-Ph in other application. (NOTE: If the neutral of the system is not grounded, select Ph-N-Isolated) |
| Connection U4 | Ph-Ph | In case of earth fault the open delta measures 100 V. This corresponds to the phase-to-phase value |
| Direction U1-3 | Normal | Figure 1-1 shows the normal VT connection, i.e. the signed • phase wires are connected to the terminals 1-3-5. (Select "Inverted" in case of inverted connection.) |
| Direction U4 | Normal | Figure 1-1 shows the normal VT connection, i.e. the signed • wire of the open delta of VT-s is connected to the terminal 7. (Select "Inverted" in case of inverted connection.) |
| VT correction | 100 | If the rated secondary value of the VT is e.g. 110 V then select this correction value to 110%. |
| Rated Primary U1-3 | 20 | Setting, according to the VT rated voltage, applied at the primary side. This parameter is used for scaling the displayed values only. |
| Rated Primary U4 | 11.55 | This parameter is used for scaling the displayed values only. In case of earth fault, the open delta measures 100 V. In primary value it is displayed as the phase voltage in the 20 kV network. |

Table 1-5 Example parameters for the voltage input function

3.3.3.1.3.2. Syncrocheck using phase-to neutral voltage

Figure 1-2 shows the application of the fourth voltage input of the VT module for syncrocheck function. Here UL2 of the busbar voltage is used for this purpose.

NOTE: Among syncrocheck parameters set "Voltage select" parameter to "L2-N".

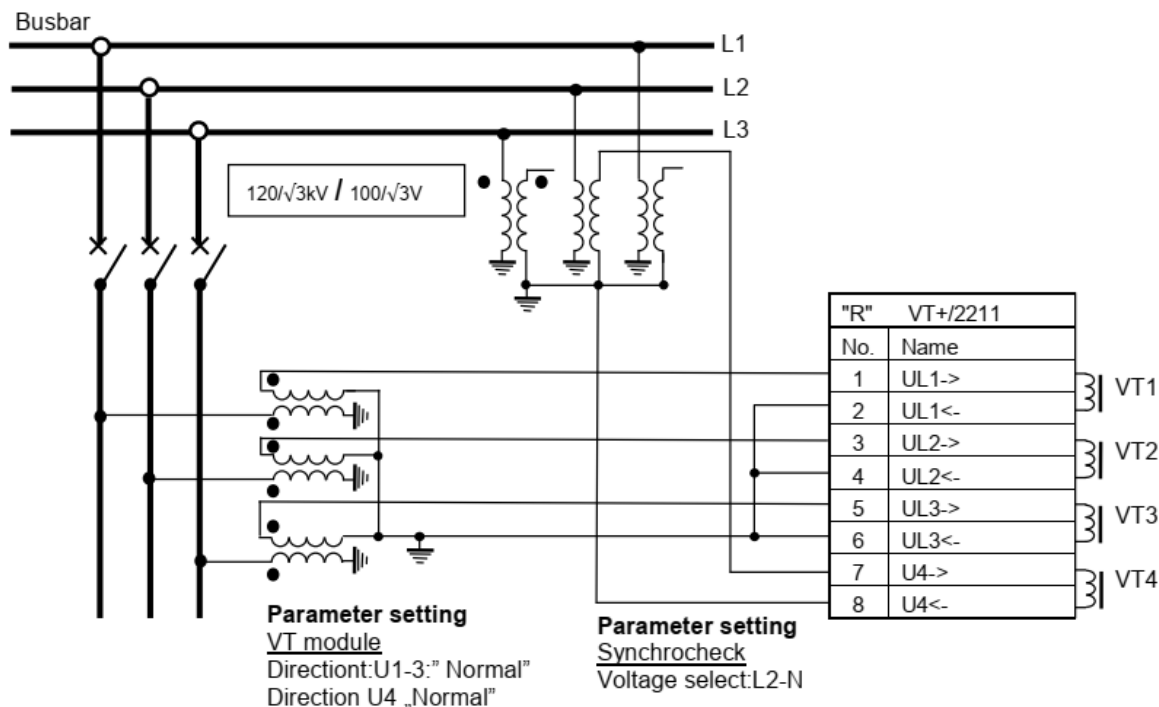


Figure 1-2 Example: Syncrocheck, using phase-to-neutral voltage

Figure 1-3 shows the screenshot indicating the proposed parameter values.

| [-] VT4 module "U" | | |
|--------------------|------------------------------|----------------------------------|
| | Device value (Default_set_1) | New value |
| Range | Type 100 | Type 100 |
| Connection U1-3 | Ph-N | Ph-N |
| Connection U4 | Ph-N | Ph-N |
| Direction U1-3 | Normal | Normal |
| Direction U4 | Normal | Normal |
| VT correction | 100 | 100 % (100 - 115 / 1) |
| Rated Primary U1-3 | 69.28 | 69.28 kV (1.00 - 1000.00 / 0.01) |
| Rated Primary U4 | 69.28 | 69.28 kV (1.00 - 1000.00 / 0.01) |

Figure 1-3 Example:Parameters for syncrocheck, using phase-to-neutral voltage

The "On-line window" of the VT4 input module shows the checking the correct voltage vector position. When the line is connected to the busbar, i.e. the CB is closed, in this example the U4 voltage is expected to have the same value and position as U2. See Figure 1-4.



Figure 1-4 Example: On-line measurement for syncrocheck, using phase-to-neutral voltage

3.3.3.1.3.3. Syncrocheck using phase-to-phase voltage

Figure 1-5 shows the application of the fourth voltage input of the VT module for syncrocheck function. Here UL1-UL3 line-to-line signal of the busbar voltage is used for this purpose.

NOTE: Among syncrocheck parameters set "Voltage select" parameter to "L3-L1". This selection is opposite to that, of the connected voltage. This can be corrected selecting the "Direction U4" parameter value to "Inverse".

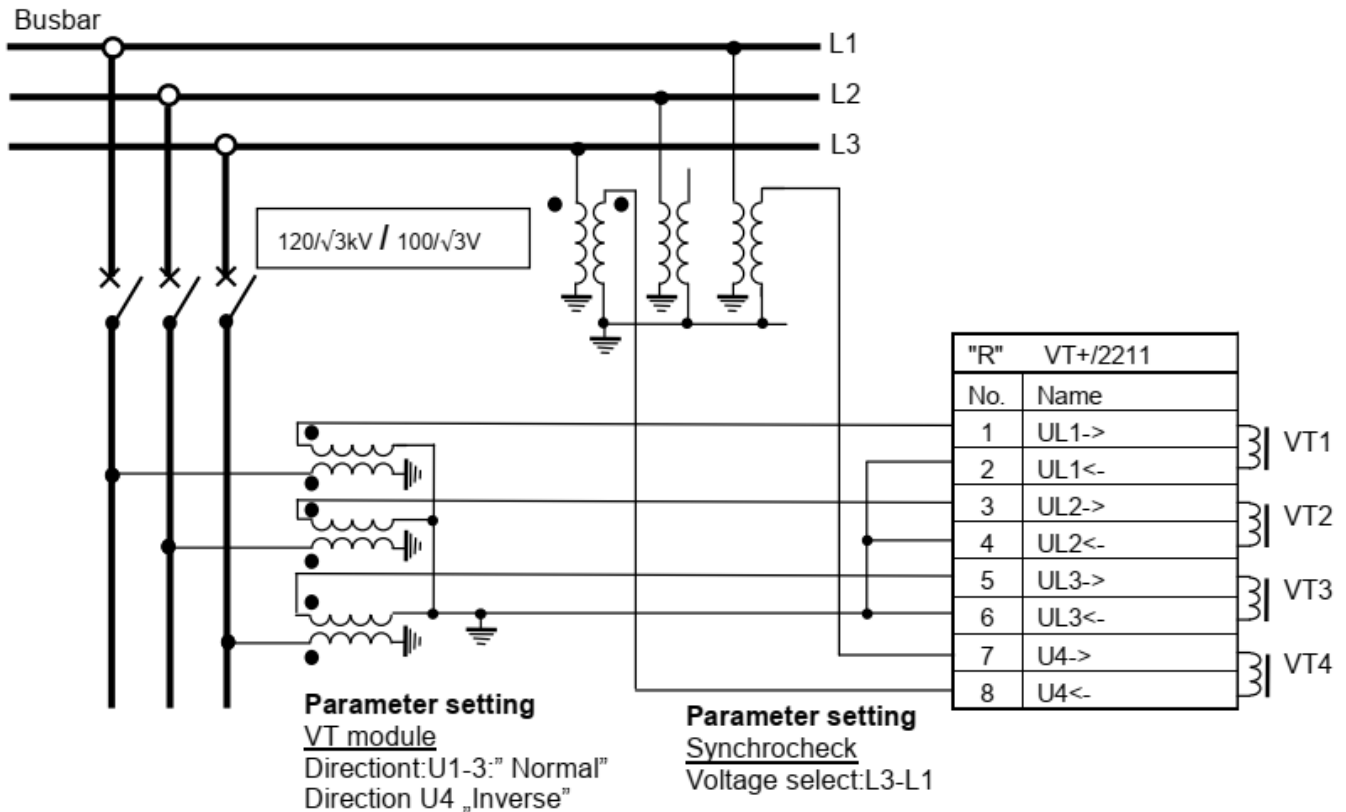


Figure 1-5 Example: Syncrocheck, using phase-to-phase voltage

Figure 1-6 shows the proposed parameter values for the connection shown above.

[-] VT4 module "U"

| | Device value (Default_set_1) | New value | | |
|--------------------|---------------------------------|-----------|----|-------------------------|
| Range | Type 100 | Type 100 | | |
| Connection U1-3 | Ph-N | Ph-N | | |
| Connection U4 | Ph-Ph | Ph-Ph | | |
| Direction U1-3 | Normal | Normal | | |
| Direction U4 | Inverted | Inverted | | |
| VT correction | 100 | 100 | % | (100 - 115 / 1) |
| Rated Primary U1-3 | 69.28 | 69.28 | kV | (1.00 - 1000.00 / 0.01) |
| Rated Primary U4 | 120.00 | 120.00 | kV | (1.00 - 1000.00 / 0.01) |

Figure 1-6 Example: Parameters for syncrocheck, using phase-to-phase voltage

The "On-line window" of the VT4 input module shows the checking the correct voltage vector position. When the line is connected to the busbar, i.e. the CB is closed, in this example the U4 voltage is expected to have a vector identical with the voltage difference U3-U1. See Figure 1-7.

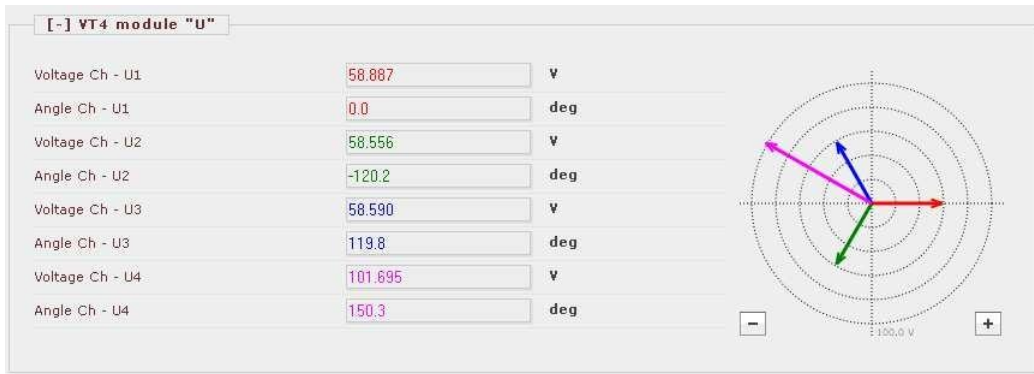


Figure 1-7 Example: On-line measurement for syncrocheck, using phase-to-phase voltage

NOTE that due to the reverse connection of the voltage difference and the parameter setting also reverted by "Inverse" setting, the indicated U4 vector corresponds to the parameter "Voltage select=L3-L1" among syncrocheck parameters.



3.3.4. Line and frequency measurement functions

3.3.4.1. Application

The input values of the EuroProt+ devices are the secondary signals of the voltage transformers and those of the current transformers when they are available in the actual configuration.

These signals are pre-processed by the “VT4 module” voltage input function block and by “CT4 module” the current input function block. These function blocks are described in separate documents. The pre-processed values include the Fourier basic harmonic phasors of the voltages and currents and the true RMS values. Additionally, it is in these function blocks that parameters are set concerning the voltage ratio of the primary voltage transformers and current ratio of the current transformers.

