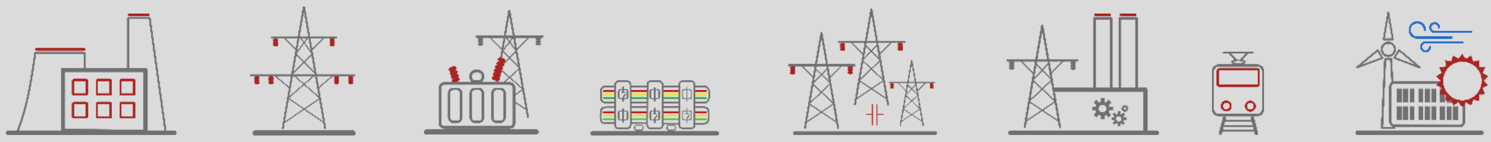

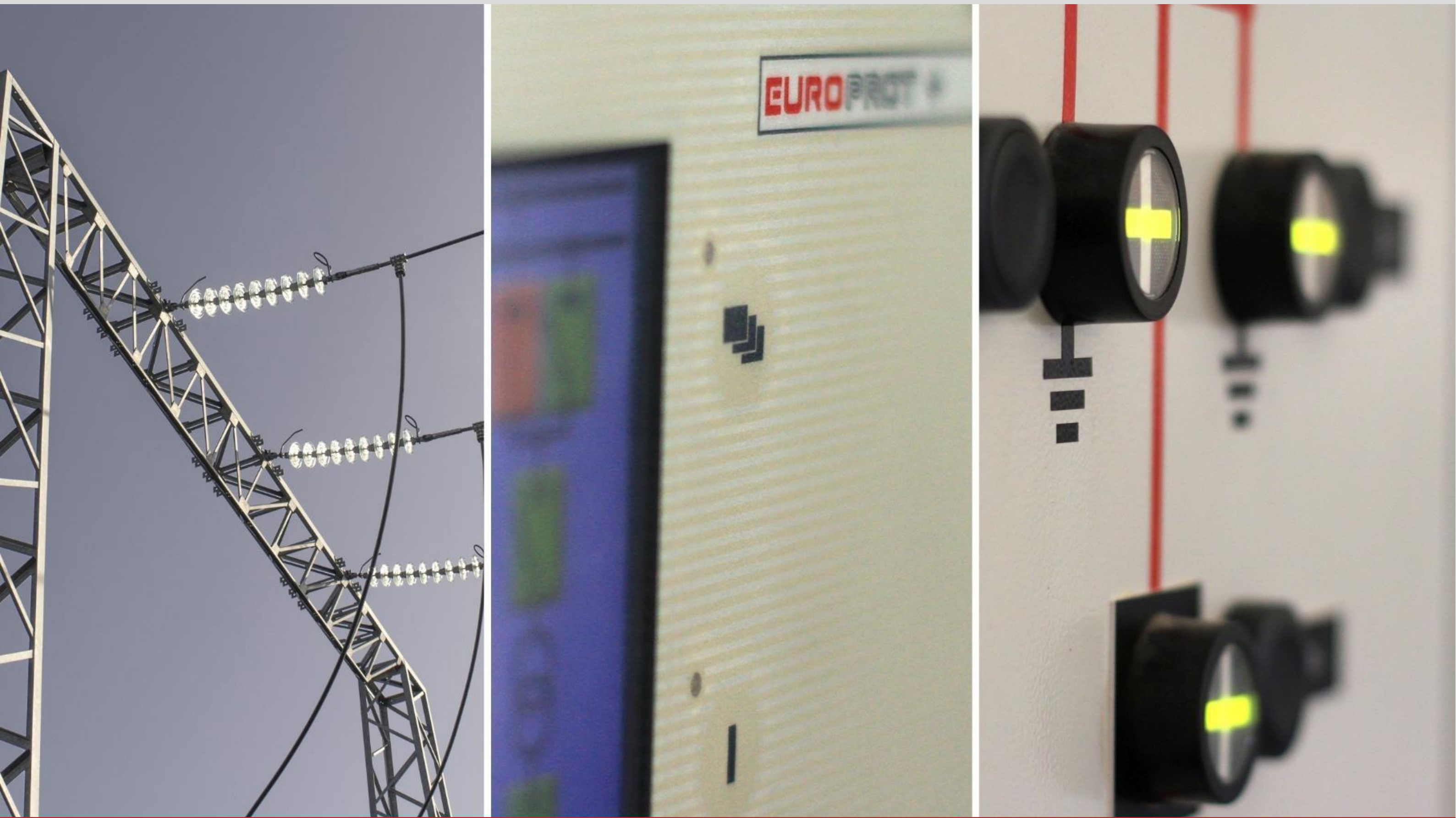

Manual

Smart Line+/S24 Series

VARIANT 1

DOCUMENT ID: VARIANT-01-23-12 VERSION: 1.2 Date: 2023/09/05

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VERSION INFORMATION

NAME	DOCUMENT ID	VERSION	DATE
S24 general specification	PP-13-20093	2.0	2021-02-19
EuroProt+ Hardware description	PP-13-19958	2.0	2023-02-10
Loss-of-load (undercurrent) protection function	VERSION 1.0	1.0	2012-03-29
Negative sequence overcurrent protection function	PP-13-20319	1.3	2022-08-09
Broken conductor protection	PP-13-22162	1.1	2020-06-29
Motor startup supervision function	PP-13-22521	2.0	2022-03-04
Line thermal protection function	VERSION 1.0	1.0	2011-10-25
Motor thermal protection function	VERSION 1.0	1.0	2011-10-25
Three-phase instantaneous overcurrent protection function	PP-13-22489	2.0	2022-03-04
Residual instantaneous overcurrent protection function	PP-13-22488	2.1	2022-11-28
Breaker failure protection functions	PP-13- 22253	2.1	2022-10-03
Three-phase time overcurrent protection function	PP-13-21408	2.4	2022-08-22
Residual overcurrent protection function	PP-13-20320	1.3	2022-08-22
Inrush current detection function	PP-13-22394	2.0	2021-08-10
Automatic reclosing function for high voltage networks	PP-13-21370	1.2	2017-02-08
Capacitor unbalance protection for blocks in double star connection function	VERSION 1.1	1.1	2012-12-03
Capacitor unbalance protection for blocks in bridge connection function	VERSION 1.1	1.1	2015-12-17
Capacitor overvoltage protection function	PP-13-21727	1.1	2018-05-30
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
Disconnector 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
Current unbalance function	PP-13-22163	2.0	2020-06-25
Current input function block setting guide	VERSION 1.1	1.0	2015-01-29
Line measurement Frequency measurement Voltage measurement Current measurement	PP-13-21168	2.3	2021-09-02
Average and maximum measurement function	PP-11-20109	1.0	2013-9-27
Disturbance recorder	PP-13-20368	3.0	2017-06-02
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
AIC current input function	PP-13-21392	1.0	2017-01-03
Automatic reclosing function for high voltage networks setting guide	PP-13-21370	1.2	2017-02-08
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

Table of Contents

1 Introduction

The IED EP+ S24 series is member of the ***EuroProt+*** product line, made by Protecta Co. Ltd. The ***EuroProt+*** type 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. The IED EP+ S24 Smart Line series is a special selection of the EuroProt+ products, bearing in mind the cost effective realization. All modules, all FW and SW are identical to the general EuroProt+ series therefore all test reports and certificates issued for EuroProt+ apply to the S24 series.

The IED provides main protection for overhead lines and cable feeders in distribution networks. EP+ S24 is a dedicated transformer protection and control IED (intelligent electronic device) for power transformers, unit and step-up transformers including power generator-transformer blocks in utility and industry power distribution systems. EP+ S24 is also used as back-up protection for motors, transformers and generators in utility and industry applications, where an independent and redundant protection system is required. Depending on the chosen standard configuration, the IED is adapted for the protection of medium voltage feeders in isolated neutral, resistance earthed, compensated and solidly earthed networks. Once the standard configuration IED has been given the application-specific settings, it can directly be put into service. Application area also covers protection functions for a large variety of applications, e.g. frequency and voltage based protection, motor protection and thermal overload protection function.

The IEDs support a range of communication protocols including the IEC 61850 substation automation standard with horizontal GOOSE communication, IEC 60870-5-101, IEC 60870-5-103 and Modbus® RTU. The IED-EP+ S24 is available in six predefined standard configurations to suit the most common feeder protection and control applications.

The relay is provided with a built-in digital disturbance recorder for up to eight analog signal channels and 32 digital signal channels. The recordings are stored in a non-volatile memory from which data can be uploaded for subsequent fault analysis.

To provide network control and monitoring systems with feeder level event logs, the relay incorporates a non-volatile memory with capacity of storing 1000 event codes including time stamps. The non-volatile memory retains its data also in case the relay temporarily loses its auxiliary supply. The event log facilitates detailed pre- and post-fault analyses of feeder faults and distribution disturbances.

The trip circuit supervision continuously monitors the availability and operability of the trip circuit. It provides open circuit monitoring both when the circuit breaker is in its closed and in its open position.

The relay's built-in self-supervision system continuously monitors the state of the relay hardware and the operation of the relay software. Any fault or malfunction detected will be used for alerting the operator. When a permanent relay fault is detected the protection functions of the relay will be completely blocked to prevent any incorrect relay operation.

1.1. Application

The IED-EP+ S24 protection device is a member of the EuroProt+ product line, made by Protecta Co. Ltd. The EuroProt+ type complex protection in respect of hardware and software is a modular device with defined variants. The modules are assembled and configured according to the requirements, and then the software determines the functions.

As of now, the IED-EP+ S24 is available in eight predefined standard configurations to suit the most common feeder protection application.

EP+S24:

- **Variant 0** serves as a simple bay control unit.
- **Variant 1** is mainly used main or backup protection as overcurrent and motor protection.
- **Variant 2** has additional provide voltage protection above **Variant 1**. Especially for those applications where small generators are connected to the network / smart grids. Additionally, it can be extended with restricted earth fault protection function for simple protection of small transformer.
- **Variant 3** is used main protection for overhead lines and cable feeders in distribution networks with distance protection function.
- **Variant 4** application has already included line differential protection function for medium voltage distribution network
- **Variant 5** is dedicated transformer protection and control IED (intelligent electronic device) for power transformers, unit and step-up transformers including power generator-transformer blocks in utility and industry power distribution systems.
- **Variant 6** is dedicated for those application where is only voltage and frequency-based protection functions are required.
- **Variant 7** provides high-impedance differential protection for machines, power transformers and busbar installations as well as for other applications where high-impedance differential protection is required.

1.2. Hardware configuration

The minimum number of inputs and outputs are listed in the Table below.

Hardware configuration	Variant 1
Housing	Panel instrument enclosure (24 HP size)
Current inputs (4th channel can be sensitive)	4 (3x 1/5 A and 1x 1/5/0,2A)
Digital inputs	6*
Digital outputs	5*
Fast trip outputs	2 (4 A)
IRF contact	1

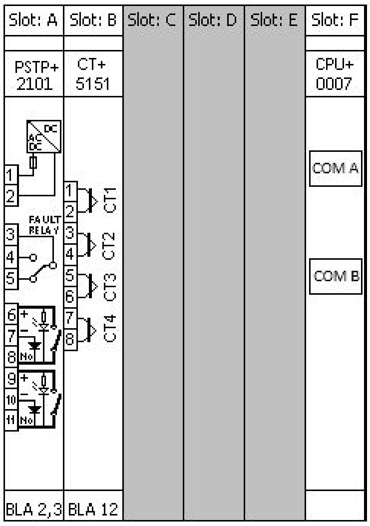
* as standard I/O card hardware configuration.

Table 3 The hardware configuration of the Variant 1 configuration

IP ratings:

- IP20 protection from rear side
- IP54 protection from front side

The module arrangement of the Variant 1 configuration is shown below.



I/O card options for Var 1:

IO card type	Slot C	Slot D	Slot E
O6R5	-	Standard	N/A
O12	-	Option	Option
O8	-	Option	Option
R8	-	Option	Option

Figure 2 Module arrangement of the Variant 1 configuration (rear view)

Communication options for Varaint 1:

Communication ports	No communication	Legacy protocols	IEC 61850	Redundant Ethernet
COM A	Standard	N/A	N/A	Option
COM B	Standard	Option	Option	N/A

1.2.1. 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
PSTP+ xx01	Power supply unit with trip contacts
O6R5+ xx01	Binary I/O module
O12+ xx01	Binary input module
O8+ xx01	Binary input module
R8+ 00	Signal relay output module
CT + 5151	Analog current input module
CPU+ xxxx	Processing and communication module

Table 4 The applied modules of the Variant 1 configuration

1.2.2. 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 *IED EP+ S24 with B&W HMI front panel* ***as standard***

Figure 4 *IED EP+S24 with true colour HMI front panel* ***as optional***

1.2.3. System design

The EuroProt+ protection device family is a scalable hardware platform to adapt to different applications. Data exchange is performed via a 16-bit high-speed digital non-multiplexed parallel bus with the help of a backplane module.

Each module is identified by its location and there is no difference between module slots in terms of functionality. The only restriction is the position of the CPU module because it is limited to the “CPU” position. The built-in self-supervisory function minimizes the risk of device malfunctions.

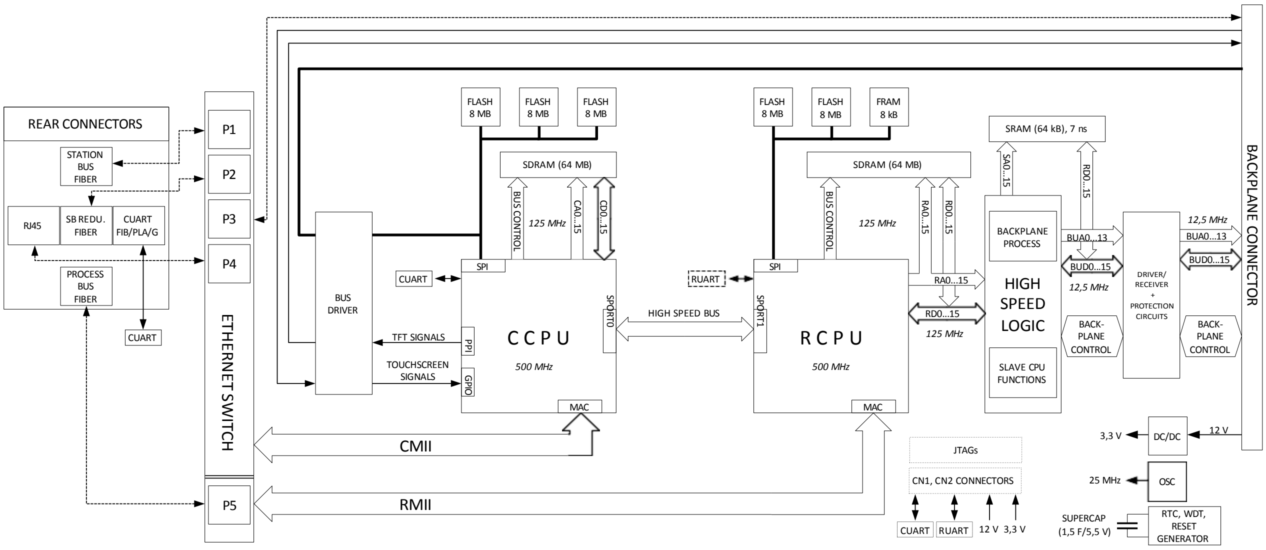


Figure 1-1 CPU block diagram

The backplane board itself is a passive board but it provides a 16-bit bus, power supply distribution, a two-wire interface (TWI) supporting module inventory management and module identification. It is designed to meet the requirements for high-speed digital buses and to comply with electromagnetic emission standards.

1.2.4. CPU and COM module

1.2.4.1. 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 firmware 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.

1.2.4.1.1. Fast start-up

After power-up the RDSP processor starts up with the previously saved configuration and parameters. Generally, the power-up procedure for the RDSP and relay functions takes only a few seconds. That is to say, it is ready to trip within this time. CDSP's start-up procedure is longer because its operating system needs time to build its file system, initializing user applications such as HMI functions and the IEC61850 software stack.

1.2.4.1.2. HMI and communication tasks

- Embedded WEB-server:
  - Firmware upgrade possibility
  - Modification of user parameters
  - Events list and disturbance records
  - Password management
  - Online data measurement
  - Commands
  - Administrative tasks

- Front panel TFT display handling: the interactive menu set is available through the TFT and the touchscreen interface

- User keys: capacitive touch keys on front panel

- The built-in 5-port Ethernet switch allows EuroProt+ to connect to IP/Ethernet-based networks. The following Ethernet ports are available:
  - Station bus (100Base-FX Ethernet) SBW
  - Redundant station bus (100Base-FX Ethernet) SBR
  - Process bus (100Base-FX Ethernet)
  - EOB2 (Ethernet Over Board) or RJ-45 Ethernet user interface on front panel
  - Optional 10/100Base-T port via RJ-45 connector

- PRP/HSR seamless redundancy for Ethernet networking (100Base-FX Ethernet)

- Other communication:
  - RS422/RS485 interfaces (galvanic interface to support legacy or other serial protocols, ASIF)
  - Plastic or glass fiber interfaces to support legacy protocols, ASIF
  - Proprietary process bus communication controller on COM+ module
  - Telecommunication interfaces: G.703, IEEE C37.94

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	+

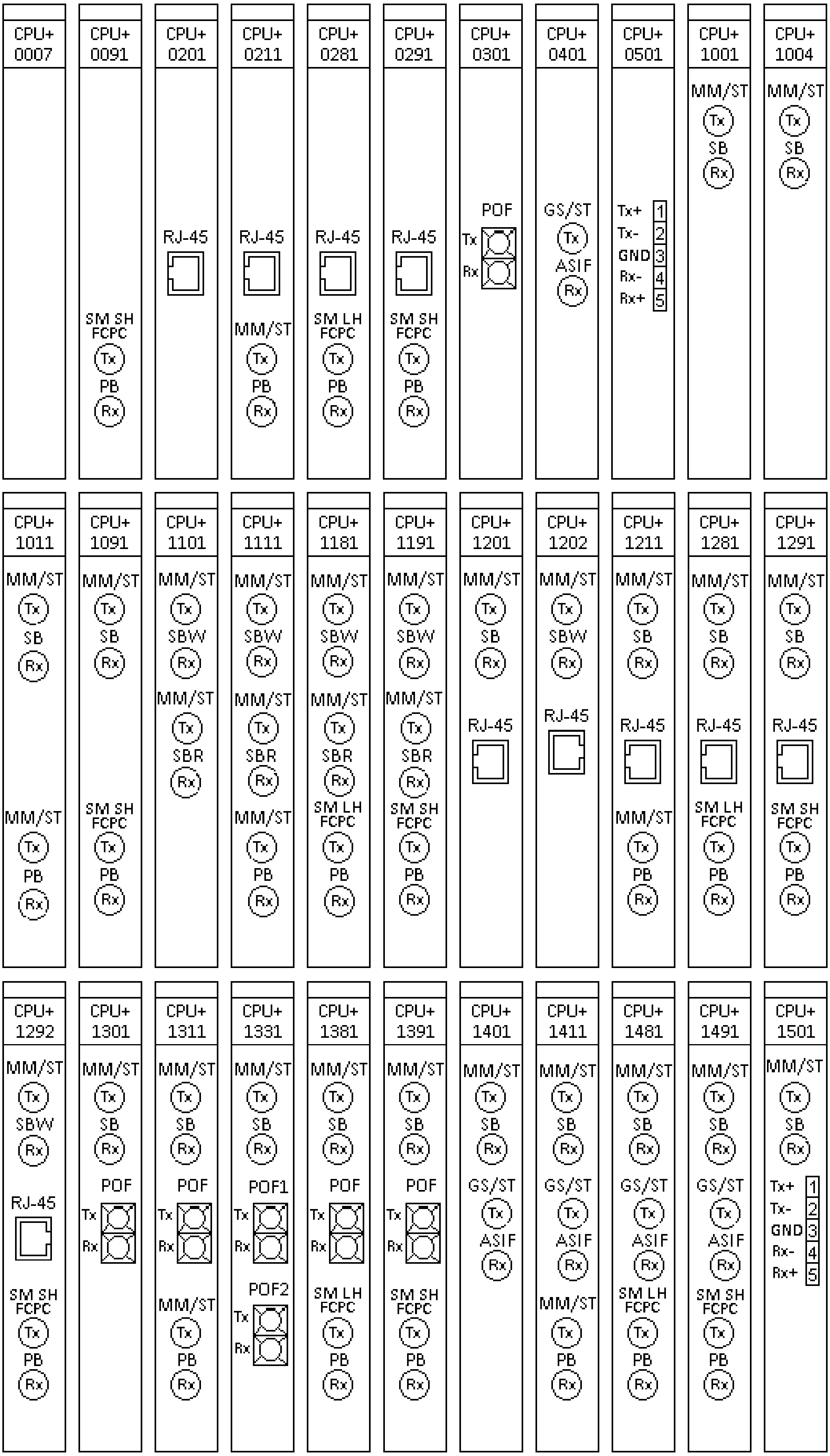
CPU VERSION	PRIMARY STATION BUS (FIBER) SBW	SECONDARY (REDUNDANT) STATION BUS SBR	LEGACY PORT/PROTOCOL	PROCESS BUS (FIBER) PB	SERVICE PORT ON FRONT PANEL EOB/ RJ45
CPU+/1581	+ MM	-	+ Galv. RS485/422	+ SM LH	+
CPU+/1611	+ MM	-	+ Galvanic sync	+ MM	+
CPU+/1681	+ MM	-	+ Galvanic sync	+ SM LH	+
CPU+/6001	+ 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


CPU+ 0007
CPU+ 0091
SM SH FCPC
Tx
PB
Rx
CPU+ 0201
RJ-45
CPU+ 0211
RJ-45
MM/ST
Tx
PB
Rx
CPU+ 0281
RJ-45
SM LH FCPC
Tx
PB
Rx
CPU+ 0291
RJ-45
SM SH FCPC
Tx
PB
Rx
CPU+ 0301
POF
Tx
Rx
CPU+ 0401
GS/ST
Tx
ASIF
Rx
CPU+ 0501
Tx+ 1
Tx- 2
GND 3
Rx- 4
Rx+ 5
CPU+ 1001
MM/ST
Tx
SB
Rx
CPU+ 1004
MM/ST
Tx
SB
Rx
CPU+ 1011
MM/ST
Tx
SB
Rx
MM/ST
Tx
PB
Rx
CPU+ 1091
MM/ST
Tx
SB
Rx
SM SH FCPC
Tx
PB
Rx
CPU+ 1101
MM/ST
Tx
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MM/ST
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SBR
Rx
CPU+ 1111
MM/ST
Tx
SBW
Rx
MM/ST
Tx
SBR
Rx
MM/ST
Tx
PB
Rx
CPU+ 1181
MM/ST
Tx
SBW
Rx
MM/ST
Tx
SBR
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SM LH FCPC
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CPU+ 1191
MM/ST
Tx
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Tx
SBR
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SM SH FCPC
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Rx
CPU+ 1201
MM/ST
Tx
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Rx
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Tx
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Rx
RJ-45
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Tx
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RJ-45
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CPU+ 1301
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POF
Tx
Rx
CPU+ 1311
MM/ST
Tx
SB
Rx
POF
Tx
Rx
MM/ST
Tx
PB
Rx
CPU+ 1331
MM/ST
Tx
SB
Rx
POF1
Tx
Rx
POF2
Tx
Rx
CPU+ 1381
MM/ST
Tx
SB
Rx
POF
Tx
Rx
SM LH FCPC
Tx
PB
Rx
CPU+ 1391
MM/ST
Tx
SB
Rx
POF
Tx
Rx
SM SH FCPC
Tx
PB
Rx
CPU+ 1401
MM/ST
Tx
SB
Rx
GS/ST
Tx
ASIF
Rx
CPU+ 1411
MM/ST
Tx
SB
Rx
GS/ST
Tx
ASIF
Rx
MM/ST
Tx
PB
Rx
CPU+ 1481
MM/ST
Tx
SB
Rx
GS/ST
Tx
ASIF
Rx
SM LH FCPC
Tx
PB
Rx
CPU+ 1491
MM/ST
Tx
SB
Rx
GS/ST
Tx
ASIF
Rx
SM SH FCPC
Tx
PB
Rx
CPU+ 1501
MM/ST
Tx
SB
Rx
Tx+ 1
Tx- 2
GND 3
Rx- 4
Rx+ 5

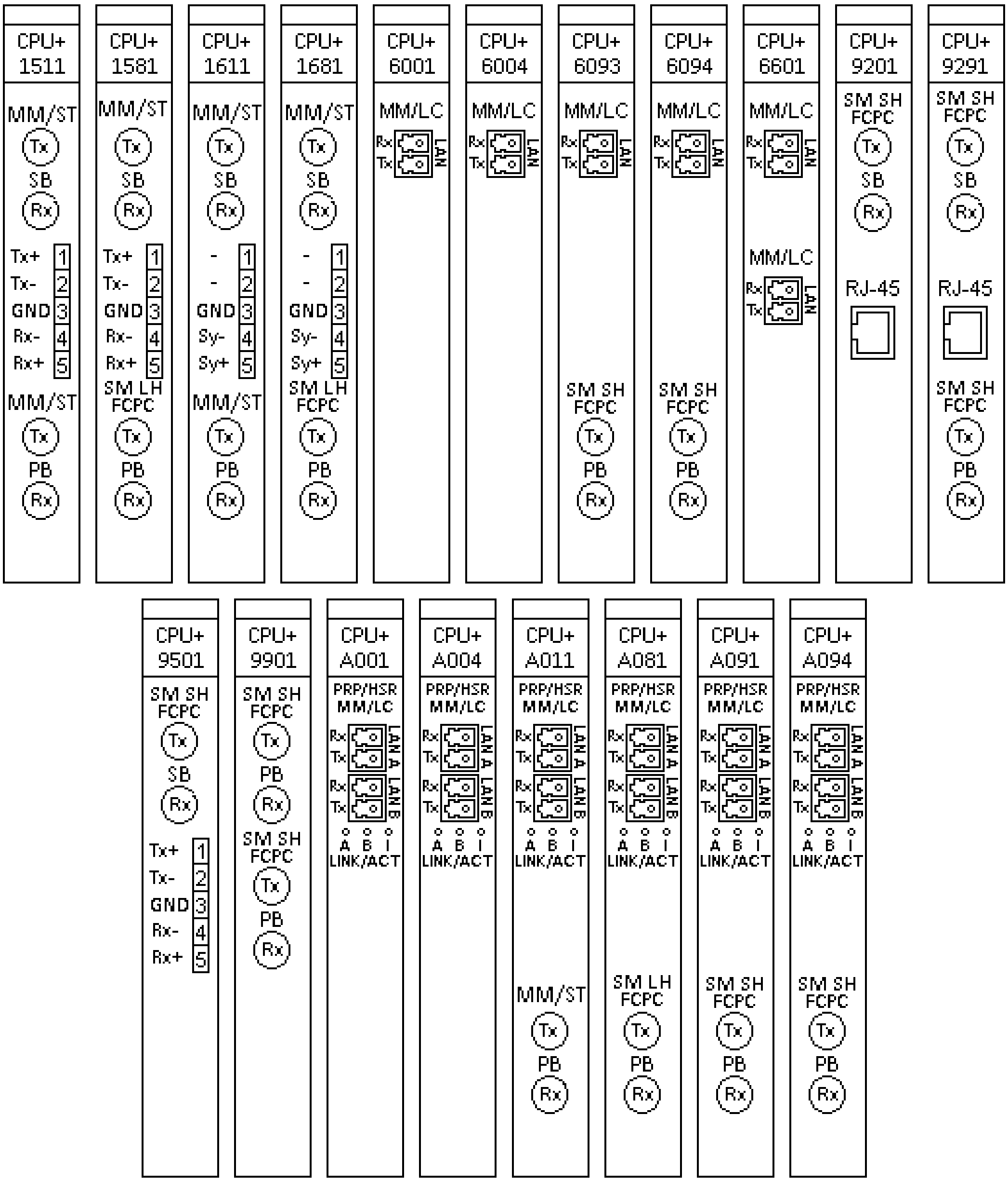


Figure 2-1 CPU versions

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)

1.2.4.2. 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

1.2.4.2.1. 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*

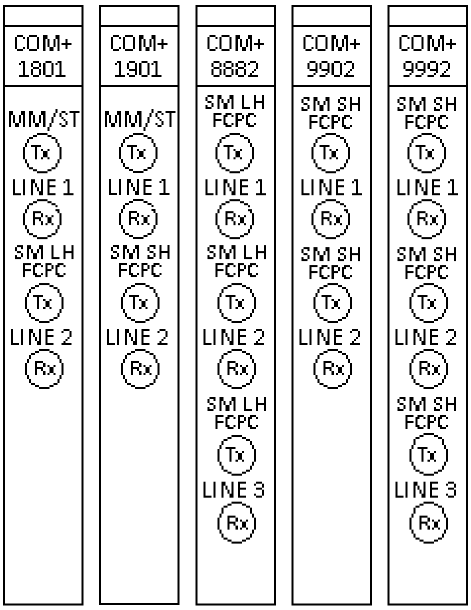


Figure 2-2 COM modules for binary signal transmission

1.2.4.2.2. COM modules for line differential communication

MODULE TYPE	INTERFACE TYPE	NUMBER OF INTERFACES	UNIT WIDTH	APPLICATION
COM+/0091	G703.1 (64 kbit/s)	1	4 HP	Line differential protection via telecom network
COM+/1101	MM/ST 1300 nm, 50/62.5/125 µm connector, 100Base-FX Ethernet	2	4 HP	3 terminals / redundant line differential protection up to 2 km
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	3 terminals / redundant line differential protection 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	3 terminals / redundant line differential protection up to 2 km and up to 50 km
COM+/8801	SM/FC 1550 nm, 9/125 µm connector, 100Base-FX Ethernet	2	4 HP	3 terminals / redundant line differential protection up to 120 km
COM+/9901	SM/FC 1550 nm, 9/125 µm connector, 100Base-FX Ethernet	2	4 HP	3 terminals / redundant line differential protection 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*

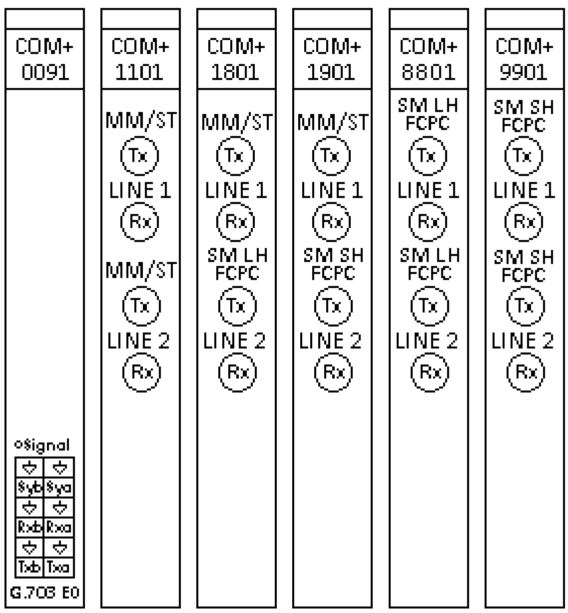


Figure 2-3 COM modules for line differential applications

1.2.4.2.3. 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

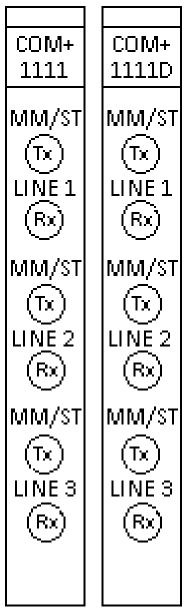


Figure 2-4 COM modules for busbar differential protections

1.2.4.2.4. 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!**

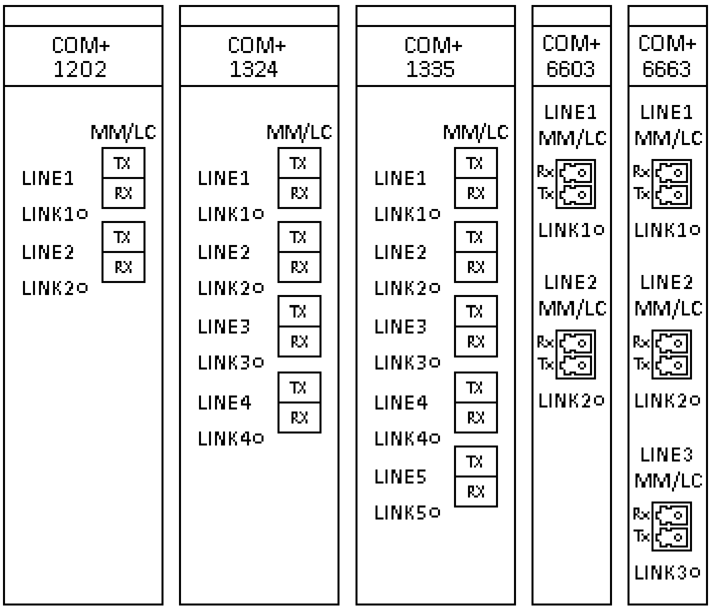


Figure 2-5 COM modules for RIO servers

1.2.4.3. Communication interface characteristics

1.2.4.3.1. Ethernet multi-mode transmitter and receiver

1.2.4.3.1.1. 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

1.2.4.3.1.2. 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 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	5	100	µs

1.2.4.3.2. Ethernet single mode transmitter and receiver

1.2.4.3.2.1. 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 = 2.5×10^{-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

1.2.4.3.2.2. 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 = 2.5×10^{-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

1.2.4.3.3. ASIF-O transmitter and receiver

1.2.4.3.3.1. 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.

1.2.4.3.3.2. 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 (λ_P = 820 nm)	P_{RH}	-25.4	-	-9.2	dBm peak
PEAK OPTICAL INPUT POWER LOGIC LEVEL LOW	P_{RL}	-	-	-40	dBm peak

1.2.4.3.4. 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 Ω, RS422)	V_{OD2}	2	-	3.6	V
DIFFERENTIAL OUTPUT VOLTAGE (LOADED, R_L = 54 Ω, 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	-	-	kΩ

1.2.4.3.5. 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 × 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

1.2.4.3.5.1. 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.

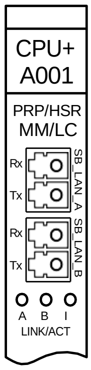


Figure 2-6 PRP/HSR connectors on a CPU+A001 module

1.2.4.3.6. 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.

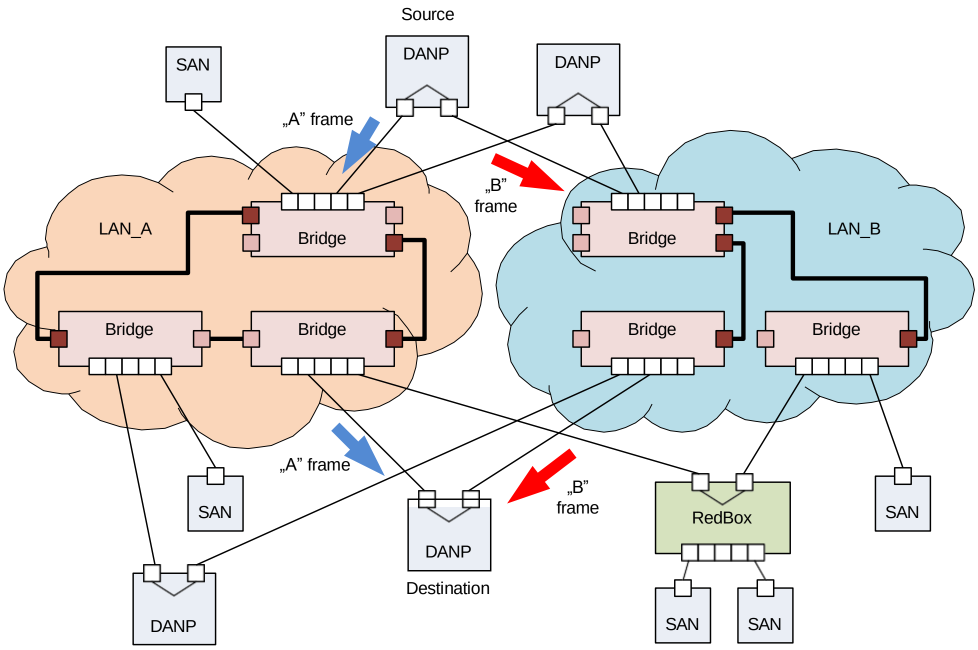


Figure 2-7 Example of a PRP redundant network

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.

1.2.4.3.6.1. 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.

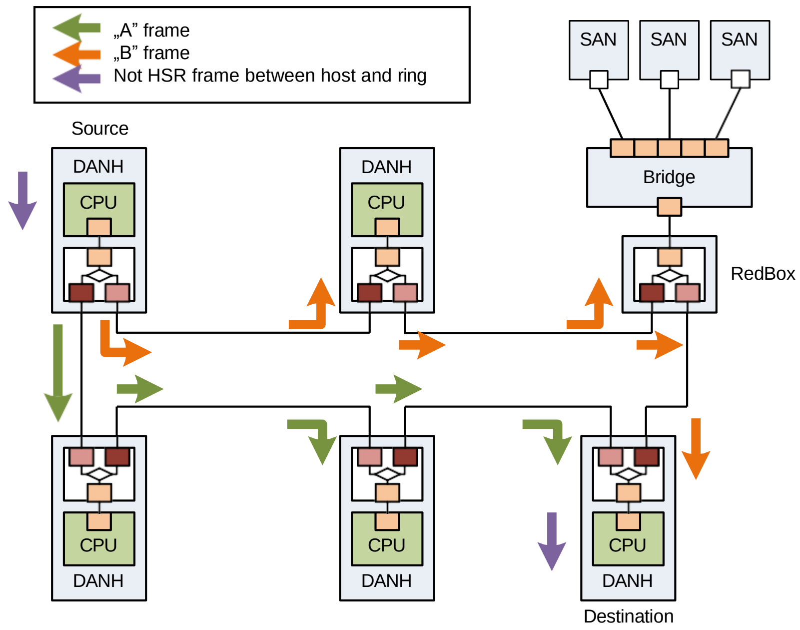


Figure 2-8 Example of an HSR redundant network

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.

1.2.5. 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.

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

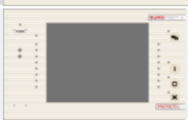
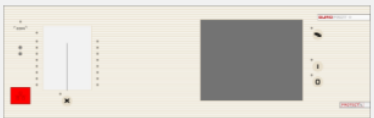
Figure 3-1 Rack configuration illustrations

1.2.6. Human-Machine Interface (HMI) module

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

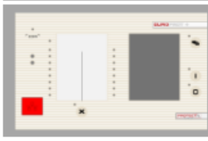
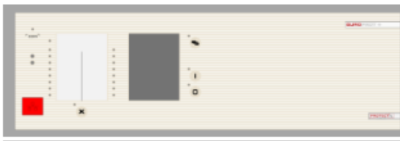
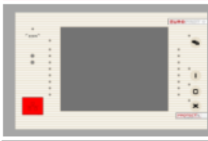
- Hardware: the HMI module, which is the front panel of the device, this is described here
- Software: the embedded web server and the menu system that is accessible through the HMI module. The web server is accessible via station bus, EOB interface or RJ-45 Ethernet connector. This is described in detail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

1.2.6.1. 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	

1.2.6.2. 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

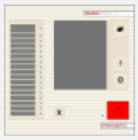
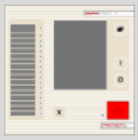
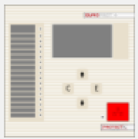
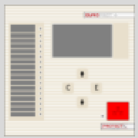
MODULE TYPE	DISPLAY	SERVICE PORT	RACK SIZE	RACK DEPTH	ILLUSTRATION
HMIT+/3505	3,5" TFT	EOB	42 HP	Reduced	
			84 HP		
HMIT+/3506	3,5" TFT	RJ-45	42 HP	Reduced	
			84 HP		
HMIT+/5706	5,7" TFT	RJ-45	84 HP	Reduced	

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	

1.2.6.3. 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	Nornal	
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	

1.2.6.4. 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 *Only for 42 HP and 84 HP devices.*
EOB CONNECTOR	**E**thernet **O**ver **B**oard: 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. **EOB1:** Supporting 10Base-T Ethernet connection. Passive device with one RJ45 type connector. Obsolete module. **EOB2:** Supporting 10/100Base-Tx Ethernet connection. An active device that has a USB port in addition to the RJ45 connector for powering up.
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.)