Based on the pre-processed values and the measured transformer parameters, the measurement function blocks calculate - depending on the hardware and software configuration - the primary RMS values of the voltages and currents and some additional values such as active and reactive power, symmetrical components of voltages and currents. These values are available as primary quantities and they can be displayed on the on-line screen of the device or on the remote user interface of the computers connected to the communication network and they are available for the SCADA system using the configured communication system.

3.3.4.2. Mode of operation

The **inputs** of the line measurement function are

- the Fourier components and true RMS values of the measured voltages and currents,
- frequency measurement,
- parameters.

The **outputs** of the line measurement function are

- displayed measured values,
- reports to the SCADA system.

NOTE: the scaling values are entered as parameter setting for the “Voltage transformer input” function block and for the “Current transformer input” function block.

3.3.4.3. The measurement

3.3.4.3.1. The measured values; variants of the function

There are six variants of the MXU function, based on their **measured values**. Parameters and measurements are alike for each. The **type of the variant** is shown in the *function block name*:

- Line Measurement (*MXU_LM*)
- Frequency Measurement (*MXU_F*)
- Voltage measurement (*MXU_V*)
- Voltage measurement (*MXU_V1*) (single voltage)
- Current measurement (*MXU_C*)
- Current measurement (*MXU_C1*) (single current)

Table 1-1 Measured values of each variant

| ON-LINE MEASURED VALUE | EXPLANATION | MXU FUNCTION BLOCK VARIANT | | | | | |
|------------------------|-----------------------------------------------------|----------------------------|---|---|----|---|----|
| | | LM | F | V | V1 | C | C1 |
| MXU_P_OLM_ | Active Power – P (Fourier base harmonic value) | X | | | | | |
| MXU_Q_OLM_ | Reactive Power – Q (Fourier base harmonic value) | X | | | | | |
| MXU_S_OLM_ | Apparent Power – S (Fourier base harmonic value) | X | | | | | |
| MXU_Fi_OLM_ | Power factor | X | | | | | |
| MXU_I1_OLM_ | Current L1 | X | | | | X | X |
| MXU_I2_OLM_ | Current L2 | X | | | | X | |
| MXU_I3_OLM_ | Current L3 | X | | | | X | |
| MXU_Ipos_OLM_ | Calculated positive seq. current | X | | | | X | |
| MXU_Ineg_OLM_ | Calculated negative seq. current | X | | | | X | |
| MXU_3Io_OLM_ | Calculated 3Io | X | | | | X | |
| MXU_U1_OLM_ | Voltage L1 | X | | X | X | | |
| MXU_U2_OLM_ | Voltage L2 | X | | X | | | |
| MXU_U3_OLM_ | Voltage L3 | X | | X | | | |
| MXU_U12_OLM_ | Voltage L12 | X | | X | | | |
| MXU_U23_OLM_ | Voltage L23 | X | | X | | | |
| MXU_U31_OLM_ | Voltage L31 | X | | X | | | |
| MXU_Upos_OLM | Calculated positive seq. voltage | X | | X | | | |
| MXU_Uneg_OLM_ | Calculated negative seq. voltage | X | | X | | | |
| MXU_3Uo_OLM_ | Calculated 3Uo | X | | X | | | |
| MXU_f_OLM_ | Frequency | | X | X | | | |

3.3.4.3.2. The measurement modes

Regarding the power measurements there are two possibilities for the measurement modes. The first one is the “ThreePhase”-method, where all three measured voltages and currents are considered in the power calculation. The second one is the “Aron”-method, where two phase-to-phase voltages and two phase currents are taken into the calculation. This method has correct results only in case when the voltages and currents are symmetrical. The user can choose the mode with the “Measurement mode” parameter. For the “Aron”-method there are three options:

Table 1-2 Explanation for the Aron measurement modes

| Measurement mode | Used phase-currents | Used phase-to-phase voltages |
|------------------|---------------------|------------------------------|
| Aron L2-L3 | L2, L3 | L1-L2, L3-L1 |
| Aron L3-L1 | L1, L3 | L1-L2, L2-L3 |
| Aron L1-L2 | L1, L2 | L2-L3, L3-L1 |



If the “Connection U1-3” parameter of the *VT4 module* function block is set to “Ph-Ph”, the “ThreePhase”-method cannot be used for the power measurements here, so either of the “Aron” methods must be set for it. Otherwise, the device will provide a warning signal (yellow Status LED, “General param. error” message).

3.3.4.4. Reporting the measured values and the changes

It is usual for the SCADA systems that they sample the measured and calculated values in regular time periods and additionally they receive the changed values as reports at the moment when any significant change is detected in the primary system. The “Line measurement” function block performs such reporting for the SCADA system. Three parameters define this reporting:

- *Report Deadband* for choosing the type of reporting, or disabling the reporting
- *Deadband Value* for defining the deadband width
- *Range (value)* for evaluating the “out-of-range” condition

The usage of these parameters is explained in the following chapters.

3.3.4.4.1. “Amplitude” mode of reporting

If the “Amplitude” mode is selected for reporting, a report is generated if the measured value leaves the deadband around the previously reported value. As an example, [Figure 1-1](#) shows that the current becomes higher than the value reported in “report1” PLUS the Deadband value, this results “report2”, etc.

For this mode of operation, the Deadband parameters are explained in the figure below.

NOTE: The “Range” parameters are needed to evaluate a measurement as “out-of-range”.

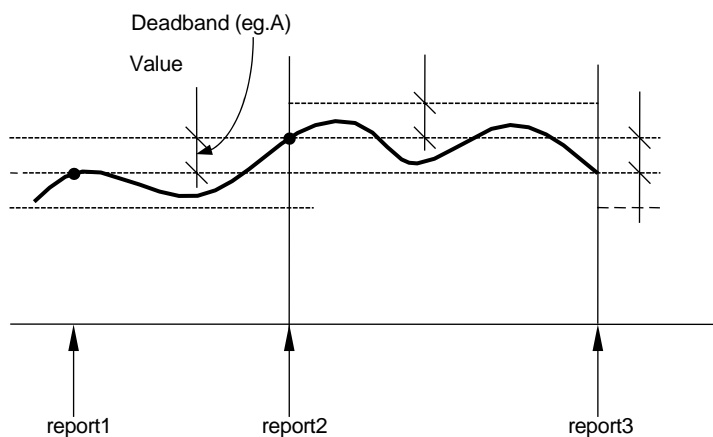


Figure 1-1 Reporting if “Amplitude” mode is selected

3.3.4.4.2. “Integrated” mode of reporting

If the “Integrated” mode is selected for reporting, a report is generated if the time integral of the measured value since the last report gets becomes larger, in the positive or negative direction, then the (deadband*1sec) area. As an example, [Figure 1-2](#) shows that the integral of the current in time becomes higher than the Deadband value multiplied by 1sec, this results “report2”, etc.

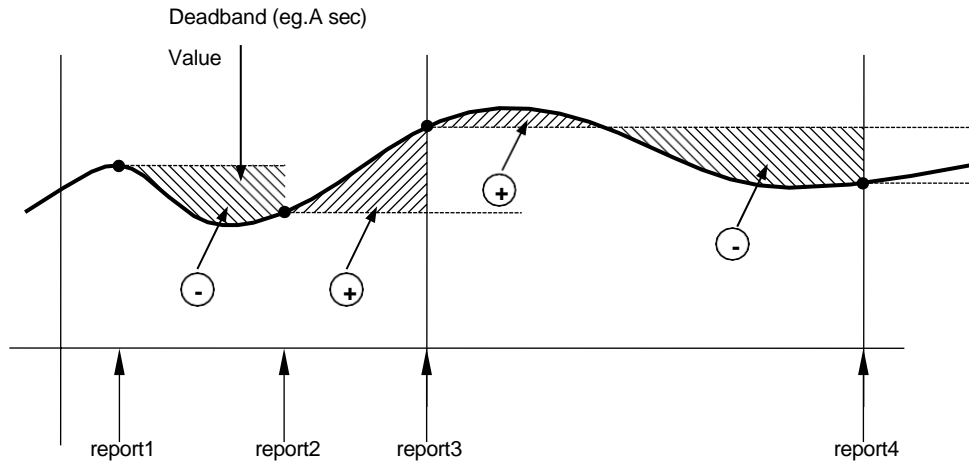


Figure 1-2 Reporting if “Integrated” mode is selected

3.3.4.4.3. Periodic reporting

Periodic reporting is generated independently of the changes of the measured values when the defined time period elapses. If the reporting time period is set to 0, then no periodic reporting is performed for this quantity.

Applying periodic reporting and setting up its interval is done by using the **Communication configurator**, a part of the **EuroCAP** software (see its description for detailed information).

Once the “Trigger period” property is set to “True”, the “Integrity period” setting becomes available to set (in milliseconds). As an example, see the picture below.

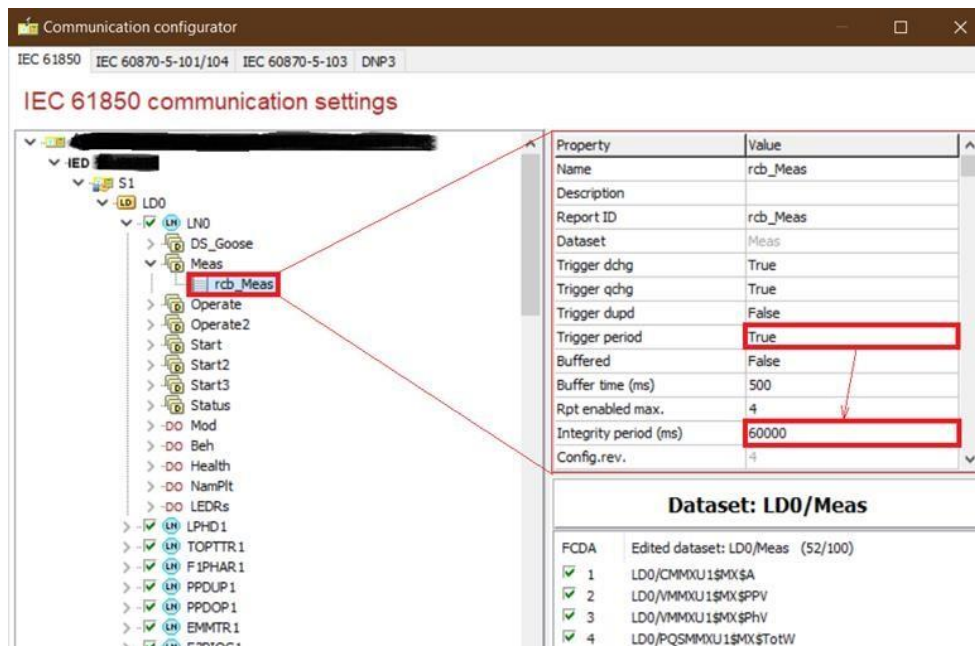
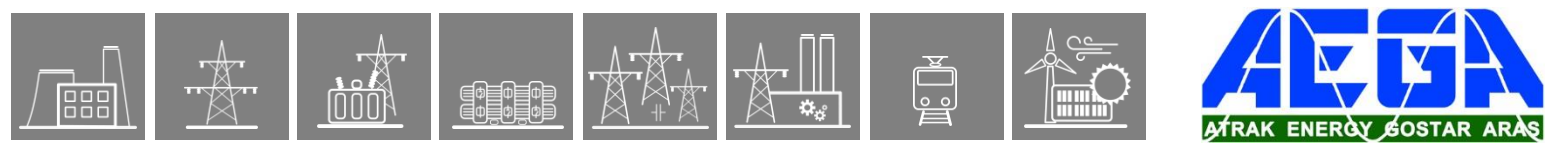


Figure 1-3 Setting up periodic reporting in EuroCAP



3.3.4.4.4. Zero-point clamping

A measured value under the zero-point clamping limit is cut off to zero.

- Three-phase current measurement 0.2% of nominal (I_n)
- Three-phase voltage measurement 2% of nominal (U_n)
- Residual current measurement 0.2% of nominal (I_n)
- Residual voltage measurement 2% of nominal (U_n)
- Phase sequence current measurement 0.2% of the nominal (I_n)
- Phase sequence voltage measurement 2% of the nominal (U_n)
- Three-phase power and energy measurement 0.23% of the nominal (S_n)

3.3.4.5. Line and frequency measurement functions overview

3.3.4.5.1. Settings

3.3.4.5.1.1. Parameters

The following parameters are the parameters of the Line Measurement and Frequency measurement function blocks (LM and F variants). The other functions' parameters follow the pattern of the corresponding measured values.