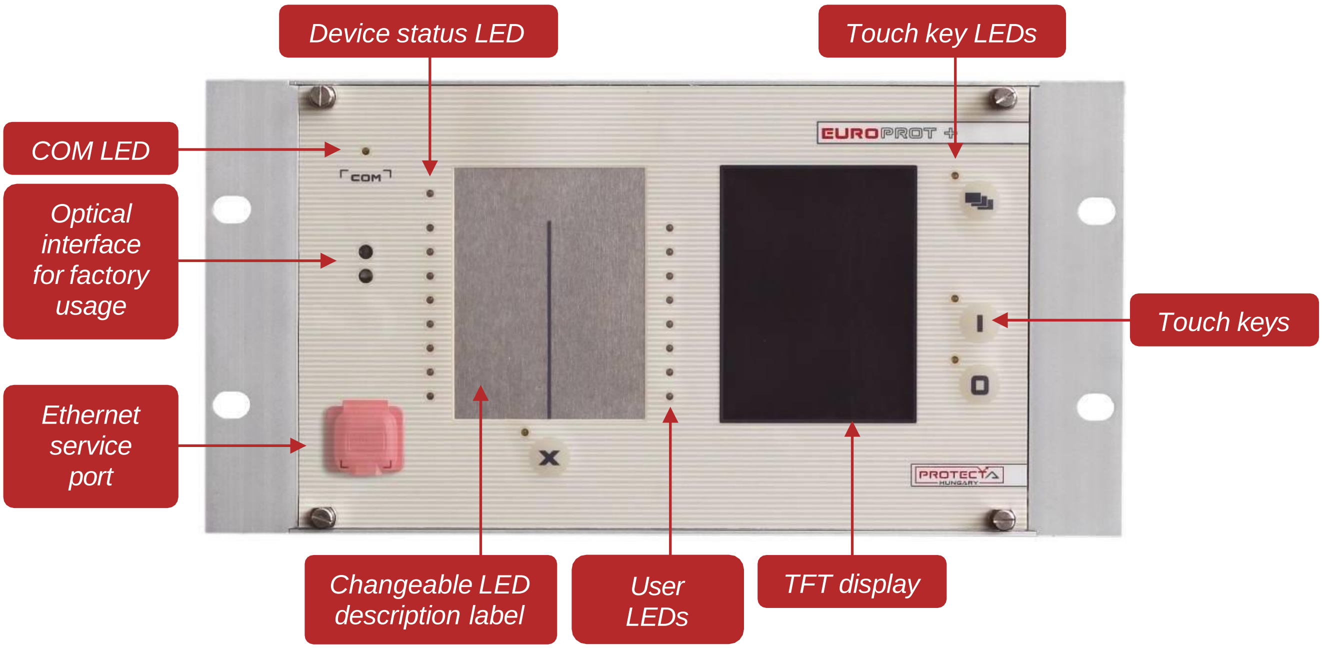


Figure 4–3 HMI signals and controls

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)

1.2.7. 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 (± 10 %)	8 × I_N		50 × I_N		12.5 × I_N		2 × 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	Default: STVS Options: -		Default: STVS Options: -		Default: STVS Options: -		Default: STVS Options: 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 × 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 (± 10 %)	2 × I_N		2 × I_N		50 × I_N		12.5 × 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	Default: STVS Options: -		Default: STVS Options: -		Default: STVS Options: -			
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 (± 10 %)	50 × I_N		50 × I_N		50 × I_N		50 × 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	Default: STVS Options: -				Default: STVS Options: 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 (± 10 %)	50 × I_N		50 × 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	Default: STVS Options: R		Default: STVS Options: -		Default: STVS Options: R		Default: STVS Options: R	
Recommended application	• 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*

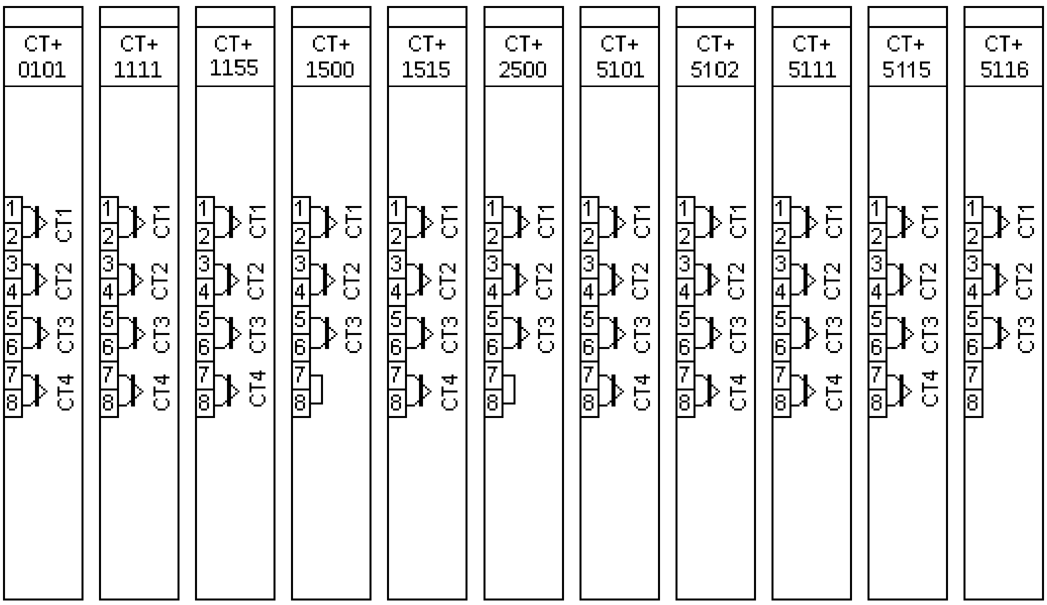
Module type	CT+/5153					CT+/5154*				
Channel number	1 – 3		4			1 – 3		4		
Selectable rated current, I_N [A]	1	5	1	0.2	0.2 sens.	1	5	5	1	0.2
Max. measured current (± 10 %)	50 × I_N				10 × I_N	50 × I_N				10 × I_N
Power consumption at rated current [VA]	0.06	1.3	0.6	0.004	0.0004	0.06	1.3	1.3	0.06	0.004
Thermal withstand [A]										
continuously	20		7			20				
10 s	175		50			175				
1 s	500		150			500				
10 ms	1200		330			1200				
Connector type	Default: STVS Options: R, T**					Default: STVS Options: 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 (± 10 %)	50 × I_N				10 × I_N	25 × 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*



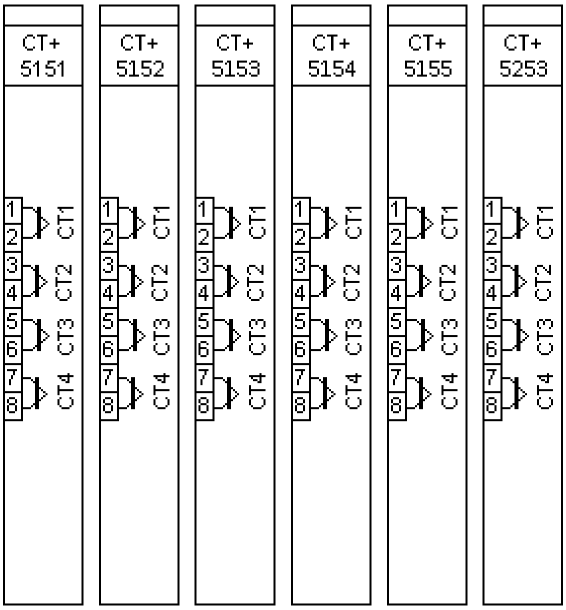


Figure 5-1 CT modules

1.2.8. 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	**Type 100:** $\frac{100}{\sqrt{3}}$, 100 V **Type 200:** $\frac{200}{\sqrt{3}}$, 200 V	**Type 100:** $\frac{100}{\sqrt{3}}$, 100 V **Type 200:** $\frac{200}{\sqrt{3}}$, 200 V	**Type 100:** $\frac{100}{\sqrt{3}}$, 100 V **Type 200:** $\frac{200}{\sqrt{3}}$, 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 (± 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	**ch. 1-3:** 0.61 VA at 200 V 0.2 VA at 100 V **ch. 4:** 50 mVA at 100 V
CONNECTOR TYPE	Default: BLA Options: F, T, R	Default: BLA Options: -	Default: BLA Options: -
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 4th 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 (± 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	Default: BLA Options: T	Default: BLA Options: -
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*

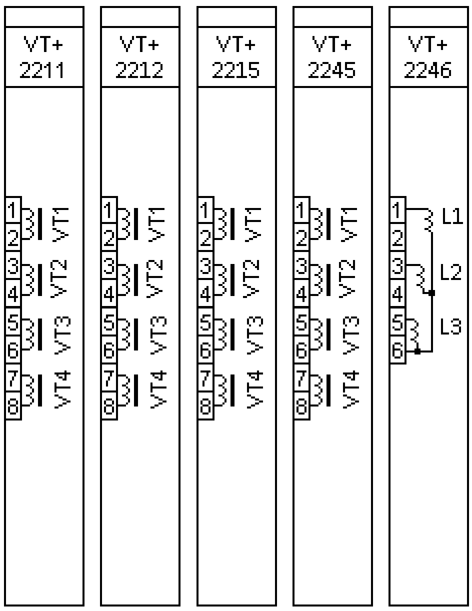


Figure 6-1 VT modules

1.2.9. 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	Default: BLA Options: T	Default: BLA Options: T	Default: BLA Options: T	Default: BLA Options: 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	Default: BLA Options: T	Default: BLA Options: F, T	Default: BLA Options: F, T	Default: BLA Options: 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	Default: BLA Options: -	Default: BLA Options: 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	Default: BL 3.5 Options: -	Default: BL 3.5 Options: -	Default: BL 3.5 Options: -	Default: BL 3.5 Options: -

***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.

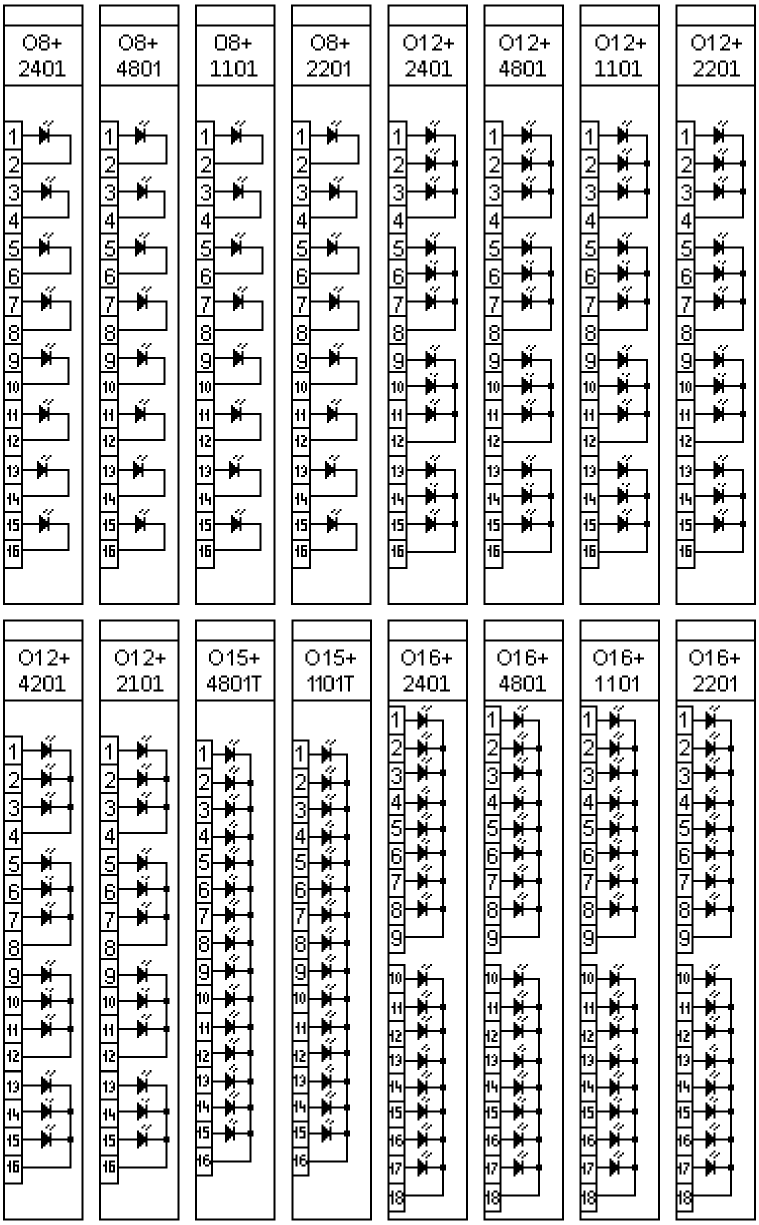


Figure 7-1 Binary input modules

1.2.10. 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	Default: BLA Options: F	Default: BLA Options: F, T	Default: BLA Options: T	Default: BLA Options: 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 × 3 common	4 × 3 common
CONNECTOR TYPE	Default: BLA Options: -	Default: BLA Options: F, T	Default: BLA Options: F, T

MODULE TYPE	R16+/0000	R16+/8000	R16+/8080
RATED VOLTAGE	250 V AC/DC	250 V AC/DC	250 V AC/DC
CONTINUOUS CARRY	8 A	8 A	8 A
CONTACT VERSIONS	16 NO	CH16 NC others NO	CH16 and CH8 NC others NO
GROUP ISOLATION	2 × 8 common	2 × 8 common	2 × 8 common
CONNECTOR TYPE	Default: BLA Options: -	Default: BLA Options: -	Default: BLA Options: -

MODULE TYPE	R4S+/01*	R4S+/16*	R1T+/0001***
RATED VOLTAGE	250 V AC/DC	250 V AC/DC	320 V AC/DC
CONTINUOUS CARRY	8 A 120 mA**	120 mA	32 A
CONTACT VERSIONS	4 CO (1 SSR, 3 normal)	4 CO (4 SSR)	1 NO
GROUP ISOLATION	4 independent	4 independent	1 independent
CONNECTOR TYPE	Default: BLA Options: -	Default: BLA Options: -	Default: BLA Options: -

*Modules with **solid-state relays (SSR)**
**If the signaling is performed via the solid-state relay the continuous carry value is 120 mA.
***Thyristor module.** Can be used only unipolarly. *For further information see our Product availability chapter.*

Main features (according to IEC 60255-1):

- 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: 10×10^6 cycles
- Circuit closing capability: typically 10 ms, maximally 22 ms, with SSR 0.5 ms.
- Bounce time: typically 6,5 ms, maximally 10 ms, with SSR 0.5 ms.
- Minimal switching requirement: 5 V
- *The signaling is also performed via a solid-state relay (SSR) channel on R4S+01 and R4S+16 module*

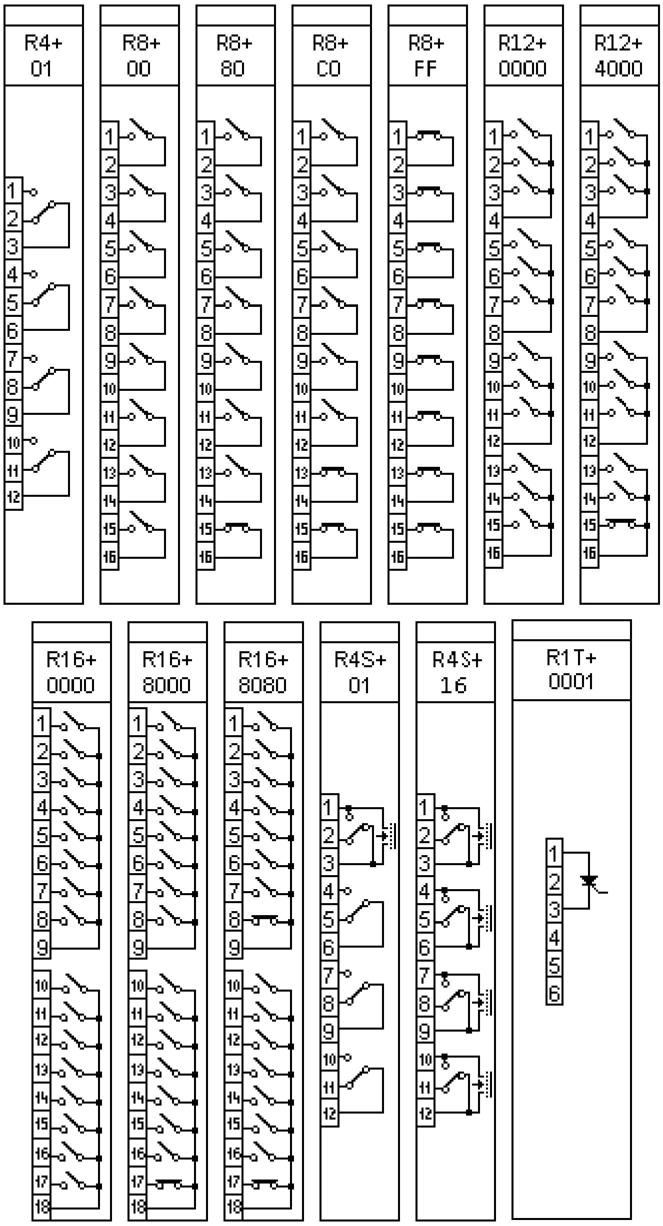


Figure 8-1 Signaling modules

1.2.11. Tripping module

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

<u>*Connector types:*</u>

- *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

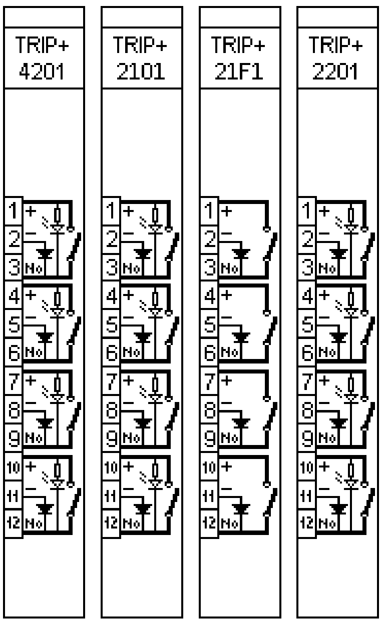


Figure 9-1 Tripping modules

1.2.11.1. 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!**

1.2.11.1.1. 3-wire TRIP+ wiring methods

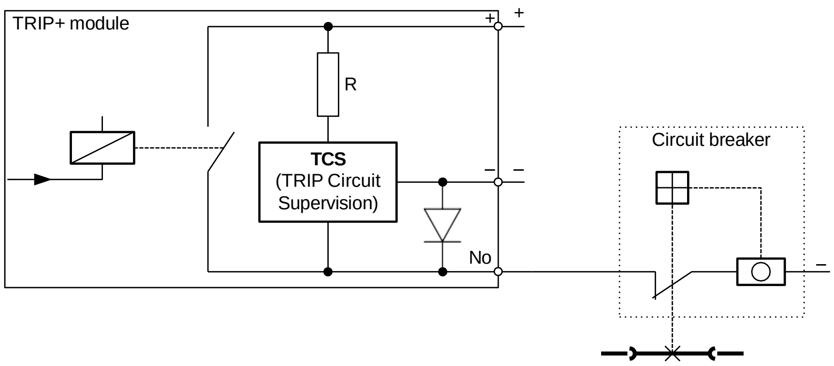


Figure 9-2 3-wire TRIP+ wiring

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

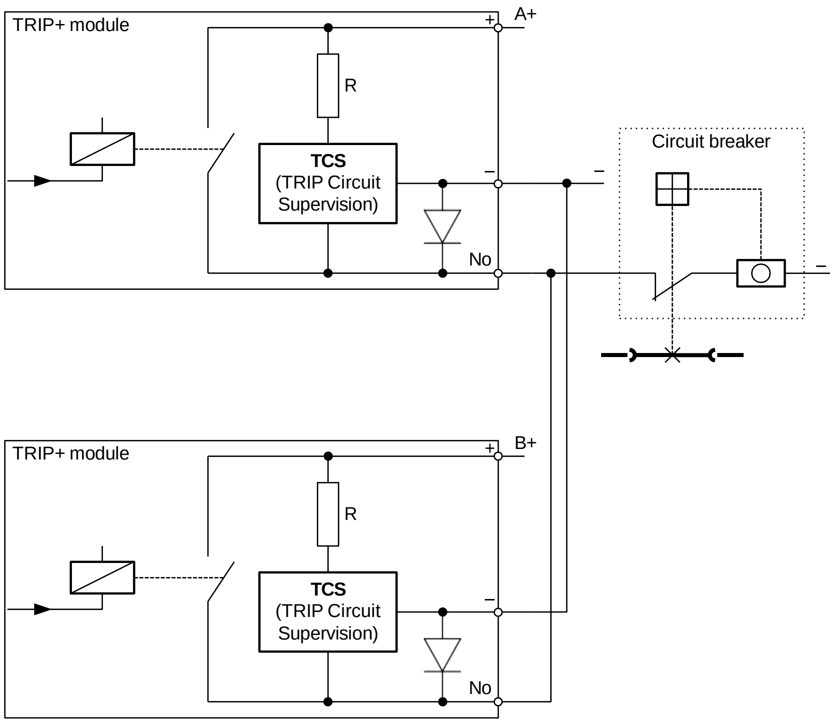


Figure 9-3 3-wire TRIP+ wiring using parallel connected TRIP+ modules

1.2.11.1.2. 2-wire TRIP+ wiring methods

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

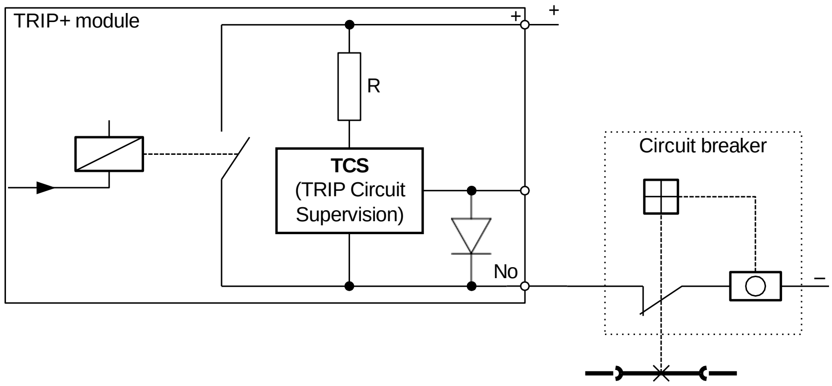


Figure 9-4 2-wire TRIP+ wiring

It is possible to use parallel connected TRIP+ modules.

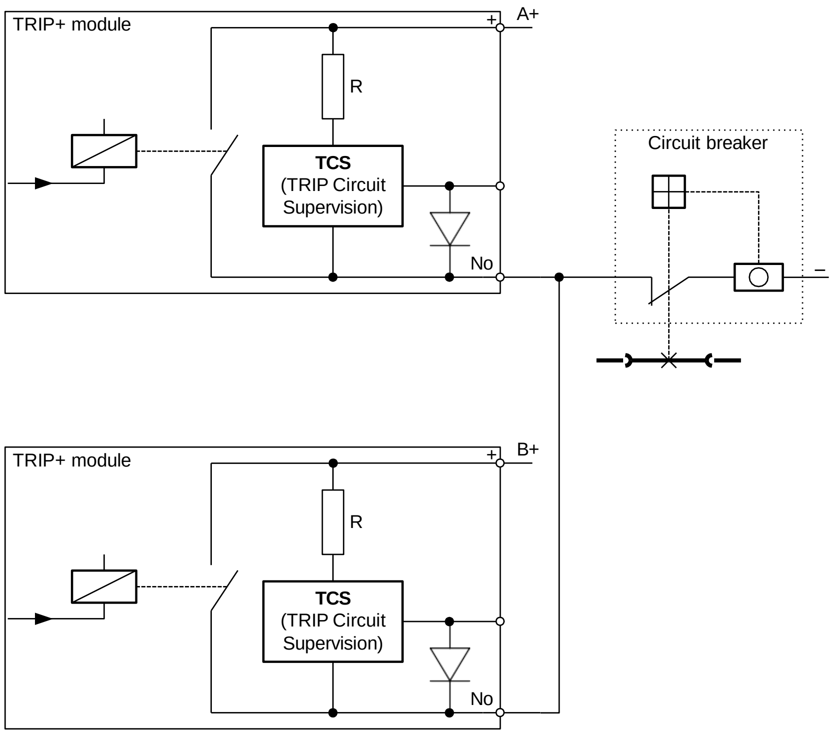


Figure 9-5 2-wire TRIP+ wiring using parallel connected TRIP+ modules

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

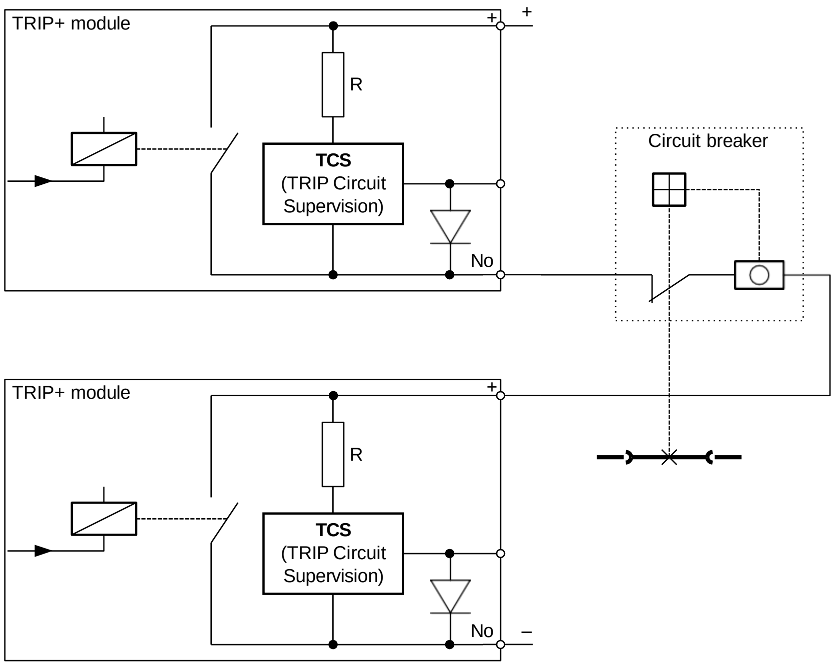


Figure 9-6 2-wire TRIP+ wiring using series connected TRIP+ modules

1.2.11.2. 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	**8.1 kΩ** @ 220 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	**4 kΩ** @ 220 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	**90 kΩ** @ 220 V DC

1.2.11.3. Relay output modules of the EuroProt+ system

1.2.11.3.1. 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

1.2.11.3.2. 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.

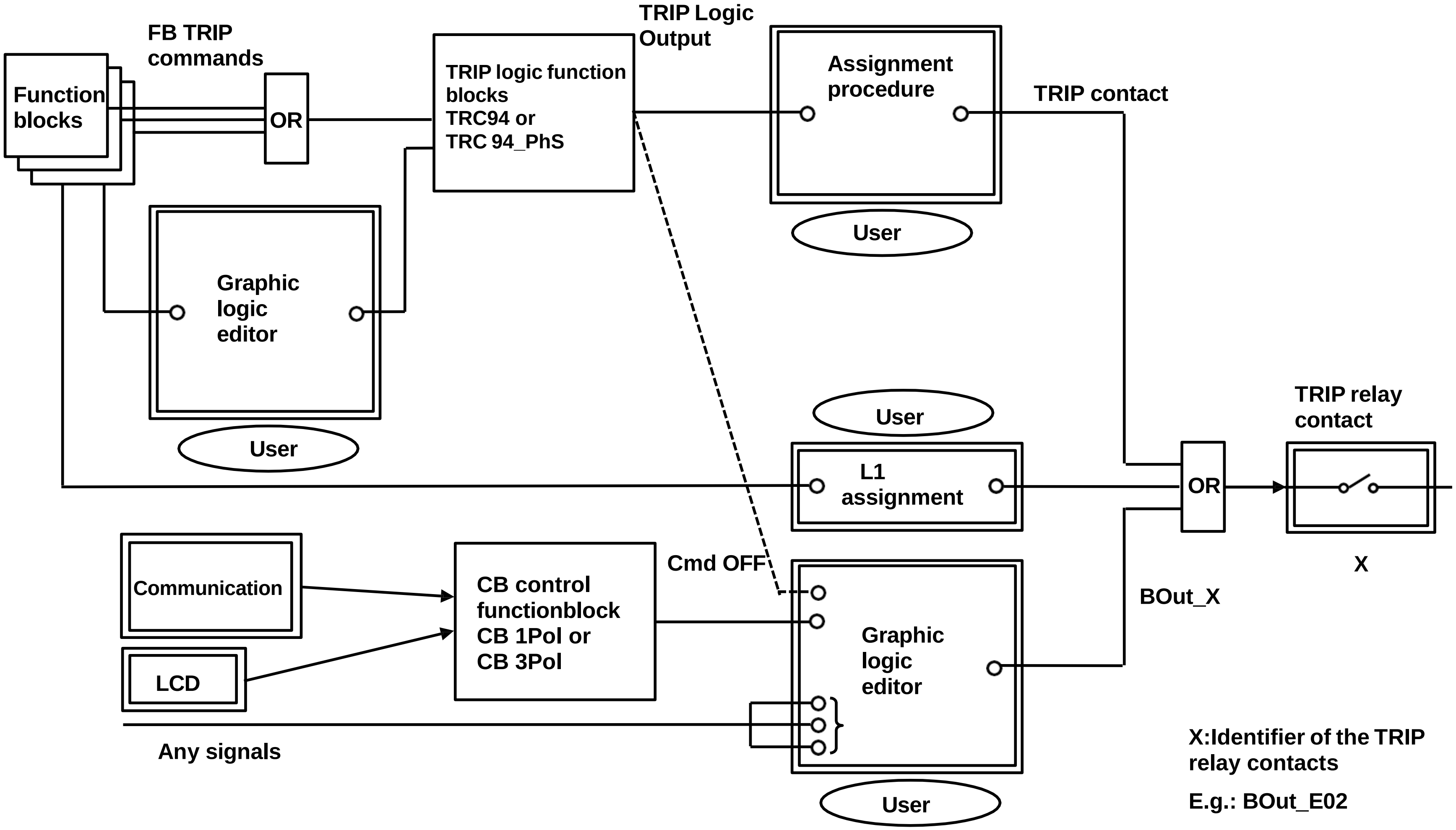


Figure 1-1 Principle of TRIP command processing

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

1.2.11.3.3.1. 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.

1.2.11.3.3.2. 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

1.2.11.3.3.2.1. 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.

1.2.11.3.3.2.2. 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!

1.2.11.3.3.3. 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).

1.2.11.3.3.4. 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*.

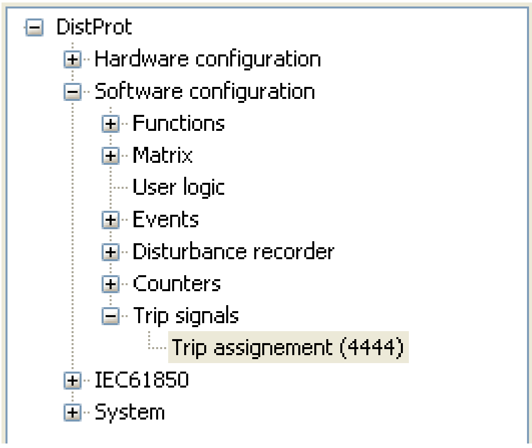


Figure 2-1 Menu item for TRIP command assignment

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.

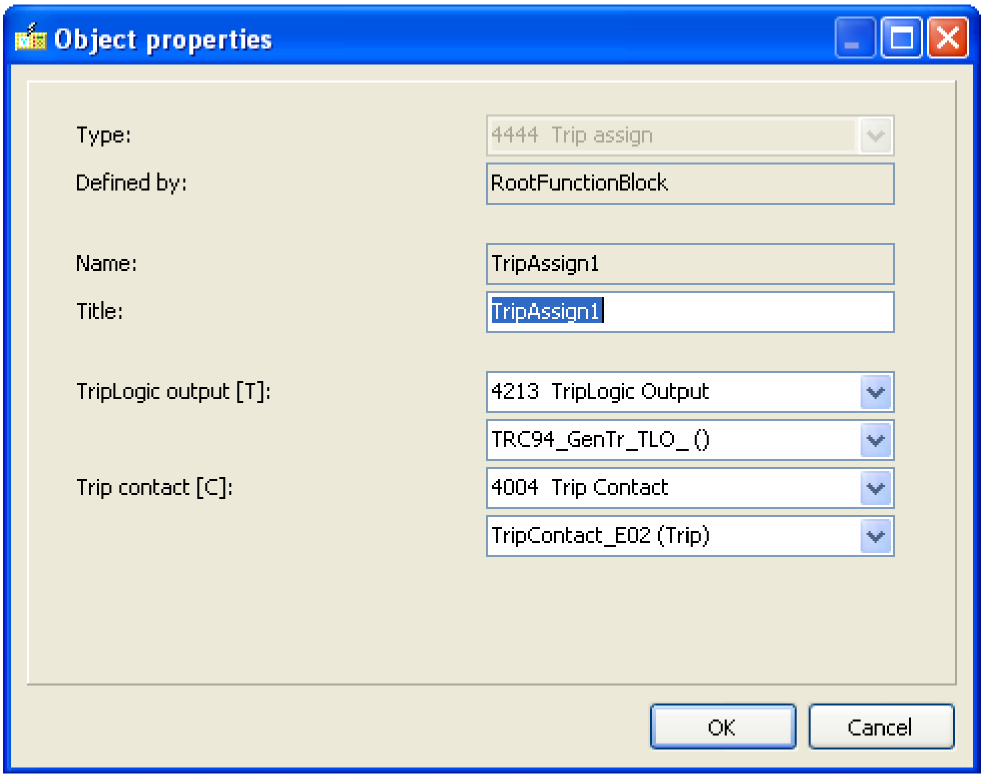


Figure 2-2 Changing the TRIP command assignment

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.

1.2.11.3.3.5. 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”.

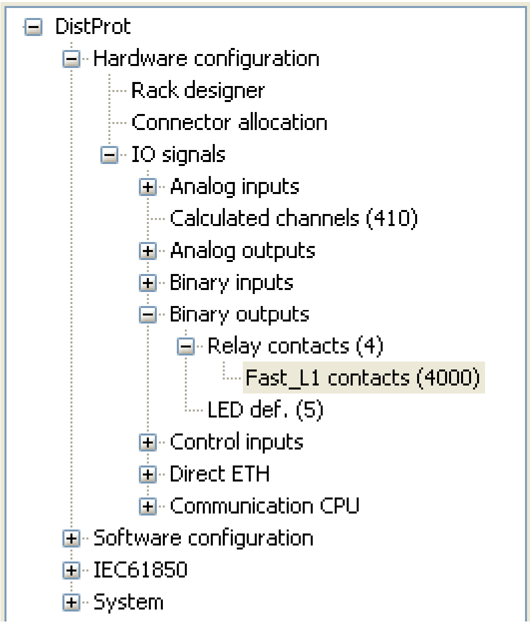


Figure 2-3 Configuring Fast L1 contacts

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.

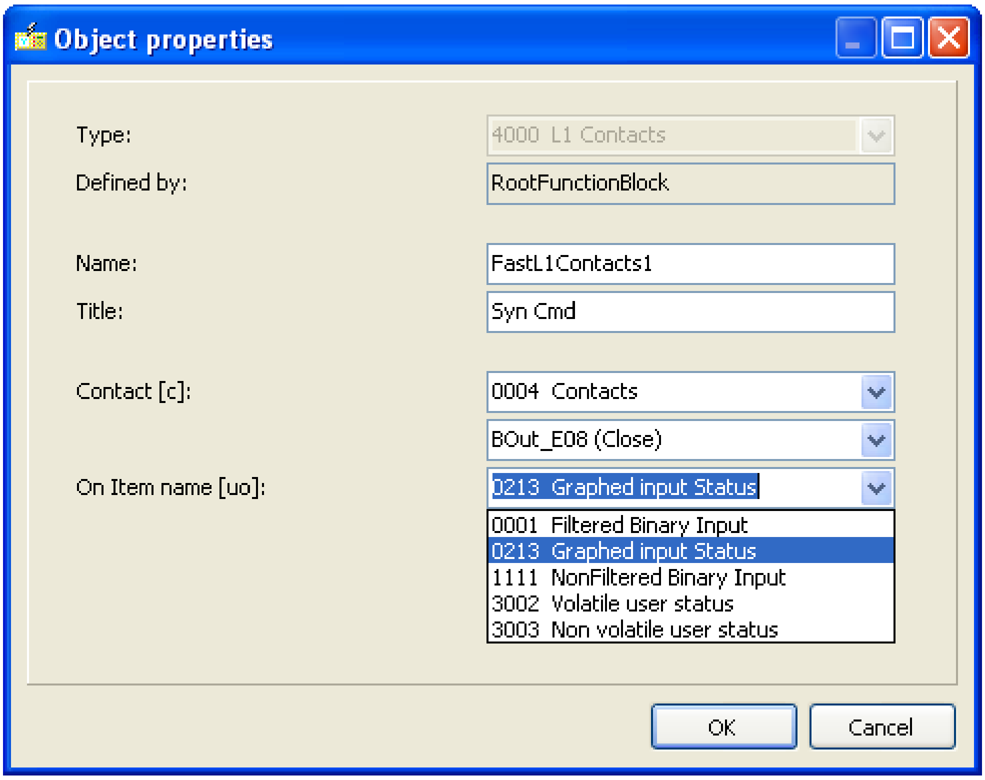


Figure 2-4 Fast L1 contact assignment

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!

1.2.11.3.4. 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.

1.2.11.3.4.1. 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.

1.2.11.3.4.2. 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).

1.2.11.3.5. 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.

1.2.11.4. Examples

1.2.11.4.1. Application of the TRIP logic

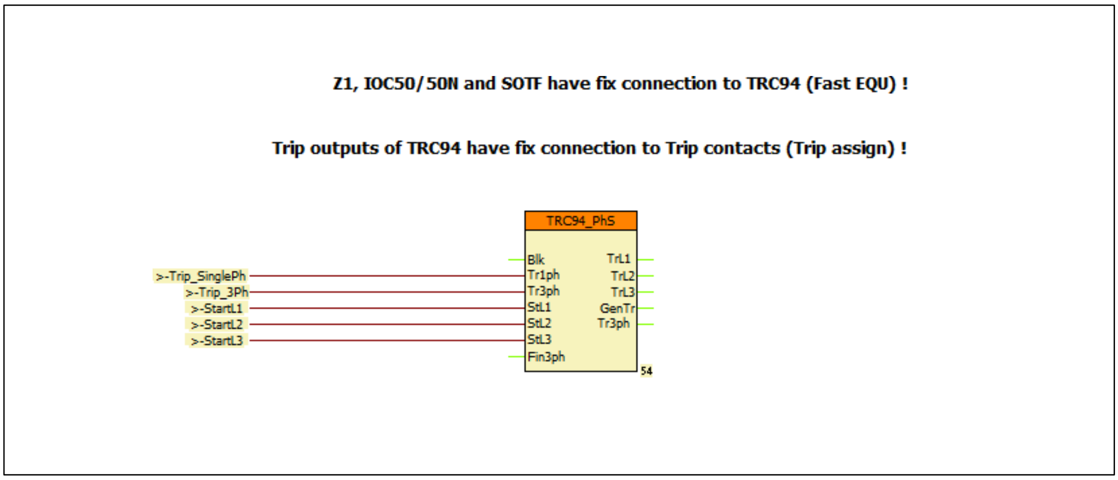


Figure 5-1 Example: A simple configuration to trip the circuit breaker

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.

1.2.11.4.2. Application of circuit breaker control block

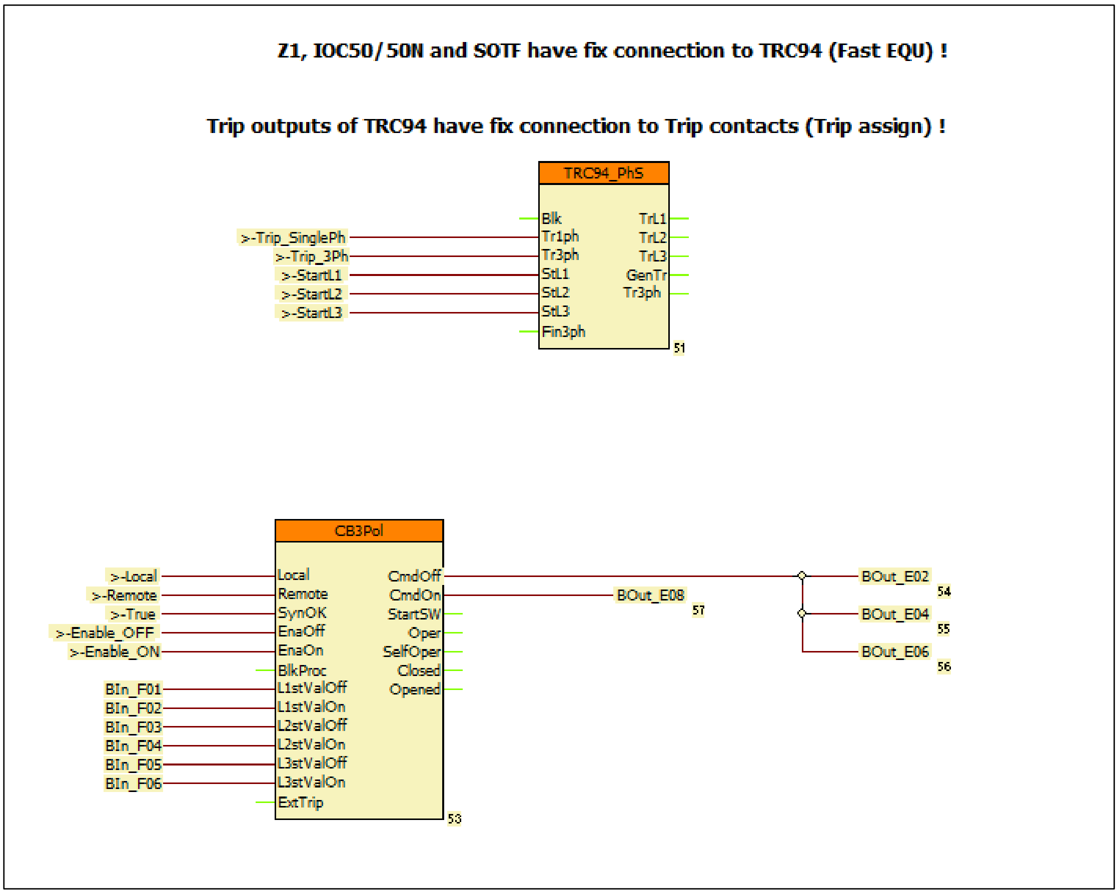


Figure 5-2 Example: Application of circuit breaker control block

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.

1.2.11.4.3. Automatic reclosing and circuit breaker control

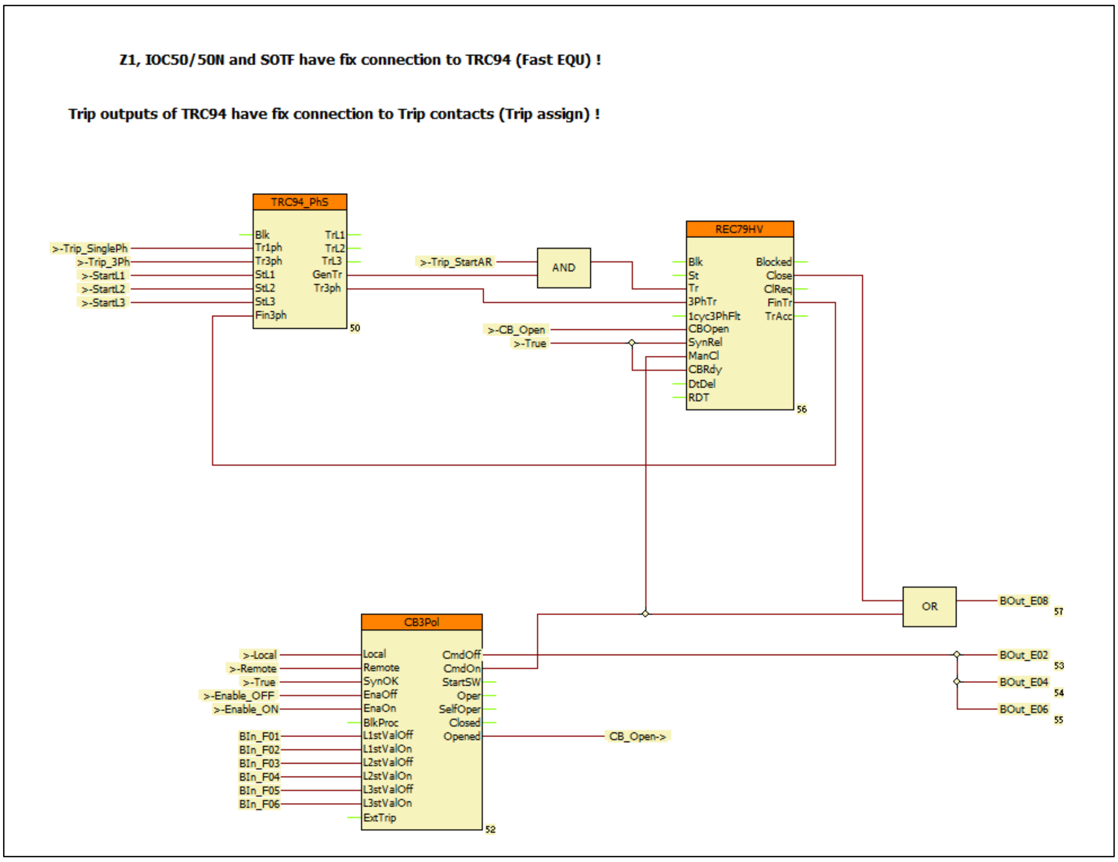


Figure 5-3 Example: Automatic reclosing and circuit breaker control

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 breker 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.

1.2.11.4.4. Closing the circuit breaker with synchro-check

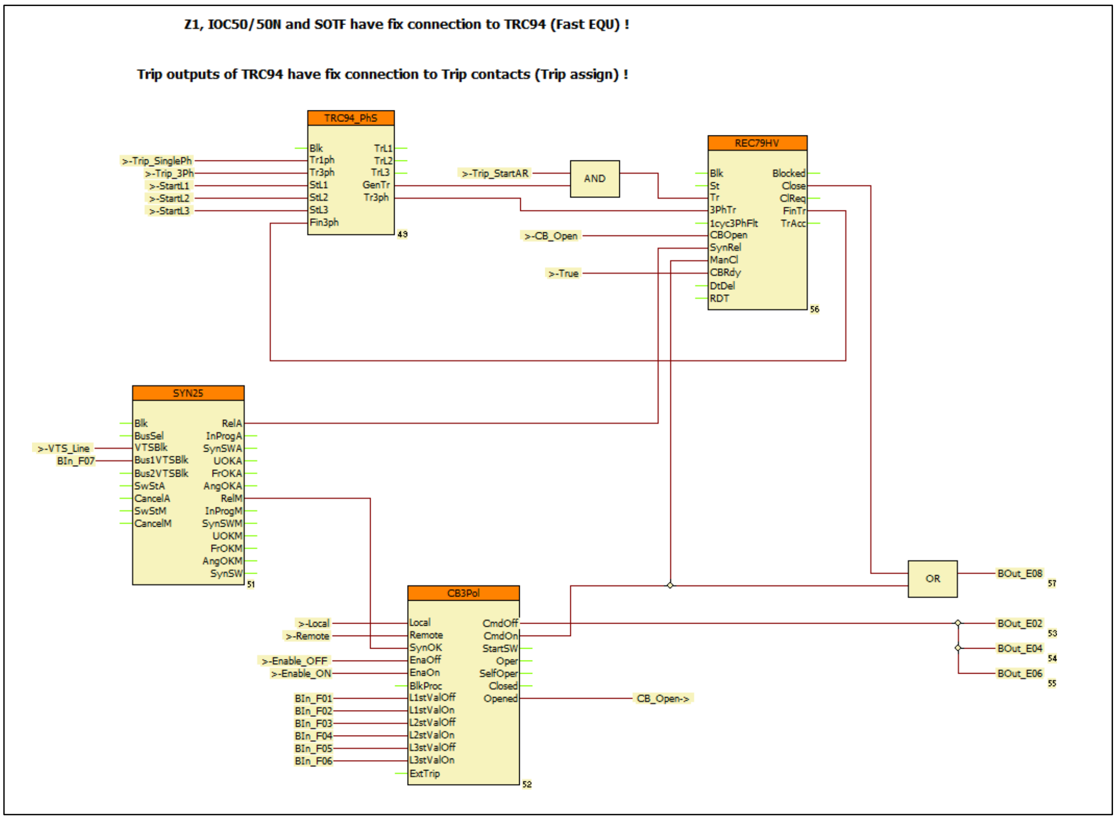


Figure 5-4 Example: closing the circuit breaker with synchro-check

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 („VTSBlk" and „Bus1VTSBlk"), 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.

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

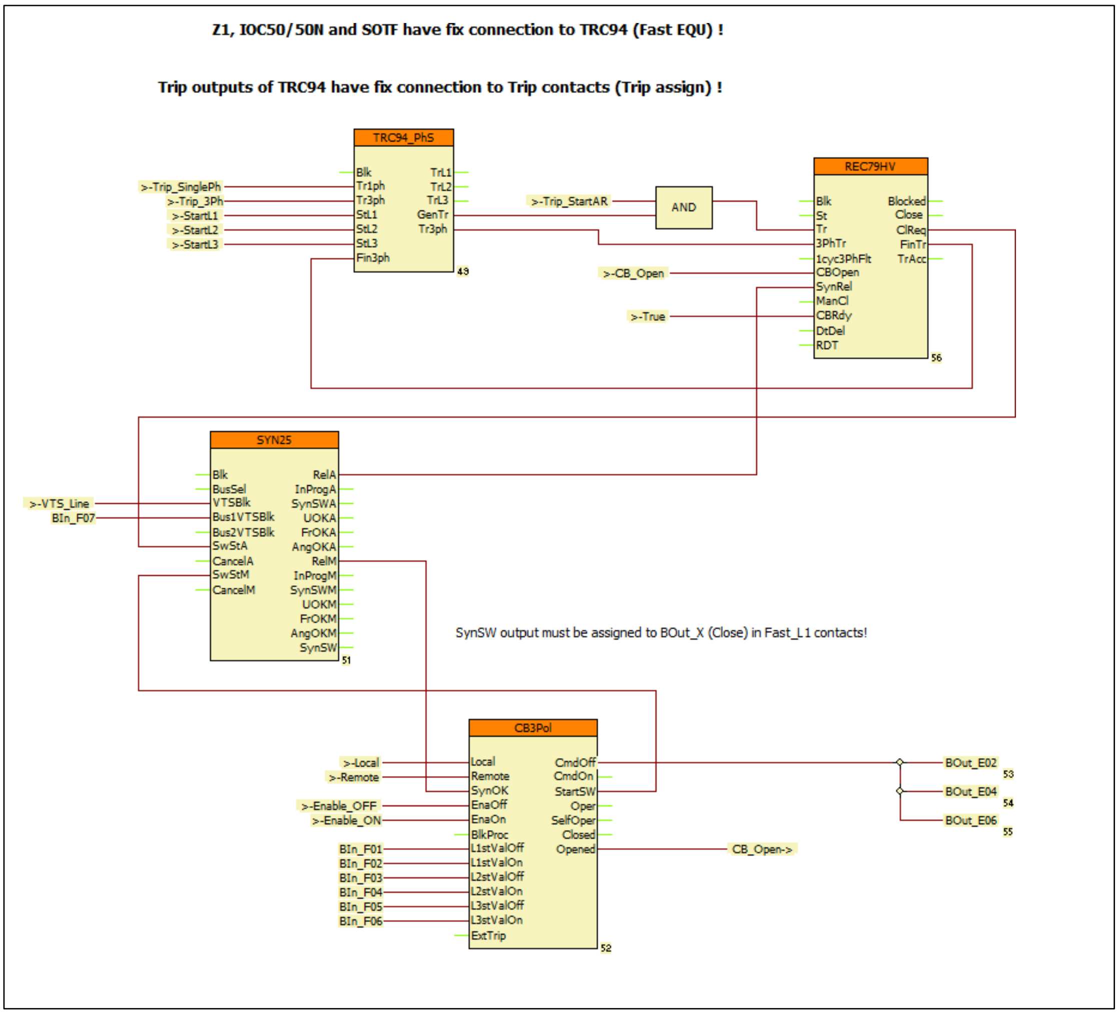


Figure 5-5 Example: closing the circuit breaker with synchro-check and synchro- switch

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 („VTSBlk” and „Bus1VTSBlk”), 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 „ClReq” 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”.

1.2.12. 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	Default: BLA Options: -	Default: BLA Options: T	Default: BLA Options: -
RECOMMENDED APPLICATION	Arc suppression coil controller	General resistance-based temperature measurement	Arc suppression coil controller

**Special module*

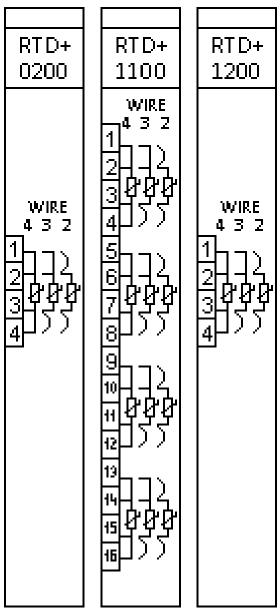


Figure 10-1 RTD input modules

1.2.12.1. 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.

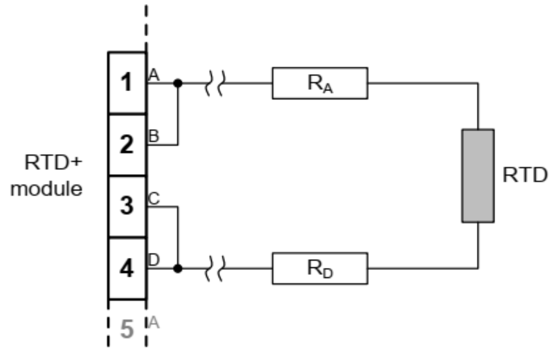


Figure 10-2 2-wire RTD wiring

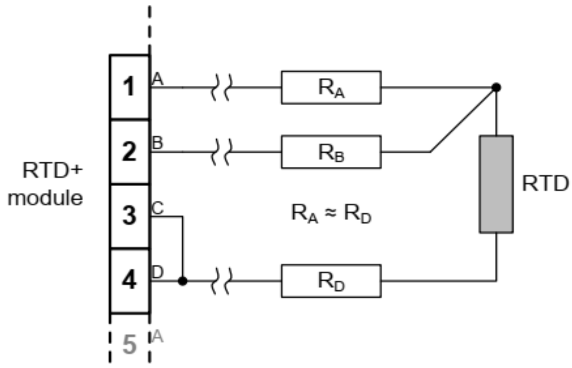


Figure 10-3 3-wire RTD wiring

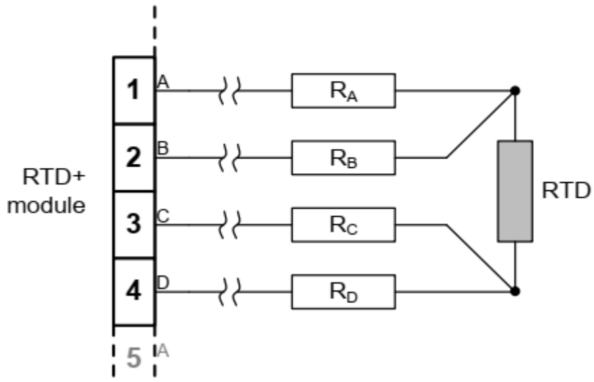


Figure 10-4 4-wire RTD wiring

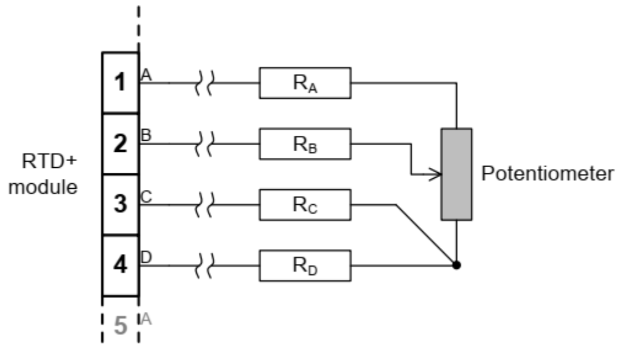


Figure 10-5 4-wire RTD wiring of potentiometer

1.2.13. 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.

<u>*Connector types:*</u>

- *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	± 0.5 % ± 1 digit	± 0.5 % ± 1 digit	± 0.5 % ± 1 digit
MEASUREMENT RANGES	**± 20 mA** (typical 0-20, 4-20 mA) R_{LOAD} = 56 Ω	**± 20 mA** (typical 0-20, 4-20 mA) R_{LOAD} = 56 Ω	**± 20 mA** (typical 0-20, 4-20 mA) R_{LOAD} = 56 Ω
CONNECTOR TYPE	<u>Default:</u> BLA <u>Options:</u> -	<u>Default:</u> BLA <u>Options:</u> -	<u>Default:</u> BLA <u>Options:</u> F, T

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

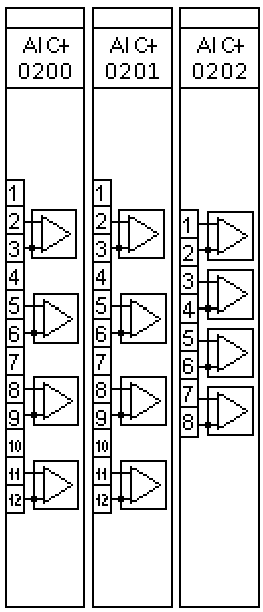


Figure 11-1 Analog input modules

1.2.13.1. AI module wiring

The following wiring method can be applied.

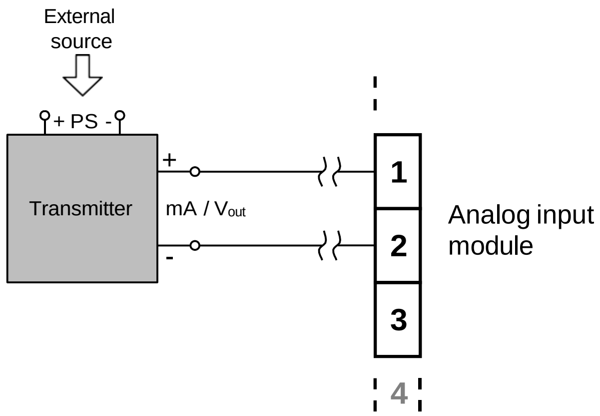


Figure 11-2 AI wiring

1.2.14. 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 $(R_{CABLE} + R_{RECEIVER})$	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: -

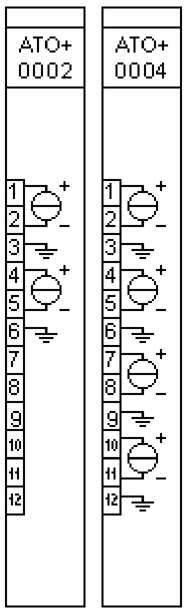


Figure 12-1 Analog output modules

1.2.14.1. ATO module wiring

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

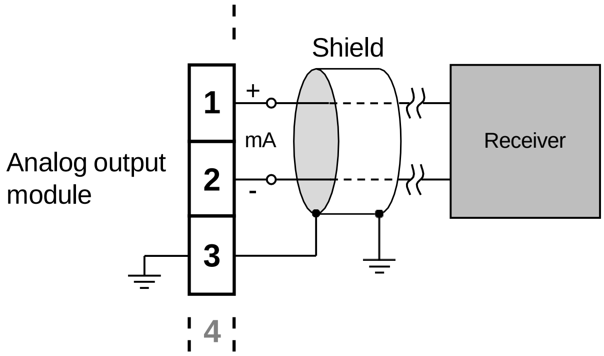


Figure 12-2 Analog output module wiring diagram

1.2.15. Sensor input module

The sensor modules receive low-level signals of current and voltage sensors (low-power instrument transformers).

<u>*Connector types:*</u>

- *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	**CVS+/0001**		**CVSR+/0001**		**VS+/0031*** **
Channel number	4 U	4 I	4 U	4 I	4 U
Nominal values	3.25 V	0.225 V*	1.27 V	0.150 V**	3.25 V
Continuous voltage withstand	35 V DC		35 V DC		35 V DC
Short time overload (1 s)	40 V AC / 56 V DC		40 V AC / 56 V DC		40 V AC / 56 V DC
Max. measured value (± 10 %)	1.8 U_N	50 I_N	2.1 U_N	50 I_N	1.6 U_N
Accuracy	≤ 0.5 % (0.1 U_N – 1.2 U_N)		≤ 0.5 % (0.1 U_N – 1.2 U_N)		≤ 0.5 % (0.1 U_N – 1.2 U_N)
Frequency range	DC – 1 kHz		DC – 1 kHz		DC – 1 kHz
Input resistance	200 kΩ ± 1%	21 kΩ ± 1%	10 MΩ ± 1%	1.1 MΩ ± 1%	200 kΩ ± 1%
Input capacitance	300 pF (1 kHz)	300 pF (1 kHz)	300 pF (1 kHz)	300 pF (1 kHz)	300 pF (1 kHz)
Connector type	RJ45 – 8 pole, shielded connector, isolated shielding		RJ45 – 8 pole, shielded connector, grounded shielding		M8 3-pin connector <u>Receptacle</u>: Hirschmann ELST 3308 RV FM 8 05 <u>Plug</u>: Binder 768 99-3360-00-03

**Voltage proportional to current*
***Voltage proportional to current change (Rogowski coil)*
******Obsolete module. These modules are not recommended for new designs!***

For more information about more available nominal values please contact our Application Team. (application@protecta.hu)

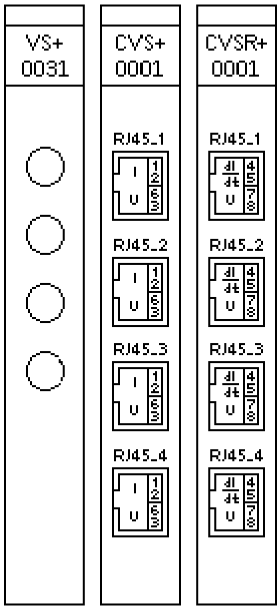


Figure 13-1 Voltage sensor modules

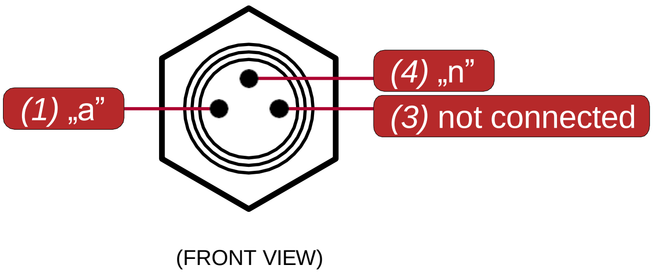


Figure 13-2 M8 connector pinout

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

1.2.16. 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*

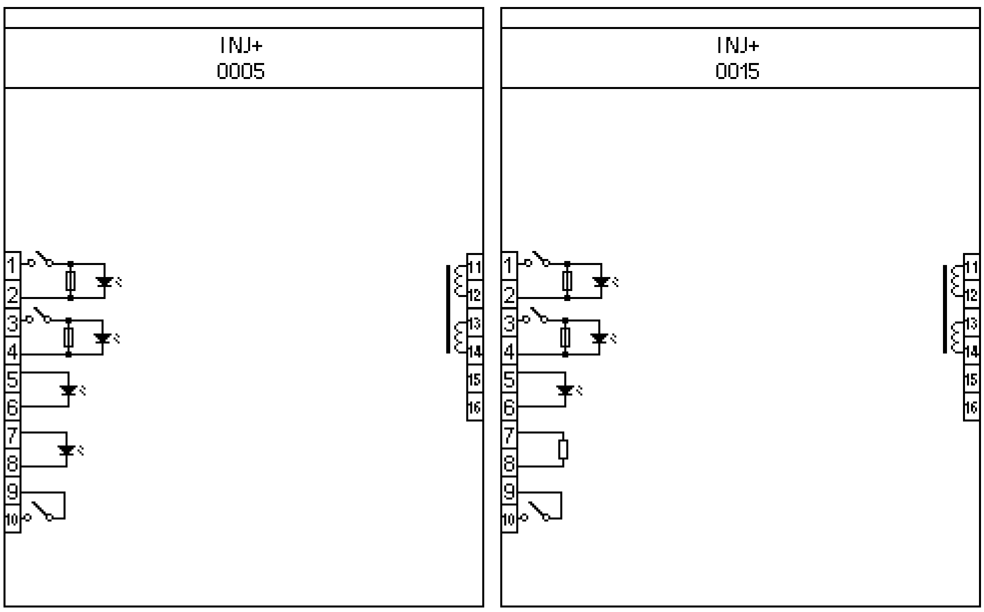


Figure 14-1 INJ modules

1.2.17. Generator protection modules

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

<u>*Connector types:*</u>

- *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 ± 2 %
Measurement range	± 20 mA	± 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*

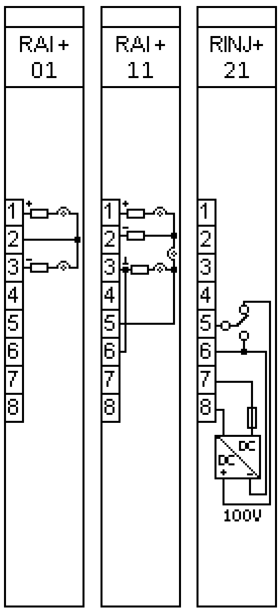


Figure 15-1 Generator protection modules

1.2.17.1. 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*

1.2.17.1.1. Use of auxiliary boxes

- **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.

- **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.

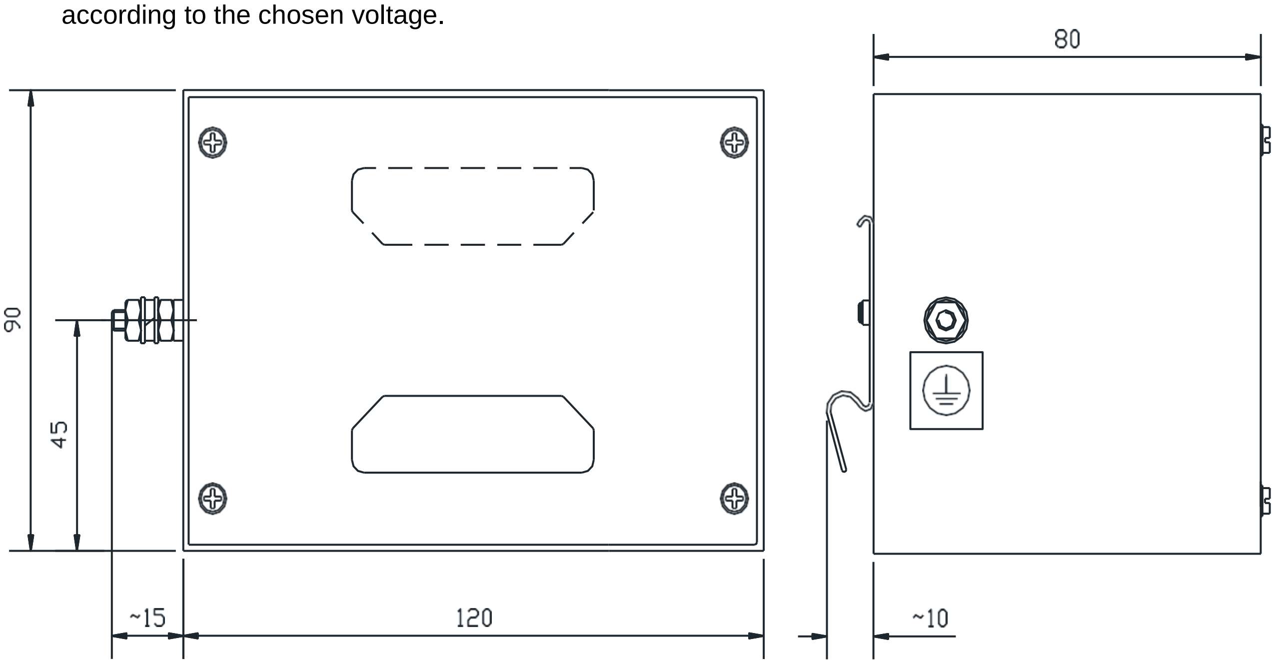


Figure 15-2 Size of the auxiliary boxes

1.2.17.2. Wiring of the rotor earth fault protection modules

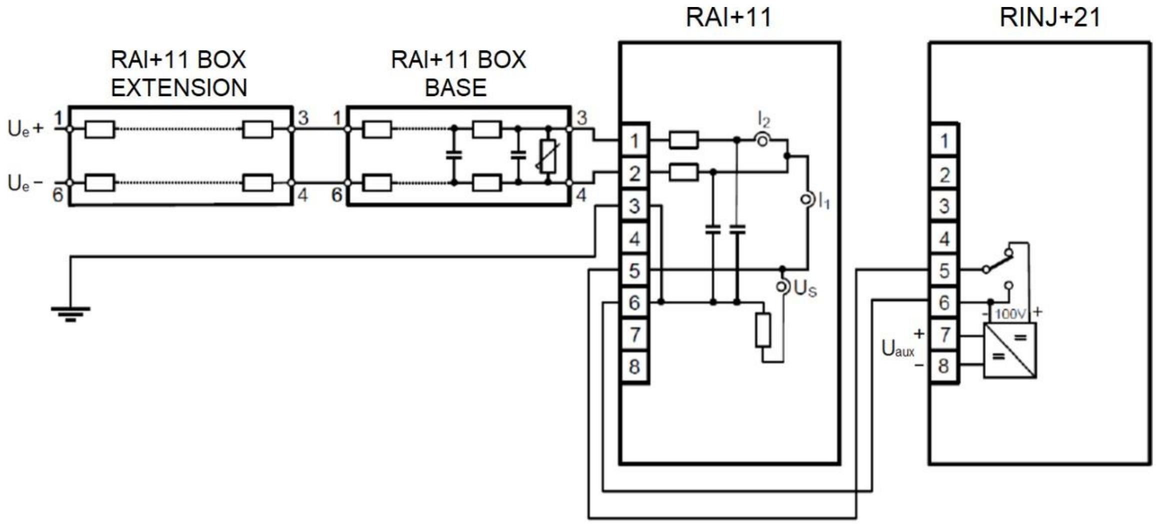


Figure 15-3 Wiring for ungrounded (isolated) rotors

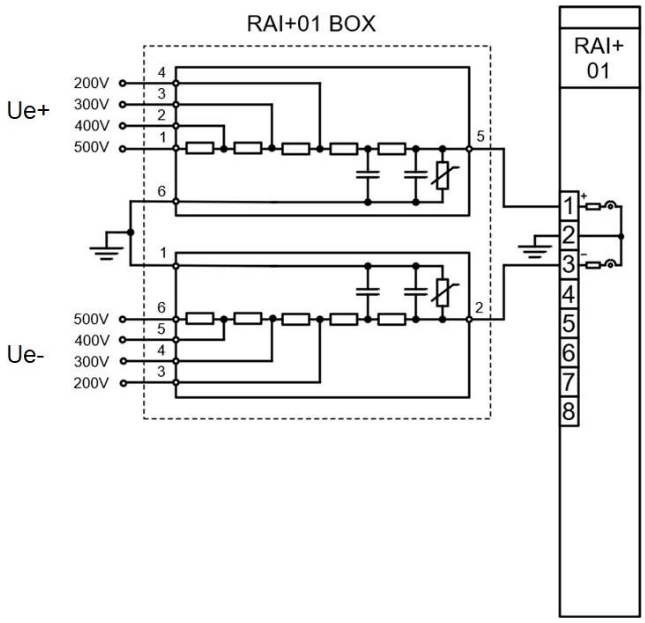


Figure 15-4 Wiring for middle-grounded rotors

1.2.18. 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	Default: BLA Options: T	Default: BLA Options: F, T

IMPORTANT
Devices with 20W or higher power consumption shall be equipped with an 8 HP wide PS module.

MODULE TYPE	PS+/1301	PS+/1303**	PS+/2301	PS+/2303**	PS+/1030*
RATED VOLTAGE	110 V DC	110 V DC	220 V DC	220 V DC	110 V DC / 220 V DC
INPUT VOLTAGE OPERATIVE RANGE	88 - 132 V DC 85 - 130 V AC	88 - 150 V DC 85 - 130 V AC	176 - 264 V DC 160 - 250 V AC	176 - 264 V DC 160 - 250 V AC	88 - 264 V DC 85 - 250 V AC
MAX. CONTINUOUS POWER OUTPUT	30 W	30 W	30 W	30 W	25 W
VOLTAGE DIP WITHSTAND AT 80% UN → 0% INPUT VOLTAGE CHANGE *(IEC 60255-26)*	**50 ms** **100 ms** at 100%Un → 0%	**50 ms** **100 ms** at 100%Un → 0%	**50 ms** **100 ms** at 100%Un → 0%	**50 ms** **100 ms** at 100%Un → 0%	**20 ms** **100 ms** at 100%Un → 0%
INTERNAL FUSE	2.5A/250V	2.5A/250V	2.5A/250V	2.5A/250V	2.5A/250V
CONNECTOR TYPE	Default: BLA Options: -	Default: BLA Options: -	Default: BLA Options: -	Default: BLA Options: -	Default: BLA Options: F, T

***Special module**, *available only in custom configurations.*
****Can be connected in parallel.**

MODULE TYPE	PS+/1060*	PS+/1601	PS+/1602*	PS+/2601	PS+/4301***
RATED VOLTAGE	110 V DC / 220 V DC	110 V DC	110 V DC	220 V DC	48 V DC
INPUT VOLTAGE OPERATIVE RANGE	88 - 264 V DC	88 - 132 V DC 95 - 130 V AC	88 - 132 V DC 95 - 130 V AC	176 - 264 V DC 160 - 250 V AC	38.4 - 57.6 V DC
MAX. CONTINUOUS POWER OUTPUT	60 W	60 W	60 W	60 W	25 W
VOLTAGE DIP WITHSTAND AT 80% UN → 0% INPUT VOLTAGE CHANGE *(IEC 60255-26)*	**20 ms** **100 ms** at 100%Un → 0%	**50 ms** **100 ms** at 100%Un → 0%	**50 ms** **100 ms** at 100%Un → 0%	**50 ms** **100 ms** at 100%Un → 0%	**20 ms** **30 ms** at 100%Un → 0%
INTERNAL FUSE	3.15A/250V	2.5A/250V	2.5A/250V	2.5A/250V	3.15A/250V
CONNECTOR TYPE	Default: BLA Options: F, T	Default: BLA Options: -	Default: BLA Options: F	Default: BLA Options: T	Default: BLA Options: -

Special module, *available only in custom configurations. PS+1602 supports* ***auxiliary voltage measurement****. The module is calibrated to DC voltage measurement.*
*****Obsolete module. These modules are not recommended for new designs!**

MODULE TYPE	PS+/2161*	PS+/2164**	PS+/4261*	PS+/4264**
RATED VOLTAGE	110 V DC / 220 V DC	110 V DC / 220 V DC	24 V DC / 48 V DC / 60 V DC	24 V DC / 48 V DC / 60 V DC
INPUT VOLTAGE OPERATIVE RANGE	88 - 264 V DC	88 - 264 V DC	19.2 - 72 V DC	19.2 - 72 V DC
MAX. CONTINUOUS POWER OUTPUT	60 W	60 W	60 W	60 W
VOLTAGE DIP WITHSTAND AT 80% UN → 0% INPUT VOLTAGE CHANGE *(IEC 60255-26)*	**40 ms**	**40 ms**	**40 ms**	**40 ms**
INTERNAL FUSE	3.15A/250V	3.15A/250V	8A/250V	8A/250V
CONNECTOR TYPE	Default: BLT Options: -	Default: BLT Options: -	Default: BLT Options: -	Default: BLT Options: -

Can be connected in parallel.**Can be connected in parallel** *and supports* ***auxiliary voltage measurement.

MODULE TYPE	PS+/4401**	PS3F+/1001*
RATED VOLTAGE	48 V DC / 60 V DC	3x100 V AC (line voltage)
INPUT VOLTAGE OPERATIVE RANGE	38.4 - 72 V DC	80 - 120 V AC
MAX. CONTINUOUS POWER OUTPUT	30 W	20 W
VOLTAGE DIP WITHSTAND AT 80% UN → 0% INPUT VOLTAGE CHANGE *(IEC 60255-26)*	**20 ms** **30 ms** at 100%Un → 0%	**50 ms** **100 ms** at 100%Un → 0%
INTERNAL FUSE	3.15A/250V	2.5A/250V
CONNECTOR TYPE	Default: BLA Options: F, T	Default: BLA Options: -

***Special module.** *At least 2 healthy phase voltages are needed for the operation of the PS3F+1001 module. LEDs on the front of the module indicate the presence of healthy phase voltages. For the correct internal signals connect the common point of the suppling 3 phase voltage to the 4th connector ("N").*
****Can be connected in parallel.**

Main features:

- Fault relay contacts (NC and NO): device fault contact and also assignable to user functions. All the three relay contact points are accessible to users.
- Redundant applications (nominal power and reliability can be increased by using parallel power supplies)
- On-board self-supervisory circuits: temperature and voltage monitors
- Short-circuit-protected outputs
- Efficiency: > 70 %, power consumption = nominal power / efficiency
- Passive heatsink

- 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.)

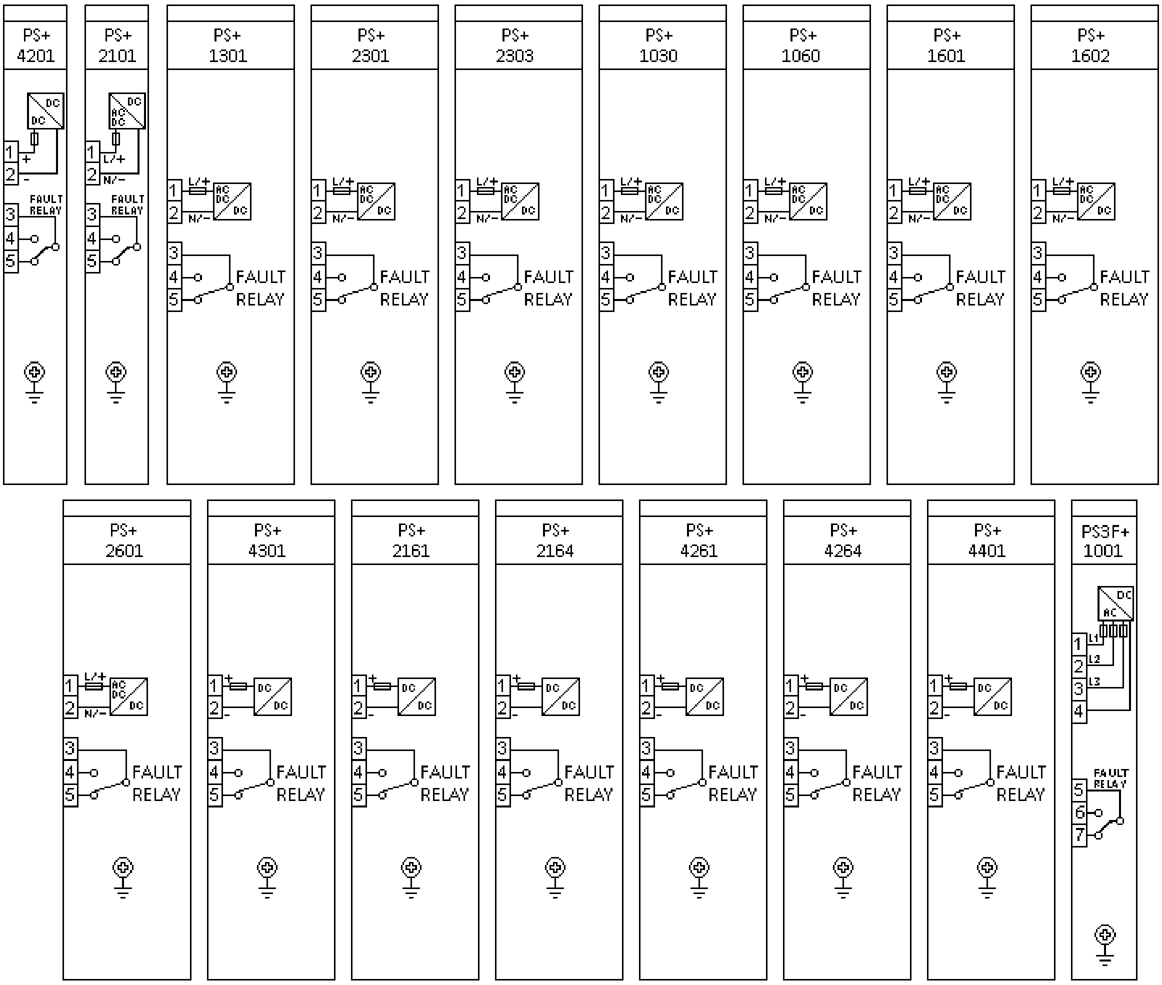


Figure 16-1 Power supply modules

1.2.19. 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*

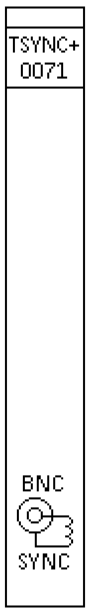


Figure 17-1 Sampling synchronization module

1.2.20. Mixed function modules

1.2.20.1. 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	Default: BLA Options: T	Default: BLA Options: 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	Default: BLA Options: T	Default: BLA Options: 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.)

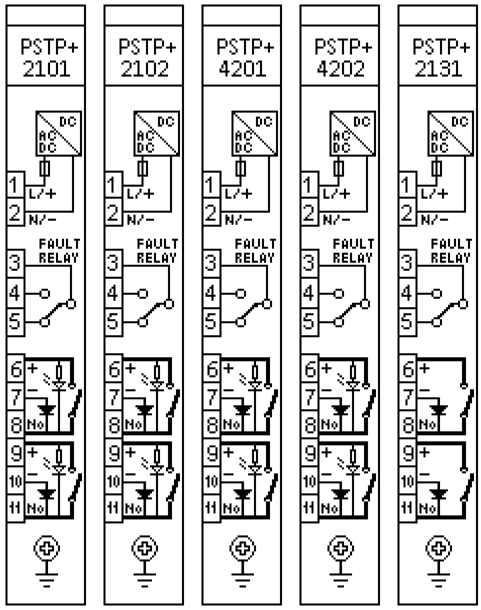


Figure 18-1 Power supply with 2 Ch. TRIP modules

1.2.20.1.1. 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

IMPORTANT
PSR2+ modules can be used only if the power consumption of the device does not reach 20 W and maximum 2 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 Signaling (Chapter 8) modules must be used.

1.2.20.2. PSR2+ module

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	PSR2+/2101
POWER SUPPLY CHARACTERISTICS	
RATED VOLTAGE	110 V / 220 V
INPUT VOLTAGE OPERATIVE RANGE	88 - 264 V DC 80 - 250 V AC
MAXIMUM CONTINUOUS POWER OUTPUT	20 W
VOLTAGE DIP DURATION AT 0% RESIDUAL VOLTAGE *(IEC 60255-26)*	**min. 100 ms** in the specified input voltage range
INTERNAL FUSE	3.15A/250V
CONNECTOR TYPE	Default: BLA Options: T
SIGNALING RELAY CHARACTERISTICS	
CHANNEL NUMBER	2
RATED VOLTAGE	250 V AC/DC
CONTINUOUS CARRY	8 A
MAKING CAPACITY	0.5 s, 30 A
CONNECTOR TYPE	Default: BLA Options: T

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: 10×10^6 cycles
- Circuit closing capability: typically 10 ms, maximally 22 ms.
- Bounce time: typically 6,5 ms, maximally 10 ms.
- Minimal switching requirement: 5 V

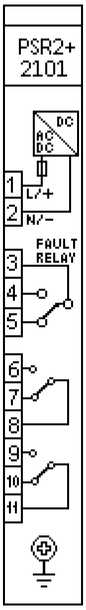


Figure 18-2 Power supply with 2 Ch. signaling modules

1.2.20.3. 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.

<u>Connector types:</u>

- *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: 10×10^6 cycles
- Circuit closing capability

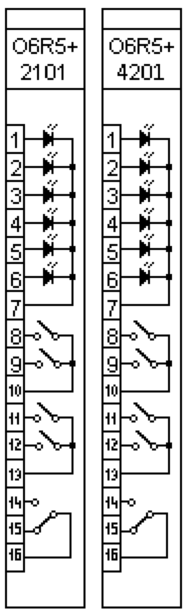


Figure 18-3 Binary input/output modules

1.2.20.4. 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	Default: BLA Options: T	Default: BLA Options: F, T	Default: - Options: F, T

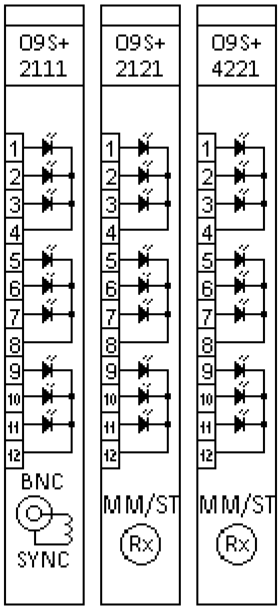


Figure 18-4 Binary input modules with time synchronization

1.2.20.5. 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	Default: BLA Options: F

**Special module*

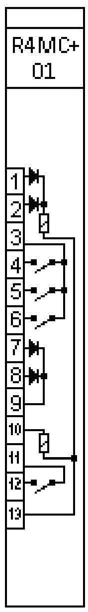


Figure 18-5 Externally driven TRIP module

1.2.21. General data

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

1.2.21.1. 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: 4 kV line-to-earth, 2 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 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

1.2.22. Mechanical data

1.2.22.1. 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

1.2.22.2. 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.*

CONNECTOR NAME (SHORT ID)	CONNECTOR TYPES	STRIP LENGTH [MM]	CONDUCTOR AREA [MM^2]	CONDUCTOR DIAMETER [MM]	TIGHTENING TORQUE [NM]	MINIMUM BEND RADIUS*
STVS (-)	Weidmüller STVS 6 SB, STVS 8 SB	9	0.5 – 4	0.8 – 2.3	0.5 – 0.6	3 × OD**
B2L 3.5	Weidmüller B2L 3.5	7	0.2 – 1	0.5 – 1.1	tension clamp connection	3 × OD**
ST/FC/LC	Bayonet/Screw/Snap Fiber Optic	-	-	-	-	30 mm
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 and the wall mounting must be approx. 5 Nm.
The tightening torque of the screw for fastening the STVS connector must be approx. 1 Nm.

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.

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

1.2.23. 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.

1.2.23.1. 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.

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

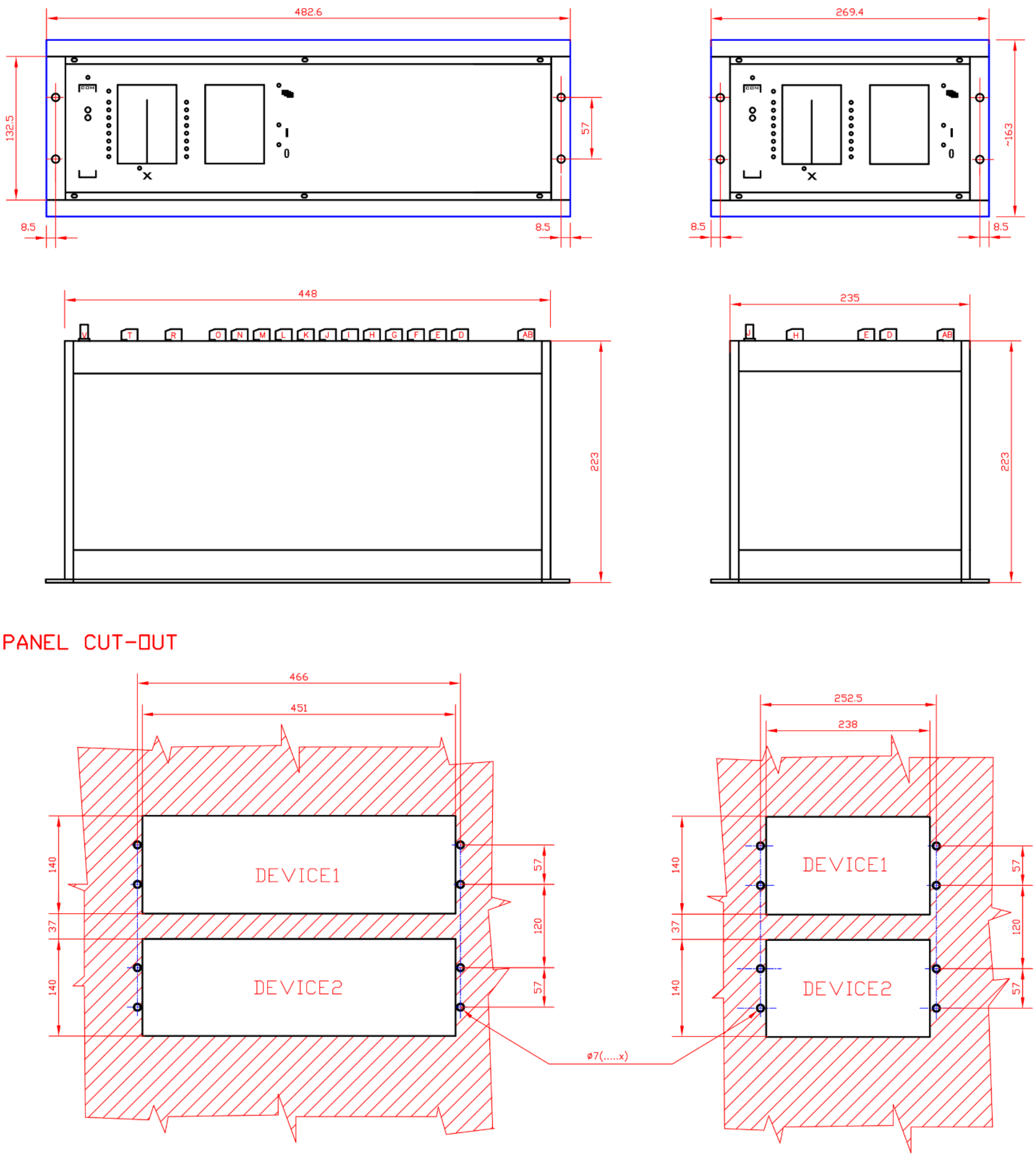


Figure 21-1 Dimensions for flush mounting of 84 HP and 42 HP single rack

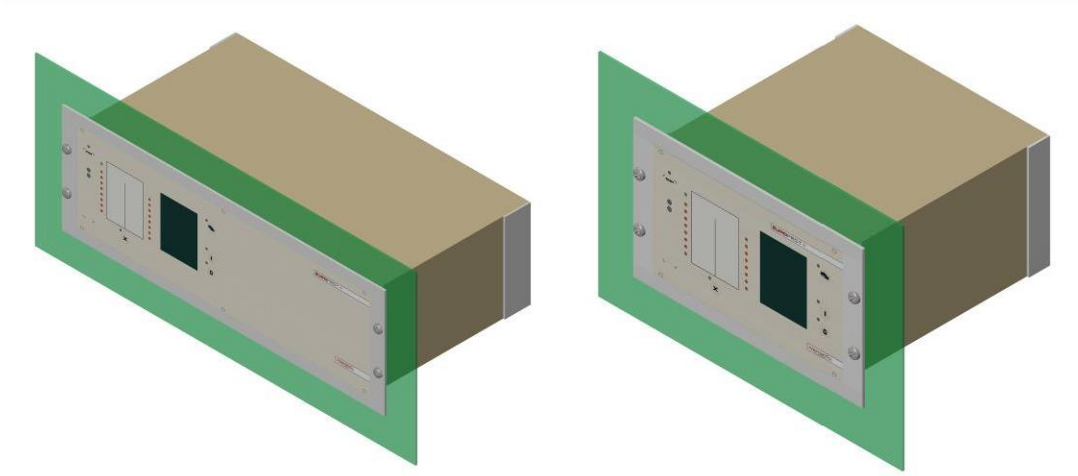


Figure 21-2 3D illustration for flush mounting of 84 HP and 42 HP devices

1.2.23.1.2. Flush mounting of 42 HP double rack

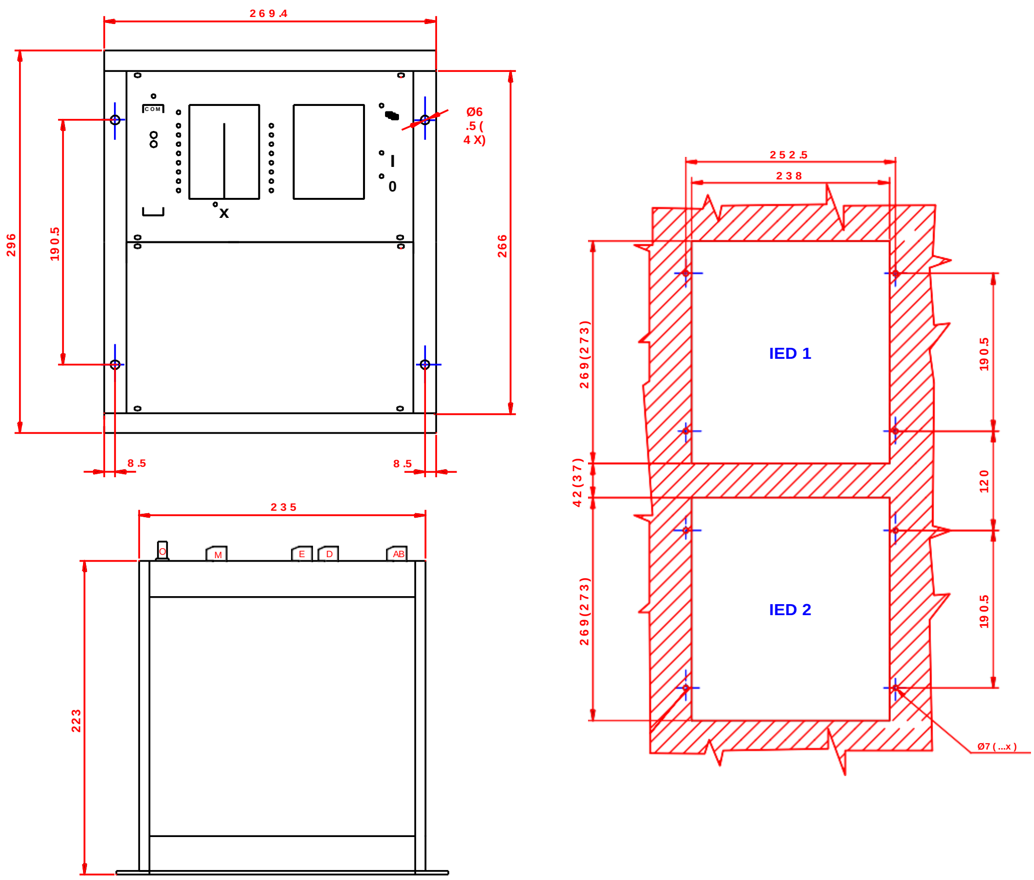


Figure 21-3 Dimensions for flush mounting of 42 HP double rack

Figure 21-4 42 HP wide cover profile

1.2.23.1.3. Flush mounting of 24 HP panel instrument case

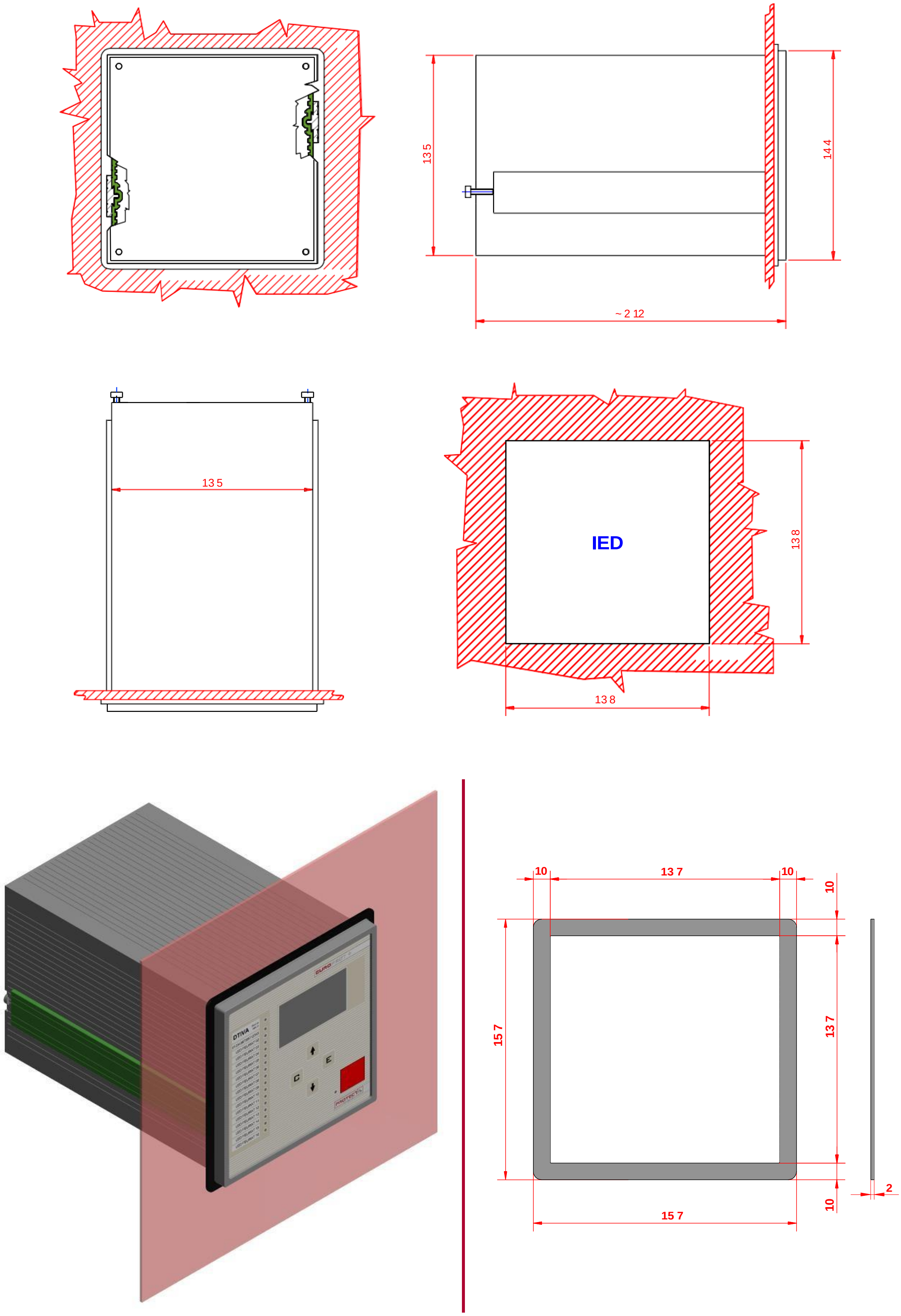


Figure 21-5 Dimensions for flush mounting of 24 HP panel instrument case with 3D illustration

1.2.23.2. 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.