Table 2-1 Parameters of the line measurement function

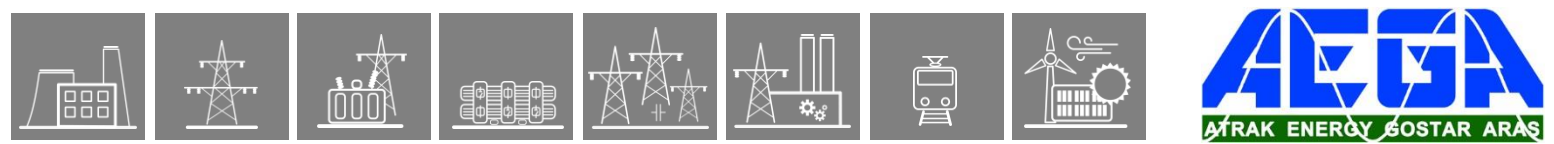
| TITLE | DIM | RANGE** | STEP | DEFAULT | EXPLANATION |
|------------------------|-----|---------------------------------------------------------|------|------------|---------------------------------------------------------|
| Measurement mode | - | Aron L2-L3, Aron L3-L1, Aron L1-L2, ThreePhase | - | ThreePhase | Measurement mode |
| Report Deadband - U | - | Off, Amplitude, Integrated | - | Amplitude | Selection of the reporting mode for voltage measurement |
| Deadband Value - Uph-N | kV* | 0.10 – 100.00 | 0.01 | 5 | Deadband value for the phase-to-neutral voltage |
| Range Value - Uph-N | kV* | 1.0 – 1000.0 | 0.1 | 231 | Range value for the phase-to-neutral voltage |
| Deadband Value Uph-ph | kV* | 0.10 – 100.00 | 0.01 | 5 | Deadband value for the phase-to-phase voltage |
| Range Value - Uph-ph | kV* | 1.0 – 1000.0 | 0.1 | 400 | Range value for the phase-to-neutral voltage |
| Deadband Value - U Res | kV* | 0.10 – 100.00 | 0.01 | 5 | Deadband value for the residual voltage |
| Range Value - U Res | kV* | 1.0 – 1000.0 | 0.1 | 20 | Range value for the residual voltage |
| Deadband Value - Uneg | kV* | 0.10 – 100.00 | 0.01 | 5 | Deadband value for the negative seq. voltage |
| Range Value - Uneg | kV* | 1.0 – 1000.0 | 0.1 | 231 | Range value for the negative seq. voltage |
| Deadband Value - Upos | kV* | 0.10 – 100.00 | 0.01 | 5 | Deadband value for the positive seq. voltage |
| Range Value - Upos | kV* | 1.0 – 1000.0 | 0.1 | 231 | Range value for the positive seq. voltage |
| Report Deadband - I | - | Off, Amplitude, Integrated | - | Amplitude | Selection of the reporting mode for current measurement |
| Deadband Value - I | A | 1 – 2000 | 1 | 10 | Deadband value for the current |
| Range Value - I | A | 1 – 5000 | 1 | 500 | Range value for the current |
| Deadband Value - I Res | A | 1 – 500 | 1 | 10 | Deadband value for the residual current |
| Range Value - I Res | A | 1 – 1000 | 1 | 100 | Range value for the residual current |
| Deadband Value - Ineg | A | 1 – 2000 | 1 | 10 | Deadband value for the negative seq. current |
| Range Value - Ineg | A | 1 – 5000 | 1 | 500 | Range value for the negative seq. current |
| Deadband Value - Ipos | A | 1 – 2000 | 1 | 10 | Deadband value for the positive seq. current |



| | | | | | |
|---------------------|-------|----------------------------|------|-----------|----------------------------------------------------------------|
| Range Value - Ipos | A | 1 – 5000 | 1 | 500 | Range value for the positive seq. current |
| Report Deadband - P | - | Off, Amplitude, Integrated | - | Amplitude | Selection of the reporting mode for active power measurement |
| Deadband Value - P | kW* | 0.10 – 10000.00 | 0.01 | 10 | Deadband value for the active power |
| Range Value - P | kW* | 1.00 – 100000.00 | 0.01 | 500 | Range value for the active power |
| Report Deadband - Q | - | Off, Amplitude, Integrated | - | Amplitude | Selection of the reporting mode for reactive power measurement |
| Deadband Value - Q | kVAr* | 0.10 – 10000.00 | 0.01 | 10 | Deadband value for the reactive power |
| Range Value - Q | kVAr* | 1.00 – 100000.00 | 0.01 | 500 | Range value for the reactive power |
| Report Deadband - S | - | Off, Amplitude, Integrated | - | Amplitude | Selection of the reporting mode for apparent power measurement |
| Deadband Value - S | kVA* | 0.10 – 10000.00 | 0.01 | 10 | Deadband value for the apparent power |
| Range Value - S | kVA* | 1.00 – 100000.00 | 0.01 | 500 | Range value for the apparent power |
| Report Deadband | Hz | Off, Amplitude, Integrated | - | Amplitude | Selection of the reporting mode for frequency measurement |
| Deadband Value | Hz | 0.01 – 1.00 | 0.01 | 0.03 | Deadband value for the frequency |
| Range Value | Hz | 0.05 – 10.00 | 0.01 | 5 | Range value for the frequency |

**the prefixes can change (i.e. kW→MW, kV→V etc.) depending on the configuration; changing these is done by Protecta personnel*

***if the setting range is to be extended, contact Protecta personnel*



3.3.4.5.2. Function I/O

This section describes briefly the analogue and digital inputs and outputs of the function block.

3.3.4.5.2.1. Analogue inputs

The analogue inputs of the measurement functions are

- the Fourier components and true RMS values of the measured and calculated secondary voltages
- the Fourier components and true RMS values of the measured secondary currents,

3.3.4.5.2.2. Analogue outputs (measurements)

See the next chapter (On-line data) for the listing of all measurements. Note again, that the measured values depend on the type of the actual measurement function block, see Chapter [1.3.1](#)

3.3.4.5.2.3. On-line data

The **on-line data** of the line measurement function depend on the available analogue values which are referring to the applied hardware configuration.

Visible values on the on-line data page:

Table 2-2 On-line data of the line measurement function

| SIGNAL TITLE | DIMENSION | EXPLANATION |
|----------------------------|-----------|----------------------------------------------------------------------------------------------------|
| Power - P | kW* | Calculated three-phase active power |
| Reactive Power - Q | kVAr* | Calculated three-phase reactive power |
| Apparent Power - S | kVA* | Calculated three-phase apparent power |
| Power factor | - | Calculated power factor |
| Current L1 | A | Measured primary current L1 based on the nominal values of the CT4 current input function |
| Current L2 | A | Measured primary current L2 based on the nominal values of the CT4 current input function |
| Current L3 | A | Measured primary current L3 based on the nominal values of the CT4 current input function |
| Positive sequence current | A | Calculated positive sequence current from the three phase currents |
| Negative sequence current | A | Calculated negative sequence current from the three phase currents |
| Calculated 3I ₀ | A | Calculated 3I ₀ from the three phase currents |
| Voltage L1 | kV* | Measured primary L1 phase voltage L1 based on the nominal values of the VT4 voltage input function |
| Voltage L2 | kV* | Measured primary L2 phase voltage L2 based on the nominal values of the VT4 voltage input function |
| Voltage L3 | kV* | Measured primary L3 phase voltage L3 based on the nominal values of the VT4 voltage input function |
| Voltage L12 | kV* | Calculated L12 phase-to-phase voltage |
| Voltage L23 | kV* | Calculated L23 phase-to-phase voltage |
| Voltage L31 | kV* | Calculated L31 phase-to-phase voltage |
| Positive sequence voltage | kV* | Calculated positive sequence voltage from the three phase voltages |
| Negative sequence voltage | kV* | Calculated negative sequence voltage from the three phase voltages |
| Calculated 3U ₀ | kV* | Calculated 3U ₀ from the three phase voltages |
| Frequency | Hz | Measured frequency |

**the prefixes may be different (i.e. kW→MW, kV→V etc.) depending on the configuration; changing these is done by Protecta personnel*

3.3.4.5.3. Technical data

Table 2-3 Technical data of the line measurement function (power)

| POWER MEASUREMENT (P, Q, S)* | RANGE | ACCURACY |
|--------------------------------------|-----------------------------------------------------|-----------------|
| HW MODULES | | |
| CT+/5115 | 0,002 – 0,01 In | ±3%, ±1 digit |
| | 0,01 – 0,03 In | ±1%, ±1 digit |
| | 0,03 – 5 In (max. 5 In for measurement purposes) | ±0,5%, ±1 digit |
| CT+/1500** | 0,002 – 0,005 In | ±1,5%, ±1 digit |
| | 0,005 – 0,02 In | ±0,5%, ±1 digit |
| | 0,02 – 2 In | ±0,2%, ±1 digit |
| CT+/5151** CT+/5153 (Channel 1-3) | 0,02 – 0,05 In | ±3%, ±1 digit |
| | 0,05 – 20 In | ±0,5%, ±1 digit |

* By using VT+/2211 with nominal voltage.

** The defined accuracy regarding the CT+/1500 and CT+/5151 modules are valid from 2020/Q2 or on customer request. For the values before this date, see [Table 2-7](#) in the next chapter.

Table 2-4 Technical data of the line measurement function (currents)

| CURRENT MEASUREMENT (PHASE AND SEQUENTIAL) | RANGE | ACCURACY |
|--------------------------------------------|-----------------------------------------------------|-----------------|
| HW MODULES | | |
| CT+/5115 | 0,002 – 0,01 In | ±3%, ±1 digit |
| | 0,01 – 0,03 In | ±1%, ±1 digit |
| | 0,03 – 5 In (max. 5 In for measurement purposes) | ±0,5%, ±1 digit |
| CT+/1500* | 0,002 – 0,005 In | ±1,5%, ±1 digit |
| | 0,005 – 0,02 In | ±0,5%, ±1 digit |
| | 0,02 – 2 In | ±0,2%, ±1 digit |
| CT+/5151* CT+/5153 (Channel 1-3) | 0,02 – 0,05 In | ±3%, ±1 digit |
| | 0,05 – 20 In | ±0,5%, ±1 digit |

* The defined accuracy regarding the CT+/1500 and CT+/5151 modules are valid from 2020/Q2 or on customer request. For the values before this date, see [Table 2-7](#) in the next chapter.

Table 2-5 Technical data of the line measurement function (voltages)

| VOLTAGE MEASUREMENT (PHASE, PHASE-TO-PHASE, SEQUENTIAL) | RANGE | ACCURACY |
|---------------------------------------------------------|---------------|-----------------|
| HW MODULES | | |
| VT+/2211 | 0,05 – 1,5 Un | ±0,5%, ±1 digit |

Table 2-6 Technical data of the frequency measurement function

| FREQUENCY MEASUREMENT | VALUE | ACCURACY |
|-----------------------|--------------------------------------------------------|----------|
| Frequency | 40 - 60 Hz (50 Hz system) 50 - 70 Hz (60 Hz system) | ± 2 mHz |

3.3.4.5.3.1. Notes for testing

If there are no measurements seen on the SCADA software, check the Report Deadband parameter and/or the settings of the periodic reporting in the Communication Configurator. The former's default value is 'Off', and the latter's is 'False', which means that by default, the reporting is disabled. It must be enabled first.

The **periodic reporting** is defined in the device configuration file (.epc/.epcs) using EuroCAP. See Chapter [1.4.3](#). This also means that changing the properties of this will require loading a new configuration file to the device (hence a full device restart).



If the "Connection U1-3" parameter of the *VT4 module* function block is set to "Ph-Ph", the "ThreePhase"-method cannot be used for the power measurements here, so either of the "Aron" methods must be set for it. Otherwise, the device will provide a warning signal (yellow Status LED, "General param. error" message).

For the devices shipped with modules manufactured before 2020/Q2, the technical data table is different:

Table 2-7 Technical data of the line measurement function

| HARDWARE MODULE | RANGE | ACCURACY |
|----------------------|-----------------|-----------------|
| CT+/5151 or CT+/5102 | 0,2 In – 0,5 In | ±2%, ±1 digit |
| | 0,5 In – 20 In | ±1%, ±1 digit |
| CT+/1500 | 0,03 In – 2 In | ±0,5%, ±1 digit |

3.3.5. Average and maximum measurement function

3.3.5.1. The measurement

The input values of the EuroProt+ devices are the secondary signals of the voltage transformers and those of the current transformers.

These signals are pre-processed by the “Voltage transformer input” function block and by the “Current transformer input” function block. These function blocks are described in separate documents. The pre-processed values include the Fourier basic harmonic phasors of the voltages and currents and the true RMS values. Additionally, it is in these function blocks that parameters are set concerning the voltage ratio of the primary voltage transformers and current ratio of the current transformers.