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

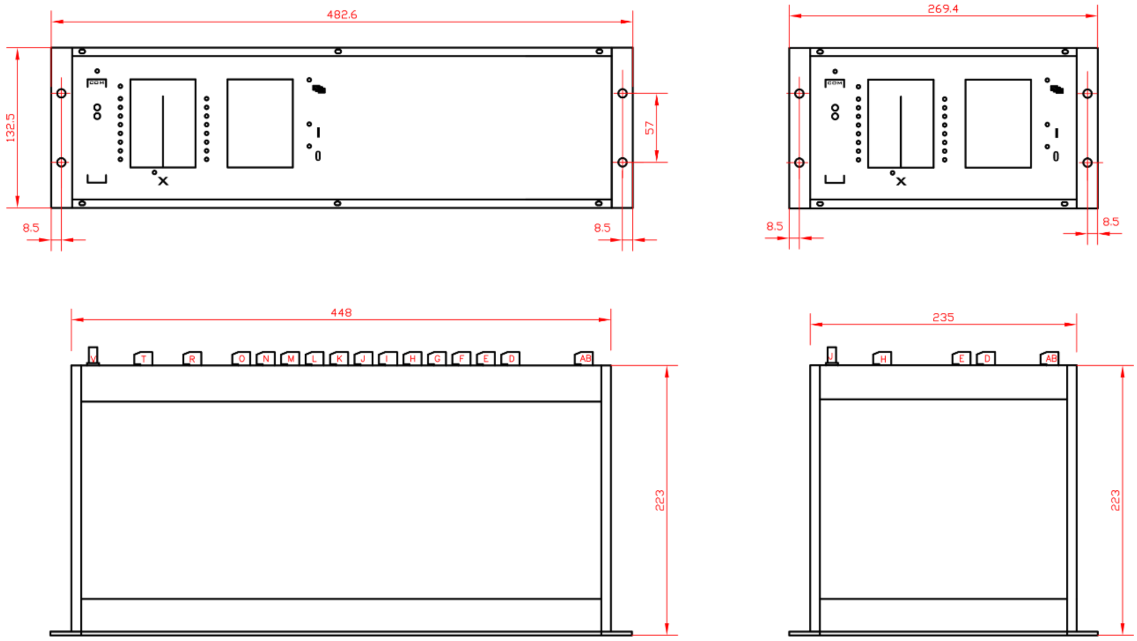


Figure 21-6 Dimensions for rack mounting of 84 HP and 42 HP single rack

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.

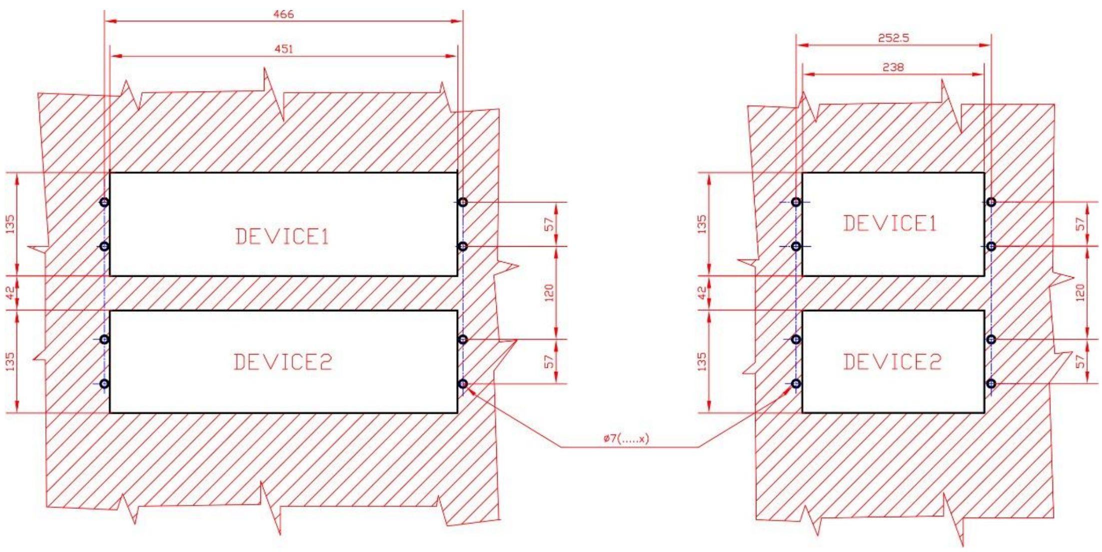


Figure 21-7 Dimensions of rack mounting cut-outs

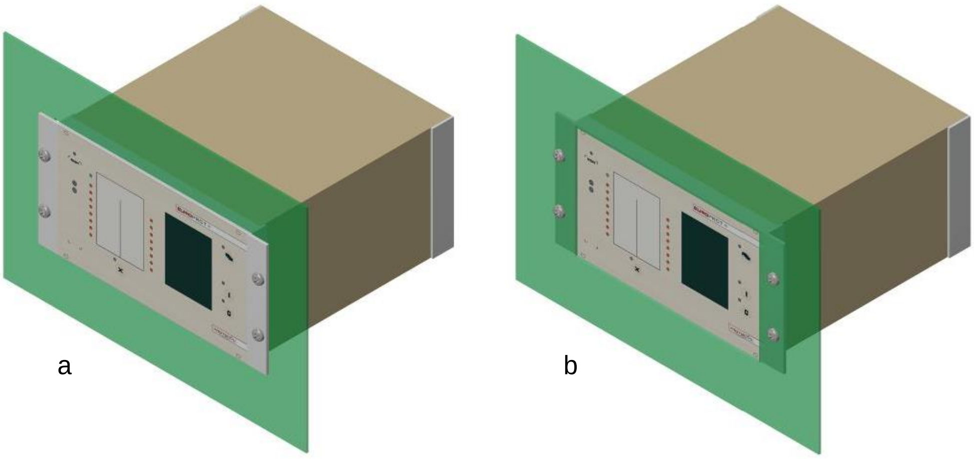


Figure 21-8 3D illustration for rack mounting of 42 HP device
(a - from the front; b - from the back)

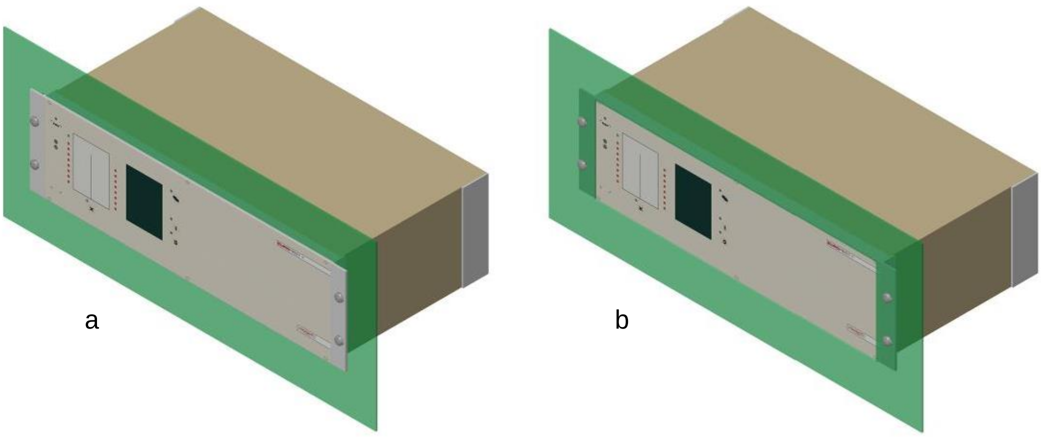


Figure 21-9 3D illustration for rack mounting of 84 HP device
(a - from the front; b - from the back)

1.2.23.2.2. Rack mounting of 42 HP double rack

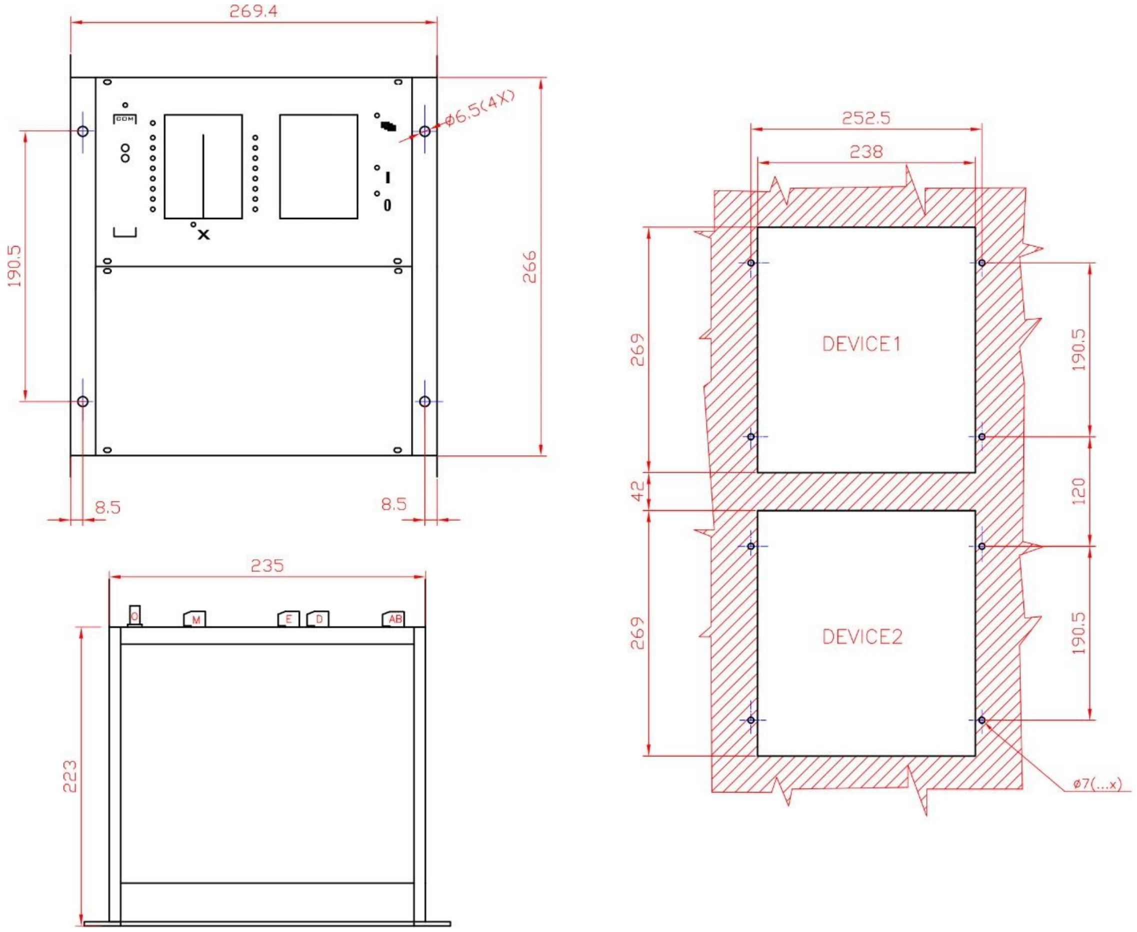


Figure 21-10 Dimensions for rack mounting of 42 HP double rack

1.2.23.3. 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.

1.2.23.3.1. Semi-flush mounting of 84 HP single rack

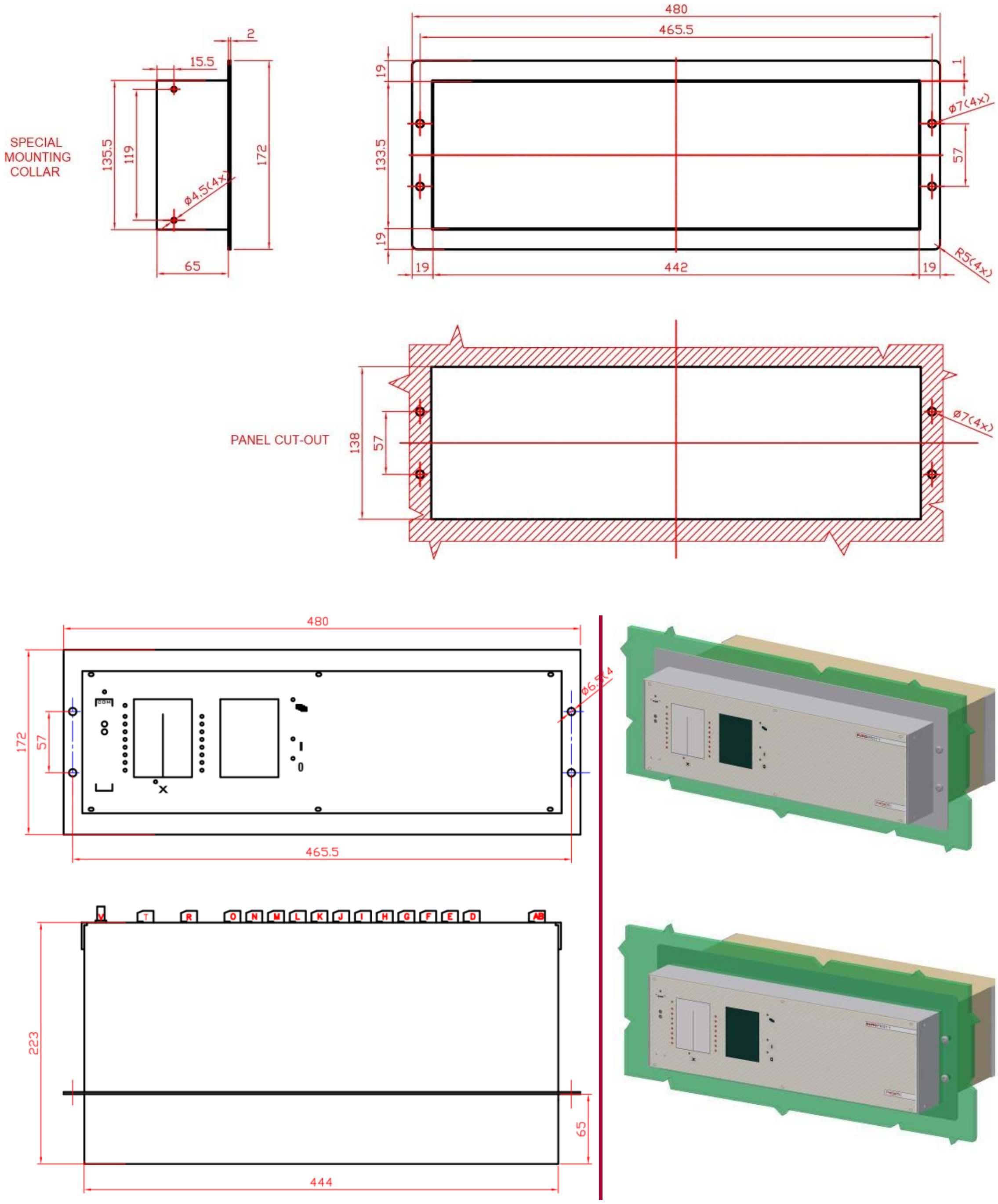


Figure 21-11 Dimensions for semi-flush mounting of 84 HP single rack with 3D illustration

1.2.23.3.2. Semi-flush mounting of 42 HP single rack

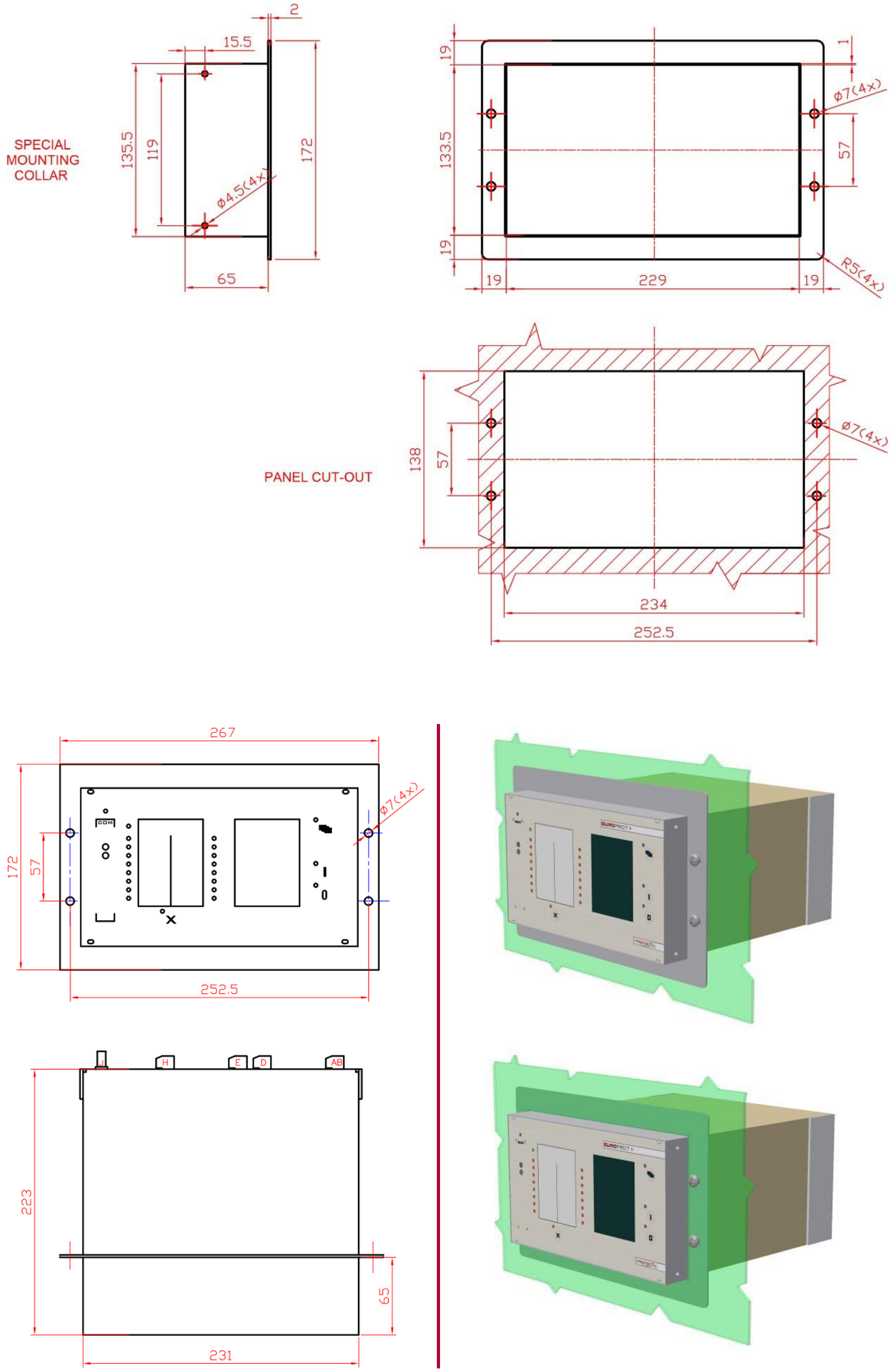


Figure 21-12 Dimensions for semi-flush mounting of 42 HP single rack with 3D illustration

1.2.23.3.3. 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 × 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.

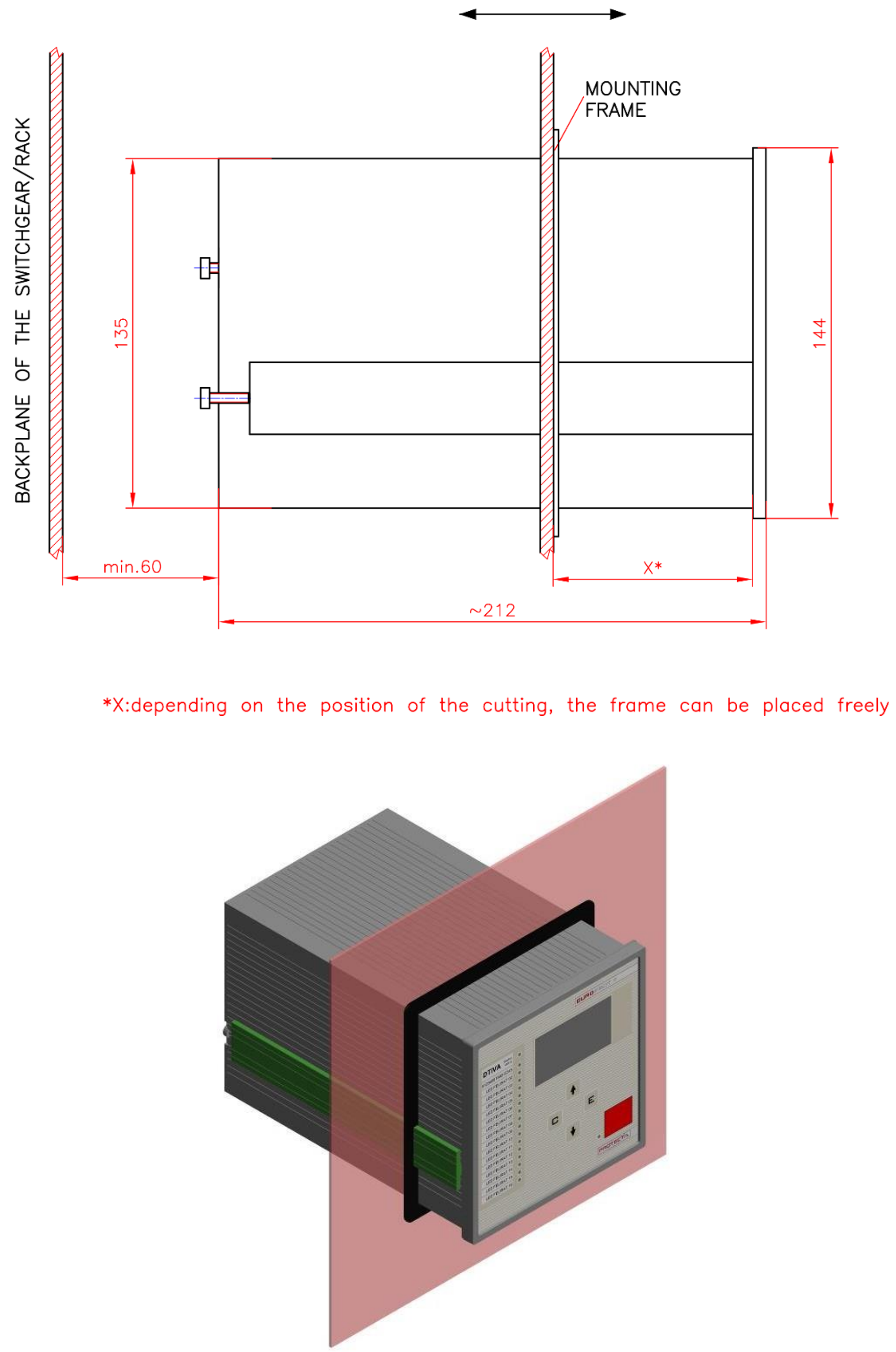


Figure 21-13 Dimensions for semi-flush mounting of 24 HP panel instrument case with 3D illustration

1.2.23.4. 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.

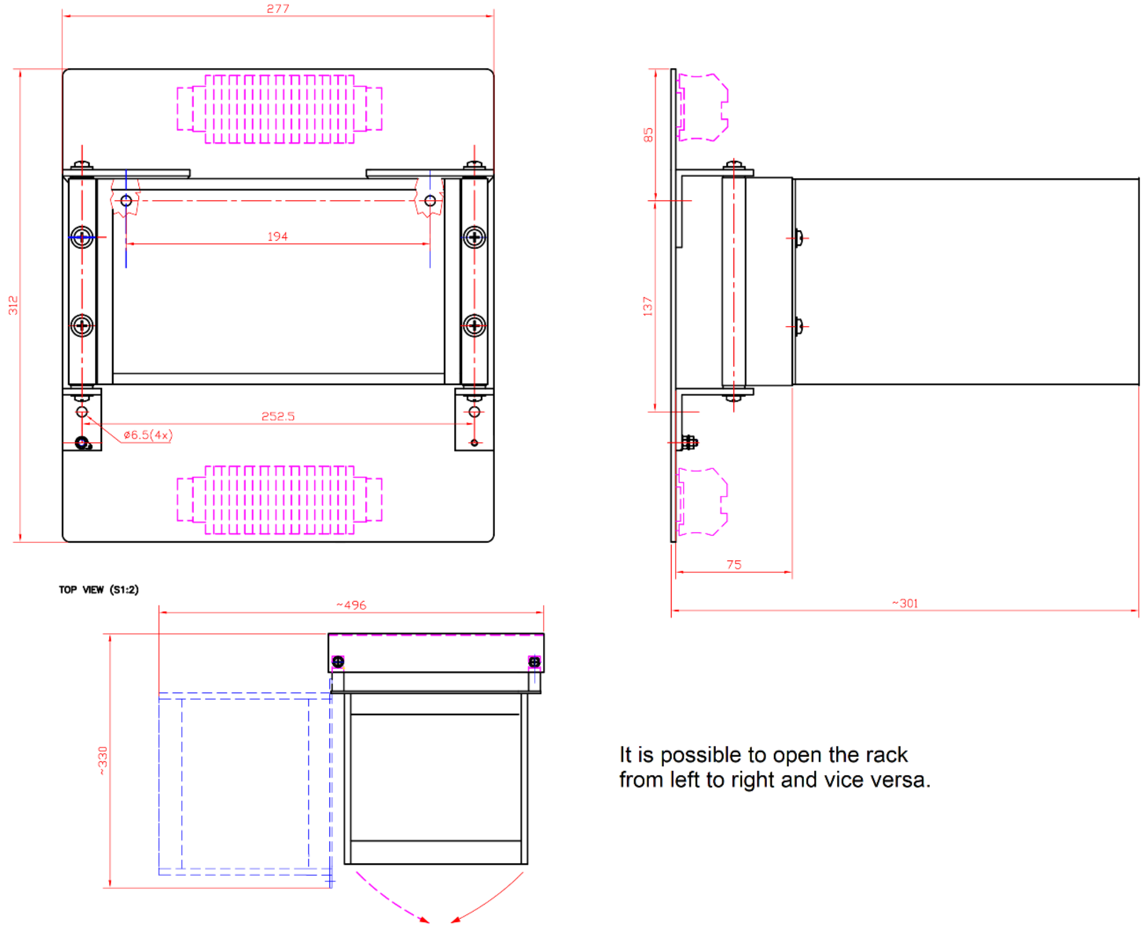


Figure 21-14 Dimensions for wall mounting of 42 HP devices (upper and lower terminals)

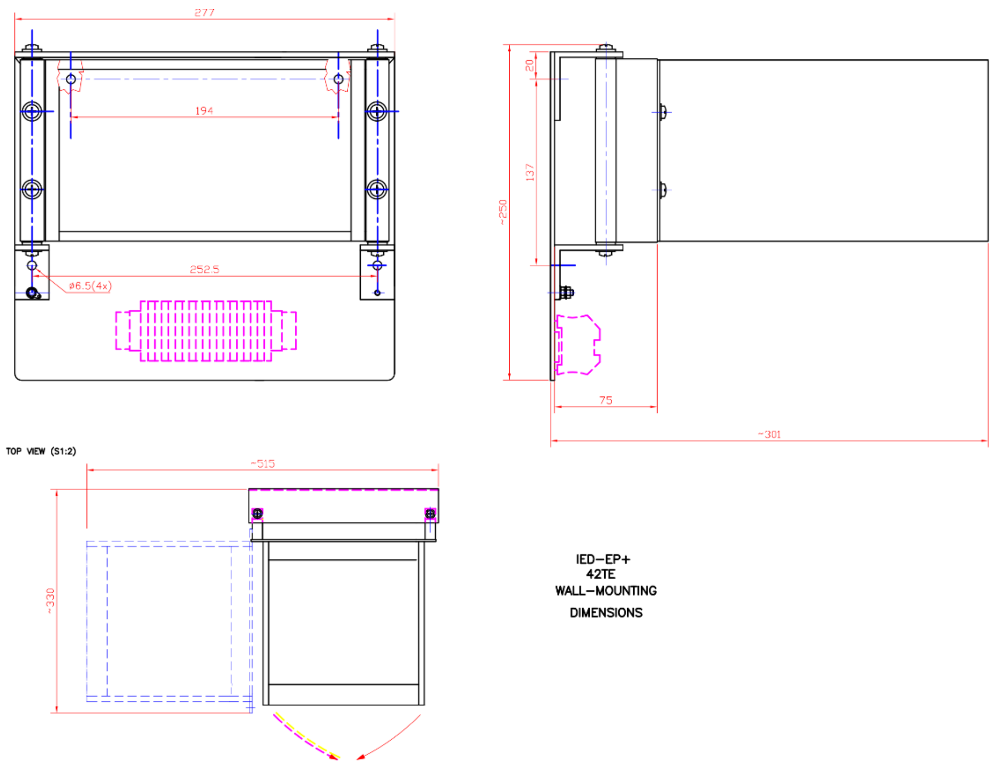


Figure 21-15 Dimensions for wall mounting of 42 HP devices (lower terminal only)

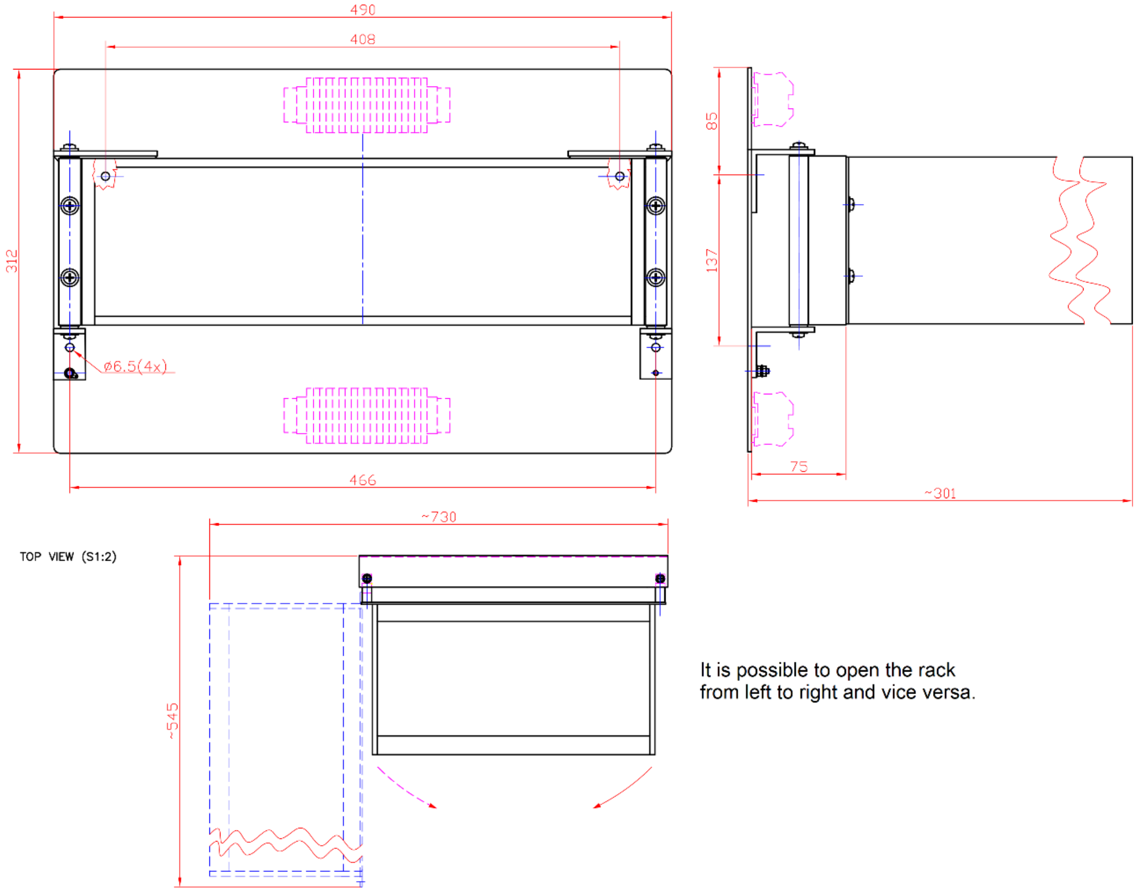


Figure 21-16 Dimensions for wall mounting of 84 HP devices (upper and lower terminals)

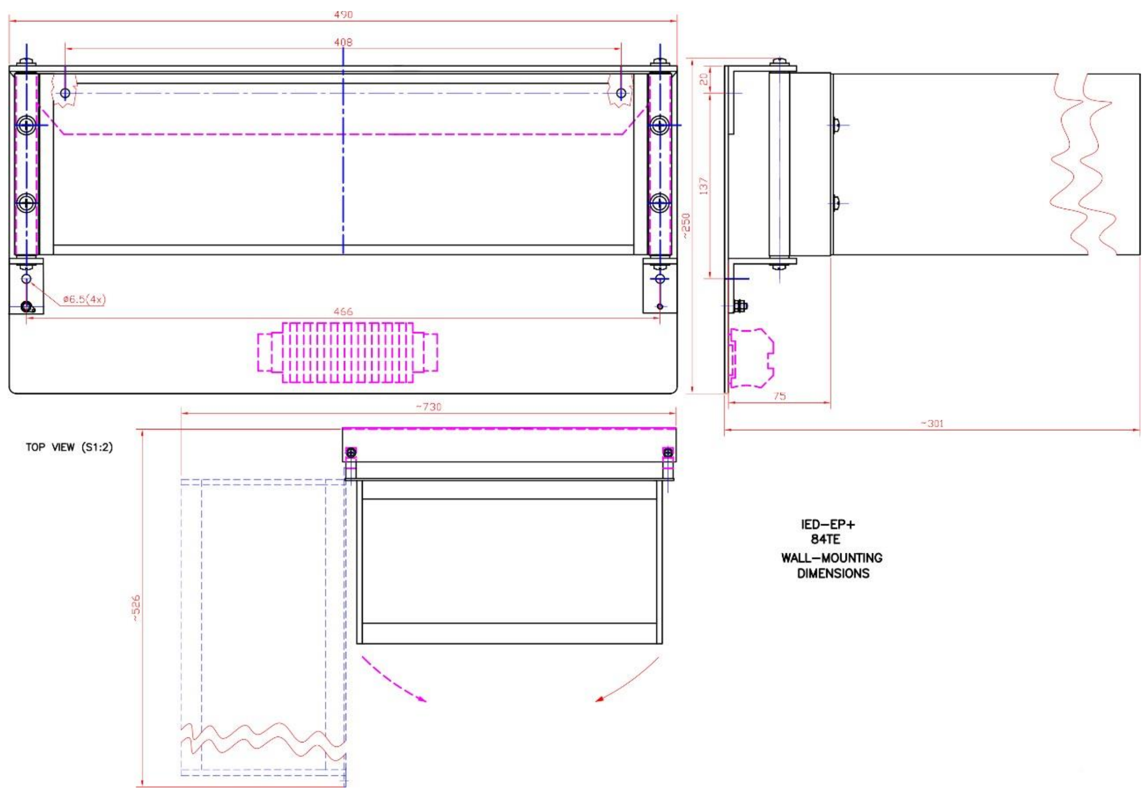


Figure 21-17 Dimensions for wall mounting of 84 HP devices (lower terminals only)

1.2.23.5. Din rail mounting of 24 HP panel instrument case

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

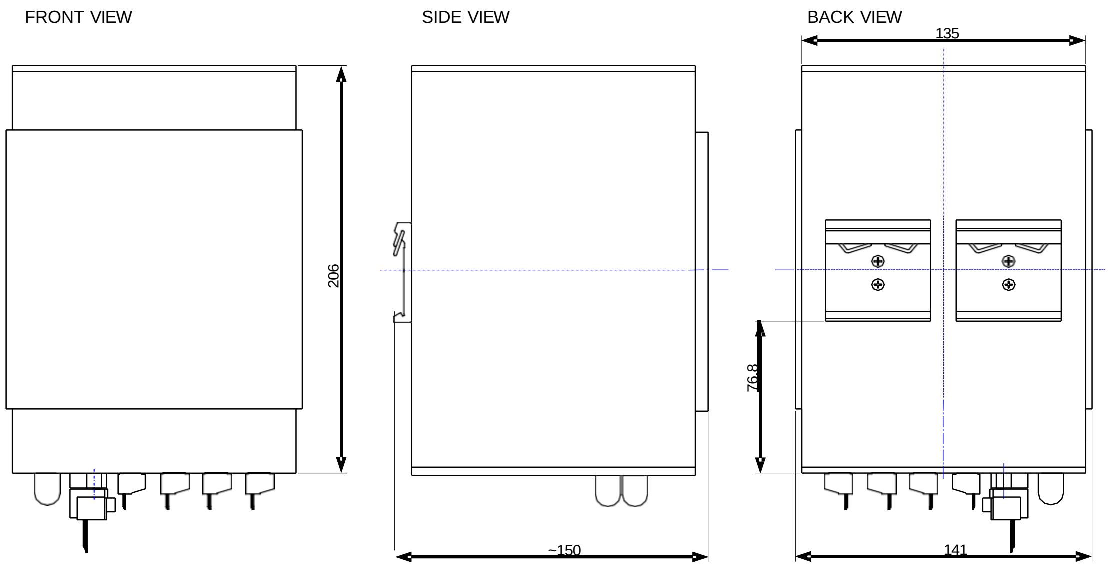


Figure 21-18 Dimensions for din rail mounting of 24 HP panel instrument case

1.2.23.6. IP54 rated mounting kit

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

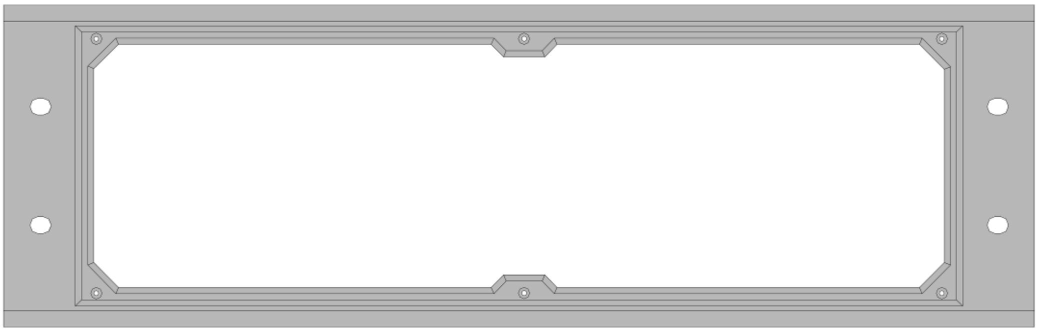


Figure 21-19 84 HP IP frame front view

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!

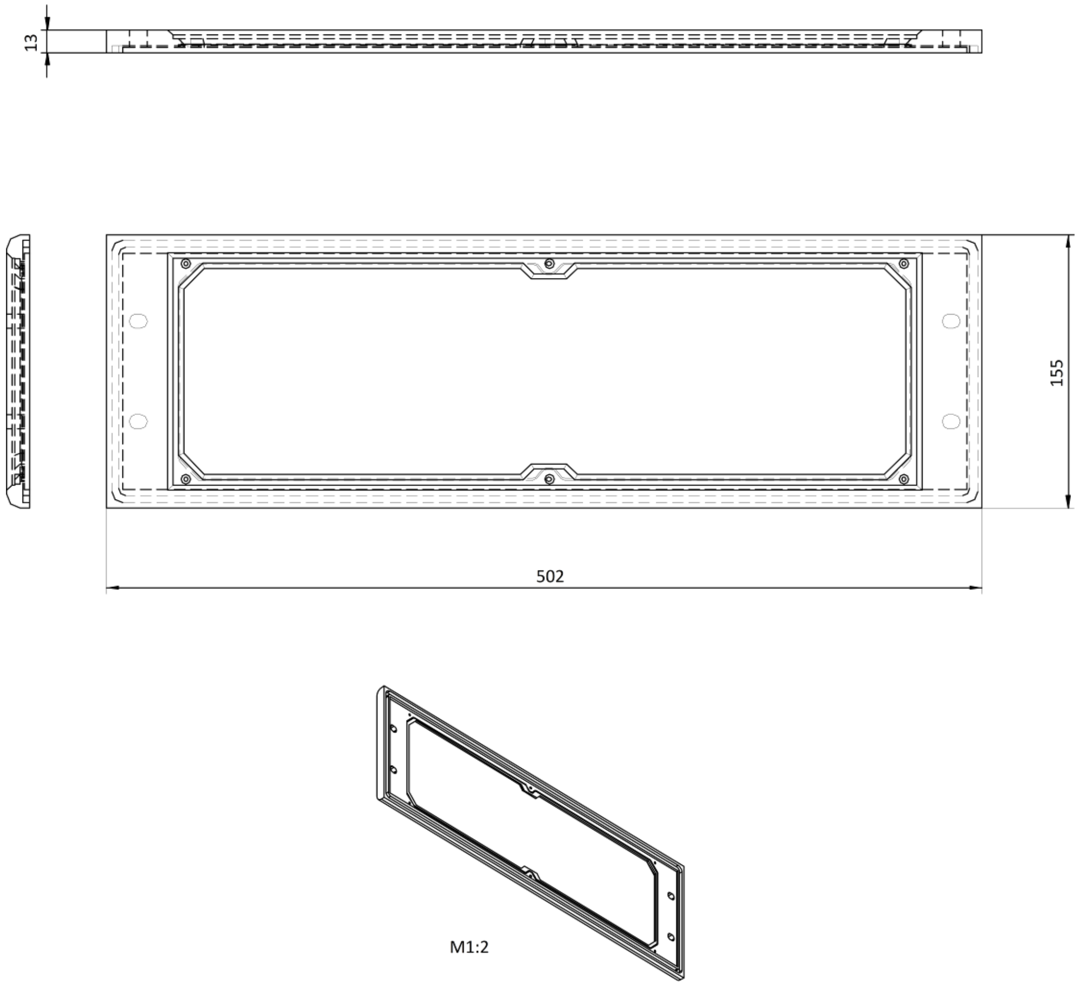


Figure 21-21: 84 HP IP frame dimensions

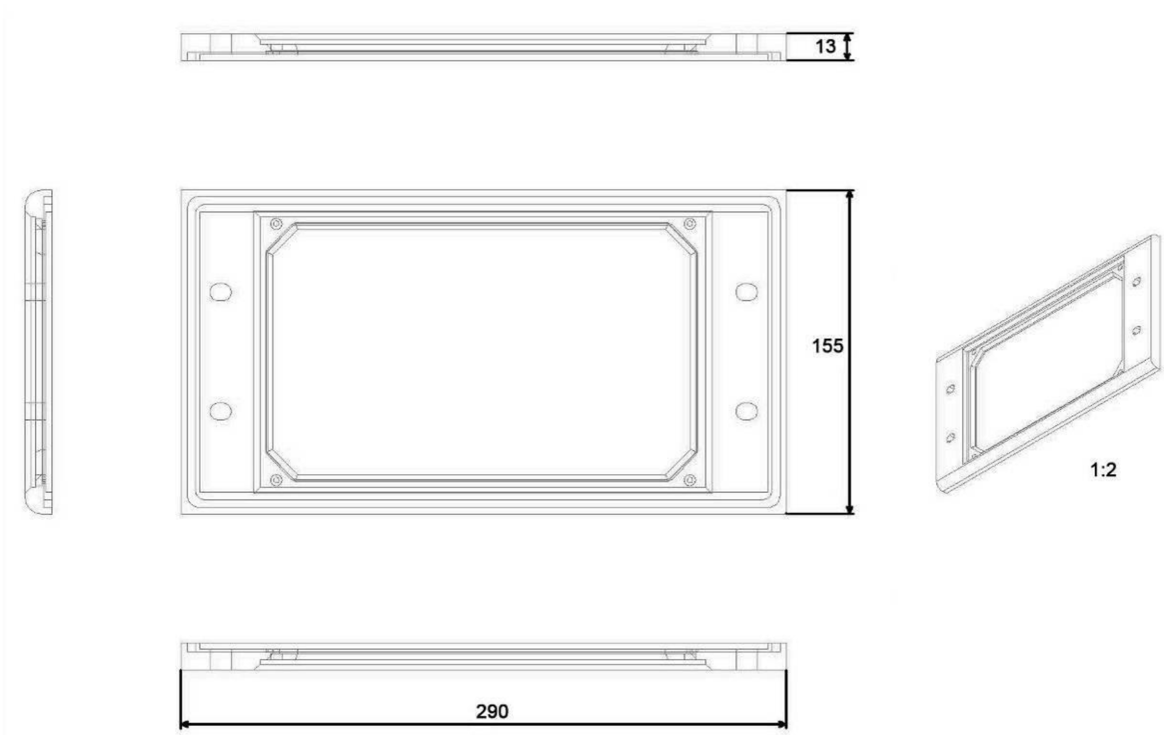


Figure 21-22 42 HP IP frame dimensions

1.2.23.7. Fold-down mounting

1.2.23.7.1. Fold-down mounting without terminals

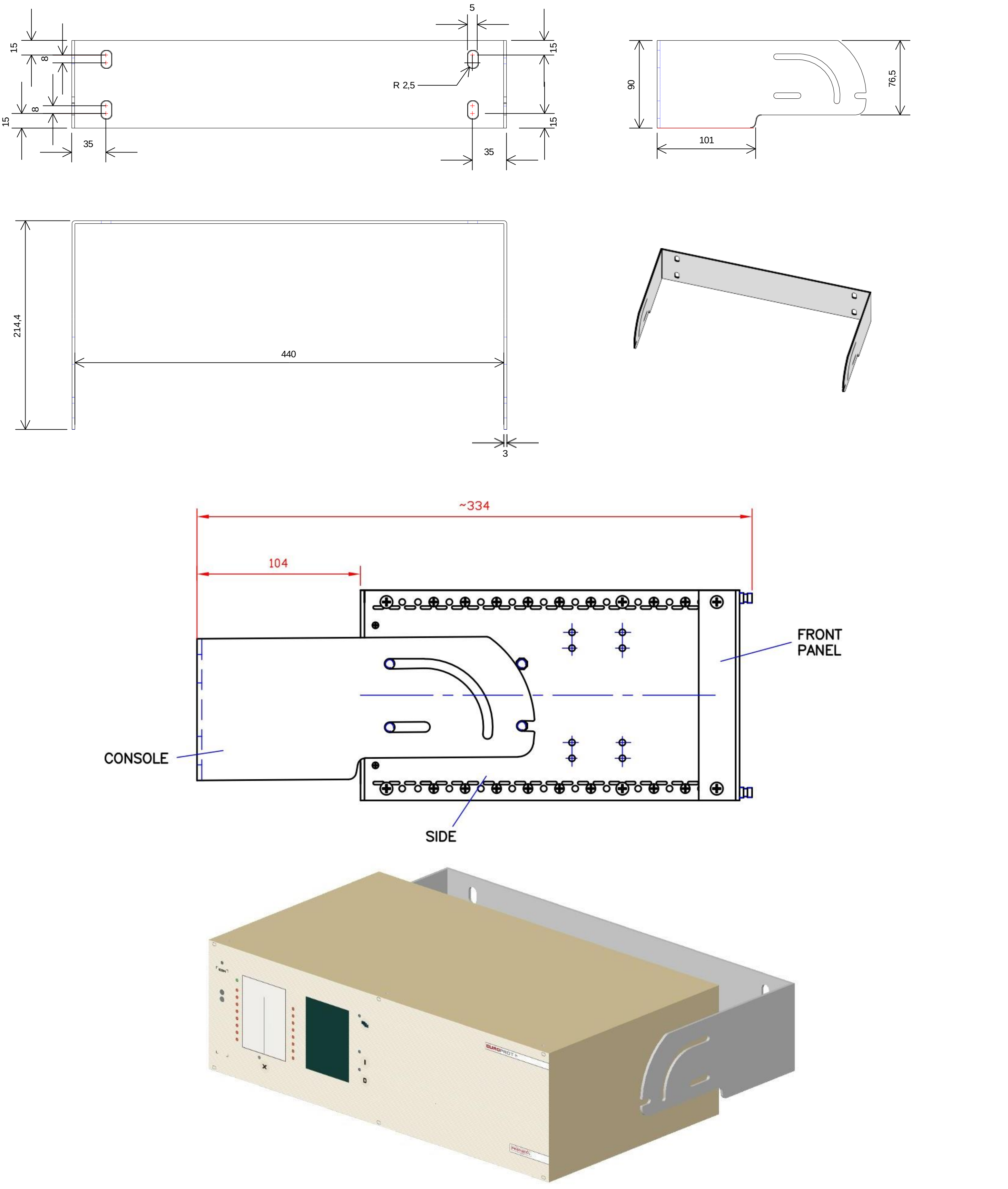


Figure 21-23 84 HP fold-down mounting

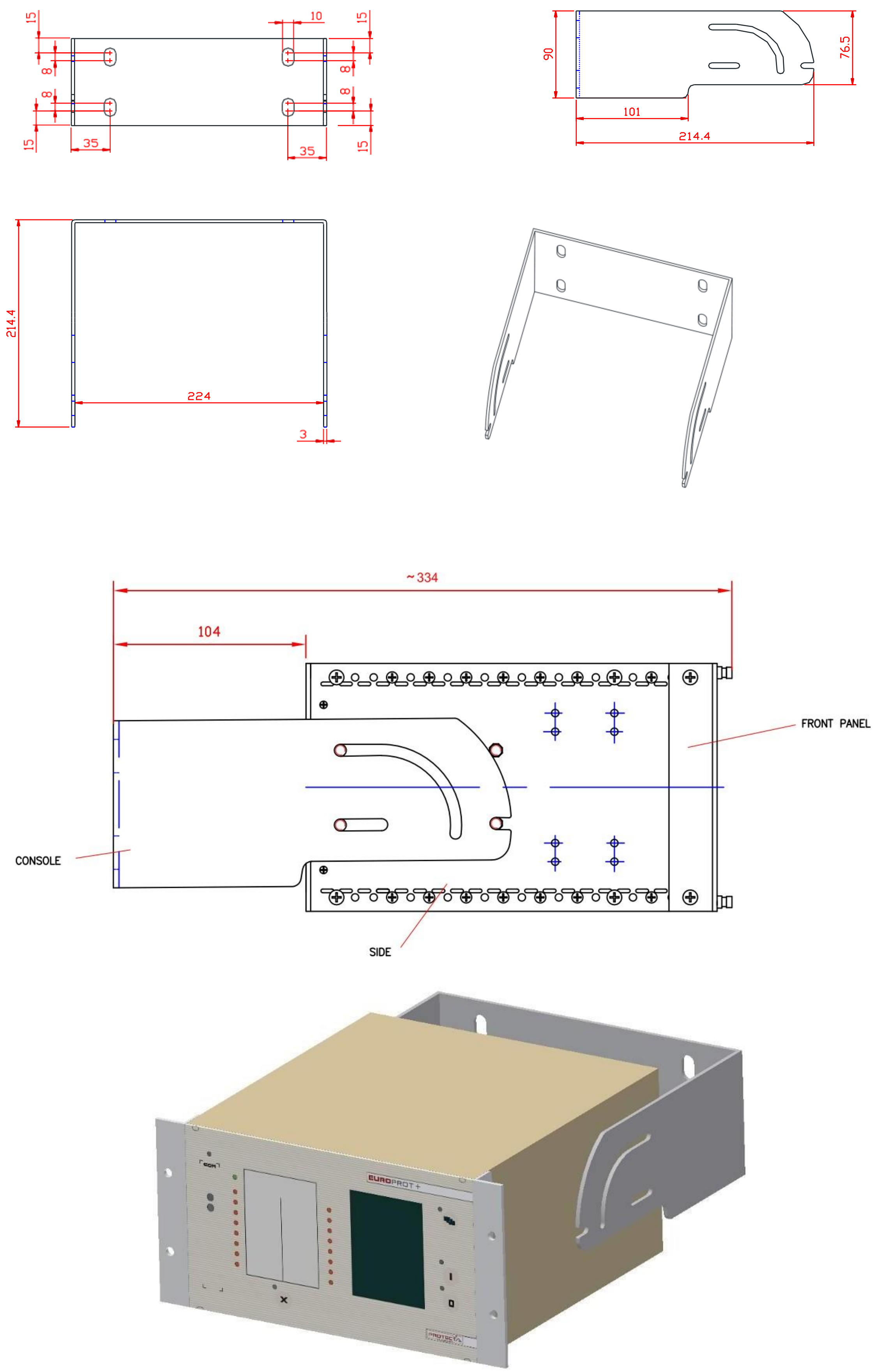


Figure 21-24 42 HP fold-down mounting

1.2.23.7.2. Fold-down mounting with terminals

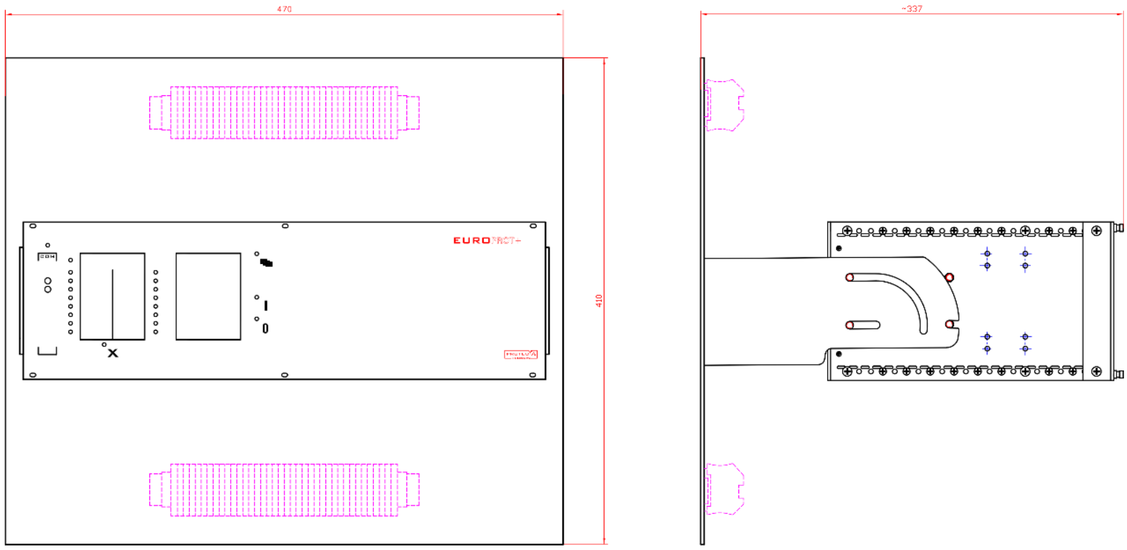


Figure 21-25 Fold-down mounting with terminals for 84HP devices

*fastening points are customized

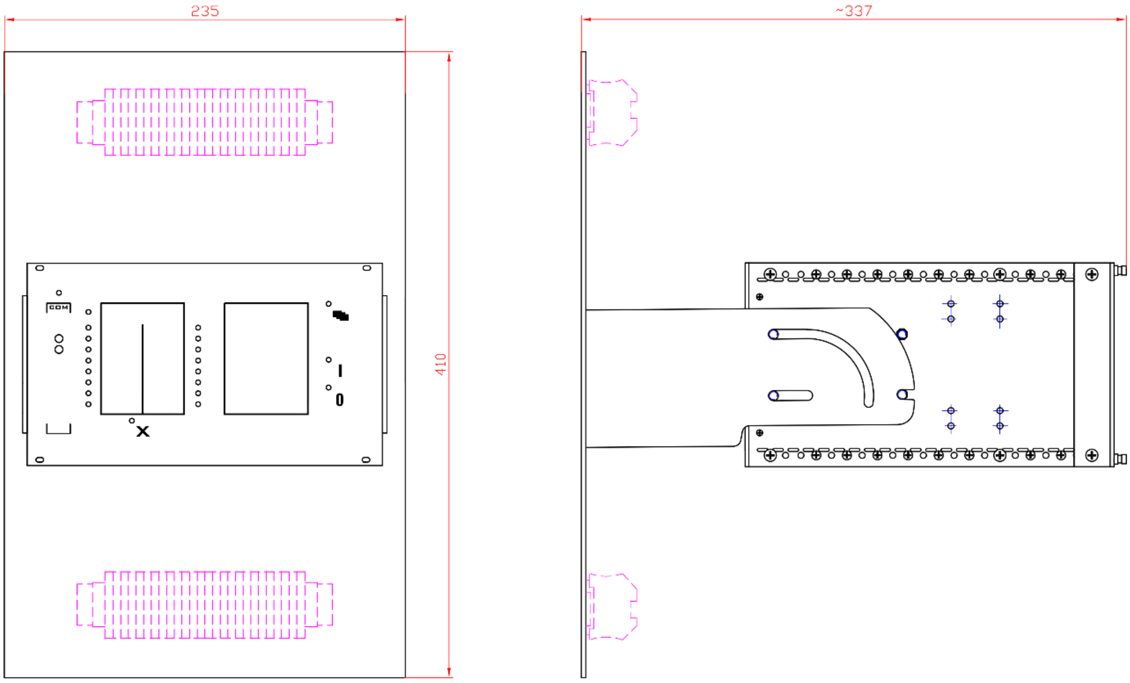


Figure 21-26 Fold-down mounting with terminals for 42HP devices

1.2.23.8. 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).

1.2.23.9. Remote HMI devices

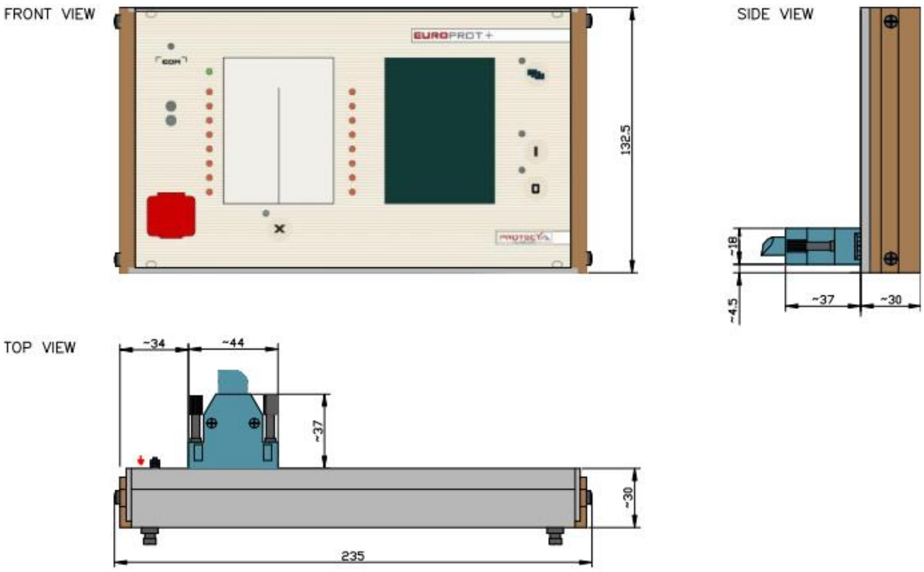


Figure 21-27 Dimensions for 42 HP wide remote HMI

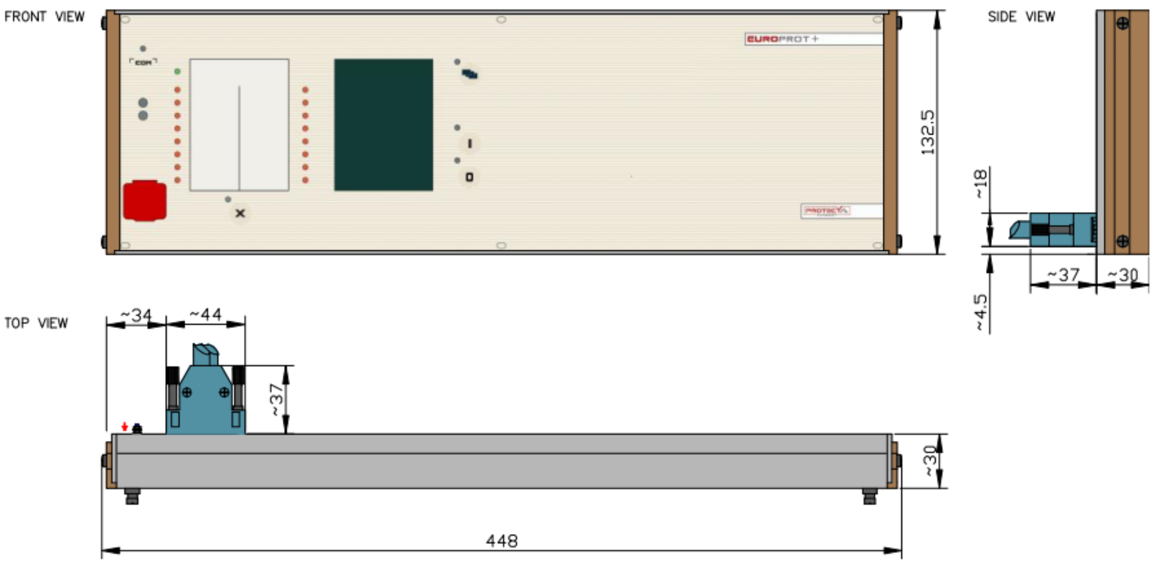


Figure 21-28 Dimensions for 84 HP wide remote HMI

1.2.24. 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

1.2.24.1. 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**.

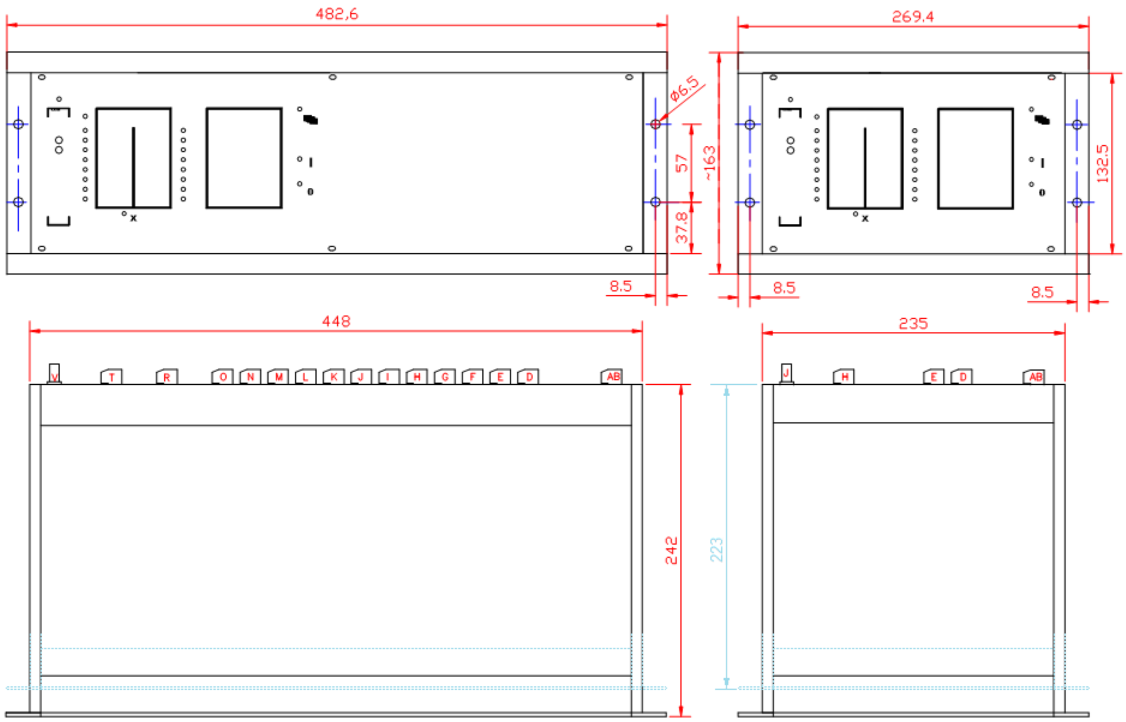


Figure 22-1 Dimensions for flush mounting of the previous 84HP and 42HP single rack, including the new (shorter) rack dimensions as well.

1.2.25. Remote I/O (RIO) server description

1.2.25.1. 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

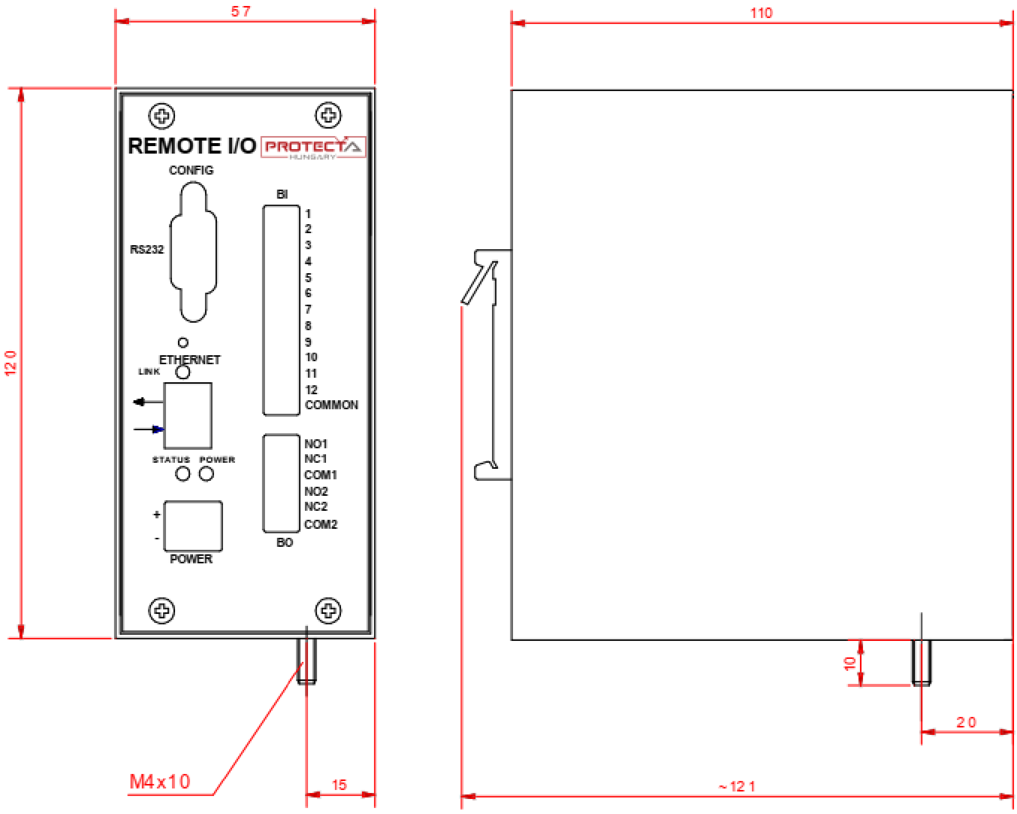


Figure 1-3 Remote I/O dimensions

1.2.25.2. Application

1.2.25.2.1. Connectors, LEDs

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

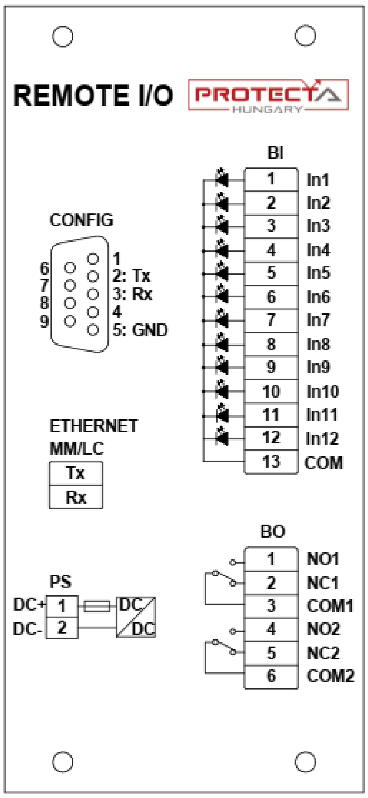


Figure 2-1 Connectors of the device

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

1.2.25.2.2. 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.

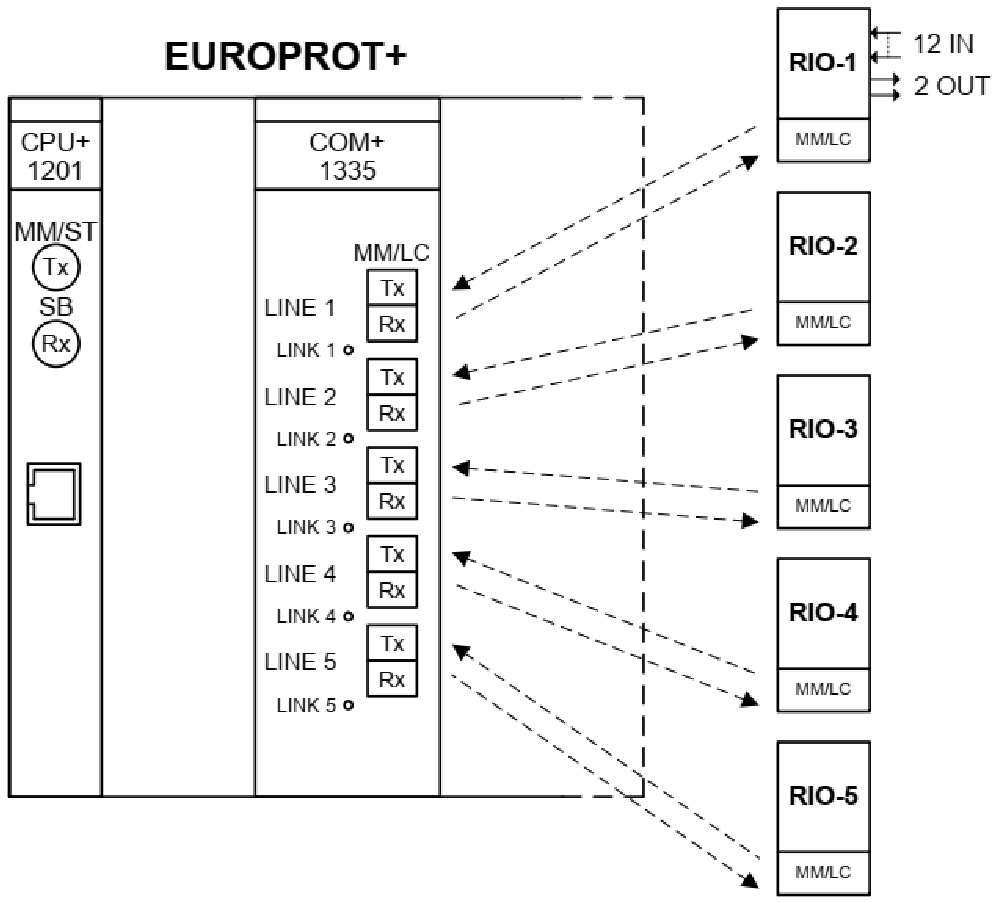


Figure 2-2 Wiring of the Remote I/O-s

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.

1.2.25.3. 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

1.2.25.3.1. SCPU/PS sub-module

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

1.2.25.3.1.1. 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*

1.2.25.3.1.2. 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**

1.2.25.3.2. SO12/R2 sub-module

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

1.2.25.3.2.1. 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.

1.2.25.3.2.2. 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

1.2.25.4. General data

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

1.2.25.4.1. 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 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

1.2.25.5. Mechanical data

1.2.25.5.1. General mechanical data

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

1.2.25.5.2. 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.

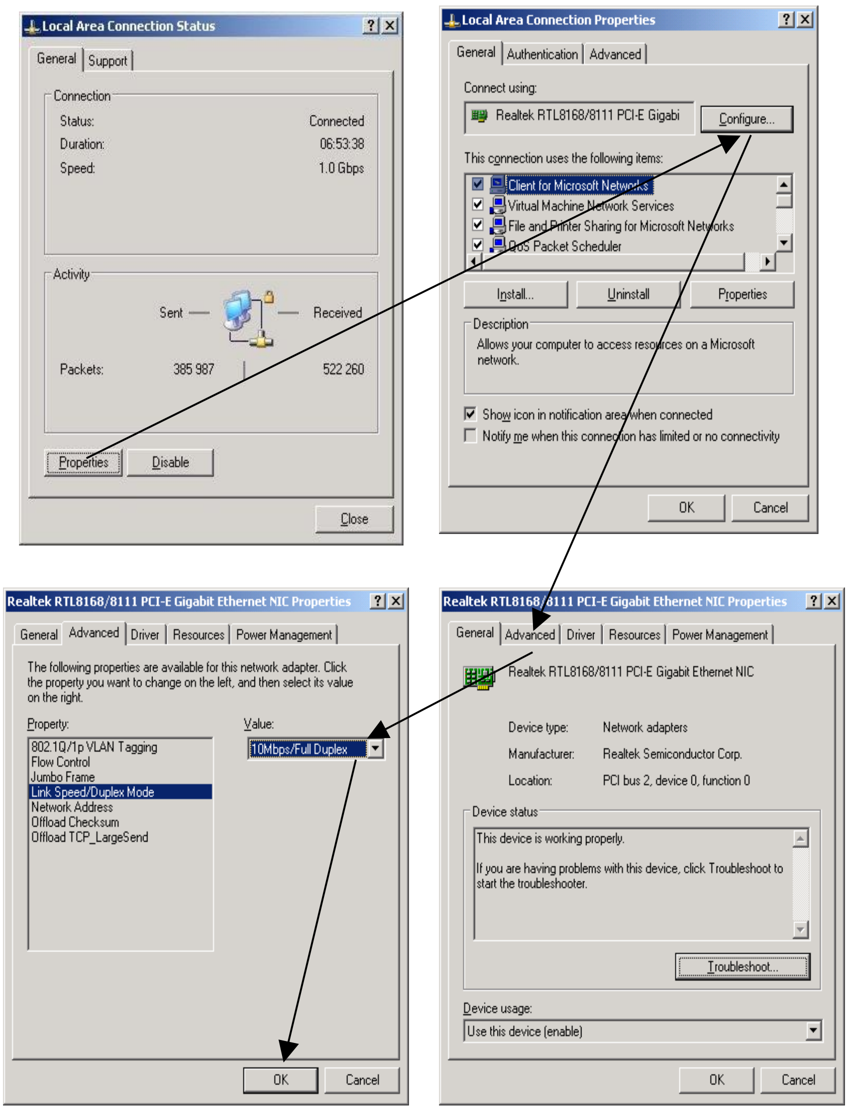
1.2.26. Technical notes on EOB interoperability

1.2.26.1. Description

We experienced some interoperability issues regarding front panel communication with EP+ devices. The link establishement 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 establishement failure. In this case the operating system periodically signals that interface is connected, then disconnected, then connected etc.

1.2.26.2. 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



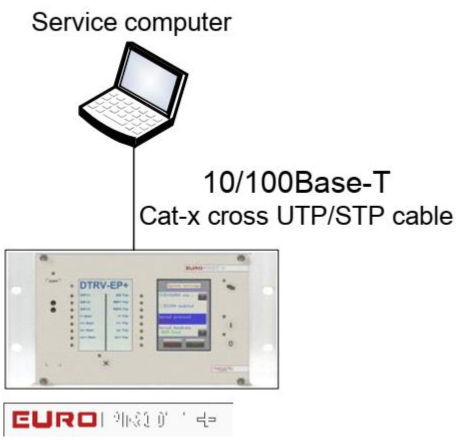
1.2.26.3. Workaround

- 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

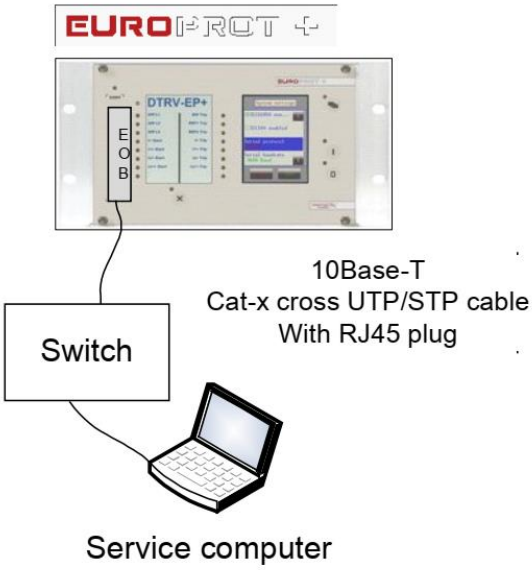
    - if the device equipped with 10/100Base-Tx station bus interface (RJ45) then connect Your computer directly to the EP+ via a crossed CATx cable

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.



1.2.26.4. Further details

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

c

1.2.27. EP+ Installation manual

USED SYMBOLS

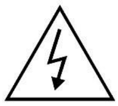
Symbols on devices:

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

1.2.27.1. 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.

1.2.27.2. Equipment handling

1.2.27.2.1. Unpacking

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

1.2.27.2.2. 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.

1.2.27.2.3. 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.

1.2.27.3. Mounting

1.2.27.3.1. 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, plyers, wrenches, etc. are necessary. For safety aspects, mechanical protective gloves shall be used to avoid injuries.

1.2.27.3.2. 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).

1.2.27.3.3. 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 betweena two EP+ devices must be at least 10 cm.

1.2.27.3.4. 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.

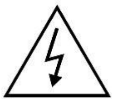
1.2.27.3.5. Safety aspects

1.2.27.3.5.1. Earth connections

1.2.27.3.5.1.1. Protective earth

The device shall be connected to the station earth system with a minimum of 2,5 mm^2 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.

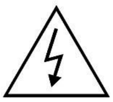


The protective earth connections should not be removed when the equipment is energized.

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

1.2.27.3.5.1.2. Stranded wires

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

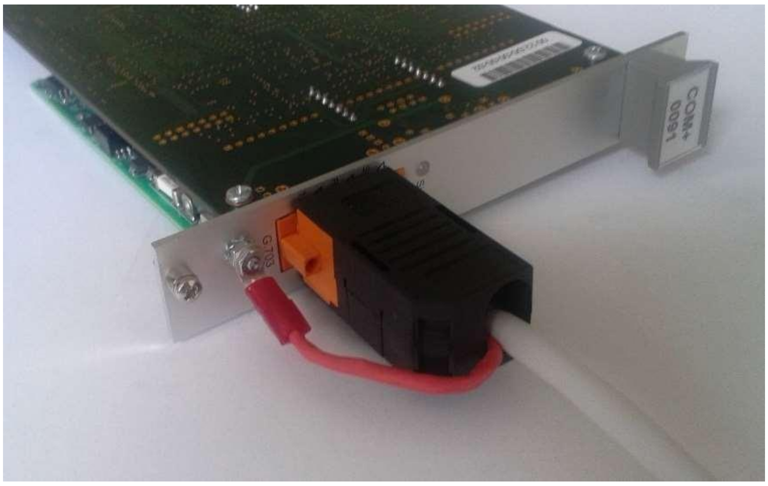


Loose strands of stranded wires can cause fire risk or electric shock. Insulated crimp terminals shall be used.

1.2.27.3.5.1.3. 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



1.2.27.3.5.1.4. CT and VT circuits

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

1.2.27.3.5.2. 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.

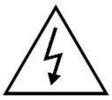
The CT connectors shall be fixed with screws provided. During the operation of the device, the CT connectors can be disconnected only after the CT circuits having short-circuited.

1.2.27.3.5.3. 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.

1.2.27.3.5.4. 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.

1.2.27.4. Wiring

1.2.27.4.1. 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.

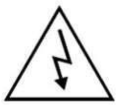
1.2.27.4.2. Connectors

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.

1.2.27.5. Deinstallation and Repair

1.2.27.5.1. 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.

1.2.27.5.2. 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.

1.2.27.5.3. 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 free slots for the options of the binary inputs and outputs are listed in the following tables. The default binary I/O module is the O6R5 module. The following modules can be chosen optionally.

Mixed I/O module:

- O6R5

Binary input modules:

- O8
- O12

Binary output modules:

- R8+/00
- R8+/C0
- R12+/0000
- R12+/4000
- R12+/4400

The configuration measures three phase currents, the residual current component and additionally three phase voltages and the busbar voltage. These measurements allow, in addition to the current- or voltage-based functions, directionality extension of the configured phase and residual overcurrent functions. It is intended to protect overhead line or cable networks. The choice of the functions is extended with the automatic reclosing function and synchrocheck. The configuration is designed to meet the requirements of a medium voltage field unit.

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

The configured protection functions are listed in Table 2-2.

Table 2-1 Binary I/O options for each variant

I/O MODULE	SLOT B	SLOT C	SLOT D	SLOT E
VARIANT 0	Default	Free	Free	Free
VARIANT 1	-	-	Default	Free
VARIANT 2	-	-	Default	Free
VARIANT 3	-	-	Default	Free
VARIANT 4	-	-	Default	Free
VARIANT 5	-	-	Default	Free
VARIANT 6	-	-	Default	Free
VARIANT 7	-	Free	Default	-

Table 2-2 Protection functions

Protection function	IEC	ANSI	Variant 0	Variant 1	Variant 2	Variant 3	Variant 4	Variant 5	Variant 6	Variant 7
Distance protection	Z <	21				1				
Overexcitation protection	V / Hz	24			1					
Synchrocheck	SYN	25				1			1	
Undervoltage protection	U <, U <<	27			2	1			2	
Directional overpower protection	P >	32				1				
Directional underpower protection	P <	37				1				
Undercurrent protection	I <	37		1						
Negative sequence overcurrent protection	I2 >	46		1	1	1	1	1		
Negative sequence overvoltage protection	U2 >	47			2	1				
Motor start-up supervision		48								
Line thermal protection	T >	49L		1	1	1		1		
Motor thermal protection	T >	49M		1						
Breaker failure protection	CBFP	50BF		1	1	1	1	2		
Instantaneous overcurrent protection	I >>>	50		1	1	1	1	2		
Residual instantaneous overcurrent protection	Io >>>	50N		1	1	1	1	2		
Phase overcurrent protection	I >, I >>	51		2	2	2	2	2		
Capacitor unbalance protection		51C		op.	op.					
Residual overcurrent protection	Io >, Io >>	51N		2	2	1	2	2		
Voltage dependent overcurrent protection	I > U <	51V			1					
Overvoltage protection	U >, U >>	59			2	1			2	
Residual overvoltage protection	Uo >, Uo >>	59N			2	1			2	
Capacitor overvoltage protection		59C		op.						
Current transformer supervision		60		1	1	1	1	1		
Voltage transformer supervision		60			1	1				
Starts per hour	I^{2}t	66		1						
Directional overcurrent protection	I Dir >	67			2	2				
Residual directional overcurrent protection	Io Dir >	67N			2	2				
Inrush detection	I2h >	68		1	1	1	1	1		
Vector jump protection	ΔφU >	78			1					
Auto-reclose	0 → 1	79		1	1	1	1			
Overfrequency protection	f >, f >>	81O			2	2			2	
Underfrequency detection	f <, f <<	81U			2	2			2	
Rate of change of frequency protection	df/dt	81R			2	2			2	
Generator/Motor differential protection	3IdG >, 3IdM	87G / 87M						op.		
Line differential protection	3IdL >	87L					1			
Restricted earth fault protection	REF	87N			op.			1		H
Transformer differential protection	3IdT >	87T						1		H*

op.: optional
H: high impedance differential protection
**mutually exclusive option*

3. Software configuration

3.1. Protection functions

The **Variant 1** configuration measures three phase currents and the zero sequence current component. It is intended to protect overhead line, cable networks and motors. The choice of the functions is extended with the automatic reclosing function. The realized current-based protection functions, including thermal replica protection function, are listed in the Table below.

Protection functions	IEC	ANSI	Variant 1
Three-phase instantaneous overcurrent protection	I >>>	50	X
Three-phase time overcurrent protection	I >, I >>	51	X
Residual instantaneous overcurrent protection	Io >>>	50N	X
Residual time overcurrent protection	Io >, Io >>	51N	X
Negative sequence overcurrent protection	I_2 >	46	X
Thermal protection	T >	49	X
Undercurrent protection	3IdB >	37	X
Inrush detection	I2h >	68	X
Startup supervision with restart inhibit		66	X
Auto-reclose	0 - > 1	79	X
Current unbalance protection		60	X
Breaker failure protection	CBFP	50BF	X

Table 1 The protection functions of the Variant 1 configuration

The configured functions are drawn symbolically in the Figure below.

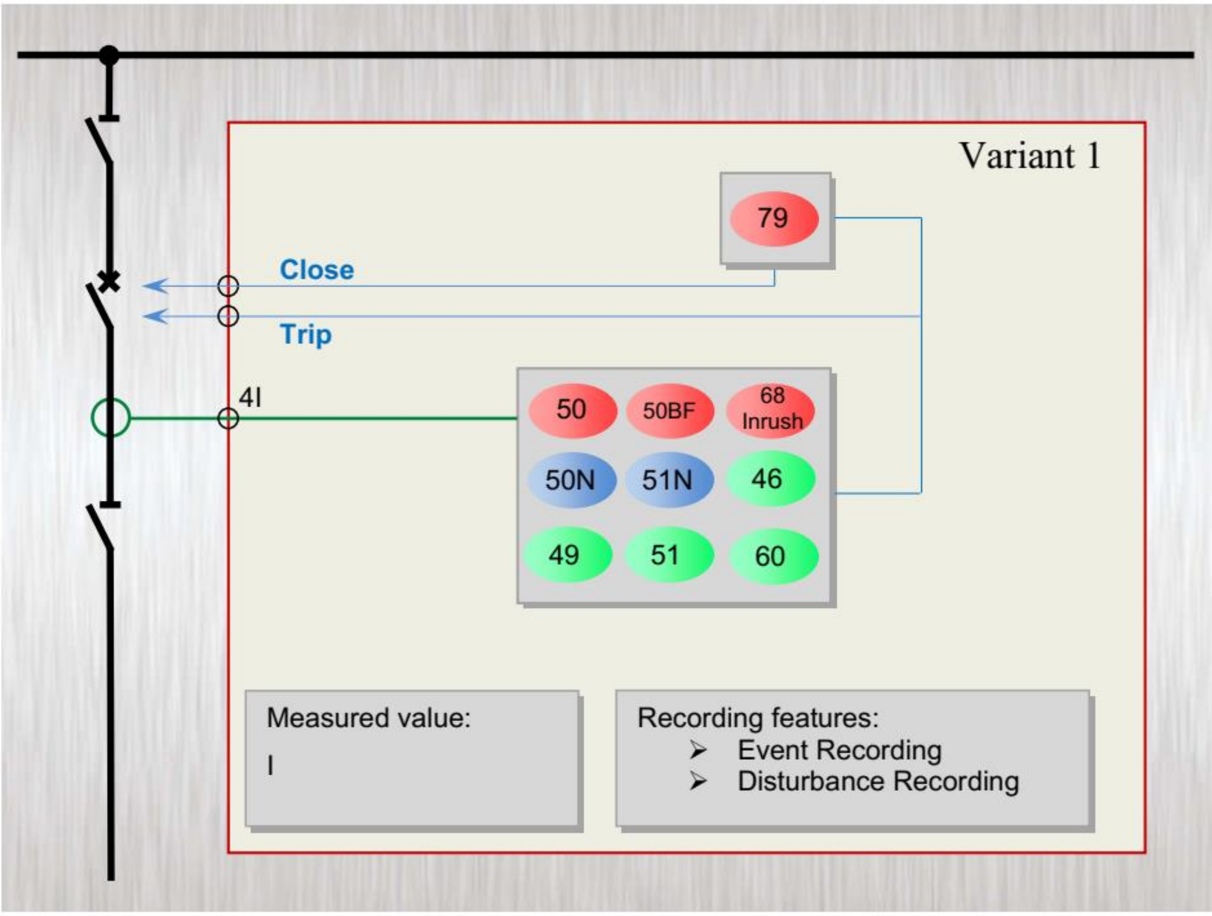


Figure 1 Implemented protection functions

3.1.1. Loss-of-load (undercurrent) protection function

The loss-of-load (undercurrent) protection function operates when the current decreases below a predetermined value.

This protection function can be applied for fan or pump drives, where the flowing media provides cooling for the motor itself. If this cooling stops, the motor must not remain in operation. In these cases the protection against low load after a given time delay disconnects the motor from the power supply.

It can also stop a motor in case of a failure in a mechanical transmission (e.g. conveyor belt).

A time delay may be required after start of the function to prevent operation during transients of the power systems.

The advantage of this function is its simplicity: no voltage measurement is needed, no power calculations are performed. The operation is based on phase currents only.

3.1.1.1. Operation of the loss-of-load (undercurrent) protection algorithm

The function starts if the current is between the start current as upper limit, defined by the parameter TUC37_StCurr_IPar_ (Start Current) and the minimal current as lower limit, defined by the parameter TUC37_Idle_IPar (Idle Current). These limit values are given in percent of the rated current of the protected object. This is defined by the parameter TUC37_CTRatio_IPar_ (InMotor/InCT). This parameter is also given as a percentage.

The function operates in all three phases individually but the general start signal output is generated if the conditions are satisfied in all three phases.

At starting, a time counter is triggered. The function generates a trip command if the time delay defined by the parameter TUC37_Delay_TPar (Time Delay) expires.

The timers operate in all three phases individually but the general trip command is output if the timers expire in all three phases.

The **inputs** of the loss-of-load protection function are
- the Fourier basic components of three phase currents,
- binary input,
- parameters.

The **outputs** of the loss-of-load protection function are
- the general start status signal,
- the general trip command.

3.1.1.2. Technical summary

3.1.1.2.1. Technical data

Function	Range	Accuracy
Current accuracy	20 – 2000% of In	±1% of In
Reset ratio at idle current	0.95 0.70	
Operating time accuracy		±5% or ± 15 ms whichever is greater
Minimum operating time	<60 ms	
Reset time	<60 ms	

Table 1-1 Technical data of the loss-of-load protection

3.1.1.2.2. Summary of the parameters

The parameters of the loss-of-load protection function are explained in the following tables.

Enumerated parameter

Parameter name	Title	Selection range	Default
Disabling or enabling the operation of the function			
TUC37_Oper_EPar_	Operation	Off,On	On

Table 1-2 The enumerated parameter of the loss-of-load protection function

Boolean parameter

Parameter name	Title	Default	Explanation
Disabling trip command			
TUC37_StOnly_BPar_	Start Signal Only	0	If this parameter is set to logic True, then no trip command is generated, only a start signal.

Table 1-3 The Boolean parameter of the loss-of-load protection function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Ratio of the rated current of the protected object and that of the current input of the device						
TUC37_CTRatio_IPar_	InMotor/InCT	%	20	150	1	100
Start current related to the rated current of the protected object, below which the function operates						
TUC37_StCurr_IPar_	Start Current	%	20	100	1	40
Minimal current related to the rated current of the protected object, above which the function operates						
TUC37_Idle_IPar_	Idle Current	%	1	20	1	10

Table 1-4 The integer parameters of the loss-of-load protection function

Timer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Time delay for the trip command:						
TUC37_Delay_TPar_	Time Delay	msec		60000	1	100

Table 1-5 The timer parameter of the loss-of-load protection function

3.1.1.2.3. Binary output status signals

The **binary output status signals** of the loss-of-load protection function.

Binary output signals	Signal title	Explanation
Start signal of the function block		
TUC37_GenSt_GrI_	General Start	Start signal of the function block
Trip command of the function block		
TUC37_GenTr_GrI_	General Trip	Trip command of the function block

Table 1-6 The binary output status signals of the loss-of-load protection function

3.1.1.2.4. Binary input status signals

The **binary inputs** are signals influencing the operation of the loss-of-load protection function. These signals are the results of logic equations graphically edited by the user.

Binary input signal	Signal title	Explanation
Disabling the function		
TUC37_Blk_GrO_	Block	The programmed True state of this input disables the operation of the function

Table 1-7 *The binary input signal of the loss-of-load protection function*

3.1.1.2.5. The function block

The function block of the loss-of-load protection 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.

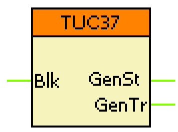


Figure 1-1 *The function block of the loss-of-load protection function*

3.1.2. 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.