Based on the pre-processed analog signals, several function blocks perform additional calculation, e.g.: active and reactive power, frequency, temperature, impedances, higher harmonics, symmetrical components, etc.

The “Average and maximum” function block calculates average values and locates maximum values of the assigned (measured and calculated) analog signals.

3.3.5.2. Operation of the function block

The **input** of the function can be:

- Any single calculated analog value: active and reactive power, frequency, temperature, impedances, higher harmonics, symmetrical components, etc. depending on the assignment in the configuration.

The **outputs** of the function are:

- Average of the analog value,
- Maximum of the analog value.

The average and the maximum values are automatically reported to the SCADA system. The maximum is logged and is sent automatically to the HMI, the average however is logged only if a binary input of the function block enables this activity.

3.3.5.3. Reporting the values

The average calculation needs a time span for calculation; this is given as a parameter value, set in minutes (or the function is switched off). When the timer expires, the calculated average is reported automatically to the SCADA system. Depending on the requirements, this value is also logged and is sent to the local HMI. This activity is controlled by a binary input of the function block.

The identification of the maximum value needs also a time span; this is given as a parameter value, set in days. When the timer expires, the found maximum value is reported automatically to the SCADA system. Additionally this value is also logged and is sent to the local HMI.

The starting of the timer is controlled by the internal real-time clock of the device. The moment of time for the starting of the processing cycles is set by a parameter value.

3.3.5.4. Parameters of the function block

Enumerated parameter

| Parameter name | Title | Selection range | Default |
|---------------------------|--------------------|----------------------------------|---------|
| Time window for averaging | | | |
| MXU_TimWin_EPar_T _ | Average TimeWindow | Off,5min,10min,15min,30min,60min | Off |

Table 1-1 The enumerated parameters of the average and maximum measurement function

Integer parameter

| Parameter name | Title | Unit | Min | Max | Step | Default |
|-------------------------------------------|-------------------|------|-----|-----|------|---------|
| Time window for finding the maximum value | | | | | | |
| MXU_MaxResInt_IPar_T | MaxReset Interval | day | 0 | 365 | 1 | 1 |
| Moment of time for reporting and reset | | | | | | |
| MXU_MaxResTime_IPar_T | MaxReset Time | hour | 0 | 23 | 1 | 12 |

Table 1-2 The integer parameters of the average and maximum measurement function

3.3.5.5. Status signals of the function block

The average and maximum measurement function block has **binary input signals**, which serve the purpose of resetting the values and enabling logging the average value. **The conditions are defined by the user, applying the graphic equation editor.**

| Binary status signal | Explanation |
|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| MXU_Reset_GrO_IL1 * | This signal resets both the calculated average and the found maximum value. At the end of the running cycles, the values found during the shortened cycle will be processed. |
| MXU_DemHMIEna_GrO_IL1 | During the active state of this signal also the calculated average value is logged |

* Note: In this example “IL1” is indicating that in the instant of the function block processes the RMS value of the current in line 1

Table 1-3 The binary input signal for the average and maximum measurement function block

The average and maximum measurement function block **has no binary output signals.**

3.3.5.6. The function block

The function block of the average and maximum measurement function is shown in Figure 1-1. This block shows all binary input (and output) status signals that are applicable in the graphic equation editor.

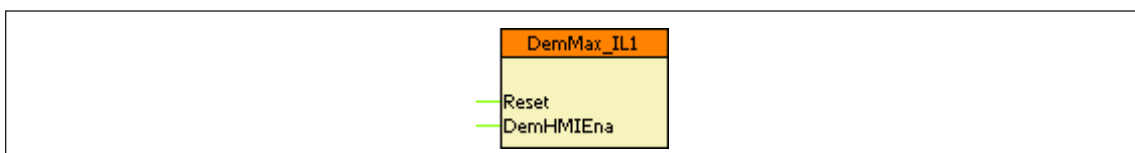
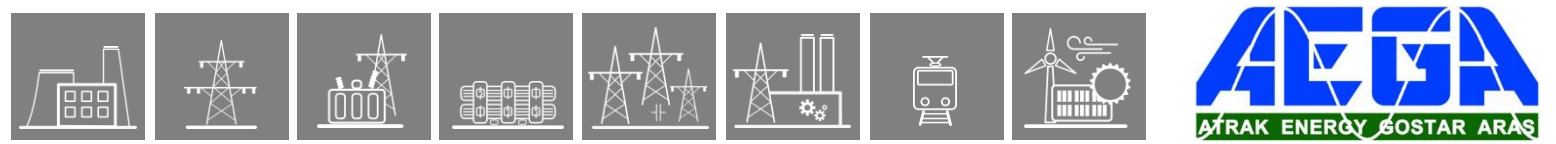


Figure 1-1 The function block of the average and maximum measurement function block



3.3.6. Metering

3.3.6.1. Application

The metering function can be applied to calculate the active and reactive energy supply and demand values based on the own measurement of the device or the energy meter impulses.

3.3.6.1.1. Mode of operation

There is an “Input selection” parameter to select the input of energy the calculation “Measurement” or “Impulse”. Chapter 1.1.1 and Chapter 1.1.2 describe the difference of operation.

3.3.6.1.2. Measurement mode

The input values of the EuroProt+ devices are the secondary signals of the voltage transformers and those of the current transformers.

These signals are pre-processed by the “Voltage transformer input” function block and by the “Current transformer input” function block. These function blocks are described in separate documents. The pre-processed values include the Fourier basic harmonic phasors of the voltages and currents. Additionally, it is in these function blocks that parameters are set concerning the voltage ratio of the primary voltage transformers and current ratio of the current transformers.

Based on the pre-processed values and the transformer parameters, the “Line measurement” function block calculates “P” and “Q” values in every process cycle and based on these values the “Metering” function block calculates the active and reactive power supply and demand. These values are accumulated to obtain, separately:

- Active power demand,
- Active power supply,
- Reactive power demand.
- Reactive power supply,

This means that the positive and negative values are accumulated separately.

The time period of the accumulation is defined by parameter setting. It can be selected in a broad range. The start of the accumulation is based on the integrated real-time clock of the device. For example, for the “Time Interval” setting of 15min, the trigger is: at 0h0min, 0h15min, 0h30min, 0h45 min, 1h0min, etc.

When the accumulation time is over, the calculated values are reported to the SCADA system. The displayed values change continuously.

The calculated values are available as primary quantities, and they can be displayed on the on-line screen of the device or on the webpage of the device and they are available for the SCADA system using the configured communication system.

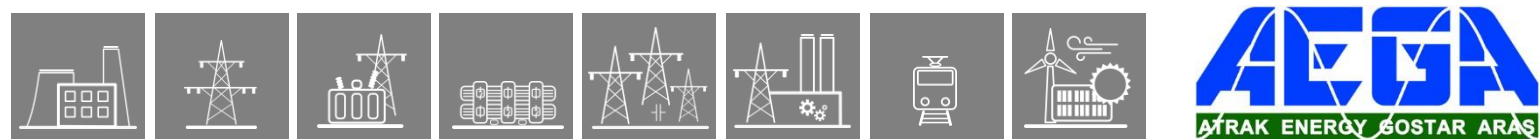
The **inputs** of the metering function are:

- the Fourier components of the measured voltages and currents,
- parameters.

The **output** of the metering function is:

- displayed measured values.

NOTE: the scaling values are entered as parameter setting for the “Voltage transformer input” function block and for the “Current transformer input” function block.



3.3.6.1.3. Impulse mode

Based on the external energy meter impulses. These impulse outputs of the meter connect as binary inputs. Metering function block calculates the active and reactive power supply and demand. These values are accumulated to obtain, separately:

- Active power demand,
- Active power supply,
- Reactive power demand.
- Reactive power supply,

Impulse scaling values are entered as parameters named “Active pulse scale” and “Reactive pulse scale”.

The time period of the accumulation is defined by parameter setting. It can be selected in a broad range. The start of the accumulation is based on the integrated real-time clock of the device. For example, for the “Time Interval” setting of 15min, the trigger is: at 0h0min, 0h15min, 0h30min, 0h45 min, 1h0min, etc.

When the accumulation time is over, the calculated values are reported to the SCADA system. The displayed values change continuously.

The calculated values are available as primary quantities and they can be displayed on the on-line screen of the device or on the webpage of the device and they are available for the SCADA system using the configured communication system

The **inputs** of the metering function are:

- the impulses of energy meter,
- parameters.

The **output** of the metering function is:

- displayed measured values.

3.3.6.1.4. Cumulation mode

“Cumulation mode” parameter defines the mode of operation. It can be “TRUE” or “FALSE”.

In “FALSE” mode the values set to zero after the values are reported to the SCADA system, based on the “Time Interval” settings.

In “TRUE” mode the values are cumulated after the report is sent to the SCADA system.

Maximum cumulated value depends on the CT module of IED and the primary nominals of CT and VT.

“Nominal primary power” = “Rated Primary U1-3” setting of VT module multiplied by “Rated Primary I1-3” setting of CT module. Unit prefix (kilo- or Mega) depends on the configuration, the “Line measurement” function uses the same unit prefix as Metering.

Maximum cumulated power value with CT+/1500 module = 3 259 602 multiplied by “Nominal primary power”

Maximum cumulated power value with CT+/5151 module = 65 192 055 multiplied by “Nominal primary power”

Maximum cumulated power value with CT+/5115 module = 8 149 006 multiplied by “Nominal primary power”

User can reset cumulated value to zero either by initiating the reset input of Metering function block or by restarting the device.

3.3.6.1.5. The measurement

3.3.6.1.5.1. Reference direction

“Reference direction” parameter setting defines the direction when voltage and current vectors are in phase. Setting can be “Demand” or “Supply”.


3.3.6.1.5.2. The measured values

Unit prefix of the **measured values** of the metering function depends on the configuration: it can be kilo or Mega. The “Line measurement” function uses the same unit prefix as the Metering.

| MEASURED VALUE | EXPLANATION |
|----------------|-------------------------------------------|
| MTR_PosP_OLM_ | Demand kWh – active power consumption |
| MTR_NegP_OLM_ | Supply kWh – active power supply |
| MTR_PosQ_OLM_ | Demand kVArh – reactive power consumption |
| MTR_NegQ_OLM_ | Supply kVArh – reactive power supply |

Table 1-1 Measured values of the metering function

The measured values available are shown as on-line information, see the figure below.



| [-] METERING | | |
|--------------|--------|-------|
| Demand kWh | 400.0 | kWh |
| Supply kWh | 300.0 | kWh |
| Demand kVArh | 500.0 | kVArh |
| Supply kVArh | 2500.0 | kVArh |

Figure 1-1 Measured values of the metering function

3.3.6.1.6. Parameter setting

The time period of accumulation is defined by parameter setting. This can be selected in a broad range, as it is shown in Table 1-2.

Enumerated parameter

| PARAMETER NAME | TITLE | SELECTION RANGE | DEFAULT |
|-------------------------------------------------|---------------|---------------------------------------|---------|
| Selection of the time period for power metering | | | |
| MTR_TimInt_EPar_ | Time Interval | Off, 5min, 10min, 15min, 30min, 60min | 30min |

Table 1-2 The enumerated parameter of the metering function

3.3.6.2. Metering function overview

The graphic appearance of the function block of the metering function is shown below. The block shows all binary input and output status signals which are applicable in the graphic equation editor.

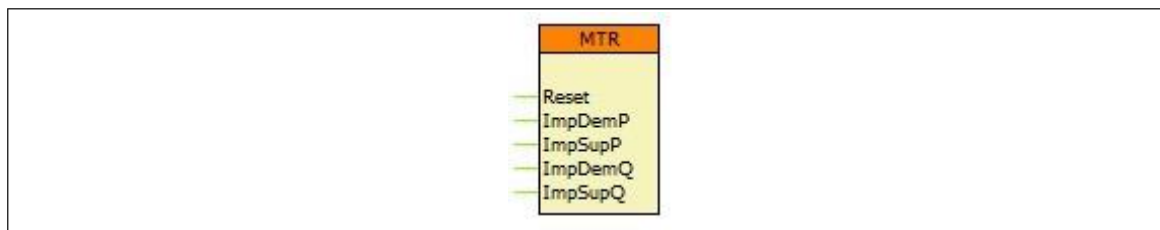


Figure 2-1 Graphic appearance of the function block of the metering function

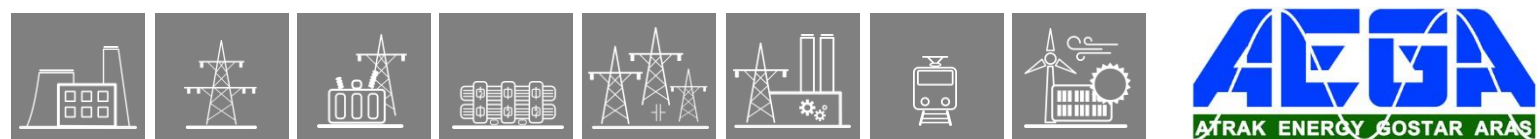
3.3.6.2.1. Settings

3.3.6.2.1.1. Parameters

The available parameters are listed below in order of their appearance in the *parameters* menu. If the setting range of a parameter should be extended, contact Protecta Support.