3.1.2.1. Operating characteristics

3.1.2.1.1. Definite time characteristic

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

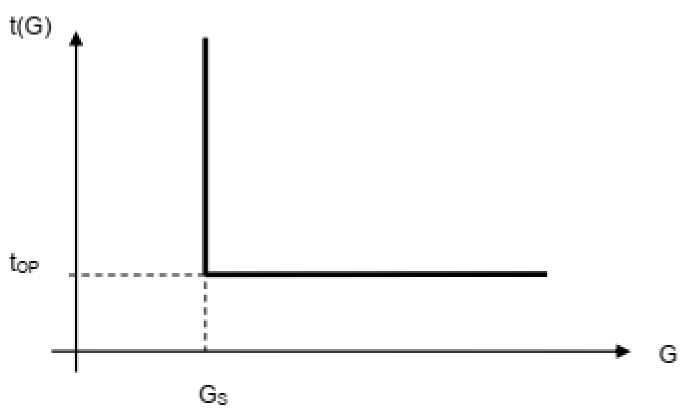


Figure 1-1 Overcurrent definite time characteristic

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).

c

3.1.2.1.2. 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.

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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).

<table>
<tr><th></th><th>IEC ref</th><th></th><th>k_r</th><th>α</th></tr>
<tr><td>1</td><td>A</td><td>IEC Inv</td><td colspan="2" rowspan="4">Resetting after fix time delay, according to preset parameter TOC46_Reset_TPar_ “Reset delay”</td></tr>
<tr><td>2</td><td>B</td><td>IEC VeryInv</td></tr>
<tr><td>3</td><td>C</td><td>IEC ExtInv</td></tr>
<tr><td>4</td><td></td><td>IEC LongInv</td></tr>
<tr><td>5</td><td></td><td>ANSI Inv</td><td>0,46</td><td>2</td></tr>
<tr><td>6</td><td>D</td><td>ANSI ModInv</td><td>4,85</td><td>2</td></tr>
<tr><td>7</td><td>E</td><td>ANSI VeryInv</td><td>21,6</td><td>2</td></tr>
<tr><td>8</td><td>F</td><td>ANSI ExtInv</td><td>29,1</td><td>2</td></tr>
<tr><td>9</td><td></td><td>ANSI LongInv</td><td>4,6</td><td>2</td></tr>
<tr><td>10</td><td></td><td>ANSI LongVeryInv</td><td>13,46</td><td>2</td></tr>
<tr><td>11</td><td></td><td>ANSI LongExtInv</td><td>30</td><td>2</td></tr>
</table>

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).

3.1.2.2. Structure of the negative sequence overcurrent protection algorithm

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

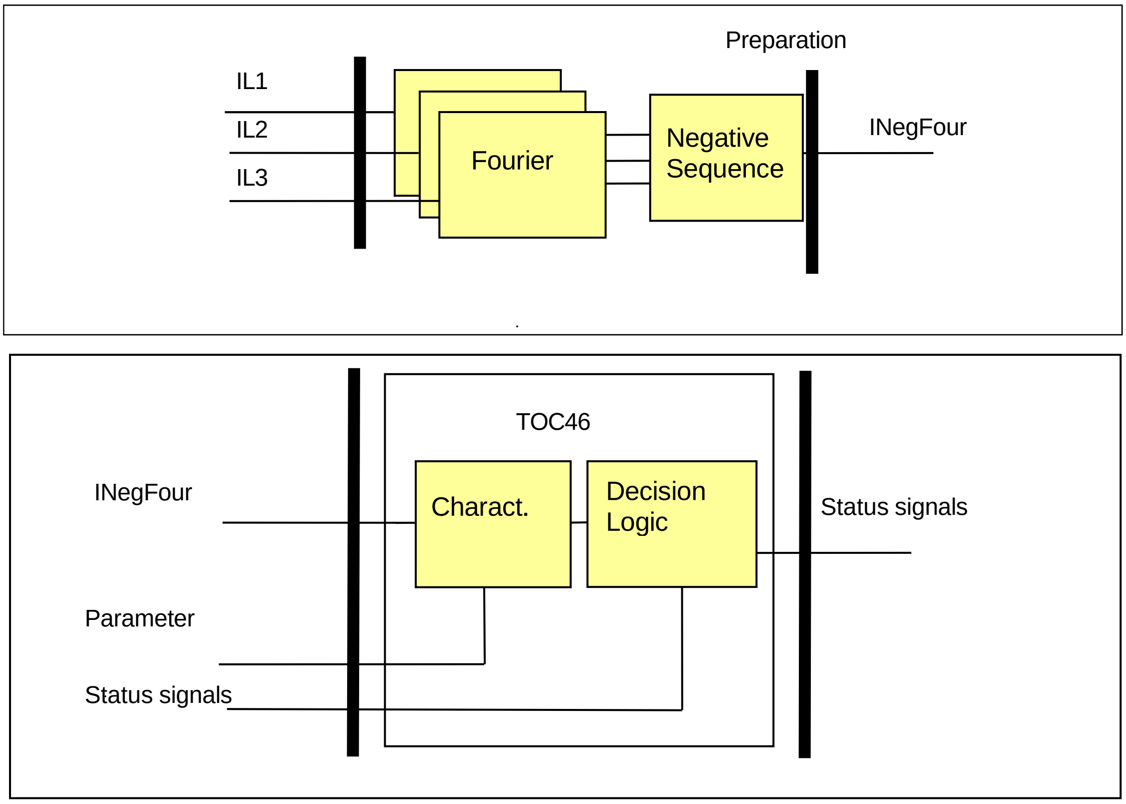

Figure 1-1 Structure of the negative sequence overcurrent protection algorithm

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.

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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.

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3.1.2.3. The Fourier calculation (Fourier)

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

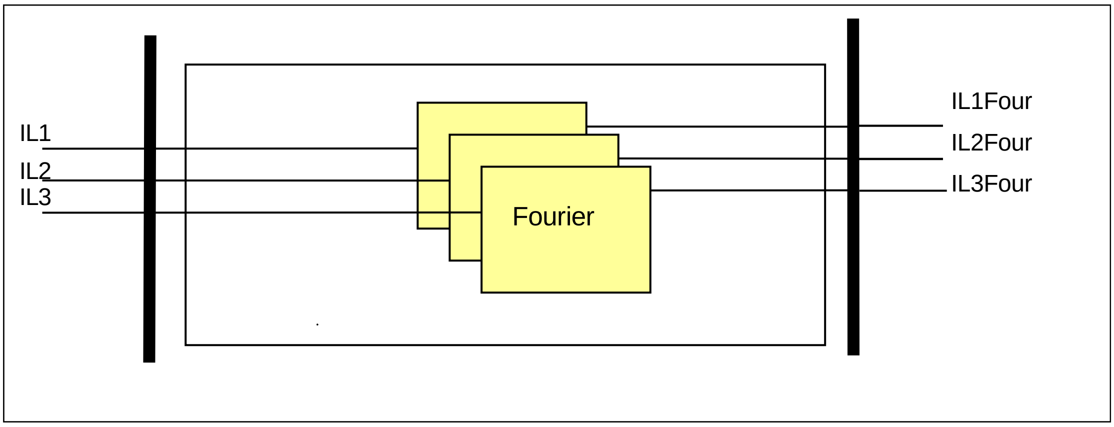

Figure 1-2 Schema of the Fourier calculation

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

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

3.1.2.4. 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).

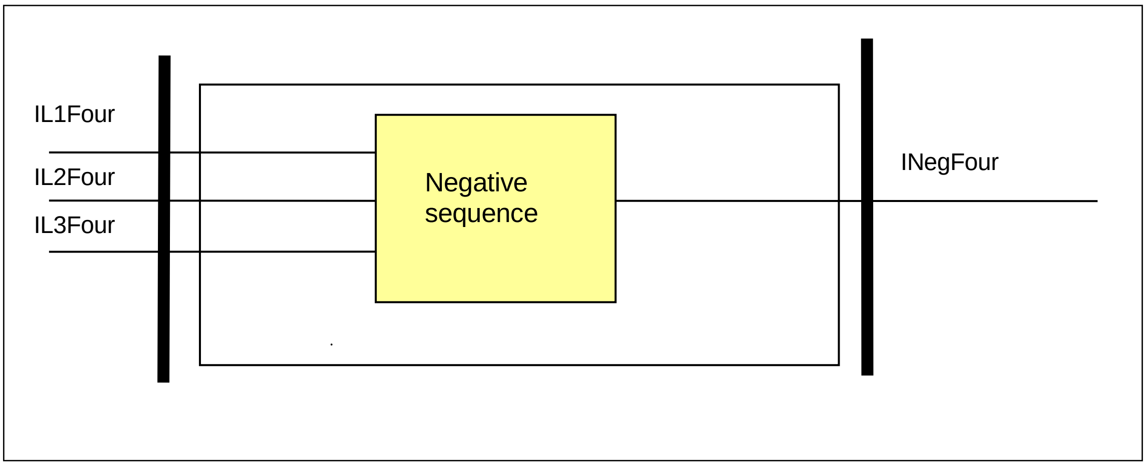

Figure 1-3 Schema of the negative sequence component calculation

c

3.1.2.5. 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.

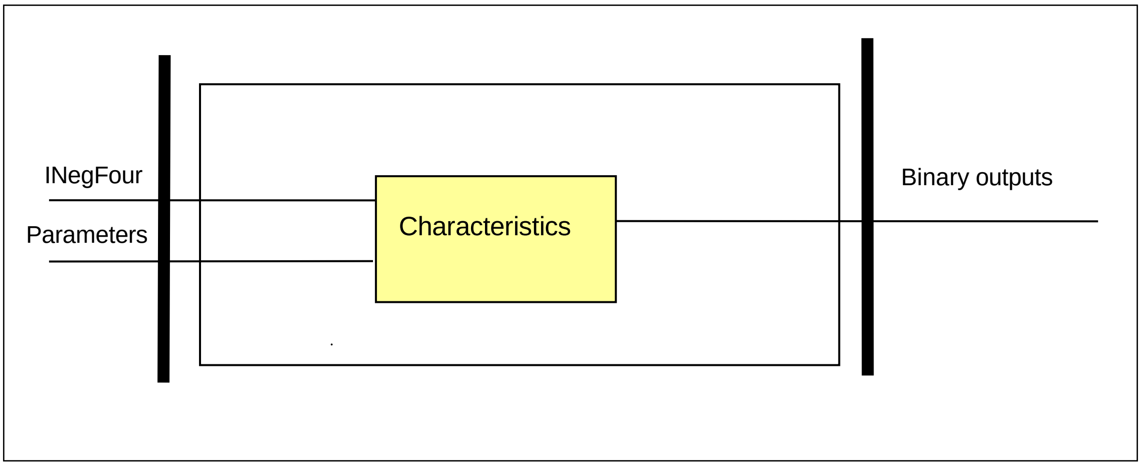

Figure 1-4 Schema of the characteristic calculation

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

Float parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Time multiplier of the inverse characteristics (OC module)						
TOC46_Multip_FPar_	Time Multiplier		0.05	15	0.01	1.0

**Valid for inverse type characteristics*

Table 1-5 The Float parameter of the negative sequence overcurrent protection

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Minimal time delay for the inverse characteristics:						
TOC46_MinDel_TPar_	Min Time Delay*	msec	40	60000	1	100
Definite time delay:						
TOC46_DefDel_TPar_	Definite Time Delay**	msec	40	60000	1	100
Reset time delay for the inverse characteristics:						
TOC46_Reset_TPar_	Reset Time*	msec	60	60000	1	100

**Valid for inverse type characteristics*

***Valid for definite type characteristics only*

Table 1-6 The timer parameters of the characteristics calculation module

The **binary output status signals** of the of the characteristics calculation module are listed in <u>Table *1-7*.</u>

Binary output signals	Signal title	Explanation
TOC46_St_GrI_	Start Neg	Starting of the function
TOC46_Tr_GrI_	Trip Neg	Trip command of the function

Table 1-7 The binary output status signals of the characteristics calculation module

3.1.2.6. The decision logic (Decision logic)

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

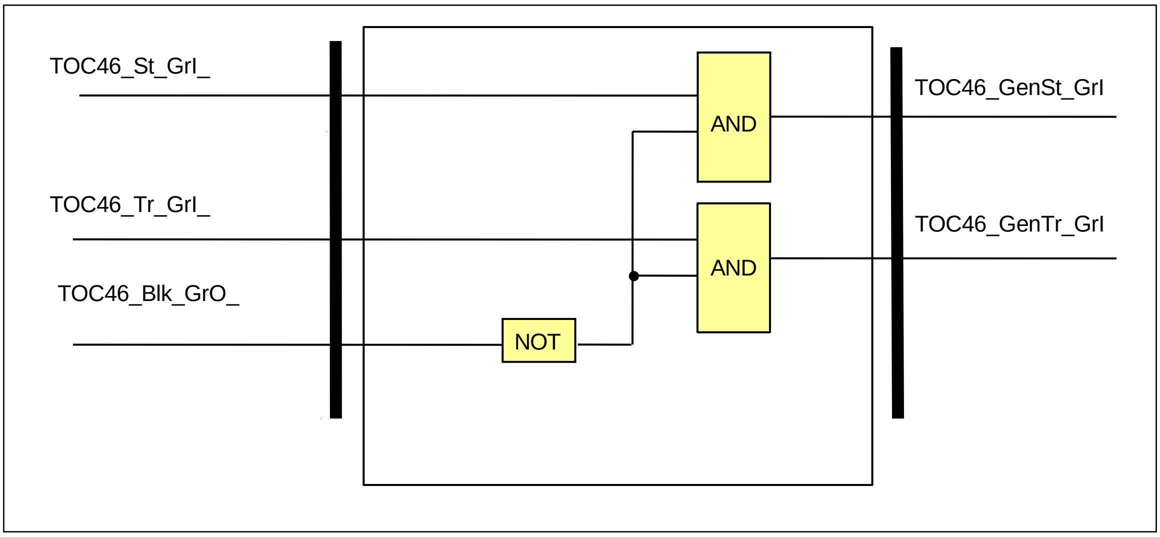

Figure 1-5 The logic scheme of the negative sequence overcurrent protection function

Binary status signals	Signal title	Explanation
TOC46_St_GrI_	Start	Starting of the function
TOC46_Tr_GrI_	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_GrI_	General Start	General starting of the function
TOC46_GenTr_GrI_	General Trip	General trip command of the function

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

3.1.2.7. Technical summary

3.1.2.7.1. Technical data

Function	Value	Accuracy
Operating accuracy	10 ≤ G_s [%] ≤ 200	< 2 %
Operate time accuracy		±5% or ±15 ms, whichever is greater
Reset ratio	0,95	
Reset time * Dependent time charact. Definite time charact.	approx. 60 ms	<2 % or ±35 ms, whichever is greater
Transient overreach		< 2 %
Pickup time at 2* 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

3.1.2.7.2. The parameters

The parameters are summarized in Chapter 3.1.1.5.

3.1.2.7.3. 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

3.1.2.7.4. 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

3.1.2.7.5. 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.

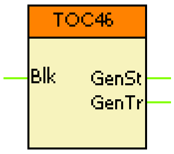

Figure 1-6 The function block of the negative sequence overcurrent protection function

3.1.3. Broken conductor protection

3.1.3.1. Application

The broken conductor protection function can be applied to detect a power lines and cables broken conductor condition or a single-pole breaker malfunction condition.

3.1.3.1.1. Mode of operation

By measuring the phase current input signals and compares the ratio of negative phase sequence current (I2) to positive phase sequence current (I1).

If the I2/I1 ratio is above the setting limit, the function generates a start signal. It is a necessary precondition of start signal generation that the *positive phase sequence current (I1) must be between **6.67%** and **100%** 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.

3.1.3.1.2. Operation principles

Figure *1-1* shows the structure of the broken conductor protection algorithm.

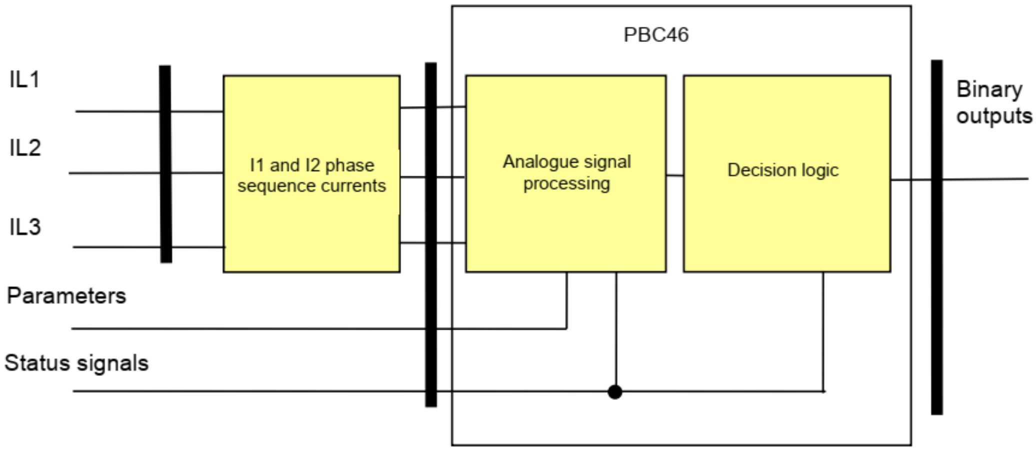

Figure 1-1 Structure of the broken conductor protection algorithm

The **inputs** of the preparatory phase are

- the three phase currents,

The **outputs** of the preparatory phase are

- positive phase sequence current (I1) and negative phase sequence current (I2) values of the fundamental Fourier component of three phase currents.
- the RMS value of the fundamental Fourier components of positive phase sequence current (I1) and negative phase sequence current (I2).

The **inputs** of the broken conductor function are

- the RMS value of the fundamental Fourier component of the positive phase sequence current (I1) and negative phase sequence current (I2),
- parameters,
- status signals.

The **outputs** are

- the binary output status signals.

The **software modules** of the broken conductor function:

Fourier calculations

These modules calculate the RMS values of the basic Fourier current components of the phase currents individually (not part of the PBC46 function).

Positive and negative sequence

This module calculates the basic Fourier current components of the positive and negative sequence currents, based on the Fourier components of the phase currents (not part of the PBC46 function).

Analogue signal processing

This module processes the positive and negative phase sequence current components 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.

3.1.3.1.3. 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 PBC46 function; they belong to the preparatory phase.

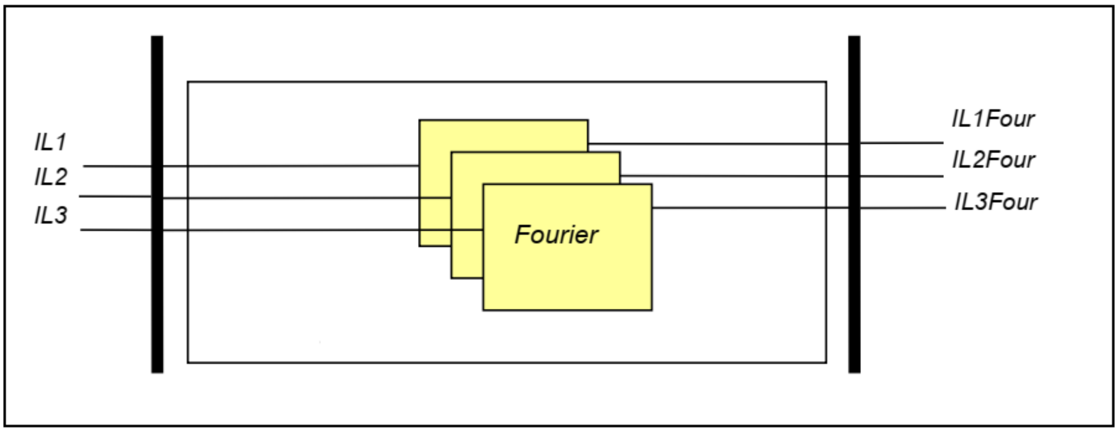

Figure 1-2 Principal scheme of the Fourier calculation

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).

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3.1.3.1.4. The positive and negative phase sequence calculation (Positive and negative sequence)

This module calculates the positive and 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 **outputs** are the basic Fourier components of the positive (IPosFour) and negative sequence current component (INegFour).

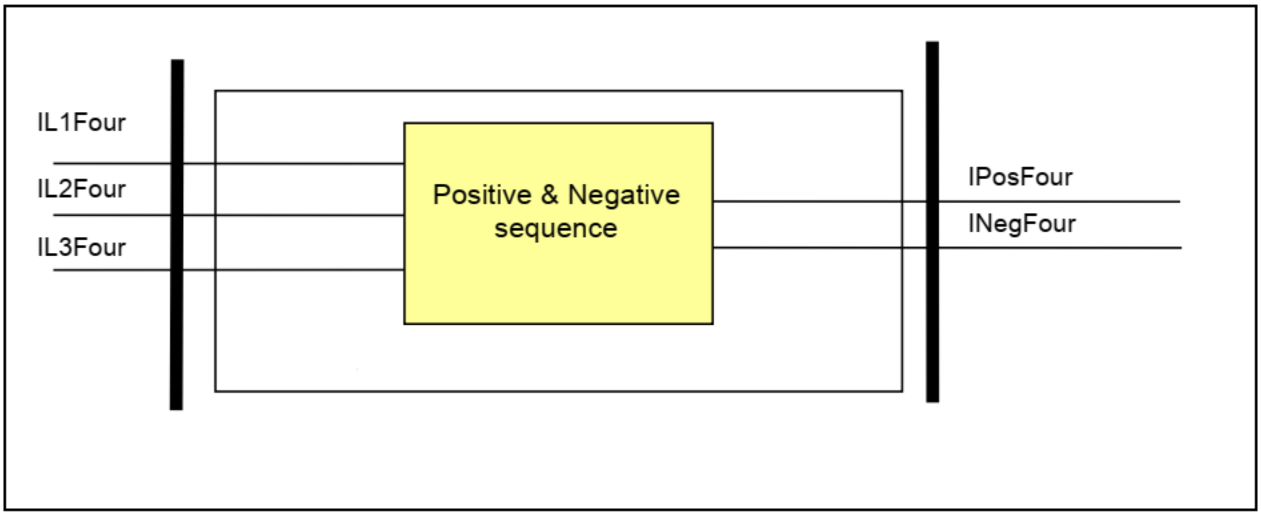

Figure 1-3 Schema of the sequence component calculation

3.1.3.1.5. The Analogue signal processing

This module processes the Fourier components of the phase currents to prepare the signals for the decision.

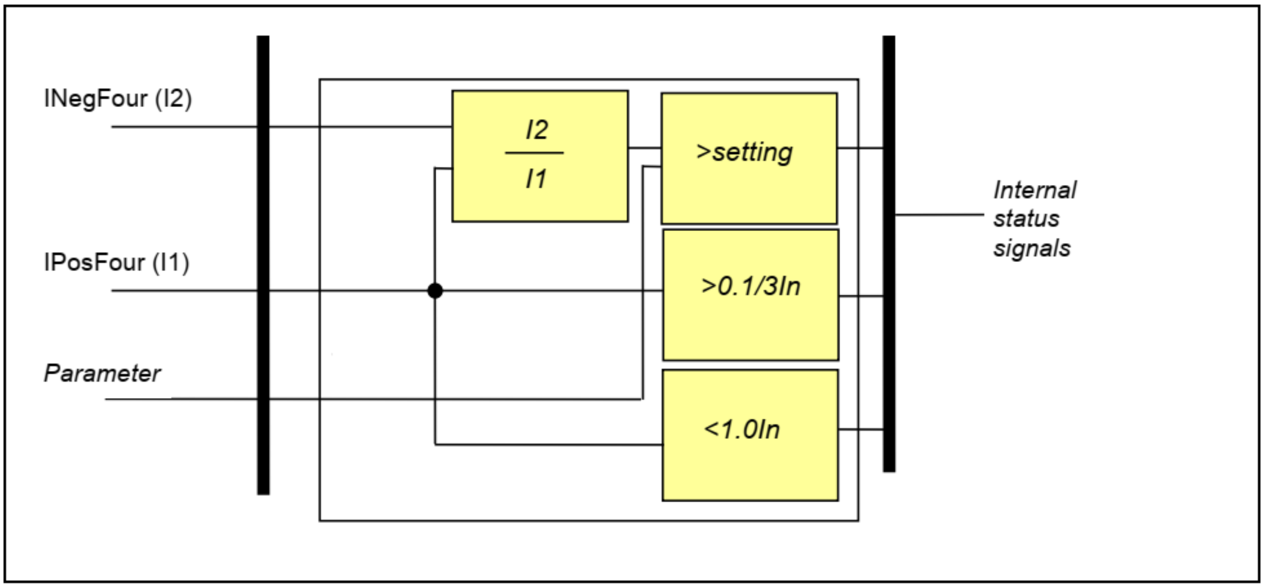

Figure 1-4 Principal scheme of the analogue signal processing

The **inputs** are the basic Fourier component of the positive (IPosFour) and negative sequence currents (INegFour) and parameters.

The **outputs** are internal binary signals:

- I2/I1> the ratio of negative sequence current (I2) to positive sequence current (I1) as a percentage is above the limit defined by the preset parameter PBC46_StCurr_IPar_ (Start current);
- I1>0.1/3In the positive phase sequence current (I1) value of the fundamental Fourier components of the phase currents is sufficient for evaluation;
- I1<1.0In the positive phase sequence current (I1) value of the fundamental Fourier components of the phase currents is sufficient for evaluation.

3.1.3.1.6. 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.

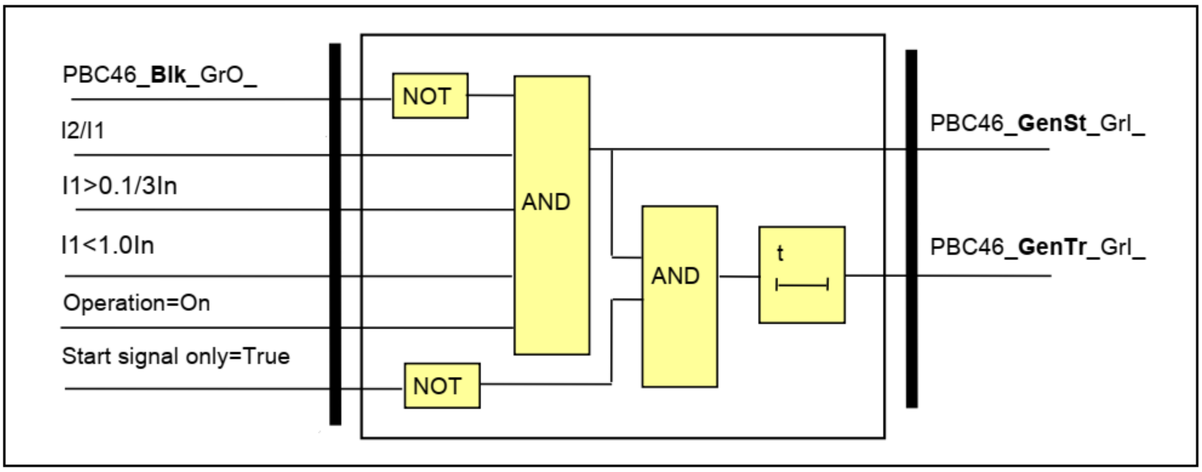

Figure 1-5 The logic scheme of the broken conductor function

The **inputs** are internal binary signals:

- I2/I1> the ratio of positive phase sequence current (I1) to negative phase sequence current (I2) as a percentage is above the limit defined by the preset parameter "Start current";
- I1>0.1/3In the positive phase sequence current (I1) value of the fundamental Fourier components of the phase currents is sufficient for evaluation;
- I1<1.0In the positive phase sequence current (I1) value of the fundamental Fourier components of the phase currents is sufficient for evaluation.

3.1.3.2. Broken conductor protection function overview

The graphic appearance of the function block of the broken conductor protection function is shown below. The block shows all binary input and output status signals which are applicable in the graphic equation editor.

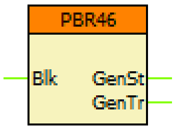

Figure 2-1 Graphic appearance of the function block of the broken conductor protection function

3.1.3.3. Settings

3.1.3.3.1. 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 broken conductor 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, but no trip signal.
Start Current	%	10 – 90	1	50	I2/I1 ratio setting
Time Delay	msec	100 – 60000	1	1000	Time delay (including the algorithm time, see Chapter 2.4 for more explanation)

3.1.3.4. Function I/O

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

3.1.3.4.1. Analogue inputs

The function uses the sampled values of a current input. This is defined in the configuration.

3.1.3.4.2. 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 broken conductor protection function

BINARY OUTPUT SIGNAL	EXPLANATION
PBC46_**Blk**_GrO_	Blocking input of the function

3.1.3.4.3. 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 broken conductor protection function

BINARY OUTPUT SIGNAL	SIGNAL TITLE	EXPLANATION
PBC46_**GenSt**_Grl_	General Start	General start signal of the function
PBC46_**GenTr**_Grl_	General Trip	General trip command of the function

3.1.3.4.4. Online data

Visible values on the *online data* page.

Table 2-4 Online displayed data of the broken conductor protection function

SIGNAL TITLE	DIMENSION	EXPLANATION
General Start	-	General start signal of the function
General Trip	-	General trip command of the function

3.1.3.4.5. 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 broken conductor protection function

EVENT	VALUE	EXPLANATION
General Start	off, on	General start signal of the function
General Trip	off, on	General trip command of the function

3.1.3.5. Technical data

Table 2-6 Technical data of the broken conductor protection function

FUNCTION	VALUE	ACCURACY
Pick-up starting accuracy		< 2 %
Reset ratio	0,95	
Min. operate time	70 ms	

3.1.3.6. 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.

3.1.4. Motor Startup Supervision

3.1.4.1.1. Monitoring the Startup

The available functions of the motor startup supervision provide optimal protection during the startup procedure.

The starting process, which is an extreme stress for the motor, is automatically detected based on the fact that the current is zero before starting (below the set *Idle Current* parameter), then it increases above that level. During the motor starting process, the duration of which is limited by the *Start-up Time* parameter, a dedicated binary output signal indicates the startup process. This signal can be applied, for instance, to activate the startup overcurrent protection function, which takes over the protection tasks from the normal overcurrent protection functions.

During the starting time the normal overcurrent protection function is not effective, but the special overcurrent function can operate without any considerable time delay: if the current rises above the increased current setting, the function generates an immediate trip command for the circuit breaker. Based on the starting signal at the end of the successful starting process, the normal overcurrent function is activated again, the setting of which can be below the starting current, providing optimal protection for the motor.

3.1.4.1.2. Locked Rotor Protection

If the starting process of the motor lasts too long, the motor is subject to a harmful overstress. If the starting current in excess of the motor *Start-up Current* parameter value can be detected after the defined *Start-up Time*, the function generates a trip command.

3.1.4.1.3. Operation of the Motor Startup Supervision

As the basic setting, the rated current of the motor must be defined as a percentage of the rated current of the current transformer. The parameter is *InMotor/InCT*.

The starting state is recognized by the algorithm if the current changes from zero value (below the *Idle Current* limit) to a higher current. This event triggers a timer, which is in “running” state for the starting time set, then it changes to the “time-out” state. The starting time is set by the parameter *Start-up Time*. The output signal is MSS48_**Starting**_GrI_ (Starting).

If the current is above the *Idle Current* limit, then the motor is considered to be in running state, which is indicated by the signal MSS48_**Running**_GrI_ (Running).

If the timer defined by the *Start-up Time* parameter runs out, then the current must be below a level defined by the parameter *Start-up Current*. Otherwise, it is an indication of prolonged startup time or a locked rotor. In this case, the function generates a signal, which can be applied to interrupt the starting procedure by tripping the circuit breaker. The output signal is MSS48_**LongStr**_GrI_ (Long Start).

When the startup timer runs out, another independent timer is started. During the running time of this second timer no restarting is allowed because the repeated increased starting current could cause overheating in the motor. This inhibition timer’s designated parameter is the *Restart Time*. The restart inhibition time is also started if the starting process is interrupted and the current falls below the *Idle Current*. The restart inhibition output signal is MSS48_**ReStrInh**_GrI_ (Restart Inhibited).

The function counts the subsequent startups within the last hours. This count must not be above the permitted startup numbers, defined by a dedicated parameter. If this parameter is 0 then no limit is considered. The last remaining restart possibility is indicated by an output status signal of the function block. After the last restart the restart inhibition output signal MSS48_**ReStrInh**_GrI_ (Restart Inhibited) is set to 1 state. This state is reset if the first considered restart attempt is out of the last hour.

The **inputs** of the motor startup supervision function are:

- the Fourier base harmonic components of three phase currents,
- binary input,
- parameters.

The **output** of the motor startup supervision function is:

- binary output status signals.

3.1.4.2. Motor Startup Supervision Function Overview

The graphic appearance of the motor startup supervision 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.

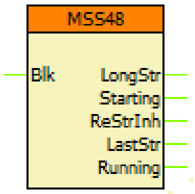

Figure 2-1 The function block of the motor startup supervision function

3.1.4.2.1. Settings

3.1.4.2.1.1. 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 motor startup supervision function

TITLE	DIM	RANGE	STEP	DEFAULT	EXPLANATION
Operation	-	Off, On	-	Off	Parameter for disabling or enabling the operation of the function.
InMotor/InCT	%	20 – 150	1	100	Rated current of the motor as a percentage of the rated current of the CT.
Start-up Current	%	50 – 1000	1	200	Current limit above which the motor is considered to be in startup mode. Set as a percentage of the *motor rated current*.
Idle Current	%	5 – 50	1	10	Current limit below which the motor is considered to be idle (not running). Set as a percentage of the *motor rated current*.
Start-up Time	sec	1 – 100	1	5	If this timer runs out, then the motor is not allowed to be in startup mode. Otherwise, it is an indication of prolonged startup or a locked rotor.
Restart Time	sec	10 – 5000	1	20	Timer parameter value below which motor is not allowed to be restarted after an unsuccessful start (restart is inhibited).
No of StartUp	StartUp/Hour	0 – 5	1	0	Number of permitted subsequent startups in a time period of 1 hour.

3.1.4.2.2. Function I/O

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

3.1.4.2.2.1. Analogue Inputs

This function uses the Fourier base harmonic components of three phase currents.

3.1.4.2.2.2. 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 motor startup supervision function

BINARY INPUT SIGNAL	SIGNAL TITLE	EXPLANATION
MSS48_**Blk**_GrO_	Block	Input for disabling the function

3.1.4.2.2.3. 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 motor startup supervision function

BINARY OUTPUT SIGNAL	SIGNAL TITLE	EXPLANATION
MSS48_**LongStr**_Grl_	Long Start	Indicates prolonged starting time or locked rotor state
MSS48_**Starting**_Grl_	Starting	The motor is in startup mode
MSS48_**ReStrInh**_Grl_	Restart Inhibited	The restart of the motor is inhibited
MSS48_**Running**_Grl_	General Trip	The motor is running
MSS48_**LastStr**_Grl_	LastStrNext	Indication if only one permitted restart is left

3.1.4.2.2.4. Online Data

The following values are visible in the *online data* page.

Table 2-4 Online data of the motor startup supervision function

SIGNAL TITLE	DIMENSION	EXPLANATION
Last Start-up Inrush	%	Magnitude of the inrush current during the last startup
Last Start-up Time	sec	Duration of the last startup
No of starts	-	Counter for number of subsequent starts
Long Start-up	-	Indicates prolonged starting time or locked rotor state
Starting	-	The motor is in startup mode
Restart Inh.	-	The restart of the motor is inhibited
Running	-	The motor is running
LastStrNext	-	Indication if only one restart is left

3.1.4.2.2.5. 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 motor startup supervision function

EVENT	VALUE	EXPLANATION
Last Start-up Inrush	…%	Magnitude of the current during the last startup
Last Start-up Time	…sec	Duration of the last startup
Long Start-up	off, on	Indicates prolonged starting time or locked rotor state

3.1.4.2.3. Technical Data

Table 2-6 Technical data of the motor startup supervision function

FUNCTION	VALUE	ACCURACY
Current accuracy	20 – 2000% of In	< 6%
Reset ratio	0.95 at startup current (0.7 at idle current)	
Operating time accuracy		+5% or ±15 ms, whichever is greater
Reset time	< 60 ms	

3.1.4.2.4. Notes for Testing

Keep in mind that setting values are set based on the motor rated current.

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

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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:

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

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
heat transfer coefficient of the surface of the conductor;
A area of the surface of the conductor;
t 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.)

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

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

Temperature(t) = Θ(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:

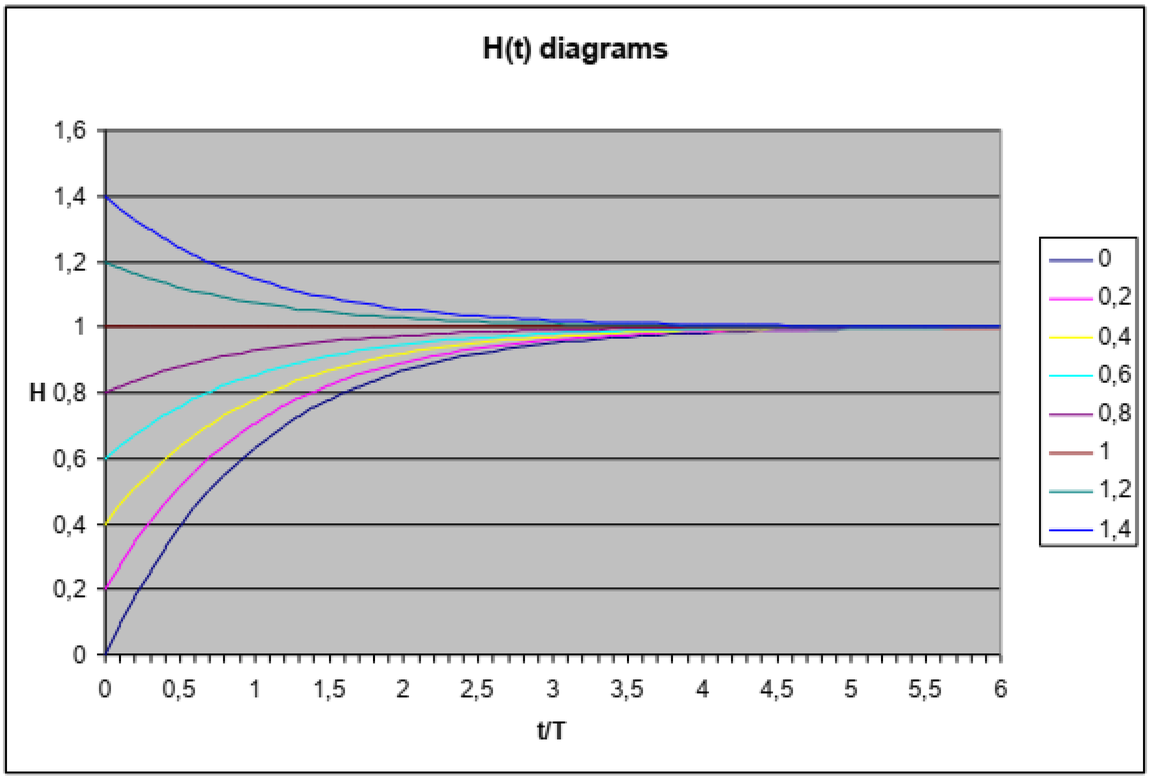
$$H(t) = \frac{\Theta(t)}{\Theta_n} = \frac{I^2}{I_n^2}\left(1 - e^{-\frac{t}{T}}\right) + \frac{\Theta_o}{\Theta_n} e^{-\frac{t}{T}} \qquad (3)$$

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 $\frac{\Theta_0}{\Theta_n}$



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:

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

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.

c

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:

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

where:

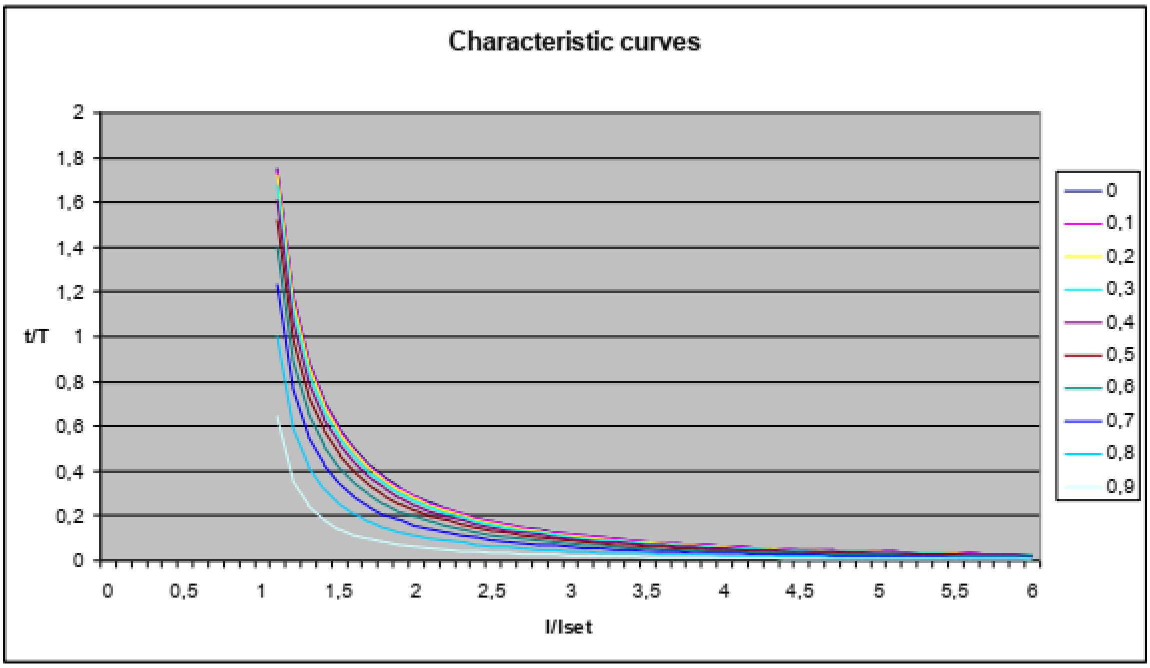
I_o is the continuous current that results Θ_o steady state "overtemperature" at the beginning of the calculation,

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 Io 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 (Io 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:

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

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.)

c

3.1.5.2. Structure of the line thermal protection

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

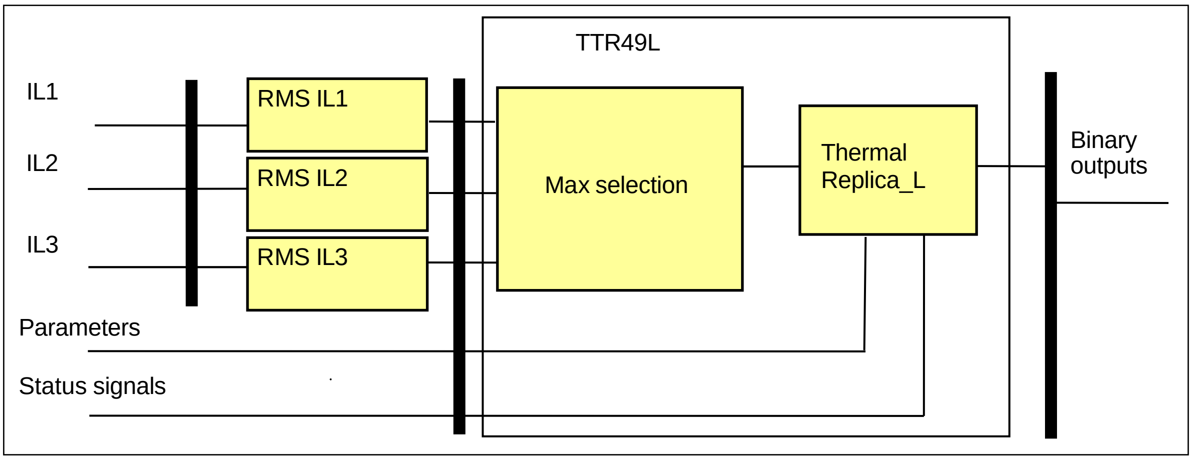


Figure 1-1 Structure of the line thermal protection algorithm

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.

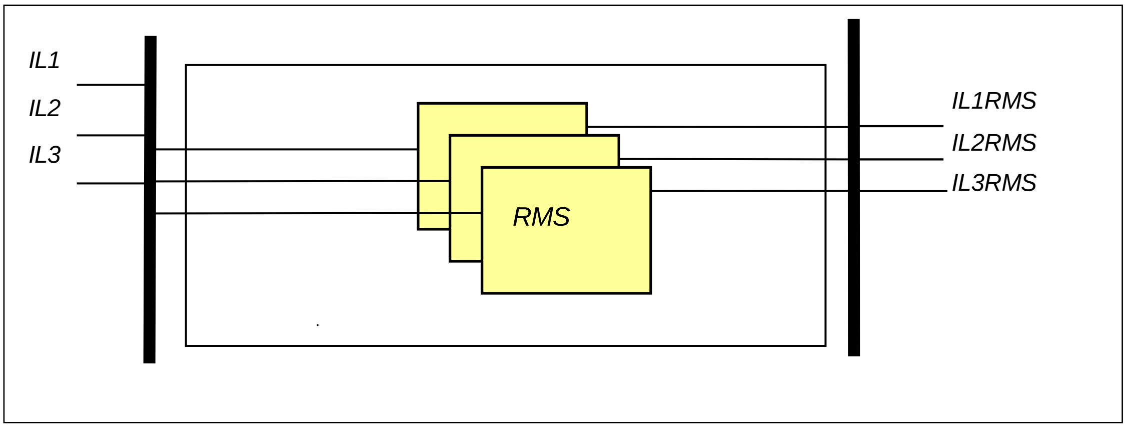


Figure 1-2 Principal scheme of the current RMS calculation

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.

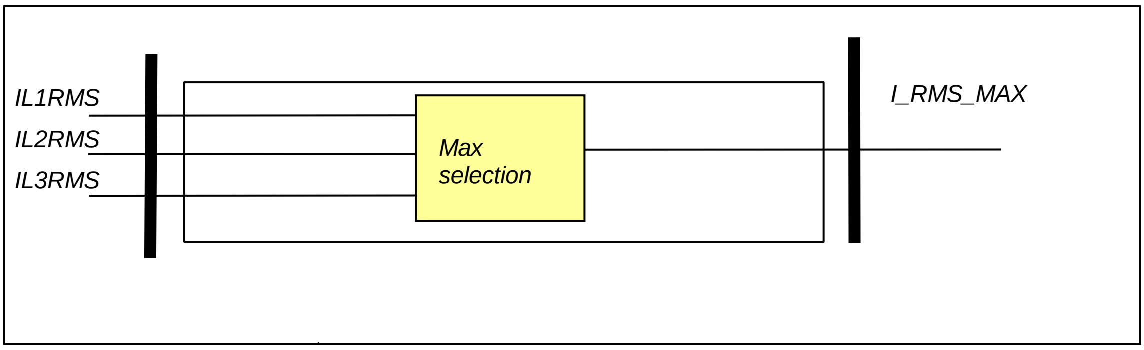


Figure 1-3 Principal scheme of the maximum selection

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.