Table 2-1 The available parameters of the metering function

| TITLE | DIM. | RANGE | STEP | DEFAULT | EXPLANATION |
|----------------------|-----------------|--------------------------------------------------------------|------|-------------|------------------------------------------------------------------------------|
| Time Interval | - | Off, 5min (On), 10min , 15min , 30min , 60min | - | 30min | Time period of accumulation parameter for general operation of the function: |
| Input selection | - | Measurement, Impulse, | - | Measurement | Input selection of energy calculation |
| Cumulation mode | | FALSE,TRUE | | FALSE | Cumulation mode is used |
| Reference direction | - | Demand, Supply | - | Demand | Energy direction reference selection. |
| Active pulse scale | kWh/ pulse | 1 - 10000 | 1 | 100 | One impulse of energy meter is equal to this setting |
| Reactive pulse scale | kVarh/ pulse | 1 - 10000 | 1 | 100 | One impulse of energy meter is equal to this setting |



3.3.6.2.2. Function I/O

This section describes briefly the analogue and digital inputs and outputs of the function block.

3.3.6.2.2.1. Analogue inputs

The function uses the sampled values of a voltage and current inputs. This is defined in the configuration.

3.3.6.2.2.2. Analogue outputs (measurements)

The measured values of the metering function are listed in the table below.

Table 2-2 The measured analogue values of the metering function

| MEASURED VALUE | DIMENSION | EXPLANATION |
|----------------|-----------|----------------------------------------------------------------------------------|
| Demand P | kWh | <i>Demand P. Unit prefix can be kilo- or mega-, depends on the configuration</i> |
| Supply P | kWh | <i>Supply P. Unit prefix can be kilo- or mega-, depends on the configuration</i> |
| Demand Q | kVArh | <i>Demand Q. Unit prefix can be kilo- or mega-, depends on the configuration</i> |
| Supply Q | kVArh | <i>Supply Q. Unit prefix can be kilo- or mega-, depends on the configuration</i> |

3.3.6.2.2.3. Binary input signals (graphed output statuses)

The conditions of the binary inputs are defined by the user, applying the graphic equation editor (*Logic Editor*). Parts written in **bold** are seen on the left side function block in the Logic editor.

Table 2-3 The binary input signal of the metering function

| BINARY OUTPUT SIGNAL | EXPLANATION |
|----------------------|--------------------------------------------------------------------------------------------------------|
| MTR_Reset_GrO_ | Reset input of the function has meaning only in cumulation mode |
| MTR_ImpDemP_GrO_ | Demand P impulse of external energy meter input of the function has meaning only in impulse input mode |
| MTR_ImpSupP_GrO_ | Supply P impulse of external energy meter input of the function has meaning only in impulse input mode |
| MTR_ImpDemQ_GrO_ | Demand Q impulse of external energy meter input of the function has meaning only in impulse input mode |
| MTR_ImpSupQ_GrO_ | Supply Q impulse of external energy meter input of the function has meaning only in impulse input mode |

3.3.6.2.2.4. Events

The following events are generated in the event list, as well as sent to the SCADA according to the configuration.

Table 2-4 Generated events of the metering function

| EVENT | DIMENSION | EXPLANATION |
|----------|-----------|-----------------------|
| Demand P | Wh | <i>Demand P value</i> |
| Supply P | Wh | <i>Supply P value</i> |
| Demand Q | VArh | <i>Demand Q value</i> |
| Supply Q | VArh | <i>Supply Q value</i> |

3.3.6.2.3. Technical data

Table 2-5 Technical data of the metering function

| FUNCTION | RANGE | ACCURACY |
|----------------|---------------|-----------|
| Power accuracy | $I > 15\%I_n$ | $\pm 3\%$ |

3.3.6.2.4. Notes for testing

Time period of the accumulation is defined by parameter setting.

Starting accumulation is based on the integrated real-time clock of the device.

For example, for a “Time Interval” setting of 15min, the trigger is: at 0h0min, 0h15min, 0h30min, 0h45 min, 1h0min, etc.

Parameter changing resets the accumulation. Using the settings of the example above, setting new parameters at 0h07min will result in the following:

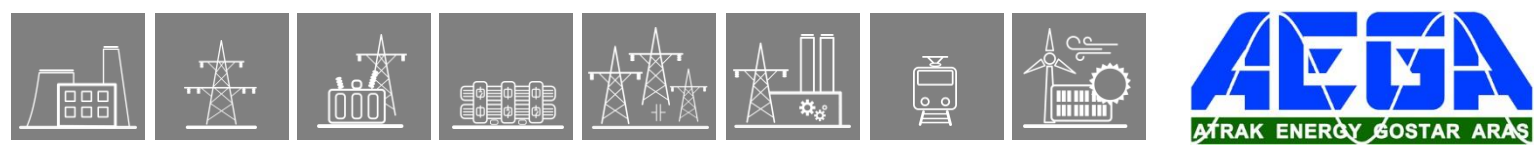
- the accumulated values are reset to zero,
- the new accumulation starts at 0h15min,
- the first report is sent at 0h30min. Measured values in Events list will also refresh at 0h30min.

3.3.6.2.5. 61850 LN

Instance number of Logical Node is not mentioned in the table below.

Table 2-6 Logical Node and Data Objects of the metering function

| LN NAME | DO NAME | DA NAME | FC | EXPLANATION |
|---------|-----------|---------|----|-------------------|
| EMMTR | DmdVArhPV | mag.f | MX | Demand VArh value |
| | | q | MX | quality |
| | | t | MX | timestamp |
| | DmdWhPV | mag.f | MX | Demand Wh value |
| | | q | MX | quality |
| | | t | MX | timestamp |
| | SupVArhPV | mag.f | MX | Supply VArh value |
| | | q | MX | quality |
| | | t | MX | timestamp |
| | SupWhPV | mag.f | MX | Supply Wh value |
| | | q | MX | quality |
| | | t | MX | timestamp |



3.3.7. Voltage selection function block

3.3.7.1. Application

In several substation configurations with double busbar, there is no voltage measurement in the bays, but voltage transformers are connected to the busbars only.

If the protection functions configured in the bay devices apply voltage measurement then the correct selection of the voltage sources is needed. The role of the voltage selection is that the protection functions get the voltage of the busbar section to which the feeder or the transformer is connected.

To solve this problem the device gets both three-phase voltages of both busbar sections, and a binary signal decides which one is valid for the protection function.

The “Voltage selection” function block assigns the correct voltages to the protection functions.

3.3.7.2. Mode of operation

The voltage selection is decided by a binary signal. **The conditions are defined by the user applying the graphic equation editor.**

If this input signal is FALSE then the voltages of the voltage input module configured as default input are assigned to the protection functions.

If however this input signal is TRUE then the voltages of the other voltage input module are assigned to the protection functions.

3.3.7.3. The binary status signals

The voltage selection function block has a binary input signal. **The conditions are defined by the user applying the graphic equation editor.**

The **binary input status signal** of the voltage selection function block is shown in Table 1-1.

| Binary status signal | Title | Explanation |
|-------------------------|---------|-------------------------------------------------|
| SelectVolt_USelect_GrO_ | USelect | Binary signal controlling the voltage selection |

Table 1-1 The binary input status signal of the voltage selection function block

The **binary output status signals** of the voltage selection function block.

The voltage selection function block has no binary output status signals.

3.3.7.4. The parameters

The voltage selection function block has no parameters.

3.3.7.5. The symbol of the function block in the graphic editor

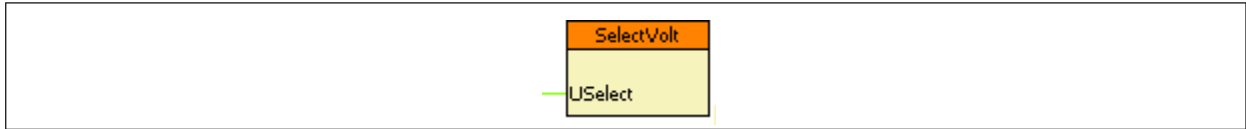


Figure 1-1 The function block of the voltage selection function block

The name of the input signal is a part of the “Binary status signal” name shown in Table 1-1.

3.3.7.6. Example

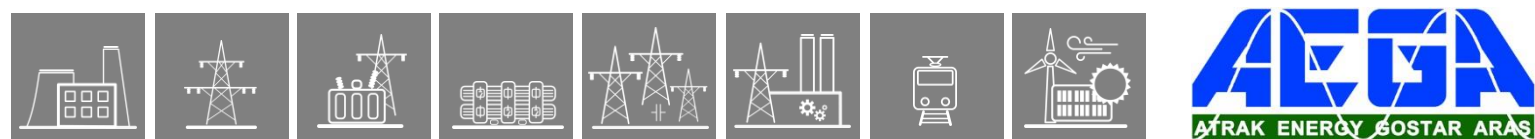
In this simple example the channel No.1 of the binary input module in position “F” is used as the signal controlling the selection.

If this input signal is FALSE then the voltages of the voltage input module configured as default input are assigned to the protection functions.

If however this input signal is TRUE then the voltages of the other voltage input module are assigned to the protection functions.



Figure 2-1 Example The simple application of the voltage selection function block



3.3.8. Trip Value Recorder

3.3.8.1. Application

For quick evaluating of network faults, it is very useful to see in the event list of the protection device the measured primary analog values (currents, voltages) before and during the fault state. The Trip value recorder function serves this purpose.

This function is not a default element of any configuration, but it can be acquired (please contact Protecta Support team).

3.3.8.1.1. The measurement

The input values of the EuroProt+ devices are the secondary signals of the voltage transformers and those of the current transformers.

These signals are pre-processed by the “Voltage transformer input” function block and by the “Current transformer input” function block. These function blocks are described in separate documents. The pre-processed values include the Fourier basic harmonic phasors of the voltages and currents and the true RMS values. Additionally, it is in these function blocks that parameters are set concerning the voltage ratio of the primary voltage transformers and current ratio of the current transformers.

Based on the pre-processed analogue signals, several function blocks perform additional calculation, e.g.: active and reactive power, frequency, temperature, impedances, higher harmonics, symmetrical components, etc.

The Trip value recorder function calculates the primary values from its three input secondary signals (currents or voltages) and uses them as described in the following chapter.

3.3.8.1.2. Operation principles

The Trip value recorder has two binary inputs: “Start” and “Trip”.

When the “Start” binary input receives a rising edge signal, the function stores the pre-fault value of the three analogue signals and the fault value of the three analogue signal as well and the function starts waiting for the trigger (Trip) signal. If no trigger signal coming and new start signal receives the stored pre-fault and fault values will be overwritten by the latest ones.

The “Trip” binary input of the function is applied for triggering the trip value recording to generate the events with the pre-fault and fault values.

After triggering the function, so the “Trip” binary input is activated, the function generates the following values in the event list and sends them automatically to the SCADA system:

- pre-fault values of the three analog signals 100 ms before the Start signal receives,
- fault values of the three analog signals: average of the values 10 ms and 20 ms after the Start.

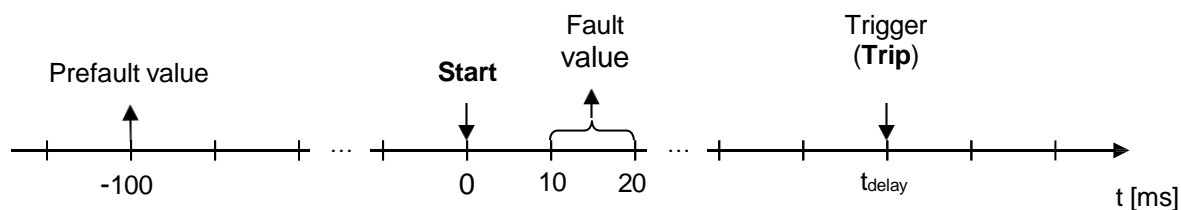


Figure 1-1 Time diagram of the trip recording behaviour

3.3.8.2. Trip value recorder function overview

The graphic appearance of the function block of the trip value recorder function is shown below. The block shows all binary input and output status signals which are applicable in the graphic equation editor.

Usually, the collected general start signal of the protection functions is assigned to the “Start” input and the general trip signal of trip logic function is connected to the “Trip” input.

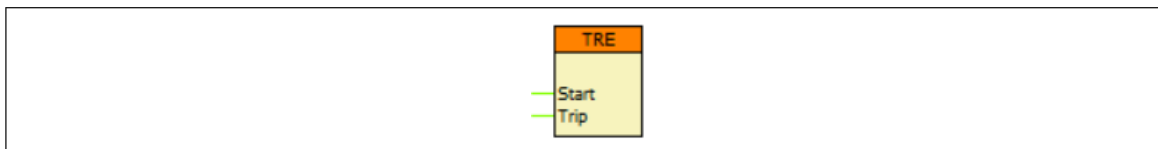


Figure 2-1 Graphic appearance of the function block of the trip value recorder function

3.3.8.2.1. Settings

3.3.8.2.1.1. Parameters

The Trip value recorder function does not have any parameters.

3.3.8.2.2. Function I/O

This section describes briefly the analogue and digital inputs and outputs of the function block.

3.3.8.2.2.1. Analogue inputs

The function uses the sampled values of a current input or voltage input. Moreover, calculated analogue signals i.e.: symmetrical values, differential/bias current values can be used as inputs.

The following table contains the available input channels of the trip value recorder function.

Table 2-1 Available analogue inputs of the trip value recorder function

| ANALOGUE INPUTS | RELATED FUNCTION BLOCK |
|---------------------------------------------------------------------------------------|------------------------|
| Phase current, phase-to-phase, symmetrical, residual currents | CT4, CalcCurr |
| Voltage in phase, phase-to-phase, and symmetrical; Reference (busbar) voltages | VT4, CalcVolt |
| Calculated Idiff/Ibias current of transformer differential protection | DIF87T |
| Calculated Idiff/Ibias current of busbar differential protection for each bus section | DIF87B |

NOTE: Displaying the fault current values of the line differential protection Idiff/Ibias current and the restricted earth fault protection Idiff/Ibias current are integrated into the protection function, thus not need additional trip value functions to display the trip values.

3.3.8.2.2.2. Binary input signals (graphed output statuses)

The conditions of the binary inputs are defined by the user, applying the graphic equation editor (*Logic Editor*). Parts written in **bold** are seen on the left side function block in the Logic editor.

Table 2-2 The binary input signal of the trip value recorder function

| BINARY OUTPUT SIGNAL | EXPLANATION |
|-------------------------|--------------------------------------------------------------------------------------------------|
| TRE_ Start _GrO_ | Dedicated input of the function to receive the start signal of the selected protection functions |
| TRE_ Trip _GrO_ | Dedicated input of the function to receive the trip signal of the selected protection functions |



3.3.8.2.2.3. Binary output signals (graphed input statuses)

The Trip value recorder function does not have any binary output signals.

3.3.8.2.2.4. Online data

No default visible values on the *online data* page.

3.3.8.2.2.5. Events

The following events are generated in the event list, as well as sent to the SCADA according to the configuration.

Table 2-3 Generated events of the trip value recorder function

| EVENT | VALUE | EXPLANATION |
|---------------|--------------------------------|--------------------------------------|
| ... Prefault* | according to the applied input | Prefault value of the applied signal |
| ... Fault* | according to the applied input | Fault value of the applied signal |

**The event text may vary according to the actual device configuration (.epcs)*

3.3.9. RTD temperature input function

3.3.9.1. Application of the RTD input

If the factory configuration includes an RTD temperature input hardware module, the temperature input function block is automatically configured among the software function blocks. Separate temperature input function blocks are assigned to each temperature input hardware module.

The RTD+1100 temperature input hardware module is equipped with four special input channels, the RTD+ 0200 has a single channel only. (See EuroProt+ hardware description document.) To each channel, a temperature sensor can be connected. The temperature is measured as the resistance value of the sensor, which depends upon the temperature.

The sensors can be connected by wiring methods, shown in Figure 1–1, Figure 1–2 and Figure 1–3. The connection mode is identified also by parameter setting.

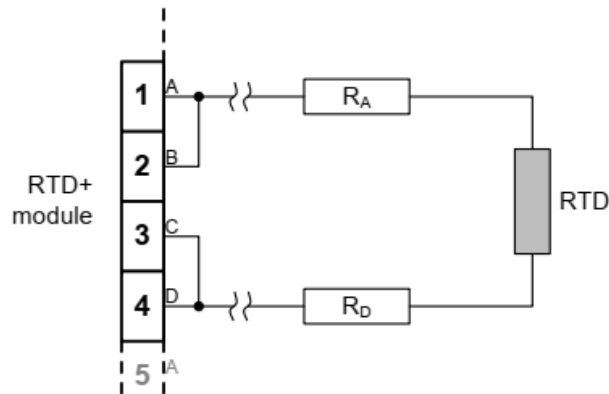


Figure 1–1 2-wire RTD wiring

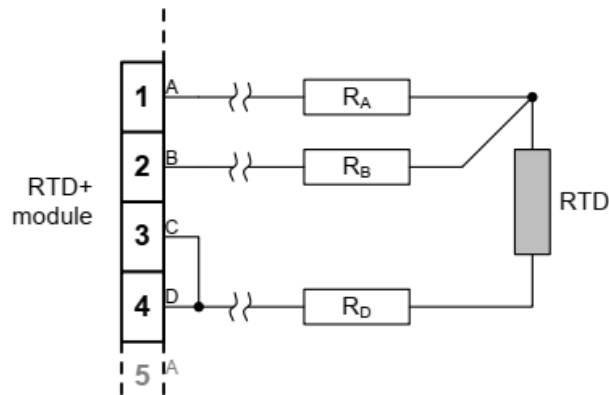


Figure 1–2 3-wire RTD wiring

When 3-wire connection is applied, it is supposed that $R_A=R_D$.

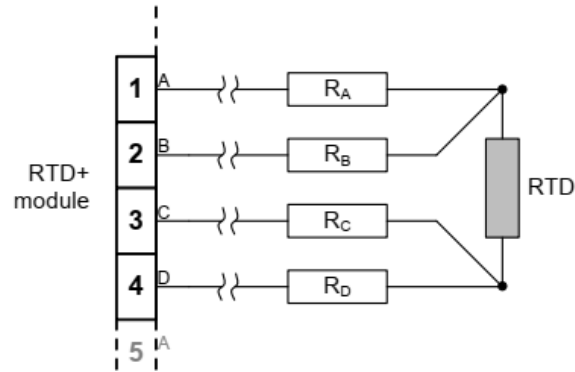
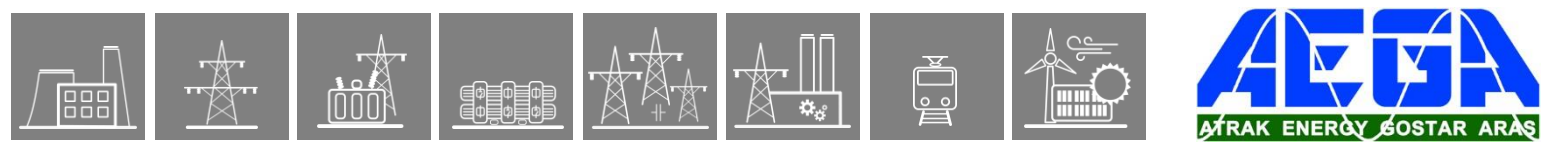


Figure 1-3 4-wire RTD wiring

The channels of the module are independent of each other. To each channel a dedicated measuring module is assigned. These measuring modules are described in a separate document: “**GGIORTD temperature measurement module function block description**”. The module is prepared to connect the following types of sensors:

- Pt100/Ni100
- Ni120/Ni120US
- Pt250/Ni250
- Pt1000/Ni1000
- Cu10
- Service-Ohm (60 Ω ... 1.6 k Ω)

The applied type of sensors define the conversion mode from measured resistance to temperature. These are selected by parameters of the temperature measuring module. See separate document: “**GGIORTD temperature measurement module function block description**”.



3.3.9.2. Technical summary

3.3.9.2.1. Technical data

The technical data of the temperature input module are related to the hardware module. This is described in the document “**EuroProt+ Hardware description**, Chapter 10: RTD input module”.

3.3.9.2.2. Summary of the parameters

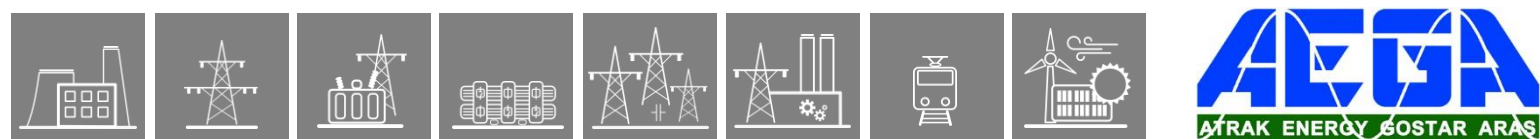
The parameters of the temperature input function are explained in the following table.

Enumerated parameters

| Parameter name | Title | Selection range | Default |
|------------------------------|------------|---------------------|---------|
| Connection mode of Channel 1 | | | |
| RTD_Ch1RangeOfMAn03_EPar_ | Channel 01 | 3wire, 4wire, 2wire | 3wire |
| Connection mode of Channel 2 | | | |
| RTD_Ch2Range2OfMAn03_EPar_ | Channel 02 | 3wire, 4wire, 2wire | 3wire |
| Connection mode of Channel 3 | | | |
| RTD_Ch3RangeOfMAn04_EPar_ | Channel 03 | 3wire, 4wire, 2wire | 3wire |
| Connection mode of Channel 4 | | | |
| RTD_Ch4Range2OfMAn04_EPar_ | Channel 04 | 3wire, 4wire, 2wire | 3wire |

Table 1-1 The enumerated parameters of the voltage input function

NOTE: The function block has no input and output binary signals, the graphic logic editor does not show this function block.



3.4. Disturbance recorder function

The disturbance recorder function can record analog signals and binary status signals. These signals are configured using the EuroCAP software tool.

The disturbance recorder function has a binary input signal, which serves the purpose of starting the function. **The conditions of starting are defined by the user, applying the graphic equation editor.** The disturbance recorder function keeps on recording during the active state of this signal but the total recording time is limited by the timer parameter setting.

The pre-fault time, max recording time and post-fault time can be defined by parameters.

3.4.1. Mode of recording

If the triggering conditions defined by the user - using the graphic equation editor – are satisfied and the function is enabled by parameter setting, then the disturbance recorder starts recording the sampled values of configured analog signals and binary signals.

The analog signals can be sampled values (voltages and currents) received via input modules or they can be calculated analog values (such as negative sequence components, etc.)

The number of the configured binary signals for recording is limited to 64, and up to 32 analog channels can be recorded.

The available memory for disturbance records is 12 MB.

There are two function blocks available. The first function (**DRE**) applies 20 sampling in a network period. Accordingly for 50 Hz, the sampling frequency is 1 kHz. (For 60 Hz the sampling frequency is 1.2 kHz). This is used in all configurations by default.

The second function (**DRE2**) is capable to be set by parameter to apply 20 or 40 sampling in a network period. This way accordingly for 50 Hz, the sampling frequency is 1 kHz or 2 kHz (and for 60 Hz the sampling frequency is 1.2 kHz or 2.4 kHz). *Except for this, the two function blocks are the same.*

As an example, for 50 Hz, if the duration of the record is 1000 ms then one analog channel needs about 7 kB and a binary channel needs 2 kB, Using the following formula the memory size can be estimated:

$$\text{Memory size of a record} = (n \cdot 7 \text{ kB} + m \cdot 2 \text{ kB}) \cdot \text{record duration (s)}$$

Here n,m: are the number of analog and binary channels respectively.

During the operation of the function, the pre-fault signals are preserved for the time duration as defined by the parameter “PreFault”.

The recording duration is limited by the parameter “Max Recording Time” but if the triggering signal resets earlier, this section is shorter.

The post-fault signals are preserved for the time duration as defined by the parameter “PostFault”.

During or after the running of the recording, the triggering condition must be reset for a new recording procedure to start.

3.4.2. Format of recording

The records are stored in standard COMTRADE format.

- The configuration is defined by the file .cfg,
- The data are stored in the file .dat,
- Plain text comments can be written in the file .inf.

3.4.3. Downloading and evaluating the disturbance records

The procedure for downloading the records is described in detail in the EuroProt+ manual “Remote user interface description”, Chapter 4.7. The three files are zipped in a file .zip. This procedure assures that the three component files (.cfg, .dat and .inf) are stored in the same location.