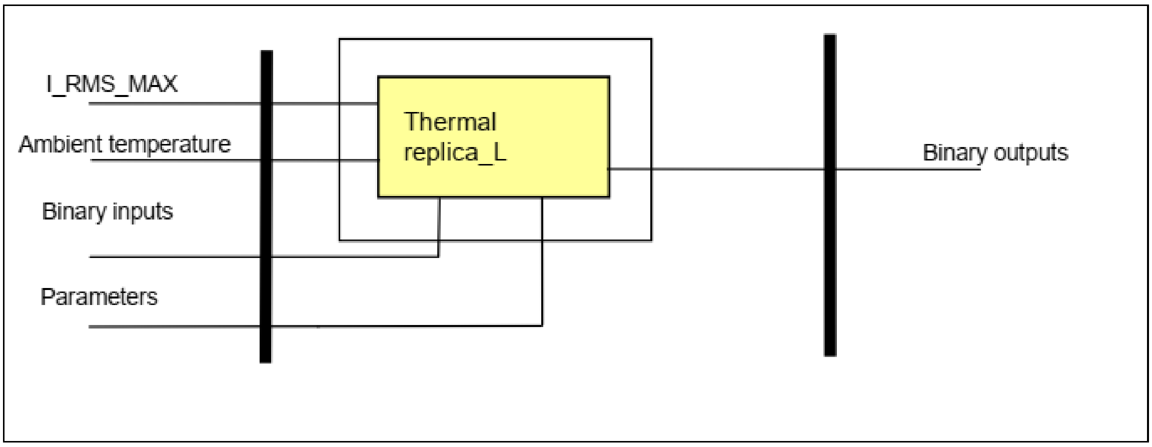


Figure 1-4 Principal scheme of the thermal replica calculation

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_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 1-4 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*Itrip	<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.

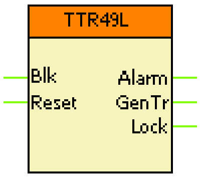


Figure 1-5 The function block of the line thermal protection function

3.1.6. Motor thermal protection function

Basically, the motor thermal protection function measures the three sampled phase currents. Positive sequence and negative sequence basic harmonic components are calculated. The temperature calculation is based on the weighted sum of the positive and negative sequence components.

$$I = \sqrt{I_1^2 + k * I_2^2}$$

Where

I_1 positive sequence current component

I_2 negative sequence current component

k weighting factor (parameter “INeg Scale”)

NOTE: I_2 is limited to 1.5 I_n. Above this value the considered I_2=1.5 I_n and the k weighting factor is constant 500%.

The weighting factor is defined by the user applying the required parameter setting TTR49M_NegScale_IPar_ (Neg.Seq. scale). The purpose of weighting is to take into consideration the increased heating of the rotor due to inverse rotating (nearly double speed) negative sequence magnetic field.

The setting allows two different thermal time constants to be considered: one for the rotating state (heating) - TTR49M_pT_IPar_ (Time constant) - and one for the still stand (cooling), which is defined by parameter TTR49M_cpT_IPar_ (Cooling/Heating) as a percentage of the heating time constant.

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 TTR49M_Amb_IPar_ (Ambient Temperature). The selection between parameter value and direct measurement is made by setting the binary parameter TTR49M_Sens_BPar_ (Temperature sensor).

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

TTR49M_Alm_IPar_ (Alarm temperature)
TTR49M_Trip_IPar_ (Trip temperature)
TTR49M_Unl_IPar_ (Unlock temperature)

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

TTR49M_Inom_IPar_	(Rated load current: the measuring continuous current)
TTR49M_Max_IPar_	(Rated temperature: the steady state temperature at rated load current)
TTR49M_Ref_IPar_	(Base Temperature: the temperature of the environment during the measurement of the rated values)
TTR49M_pT_IPar_	(Time constant: separately measured heating/cooling time constant of the exponential temperature functions.)

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

TTR49M_Str_IPar_ (Startup Term.: Initial temperature above the temperature of the environment as compared to the rated temperature above the temperature of the environment)

For motors with heavy starting conditions a binary signal can decrease the calculated heat to the half value ($I^2/2$), preventing trip command for overheating during motor starting.

The application of thermal protection of the motor is a better solution than simple overcurrent-based overload protection because thermal protection “remembers” the preceding load state of the motor, consequently, the setting of the thermal protection does not need such a high security margin between the permitted current and the permitted continuous thermal current of the motor. In case of previous 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 motor.

3.1.6.1. Theory of the thermal replica calculations

3.1.6.1.1. The thermal differential equation

The theory of solving the thermal differential equation is described and explained in detail in a separate document [“The thermal differential equation”].

The source of the formulas below is that document.

The thermal differential equation to be solved is:

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

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 motor;
c	specific heat capacity of the conductor;
m	mass of the conductor;
θ	rise of the temperature above the temperature of the environment;
h	heat transfer coefficient of the surface of the conductor;
A	area of the surface of the conductor;
t	time.

3.1.6.1.2. 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.)

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

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

Temperature(t) = Θ(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:

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

where:

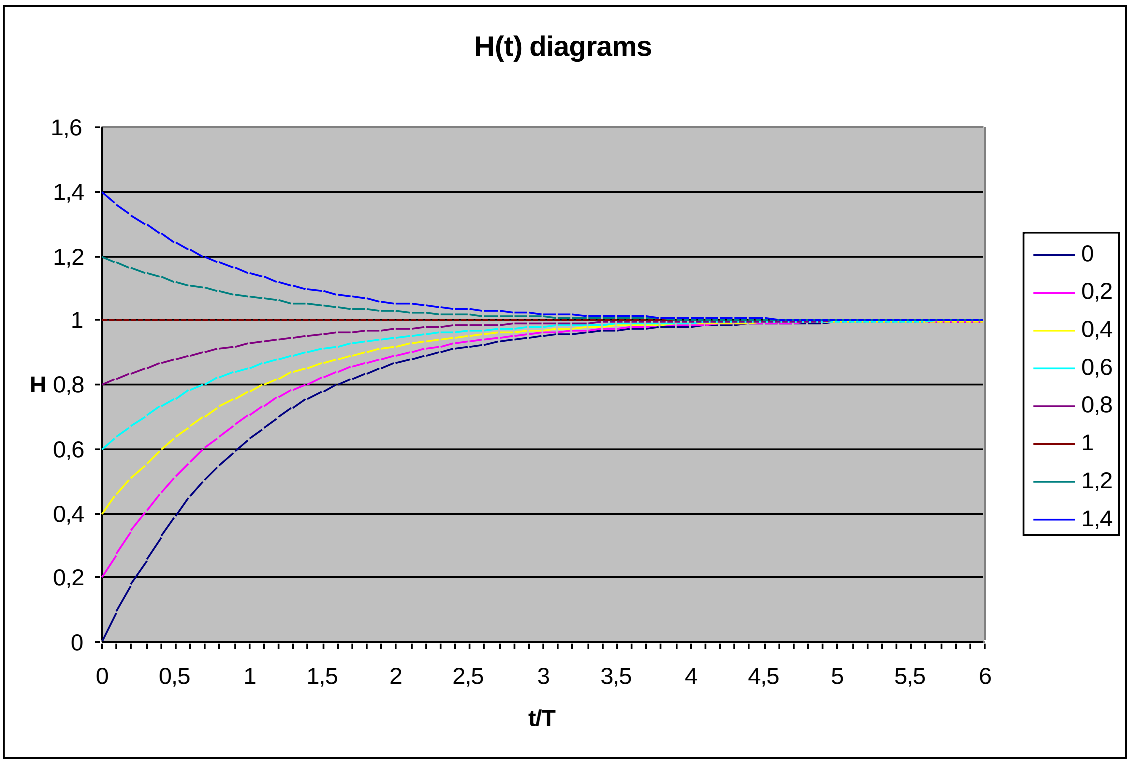
H(t) is the „thermal level" of the heated object, **this is the temperature as a percentage of the Θ_n reference temperature.** (This is a dimensionless quantity but it can also be expressed in a percentage form.)

Θ_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.

3.1.6.1.3. 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 of the individual curves is the starting temperature as a percentage of 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:

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

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:

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

where:

I_o is the continuous current that results Θ_o steady state "overtemperature" at the beginning of the calculation,

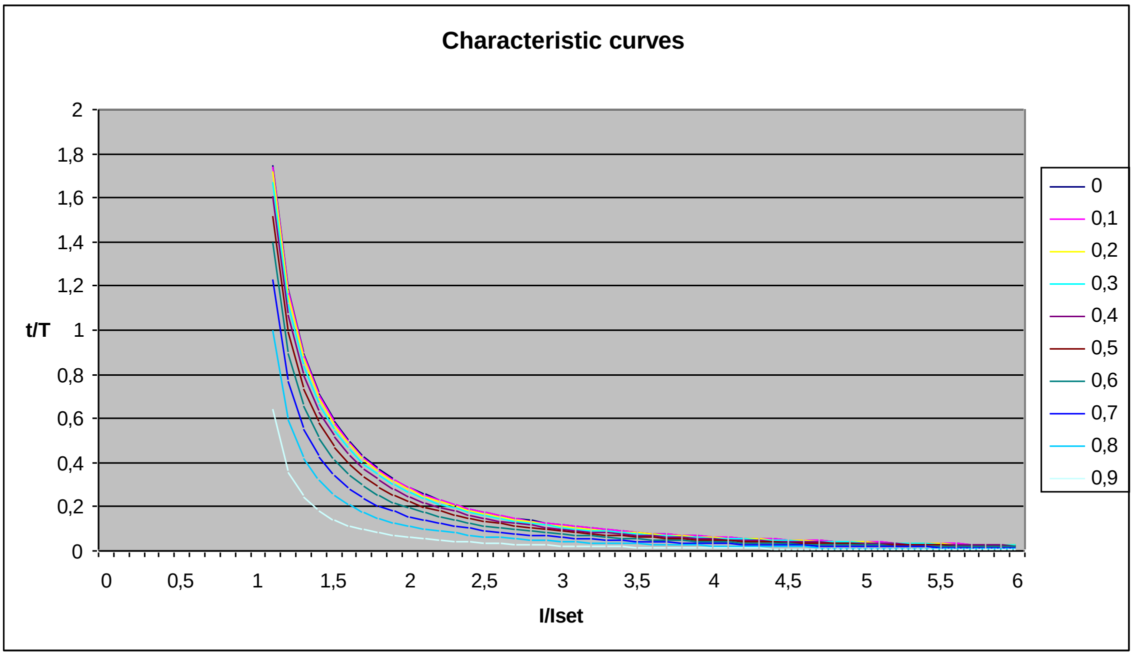
I is the current that is applied to reach the steady state Θ_S "overtemperature",

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

I_{set} is the setting current of the „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 Io current related to the I_n rated current, which generates the steady state starting temperature. The top-most curve is the „cold curve".

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



3.1.6.1.4. Numerical solution of the thermal differential equation

The formulas (2-6) above refer to a constant current and can be used to test the thermal protection. In reality, the RMS value of the currents change over time; consequently, differential equation (1) must be solved using a numerical method. The separate document explains the steps to obtain the calculation formula:

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

where:

Θ_k is the temperature (above the temperature of the environment) at the k-th calculation step;

Θ_k is the temperature (above the temperature of the environment) one calculation step before.

(The user of the thermal protection does not need to apply formula (6) above.)

3.1.6.2. Structure of the motor thermal overload protection

Fig.1-1 shows the structure of the motor thermal overload protection (TTR49M) algorithm.

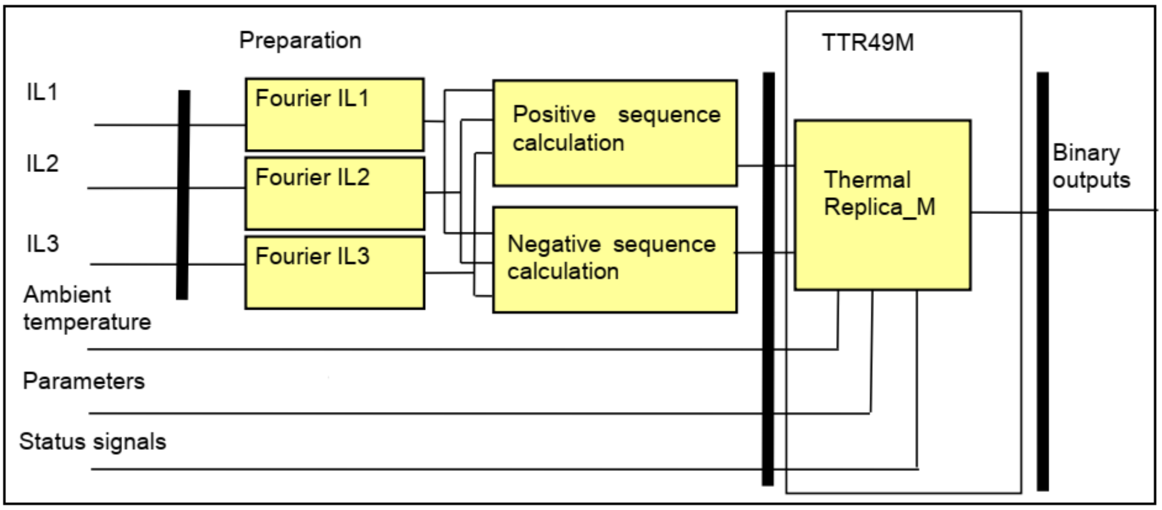


Figure 1-1 Structure of the motor thermal overload protection algorithm

For the preparation phase:
The **inputs** are

- the sampled values of three primary phase currents,

The **outputs** are

- the fundamental Fourier components of the positive and negative sequence currents, calculated using the phase currents.

For the thermal overload function:
The **inputs** are

- the fundamental Fourier components of the positive and negative sequence currents, calculated using the phase currents.
- the signal proportional to the ambient temperature,
- parameters,
- status signals.

The **outputs** are

- the binary output status signals.

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

Fourier calculations

These modules calculate the basic harmonic component values of the phase currents individually. These modules are not part of the thermal overload function; they belong to the preparatory phase.

Positive sequence calculation

Negative sequence calculation

These modules calculate the positive and negative sequence basic harmonic components of the phase currents. These modules are not part of the thermal overload function; they belong to the preparatory phase.

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.

3.1.6.3. Fourier calculations (Fourier calculations)

These modules calculate the basic harmonic component values of the phase currents individually. These modules are not part of the thermal overload function; they belong to the preparatory phase.

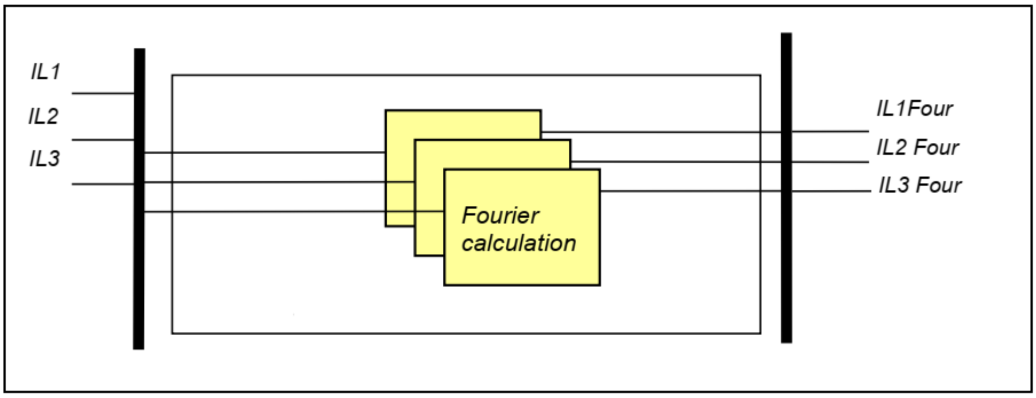


Figure 1-2 Principal scheme of the Fourier calculation

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

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

3.1.6.4. Positive sequence calculation and negative sequence calculation

These modules calculate the positive and negative sequence basic harmonic components of the phase currents. These modules are not part of the thermal overload function; they belong to the preparatory phase.

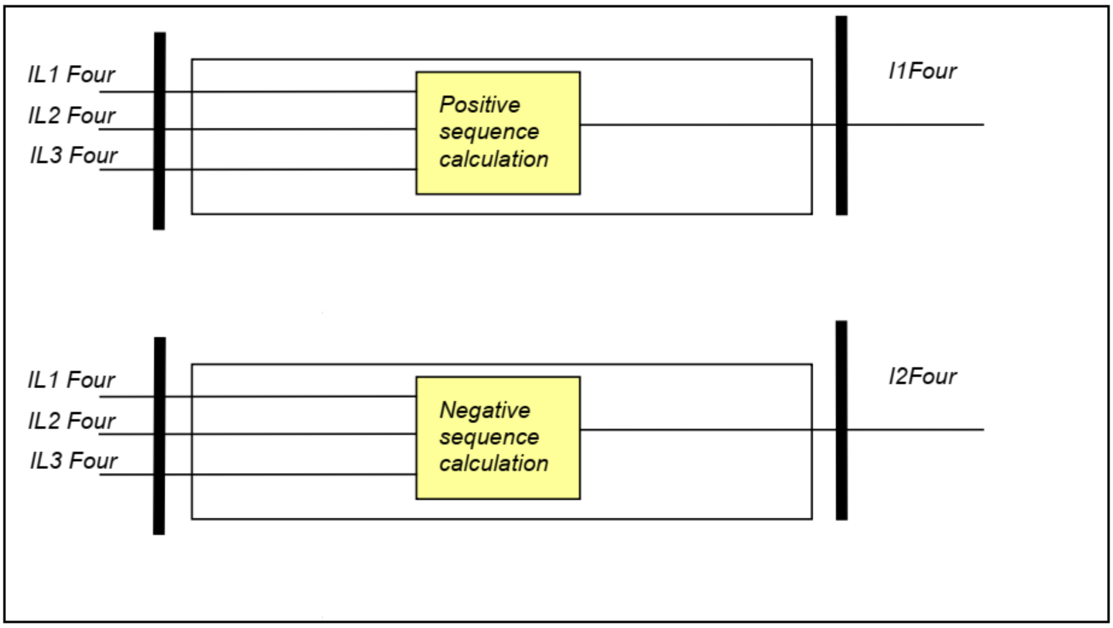


Figure 1-3 Schema of the positive and negative sequence component calculation

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

The **outputs** are the positive and negative sequence fundamental harmonic Fourier components of the phase currents.

3.1.6.5. The temperature calculation and decision (Thermal replica M)

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 positive and negative sequence fundamental harmonic Fourier components of the phase currents,
- The value proportional to the ambient temperature (this signal is optional, defined at parameter setting),
- The basic Fourier components of the phase currents (IL1Four, IL2Four, IL3Four). These values support the decision about the running (heating) or still-stand (cooling) state of the motor,
- Binary input status signals,
- Parameters.

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

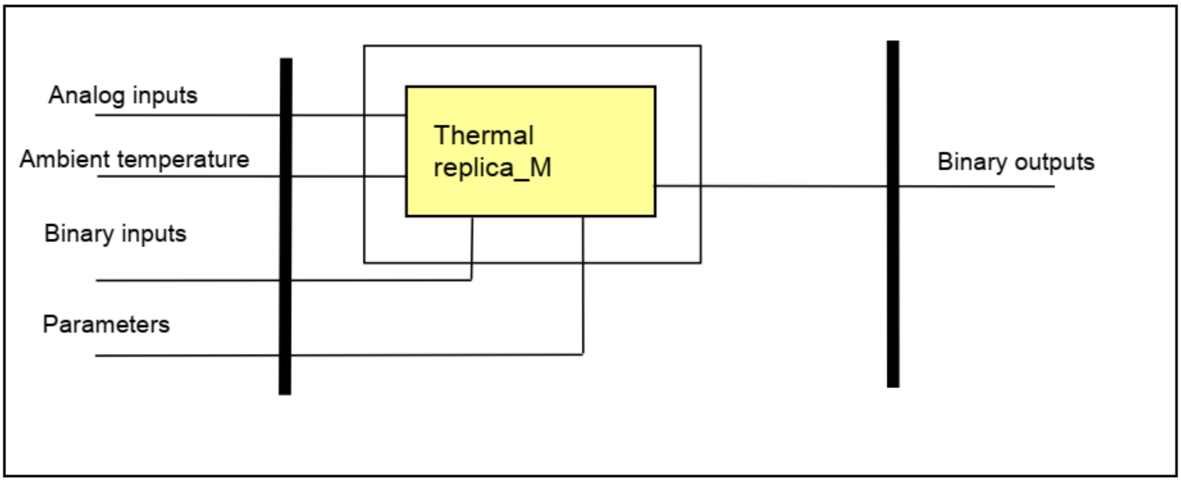


Figure 1-4 Principal scheme of the thermal replica calculation

Enumerated parameter

Parameter name	Title	Selection range	Default
Parameter for mode of operation			
TTR49M_Oper_EPar_	Operation	Off, Pulsed, Locked	Pulsed

Table 1-1 The enumerated parameters of the motor 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						
TTR49M_Alm_IPar_	Alarm Temperature	deg	60	200	1	80
Trip Temperature						
TTR49M_Trip_IPar_	Trip Temperature	deg	60	200	1	100
Rated Temperature						
TTR49M_Max_IPar_	Rated Temperature	deg	60	200	1	100
Base Temperature						
TTR49M_Ref_IPar_	Base Temperature	deg	0	40	1	25
Unlock Temperature						
TTR49M_Unl_IPar_	Unlock Temperature	deg	20	200	1	60
Ambient Temperature						
TTR49M_Amb_IPar_	Ambient Temperature	deg	0	40	1	25
Startup Temperature						
TTR49M_Str_IPar	Startup Temp.	%	0	60	1	0
Rated LoadCurrent						
TTR49M_Inom_IPar_	Rated LoadCurrent	%	20	150	1	100
Idle Current, below which the “cooling” time constant is valid						
TTR49M_Imin_IPar_	Idle Current	%	1	30	1	5
Time constant						
TTR49M_pT_IPar_	Time constant	min	1	999	1	10
Cooling/Heating						
TTR49M_cpT_IPar_	Cooling/Heating	%	100	400	1	200
Neg.Seq. scale (k)						
TTR49M_NegScale_IPar_	INeg Scale	%	100	500	1	200

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

Boolean parameter

Boolean parameter	Signal title	Selection range	Default
Parameter for ambient temperature sensor application			
TTR49M_Sens_BPar_	Temperature Sensor	No, Yes	No

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

3.1.6.6. Technical summary

3.1.6.6.1. Technical data

Function	Accuracy
Current in range of 20 - 2000% of In	< ± 1% of In
Operate time at I>1.5*Itrip	<5 %

Table 1-4 *Technical data of the motor thermal protection function*

3.1.6.6.2. The parameters

The parameters are summarized in Chapter 1.5.

3.1.6.6.3. Binary output signals

The **binary output status signals** of the motor thermal protection function are shown in Table *1-5*.

Binary output signals	Signal title	Explanation
TTR49M_Alarm_GrI_	Alarm	Alarm signal of the motor thermal protection function
TTR49M_GenTr_GrI_	General Trip	General trip signal of the motor thermal protection function
TTR49M_Lock_GrI_	Reclose locked	Motor restart blocking signal of the motor thermal protection function

Table 1-5 *The binary output status signals of the motor thermal protection function*

3.1.6.6.4. Binary input status signals

The motor 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 motor thermal protection function are shown in Table *1-6*.

Binary status signal	Explanation
TTR49M_Blk_GrO_	Output status of a graphic equation defined by the user to disable the motor thermal protection function.
TTR49M_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.`
TTR49M_StartUp_GrO_	For motors with heavy starting conditions the presence of this signal decreases the generated heat amount to the half value ($I^2/2$)

Table 1-6 *The binary input signals of the motor thermal protection function*

3.1.6.6.5. The function block

The function block of the motor 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.

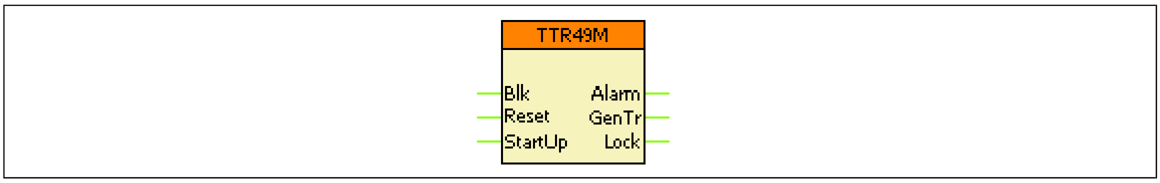


Figure 1-5 *The function block of the motor thermal protection function*

3.1.7. Three-phase instantaneous Overcurrent Protection

3.1.7.1. 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.

3.1.7.1.1. Operating Characteristics

$$t(I) = t_{OP} \quad \text{when } I > I_S$$

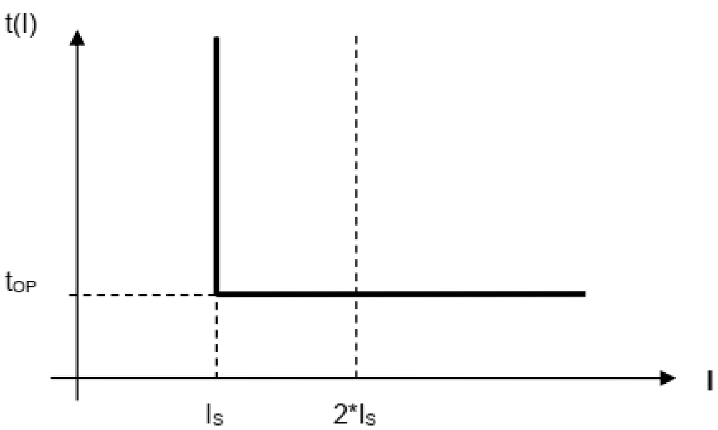


Figure 1-1 Overcurrent independent time characteristic

where:

t_{OP} (sec.)	theoretical operating time if I> IG_S (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*)

3.1.7.1.2. Structure of the Protection Algorithm

Figure 1-2 shows the structure of the instantaneous overcurrent protection (IOC50) algorithm.

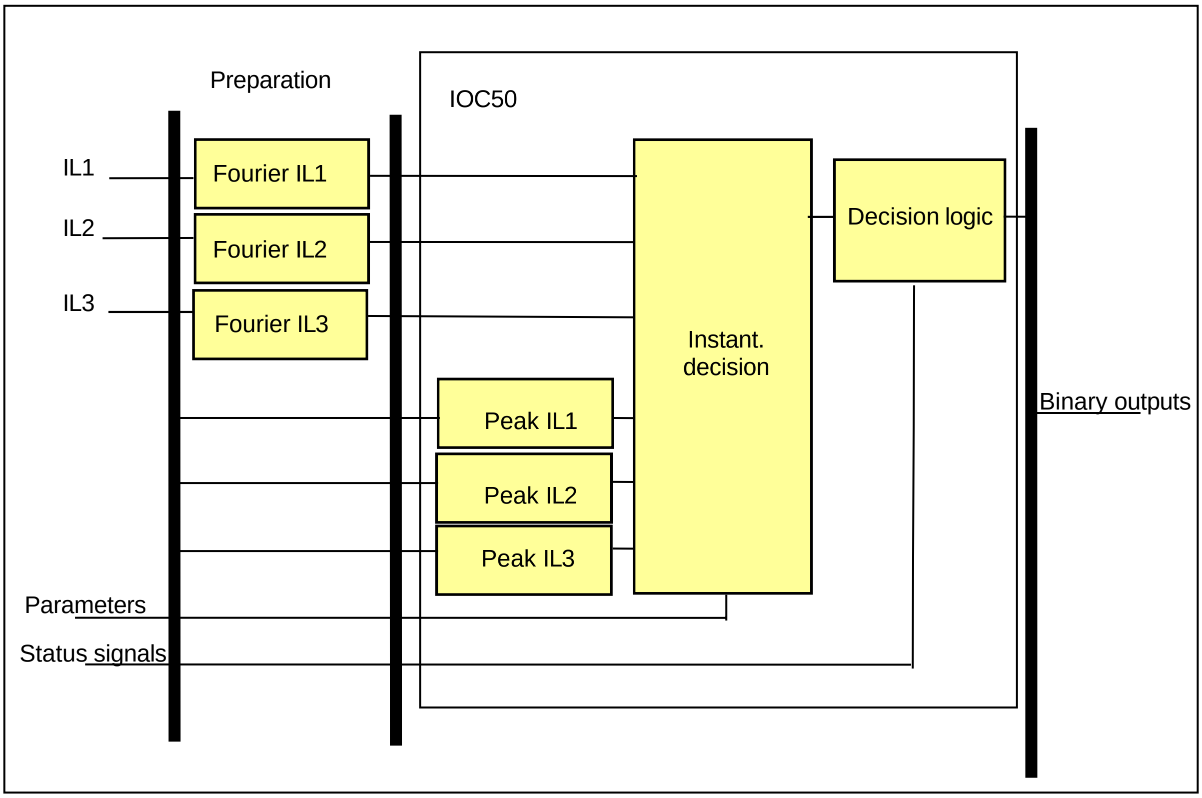


Figure 1-2 Structure of the instantaneous overcurrent protection algorithm

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.

3.1.7.1.3. 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.

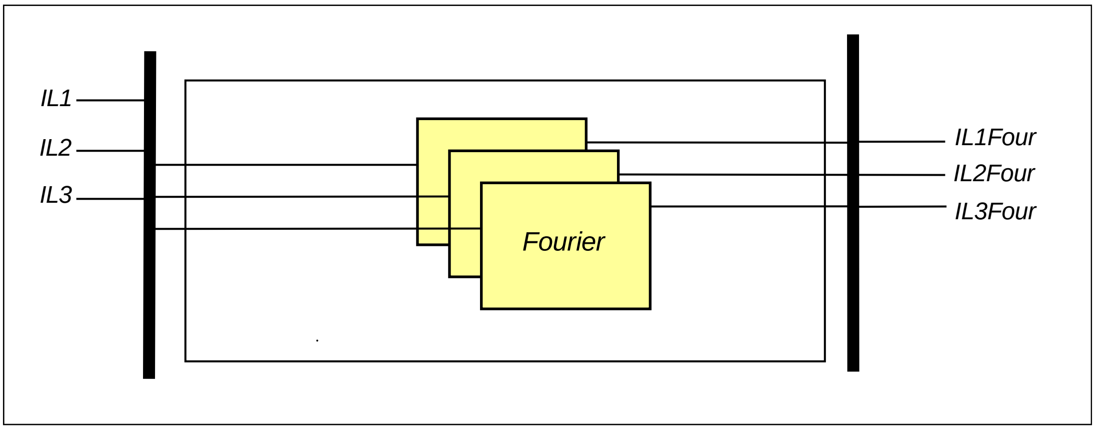


Figure 1-3 Principal scheme of the Fourier calculation

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).

3.1.7.1.4. The Peak Selection (Peak selection)

These modules select the peak values of the phase currents individually.

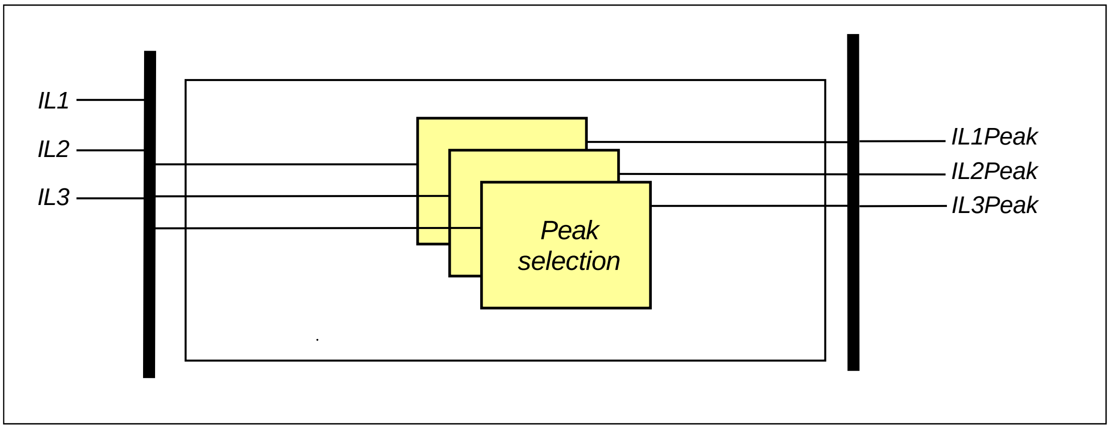


Figure 1-4 Principal scheme of the peak selection

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).

3.1.7.1.5. 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.

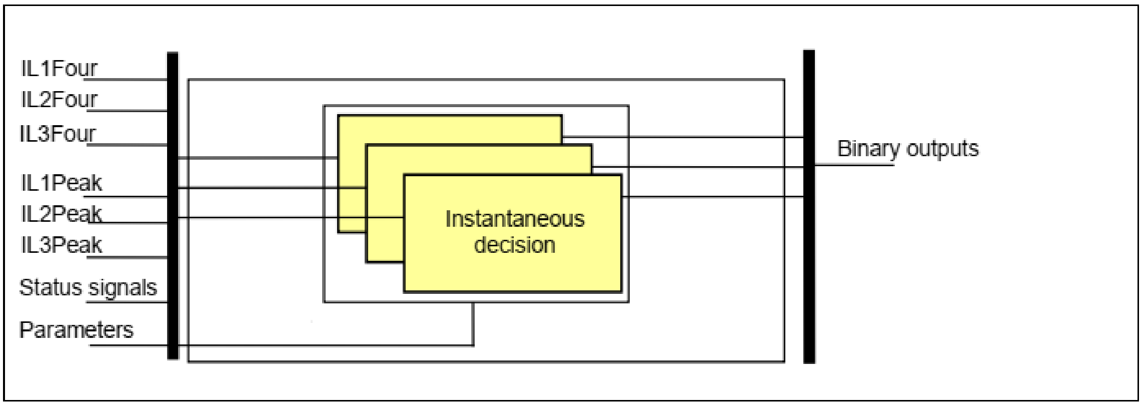


Figure 1-5 Principal scheme of the instantaneous characteristic calculation

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

3.1.7.1.6. The Decision Logic (Decision logic)

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

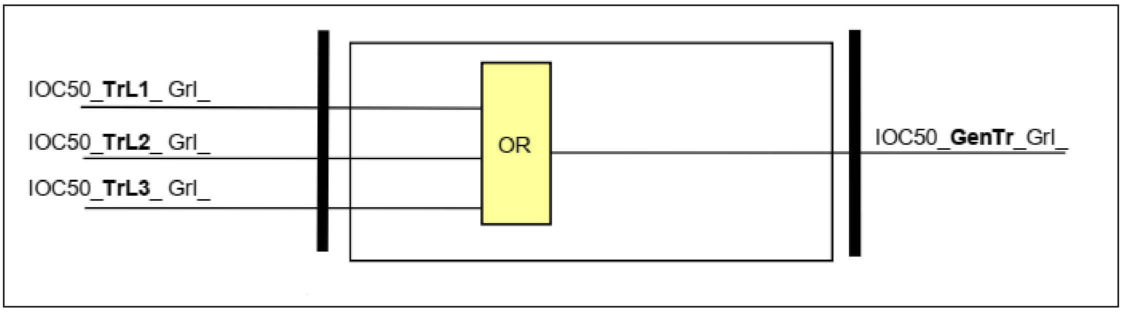


Figure 1-6 The logic scheme of the instantaneous overcurrent protection function

Table 1-5 The binary input status signals of the decision logic

BINARY INPUT SIGNAL	SIGNAL TITLE	EXPLANATION
IOC50_**TrL1**_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

Table 1-6 The binary output status signal of the decision logic

BINARY OUTPUT SIGNAL	SIGNAL TITLE	EXPLANATION
IOC50_**GenTr**_GrI_	General Trip	General trip command of the function

3.1.7.2. 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.

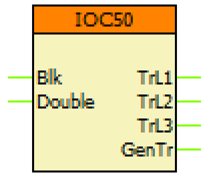


Figure 2-1 The function block of the 3-phase instantaneous overcurrent protection

3.1.7.2.1. 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 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}).

3.1.7.2.2. 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 RMS values of the fundamental Fourier component of the three phase currents.

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 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”.

3.1.7.2.2.3. 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 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

3.1.7.2.2.4. 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

3.1.7.2.2.5. 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 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

3.1.7.2.3. Technical Data

Table 2-6 Technical data of the 3-phase IOC protection function

FUNCTION	VALUE	ACCURACY
Using peak value calculation		
Operating characteristic	Instantaneous	< 6%
Reset ratio	0.85	
Operate time at 2*Is	< 15 ms	
Reset time*	< 40 ms	
Transient overreach	90%	
Using Fourier fundamental harmonic calculation		
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*

3.1.7.2.4. 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.

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.

3.1.8. Residual Instantaneous Overcurrent Protection

3.1.8.1. Application

The residual instantaneous overcurrent protection function operates according to instantaneous characteristics, using the residual current ($IN=3I_0$). 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.

3.1.8.1.1. Operating Characteristics

$$t(I) = t_{OP} \text{ when } I > I_S$$

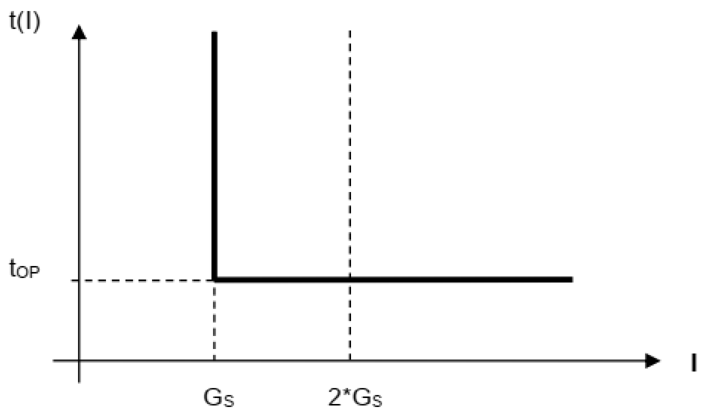


Figure 1-1 Overcurrent independent time characteristic

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*)

3.1.8.1.2. Structure of the Protection Algorithm

Figure 1-2 shows the structure of the residual instantaneous overcurrent protection (IOC50N) algorithm.

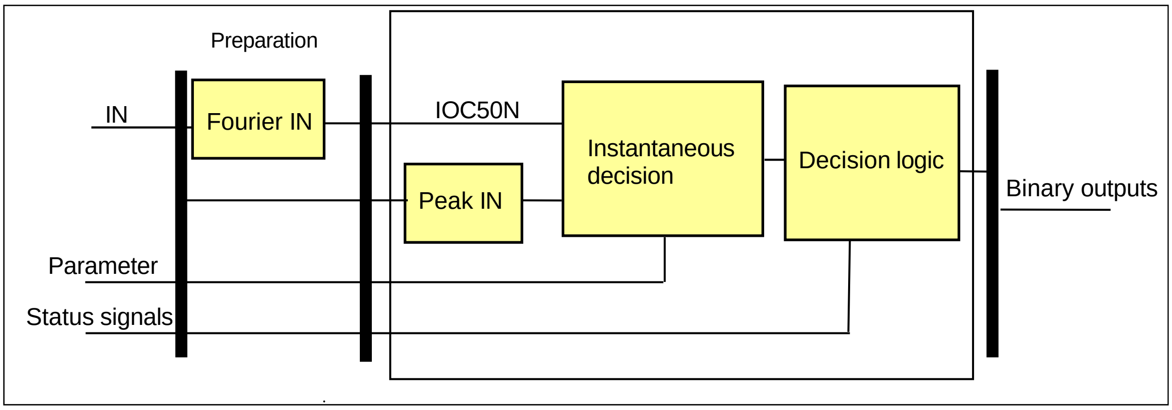


Figure 1-2 Structure of the residual instantaneous overcurrent protection algorithm

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.

3.1.8.1.3. 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.

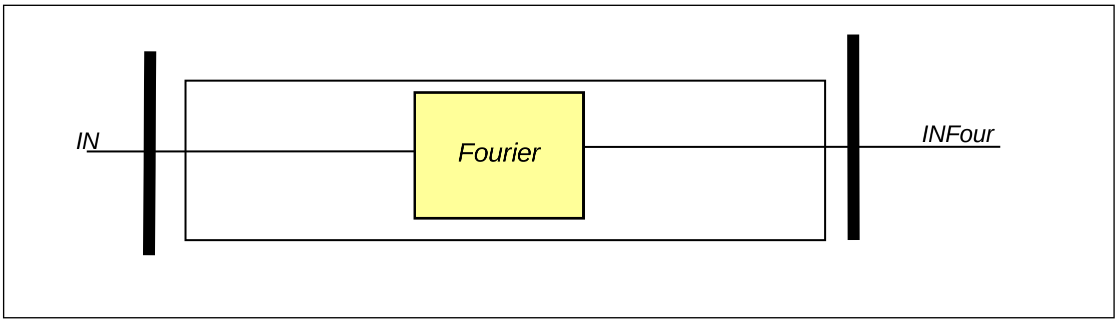


Figure 1-3 Principal scheme of the Fourier calculation

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).

3.1.8.1.4. The Peak Selection (Peak selection)

This module selects the peak values of the residual current.

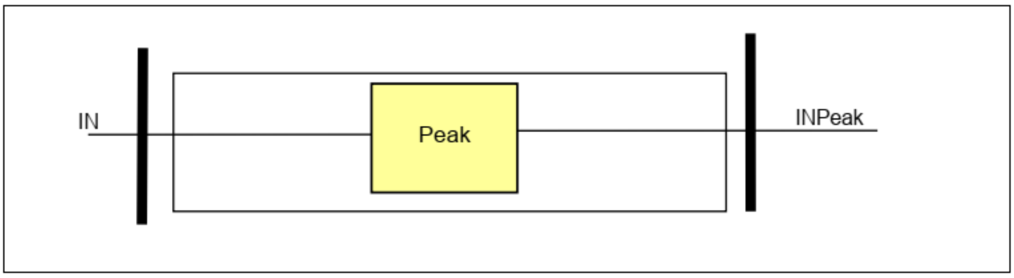


Figure 1-4 Principal scheme of the peak selection

The **inputs** are the sampled values of the residual current (IN).

The **outputs** are the peak values of the analyzed current (INPeak).

3.1.8.1.5. 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.

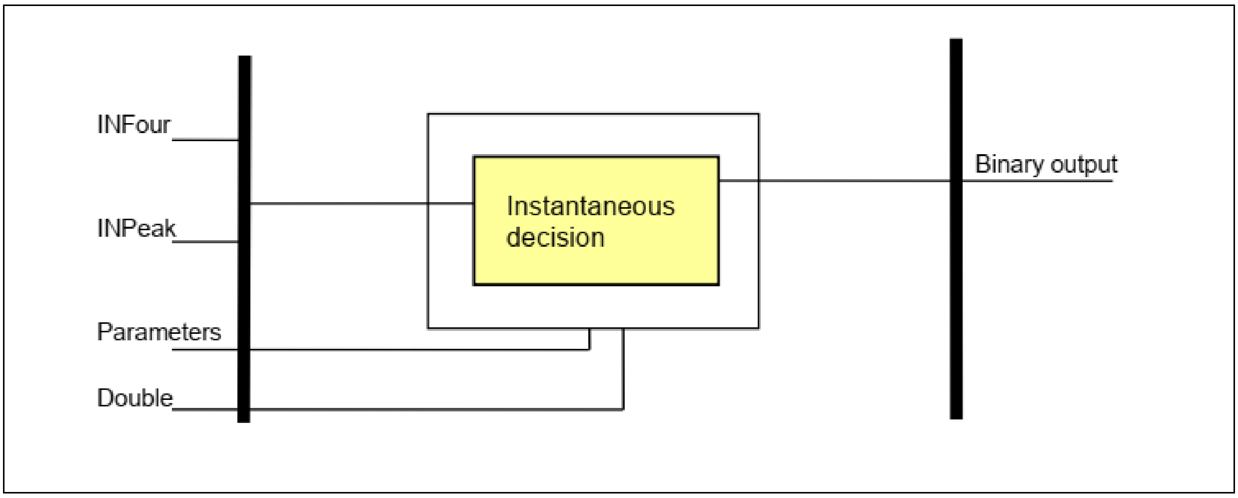


Figure 1-5 Principal scheme of the residual instantaneous characteristic calculation

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

3.1.8.1.6. 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.

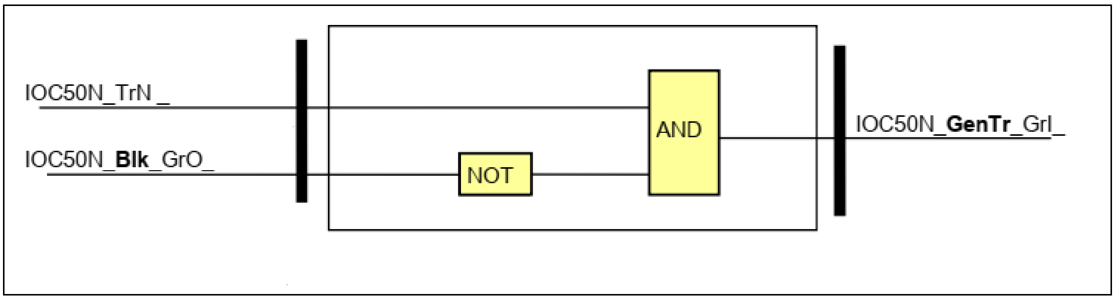


Figure 1-6 The logic scheme of the residual IOC protection function

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

3.1.8.2. 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.

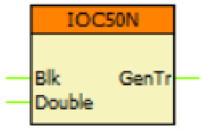


Figure 2-1 The function block of the residual instantaneous overcurrent protection

3.1.8.2.1. 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 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*

3.1.8.2.2. Function I/O

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

3.1.8.2.2.1. Analogue inputs

The analogue inputs are the sampled values of the residual current.

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 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".

3.1.8.2.2.3. 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 residual IOC function

BINARY OUTPUT SIGNAL	SIGNAL TITLE	EXPLANATION
IOC50N_**GenTr**_GrI_	General Trip	General trip command of the function

3.1.8.2.2.4. 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

3.1.8.2.2.5. Events

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

Table 2-5 Generatable events of the residual IOC function

EVENT	VALUE	EXPLANATION
General Trip	off, on	General trip command of the function

3.1.8.2.3. Technical Data

Table 2-6 Technical data of the residual IOC protection function

FUNCTION	VALUE	ACCURACY
Using peak value calculation		
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%	
Using Fourier fundamental harmonic calculation		
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*

3.1.8.2.4. 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.