The evaluation can be performed using any COMTRADE evaluator software. Protecta offers the “**srEval**” software for this purpose. The application of this software is described in detail in the “srEval manual”. This manual can be downloaded from the following Internet address: http://www.softreal.hu/product/sreval_en.shtml.

3.4.4. Parameters of the disturbance recorder functions

Enumerated parameters

| Parameter name | Title | Selection range | Default |
|--------------------------|--------------|--------------------|----------|
| Parameter for activation | | | |
| DRE_Oper_EPar_ | Operation | Off, On | Off |
| DRE_Resolution_EPar_ | Resolution * | 1/1.2kHz, 2/2.4kHz | 1/1.2kHz |

*only on the optional 2/2.4 kHz disturbance recorder function

Table 1-1 The enumerated parameters of the disturbance recorder functions

Timer parameters

| Parameter name | Title | Unit | Min | Max | Step | Default |
|---------------------------|--------------------|------|-----|-------|------|---------|
| Pre-fault time: | | | | | | |
| DRE_PreFault_TPar_ | PreFault | msec | 100 | 1000 | 1 | 200 |
| Post-fault time: | | | | | | |
| DRE_PostFault_TPar_ | PostFault | msec | 100 | 1000 | 1 | 200 |
| Overall-fault time limit: | | | | | | |
| DRE_MaxFault_TPar_ | Max Recording Time | msec | 500 | 10000 | 1 | 1000 |

Table 1-2 The timer parameters of the disturbance recorder functions

NOTE: The device goes automatically in “Warning” state and sends a warning message (see [Figure 1-1](#)) if the sum of the pre-fault time and post-fault time is longer than the overall-fault time. The corresponding message in the RDSP log file is: „Wrong DR settings. PreFault + PostFault must be less than MaxFault. Check the parameters.”

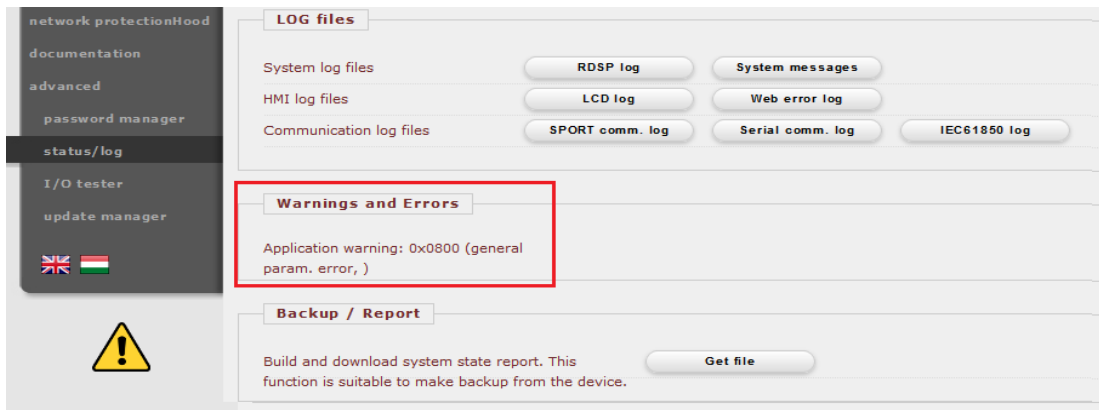


Figure 1-1 Warning message if the settings are invalid

3.4.5. The input signals of the disturbance recorder functions

Binary status signals

The disturbance recorder function has a binary input signal, which serves the purpose of starting the function. **The conditions of starting are defined by the user, applying the graphic equation editor.**

| Binary status signal | Explanation |
|----------------------|-----------------------------------------------------------------------------------------------------|
| DRE_Start_GrO_ | Output status of a graphic equation defined by the user to start the disturbance recorder function. |

Table 1-3 The binary input signal of the disturbance recorder functions

The recording is performed if the function is enabled by the parameter setting AND the triggering condition as defined by the user is “True” as well.

3.4.6. The function blocks

The two function blocks of the disturbance recorder function is shown in [Figure 1-2](#). The block shows the binary input status signal, which serves the purpose of triggering the record. It is defined by the user in the graphic equation editor.

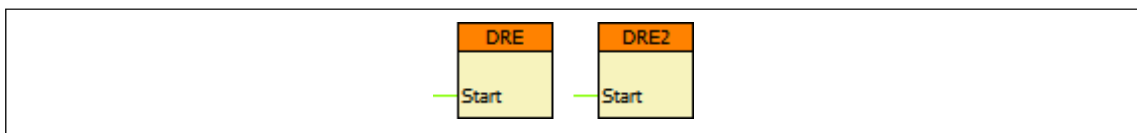
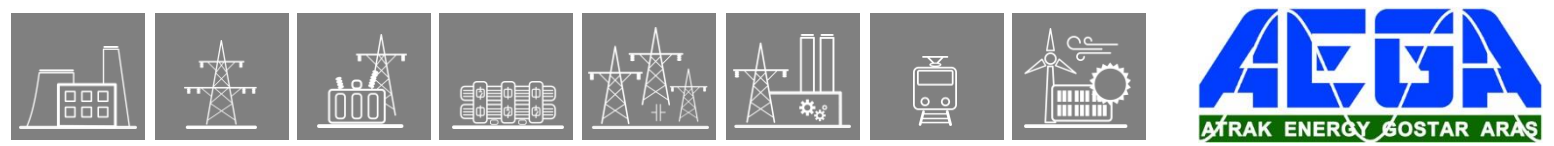


Figure 1-2 The function blocks of the disturbance recorder functions

3.4.7. The recorded signals

The analog and binary signals to be recorded are configured using the EuroCAP software tool in the menu item “Software configuration/Disturbance recorder”. (The access level of the user must be at least “Master”.) The application of this software is described in detail in the EuroCAP manual.



3.5. Event recorder

The events of the device and those of the protection functions are recorded with a time stamp of 1 ms time resolution. This information with indication of the generating function can be checked on the touch-screen of the device in the “Events” page, or using an Internet browser of a connected computer

4. Maintenance guide for EuroProt+ devices

4.1. Foreword

The EuroProt+ devices are designed with the most up-to-date and durable components available, to keep appliances in continuous operation for decades. For this range, the only type of components that can age and lead to equipment failure are the power supply capacitors. Therefore, this document, in addition to suggesting some general steps for planned inspections, contains important information on the inspection of power supply modules.

4.2. Safety precautions

The EP+ protection-family, depending on the type, operates at dangerous power supply voltages (220 VDC, 230 VAC, 60 VDC, 48 VDC).



In all cases where the connections of the appliance are to be installed or opened, the work must be carried out by a suitably qualified person.

In all cases, the first step of activity should be to switch off the power



The EuroProt+ protection family has a high operating internal temperature. Operations carried out immediately after operation may lead to dangerous burns.



The hardware and software of the EP+ protection family form a complex system. Setting, modifying, and mounting the individual components may severely affect the operation of the whole system.

In all cases where the device is to be operated or maintained, the activity must be carried out by qualified personnel only

4.2.1. General guidelines for a scheduled maintenance of EP+ devices

1. As a first step, it is recommended to send an email attaching a report.zip file to the Protecta Application Department on the email address application@protecta.hu. In the report file, the logs contain information that can indicate abnormal operation of a module before it causes an operational fault. Based on this information, Protecta can make recommendations for the replacement or repair of the modules concerned.



The report.zip file can be downloaded from the device's web interface, in the Backup / Report section of the Advanced / Status / Log menu, by pressing the "Get file" button. Attention! The file size should be about 700kB. If the downloaded file size is significantly smaller than this, please try again or contact Protecta's Application Department via our web-based support system (<https://support.protecta.hu/?language=English>)!

2. It is usually recommended to update the firmware of the devices during scheduled maintenance. Information about the new firmware releases can be found in the [Release Notes on the Protecta homepage](#). The information here can be used to consider upgrading the basic software for a single device, or all devices in a substation.



Before starting the upgrade, always contact the Protecta Application Department or submit a ticket in the web-based support system from the following link: <https://support.protecta.hu/>

For more details on the firmware update, please refer to Chapter 4.2.10.4 of the [EuroProt+ Operating Manual](#).

4.3. Power supply maintenance

Power supplies are designed with the longest possible life electrolytic capacitors. Their expected lifetime depends significantly on the environmental conditions of the device. During a scheduled inspection, we recommend visual inspection of the power supply for any abnormalities in the capacitors. The most common phenomena are: bloating, electrolyte leakage, discoloration, which typically occurs on capacitors, but can also occur on the surface of the PCB board due to leakage. In case of abnormality, the capacitors should be replaced. In such a case, please contact Protecta's Application Department via our support page (<https://support.protecta.hu/>)!

The following figures illustrate the different capacitor states in several photos.



Figure 4-1 The capacitor on the right is already discolored

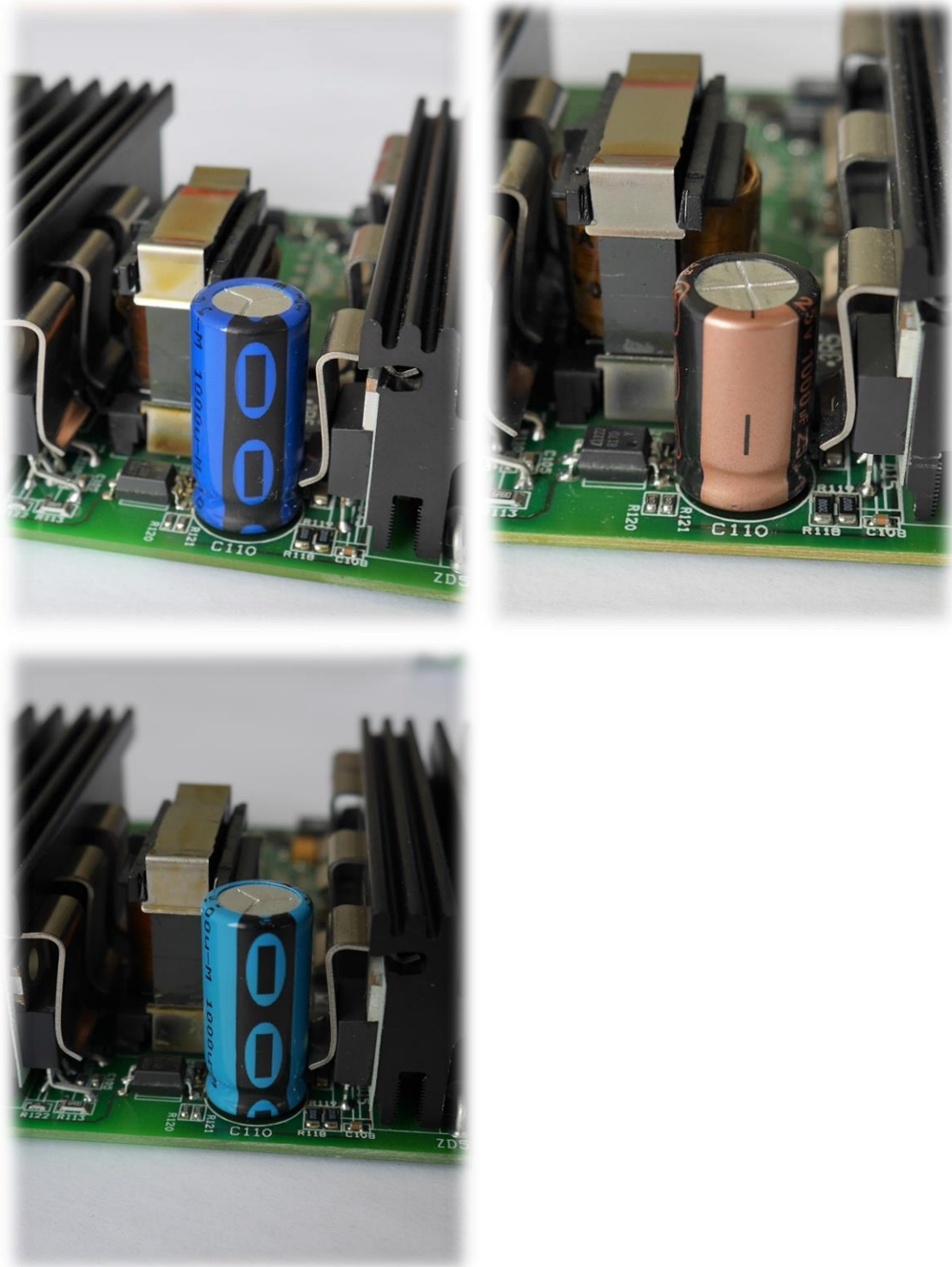


Figure 4-2 Healthy capacitors on visual inspection

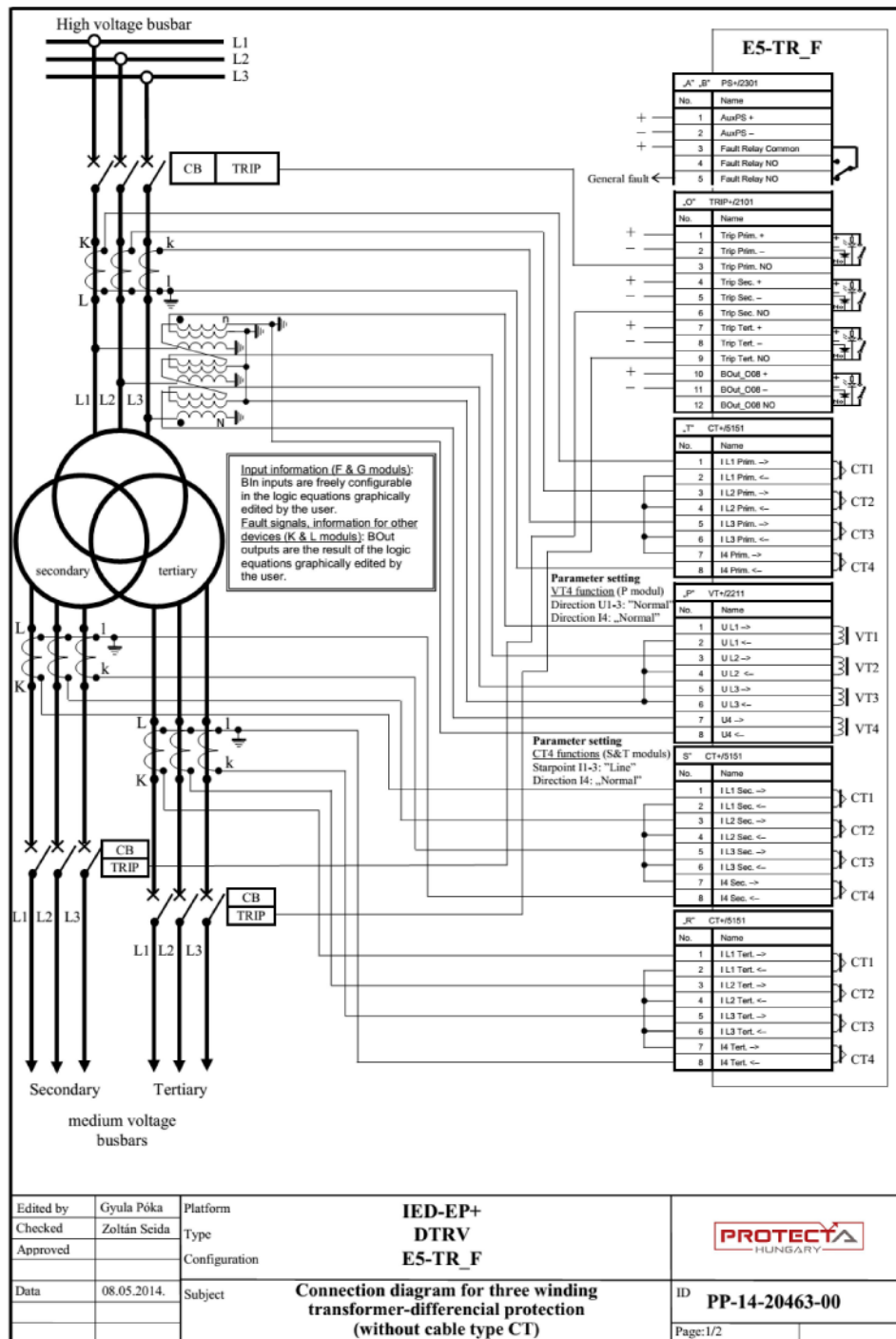


Figure 4-3 Faulty capacitances on visual inspection. The discoloration compared to the original blue color is clearly visible, bloating can be seen on 2 of them

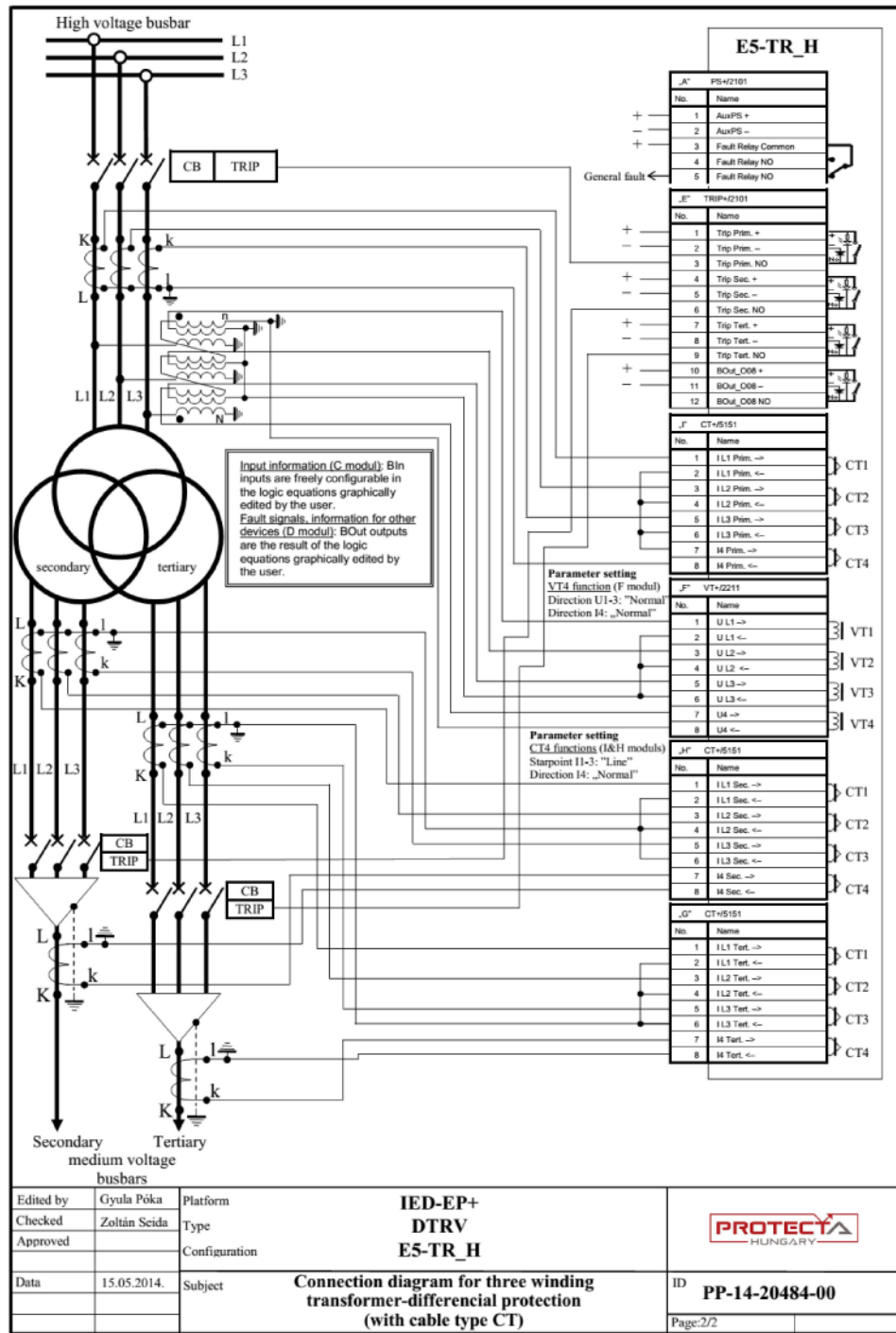
4.4. Elements and Batteries

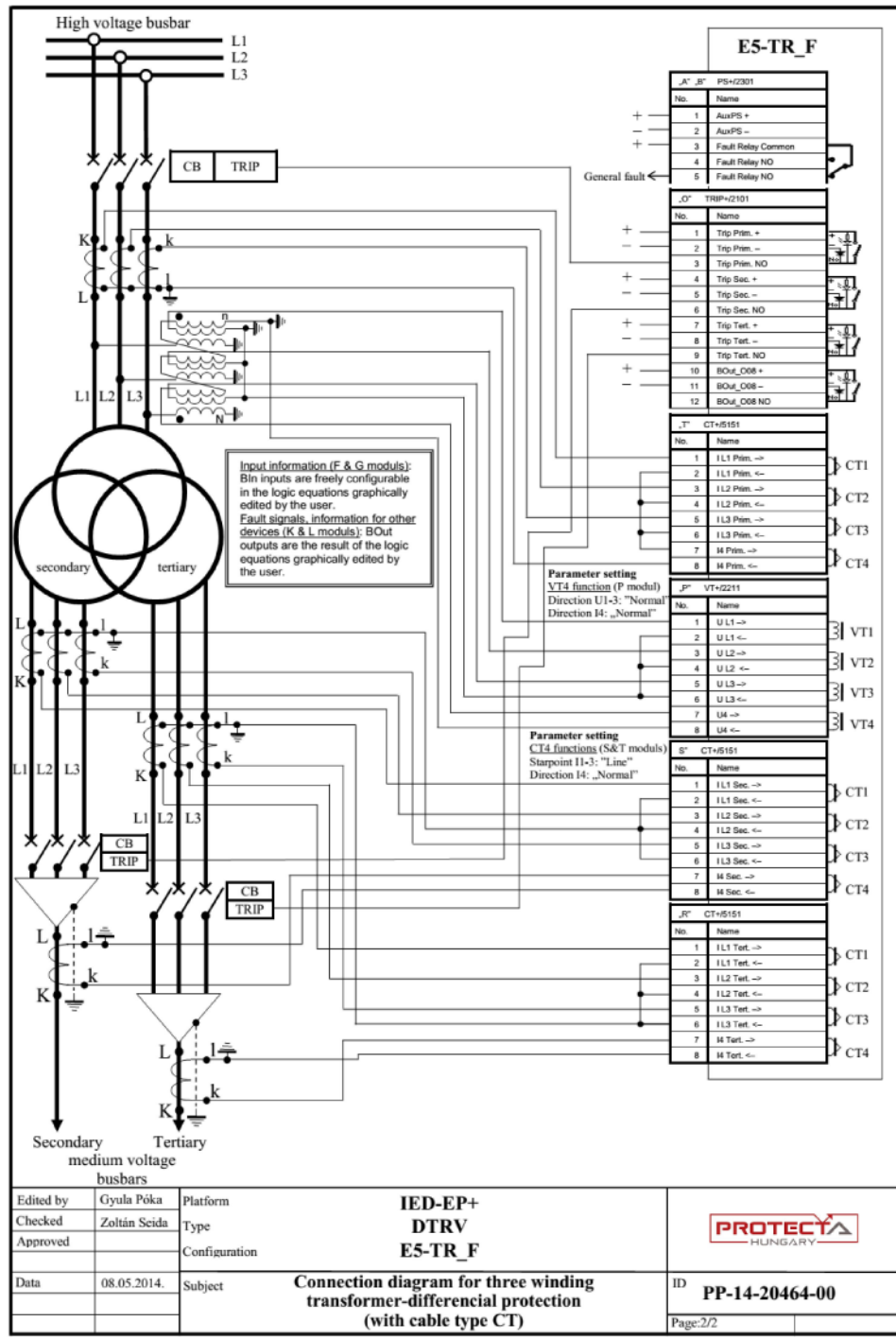
Az EuroProt+ protection family devices do not contain either a single-use battery or a rechargeable battery.

5. External connections



| | | | | |
|-----------|--------------|---------------|---------------------------------------------------------------------------------------------------------|---------------------------|
| Edited by | Gyula Póka | Platform | IED-EP+ | PROTECT HUNGARY |
| Checked | Zoltán Seida | Type | DTRV | |
| Approved | | Configuration | E5-TR_F | |
| Data | 08.05.2014. | Subject | Connection diagram for three winding transformer-differential protection (without cable type CT) | ID PP-14-20463-00 |
| | | | | Page:1/2 |





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|-----------|--------------|---------------|------------------------------------------------------------------------------------------------------|--------------------------|
| Edited by | Gyula Póka | Platform | IED-EP+ | |
| Checked | Zoltán Seida | Type | DTRV | |
| Approved | | Configuration | E5-TR_F | ID PP-14-20464-00 |
| Data | 08.05.2014. | Subject | Connection diagram for three winding transformer-differential protection (with cable type CT) | |