3.1.9. Breaker failure protection

3.1.9.1. 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.

3.1.9.1.1. 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.
  - <u>By using "BRF50" variant:</u> the input variable to be programmed is: BRF50_**CBClosed**_GrO_ (CB Closed),

BRF50SP

  - *<u>By using "BRF50SP" variant</u>: the input variables to be programmed are: BRF50_**CBClL1**_GrO_ (CB closed L1), BRF50_**CBClL2**_GrO_ (CB closed L2) and BRF50_**CBClL3**_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.

- 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”.

BRF50SP

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.

Dynamic blocking is possible using the binary input BRF50_**Blk**_GrO_ (Block). The conditions are to be programmed by the user, using the graphic equation editor.

3.1.9.1.2. 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_**Blk**_GrO_	Block	Blocking of the breaker failure protection function
	BRF50_**CBClosed**_GrO_	CB closed	Signal indicating the closed state of the circuit breaker
	*BRF50SP_**CBClL1**_GrO_*	*CB closed L1*	*Signal indicating the closed state of the circuit breaker in phase L1*
BRF50SP	*BRF50SP_**CBClL2**_GrO_*	*CB closed L2*	*Signal indicating the closed state of the circuit breaker in phase L2*
	*BRF50SP_**CBClL3**_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	*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

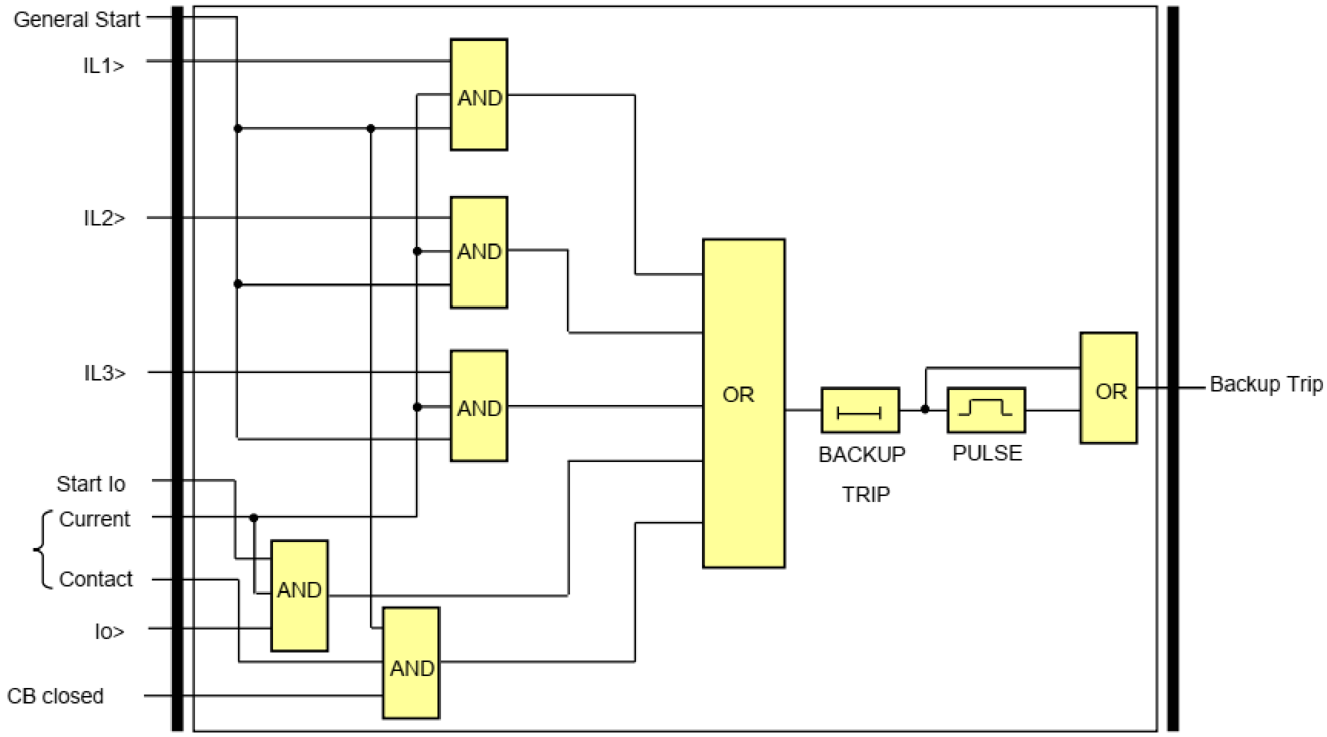


Figure 1-1 The logic scheme of the decision logic of "BRF50" variant

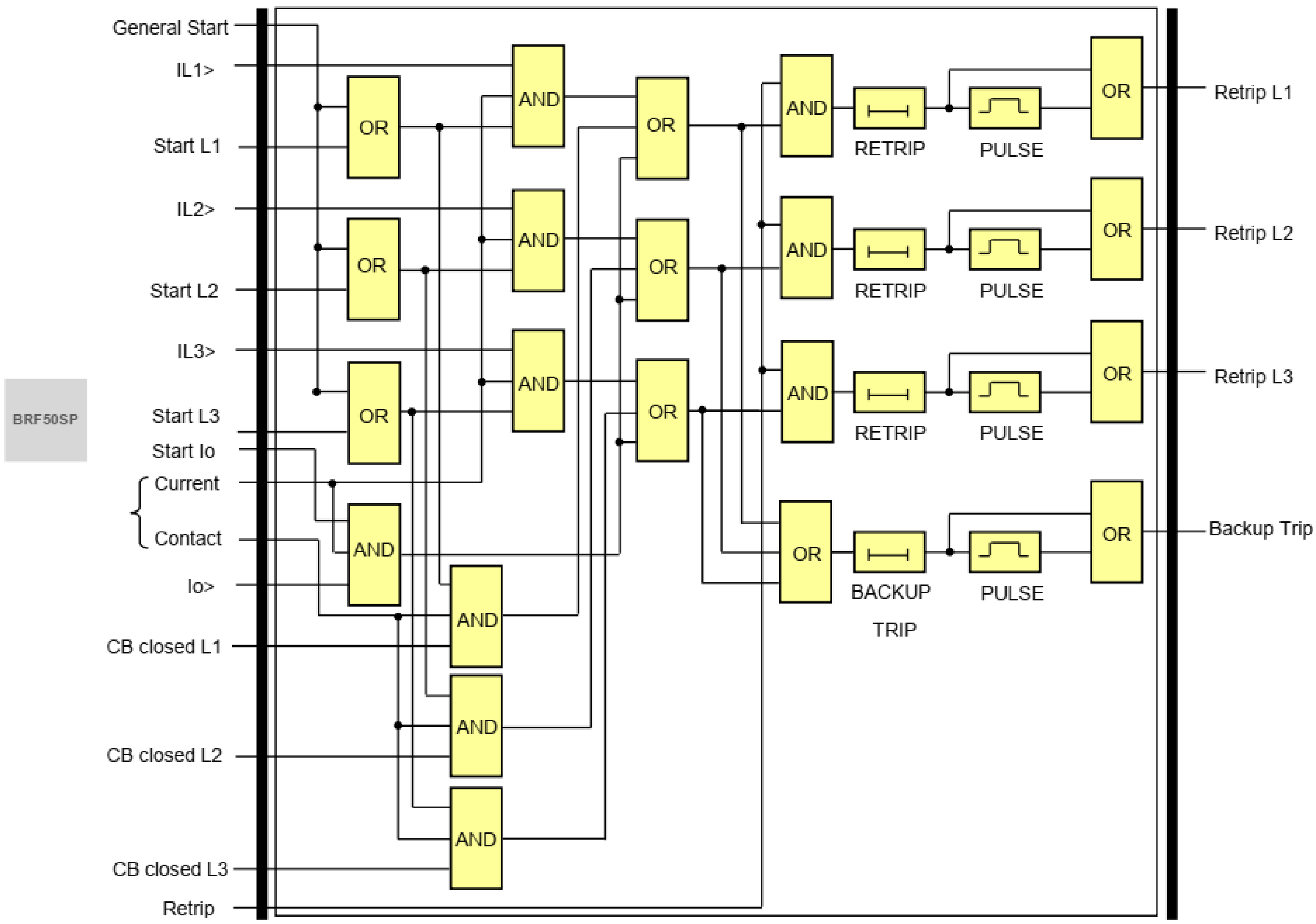


Figure 1-2 The logic scheme of the decision logic of "BRF50SP" variant

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

BINARY STATUS SIGNAL	TITLE	EXPLANATION
BRF50_**BuTr**_Grl_	Backup Trip	Trip command generated for the backup circuit breakers
*BRF50_**TrL1**_Grl_*	*Retrip L1*	*Repeated trip command in phase L1*
*BRF50_**TrL2**_Grl_*	*Retrip L2*	*Repeated trip command in phase L2*
*BRF50_**TrL3**_Grl_*	*Retrip L3*	*Repeated trip command in phase L3*

BRF50SP

3.1.9.2. 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.

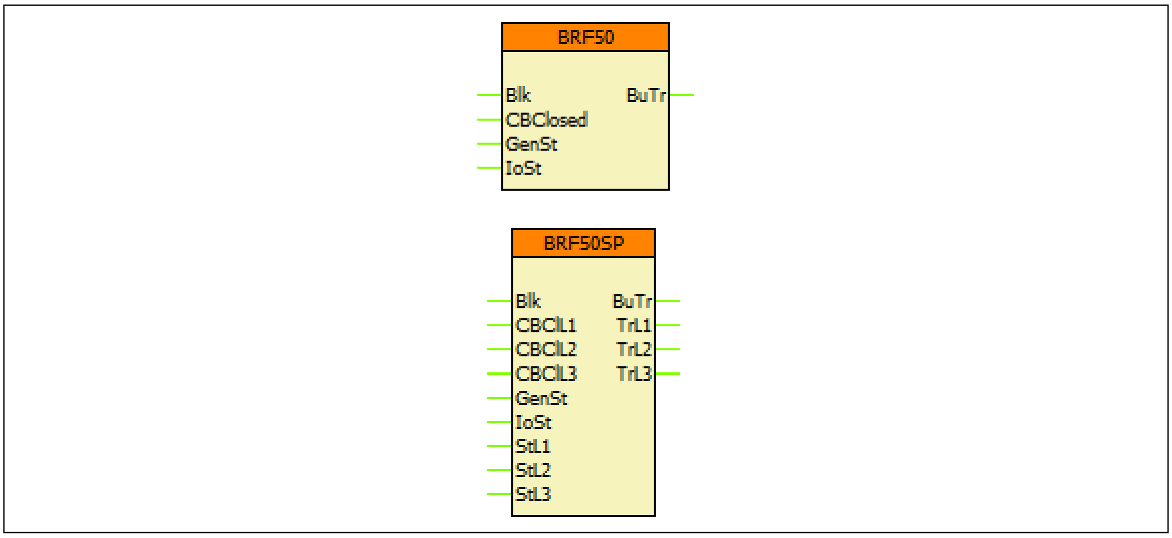


Figure 2-1 Graphic appearance of the variants of the breaker failure protection function block

3.1.9.2.1. Settings

3.1.9.2.1.1. 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 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

3.1.9.2.2. 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 a current input. This is defined in the configuration.

3.1.9.2.2.2. 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 signals of the breaker failure protection functions

	BINARY STATUS SIGNAL	TITLE	EXPLANATION
	BRF50_**Blk**_GrO_	Block	Blocking of the breaker failure protection function
	BRF50_**CBClosed**_GrO_	CB closed	Signal indicating the closed state of the circuit breaker
	*BRF50SP_**CBClL1**_GrO_*	*CB closed L1*	*Signal indicating the closed state of the circuit breaker in phase L1*
BRF50SP	*BRF50SP_**CBClL2**_GrO_*	*CB closed L2*	*Signal indicating the closed state of the circuit breaker in phase L2*
	*BRF50SP_**CBClL3**_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	*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

3.1.9.2.2.3. 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 breaker failure protection function

	BINARY STATUS SIGNAL	TITLE	EXPLANATION
	BRF50_**BuTr**_GrI_	Backup Trip	Trip command generated for the backup circuit breakers
	*BRF50_**TrL1**_GrI_*	*Retrip L1*	*Repeated trip command in phase L1*
BRF50SP	*BRF50_**TrL2**_GrI_*	*Retrip L2*	*Repeated trip command in phase L2*
	*BRF50_**TrL3**_GrI_*	*Retrip L3*	*Repeated trip command in phase L3*

3.1.9.2.2.4. 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	*Retrip L1*	-	*Repeated trip command in phase L1*
	Retrip L2	-	*Repeated trip command in phase L2*
	Retrip L3	-	*Repeated trip command in phase L3*

3.1.9.2.2.5. 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 breaker failure protection function

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*

BRF50SP

3.1.9.2.3. 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	

3.1.9.2.4. 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.

3.1.10. Three-phase time overcurrent protection

3.1.10.1. 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.

3.1.10.1.1. Operating characteristics

3.1.10.1.1.1. Independent time characteristic

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

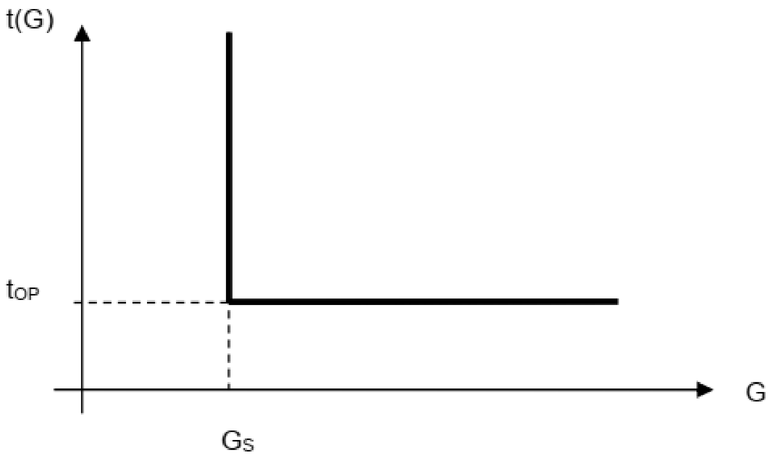


Figure 1-1 Overcurrent independent time characteristic

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).

c

3.1.10.1.1.2. 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_r(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

3.1.10.1.2. Structure of the overcurrent protection algorithm

Fig.1-2 shows the structure of the overcurrent protection (TOC51) algorithm.

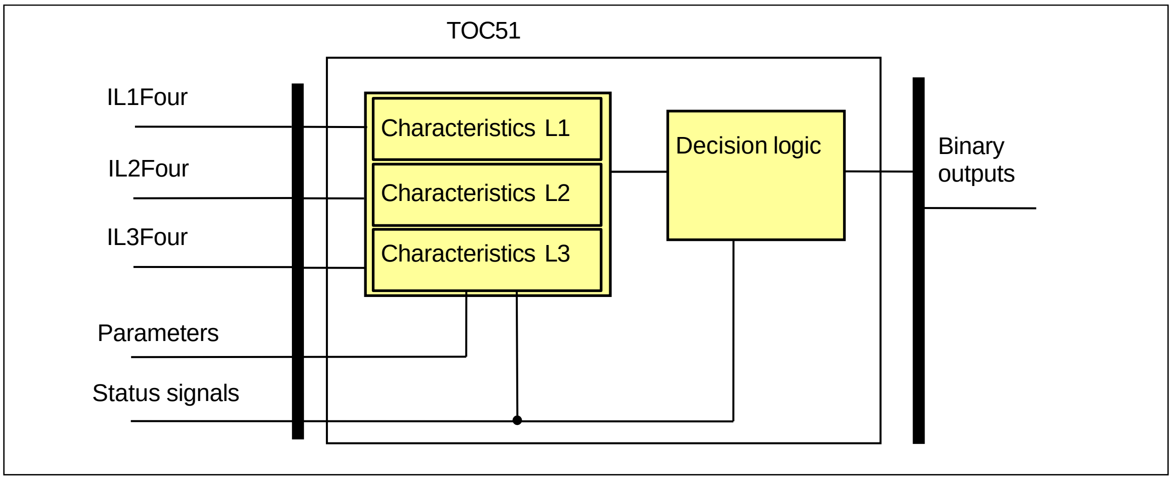


Figure 1-2 Structure of the overcurrent protection algorithm

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.

3.1.10.1.3. 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.

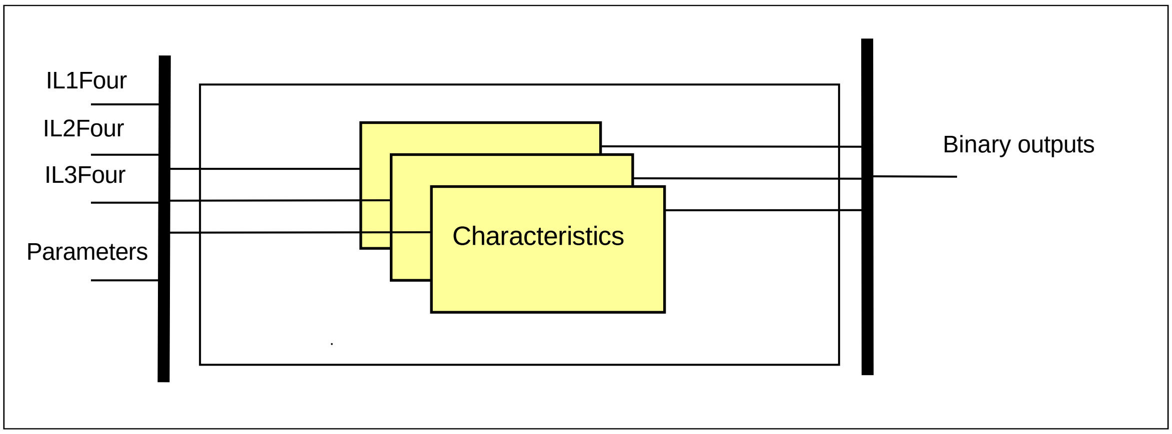


Figure 1-3 Schema of the characteristic calculation

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.

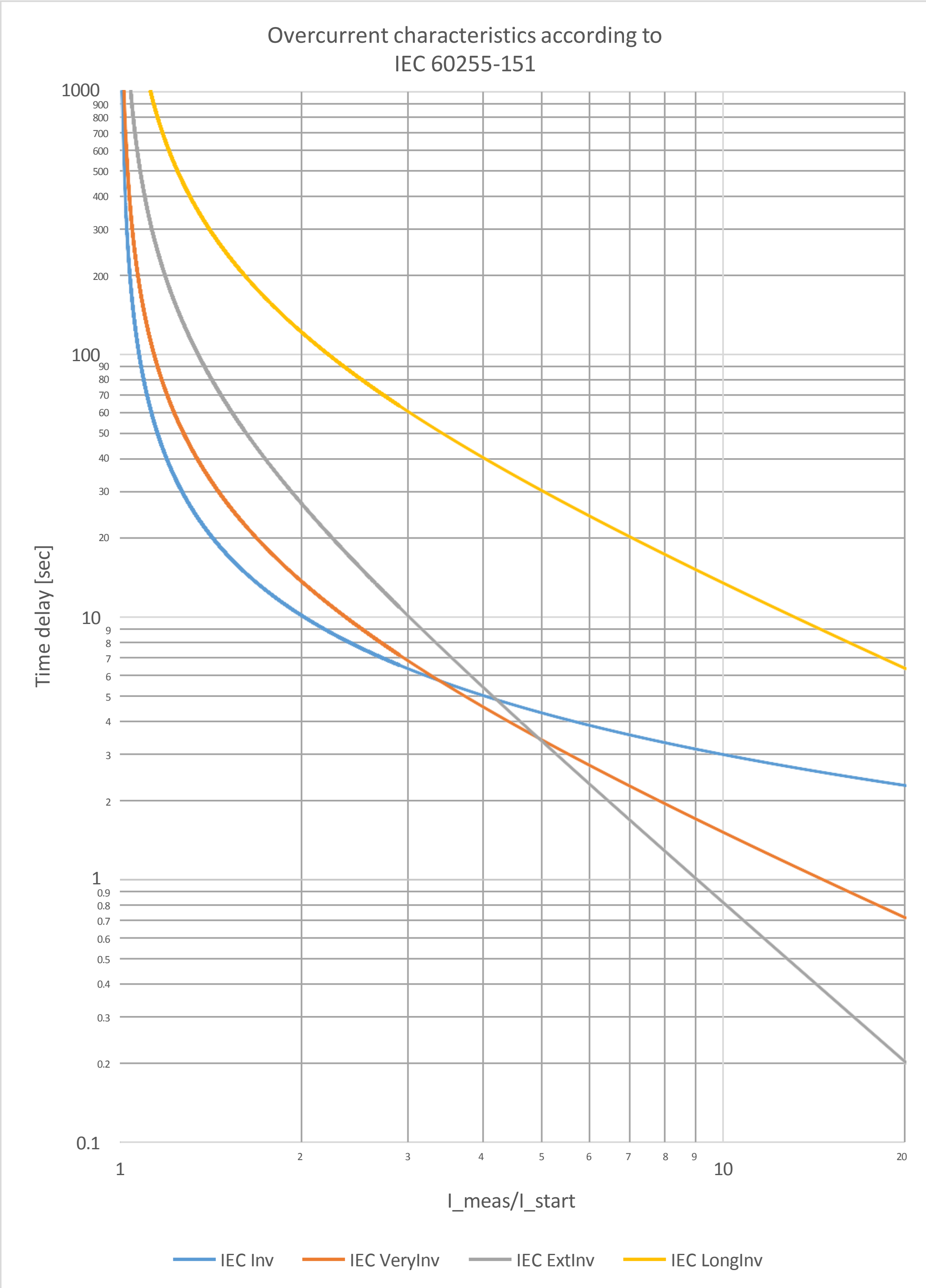


Figure 1-4 Overcurrent characteristics according to IEC 60255-151

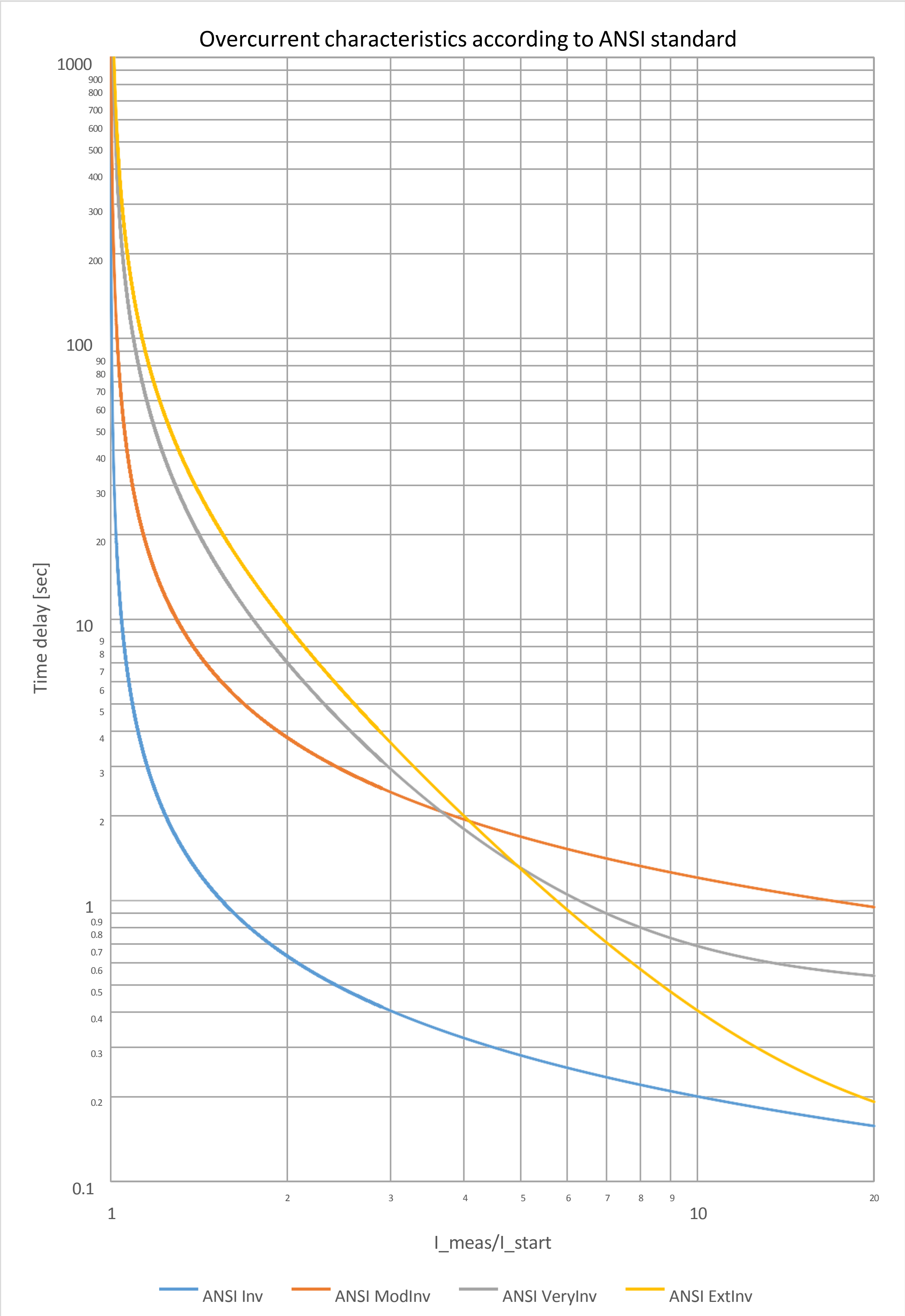


Figure 1-5 Overcurrent characteristics according to ANSI standard

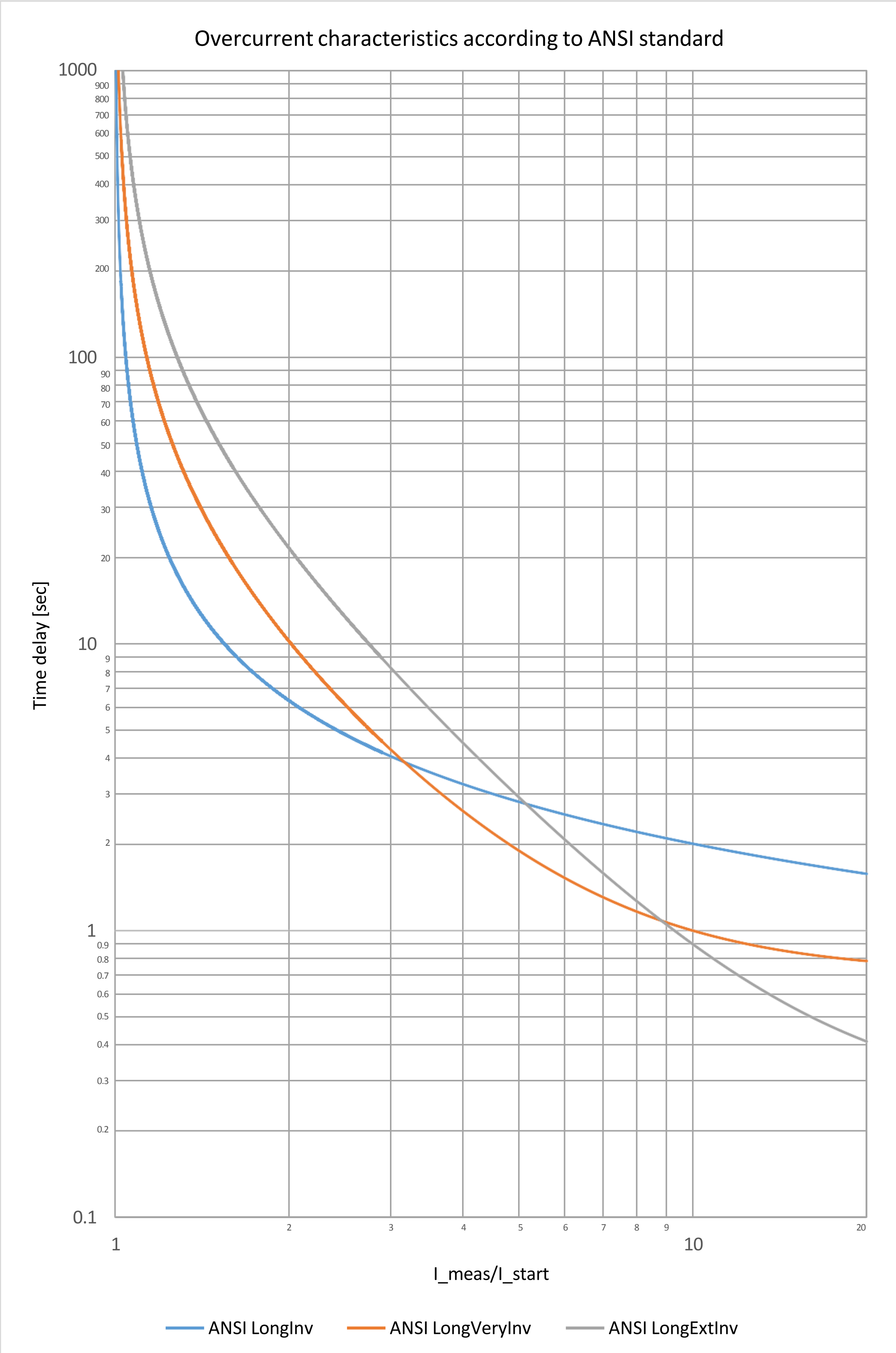


Figure 1-6 Overcurrent characteristics according to ANSI standard

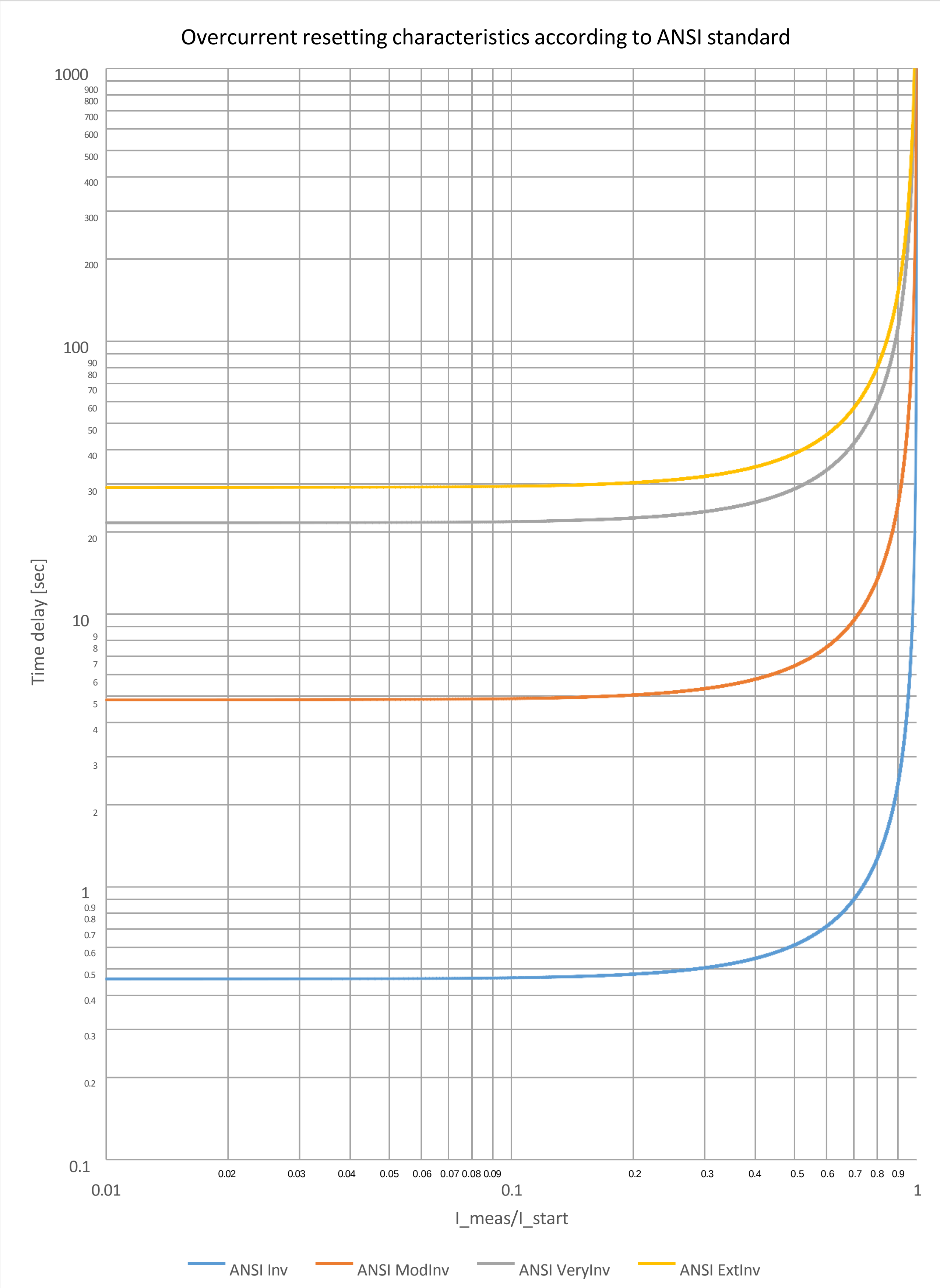


Figure 1-7 Overcurrent resetting characteristics according to ANSI standard

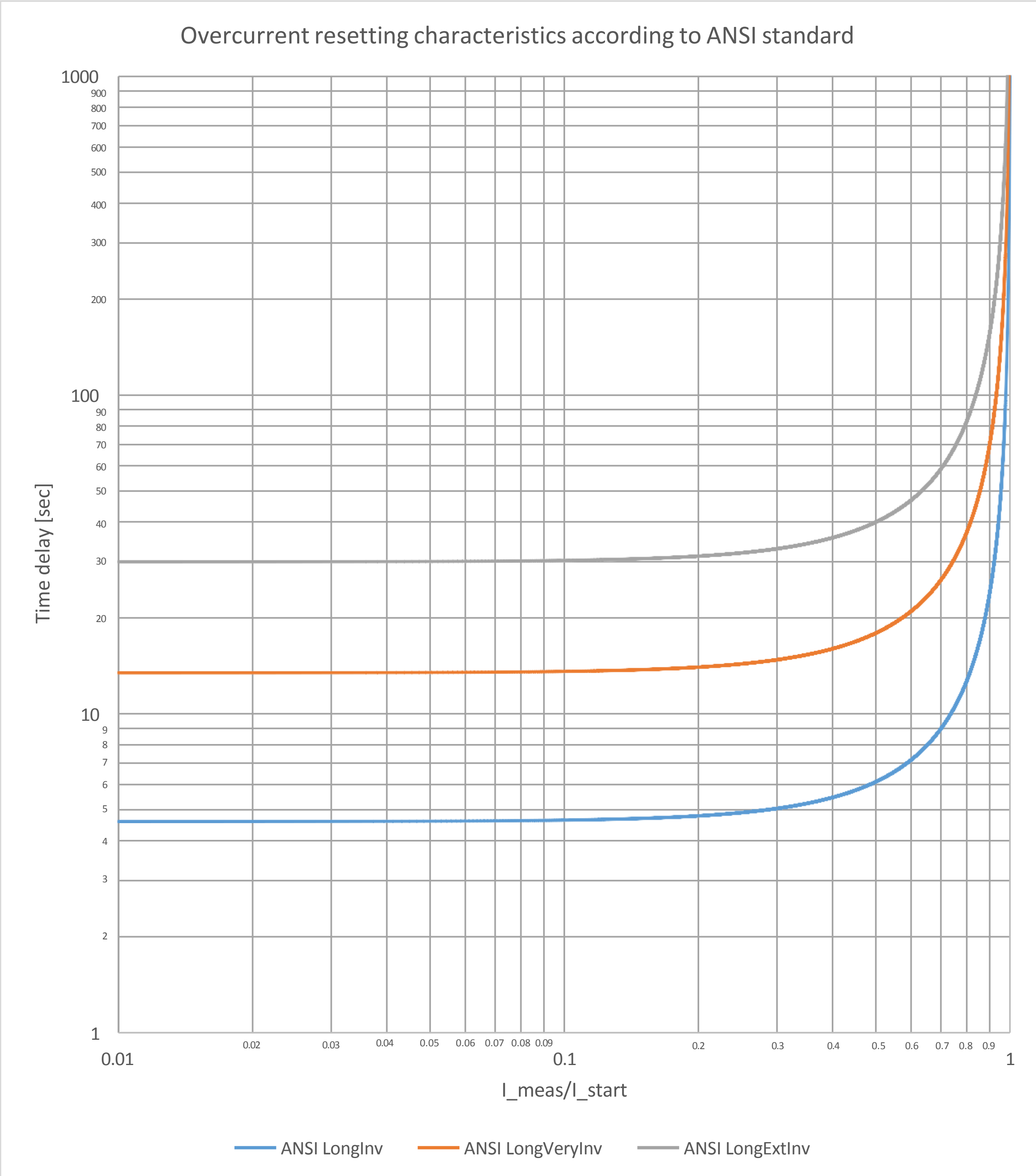


Figure 1-8 Overcurrent resetting characteristics according to ANSI standard

3.1.10.1.4. 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.

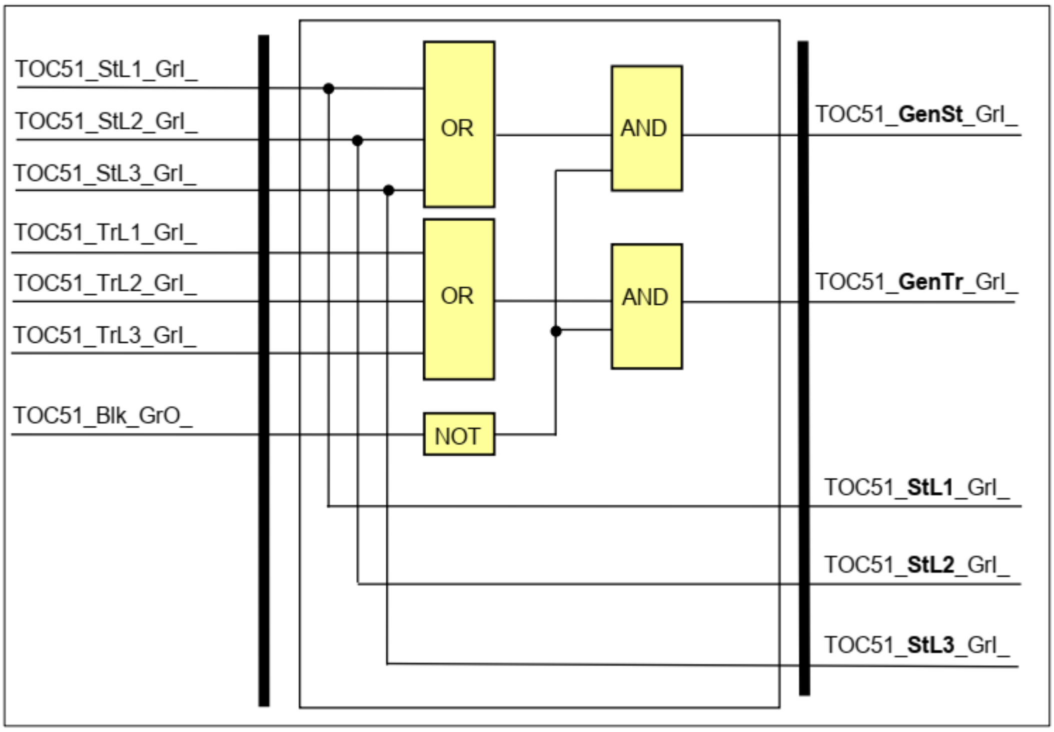


Figure 1-9 The logic scheme of the overcurrent protection function

Table 1-3 The binary input status signals of the overcurrent protection function

BINARY INPUT SIGNALS	SIGNAL TITLE	EXPLANATION
TOC51_StL1_GrI_	Start L1	Starting of the function in phase L1
TOC51_TrL1_GrI_	Trip L1	Trip command of the function in phase L1
TOC51_StL2_GrI_	Start L2	Starting of the function in phase L2
TOC51_TrL2_GrI_	Trip L2	Trip command of the function in phase L2
TOC51_StL3_GrI_	Start L3	Starting of the function in phase L3
TOC51_TrL3_GrI_	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_GrI_	Start L1	Starting of the function in phase L1
TOC51_StL2_GrI_	Start L2	Starting of the function in phase L2
TOC51_StL3_GrI_	Start L3	Starting of the function in phase L3
TOC51_GenSt_GrI_	Gen. Start	General starting of the function
TOC51_GenTr_GrI_	Gen. Trip	General trip command of the function

3.1.10.2. 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.

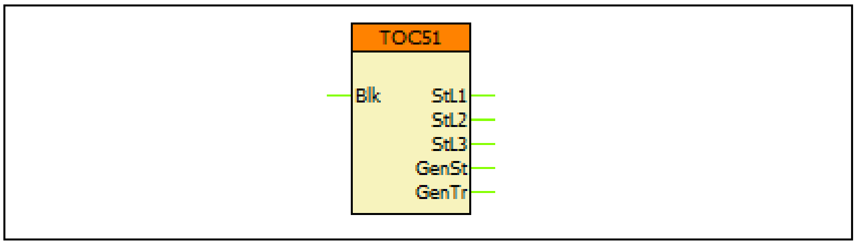


Figure 2-1 The function block of the overcurrent protection function

3.1.10.2.1. Settings

3.1.10.2.1.1. 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

3.1.10.2.2. Function I/O

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

3.1.10.2.2.1. Analogue inputs

The function uses the sampled values of the three phase currents.

3.1.10.2.2.2. 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_**StL1**_GrI_	Start L1	Starting of the function in phase L1
TOC51_TrL1_GrI_	Trip L1	Trip command of the function in phase L1
TOC51_**StL2**_GrI_	Start L2	Starting of the function in phase L2
TOC51_TrL2_GrI_	Trip L2	Trip command of the function in phase L2
TOC51_**StL3**_GrI_	Start L3	Starting of the function in phase L3
TOC51_TrL3_GrI_	Trip L3	Trip command of the function in phase L3
TOC51_**GenSt**_GrI_	General Start	General start of the function
TOC51_**GenTr**_GrI_	General Trip	General trip command of the function

3.1.10.2.2.3. 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_**Blk**_GrO_	Output status of a graphic equation defined by the user to disable the overcurrent protection function.

3.1.10.2.2.4. 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

3.1.10.2.2.5. 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

3.1.10.2.3. Technical data

Table 2-6 Technical data of the 3ph overcurrent protection function

FUNCTION	VALUE	ACCURACY
Operating accuracy	20 ≤ GS ≤ 1000	< 2 %
Operate time accuracy		±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*

3.1.10.2.3.1. 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.

3.1.11. 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 (3Io) or the calculated zero sequence current component. The characteristics are harmonized with IEC 60255-151, Edition 1.0, 2009-08.

3.1.11.1. Operating characteristics

3.1.11.1.1. Independent time characteristic

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

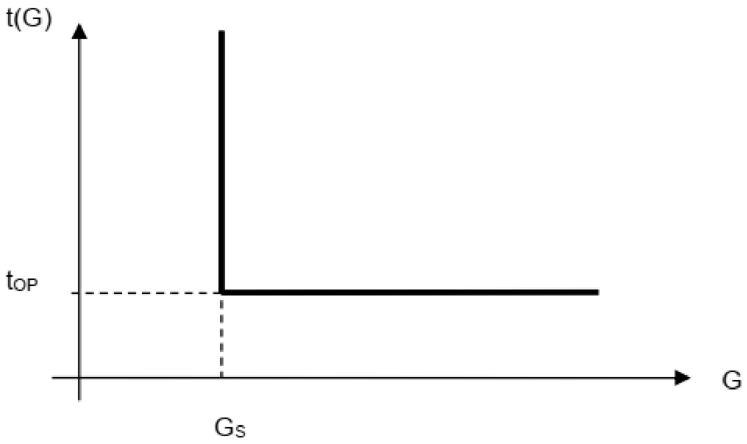


Figure 1-1 Overcurrent independent time characteristic

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 residual current,
G_S	preset value of the characteristic quantity (TOC51N_StCurr_IPar_, Start current).

3.1.11.1.2. 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)	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 residual current,
G_S	preset value of the characteristic quantity (TOC51N_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 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.

3.1.11.2. Structure of the residual overcurrent protection algorithm

Fig.1-2 shows the structure of the residual overcurrent protection (TOC51N) algorithm.

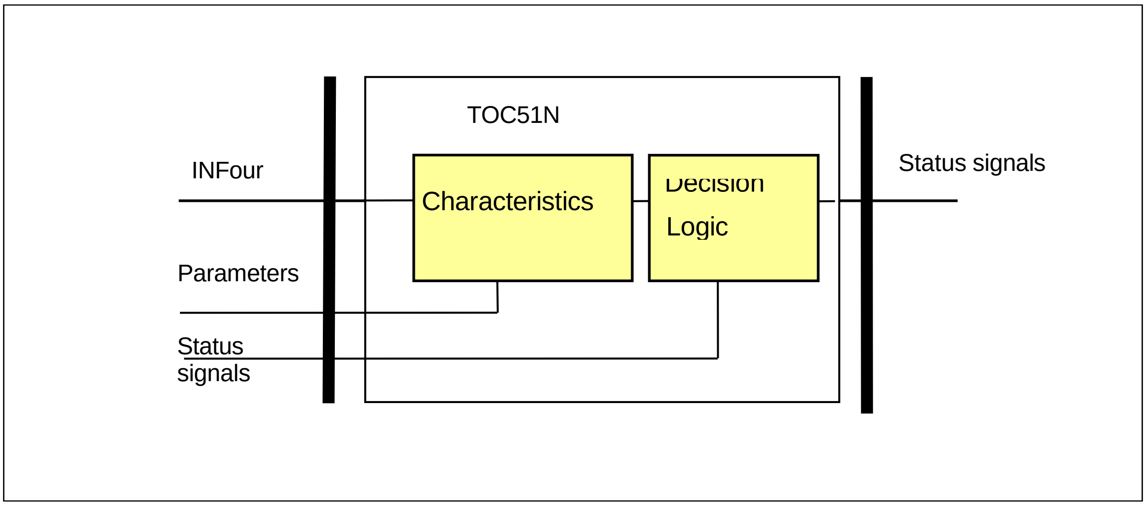


Figure 1-2 Structure of the residual overcurrent protection algorithm

The **inputs** are
- the RMS value of the fundamental Fourier component of the residual current (IN=3Io),
- 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.

3.1.11.3. 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.

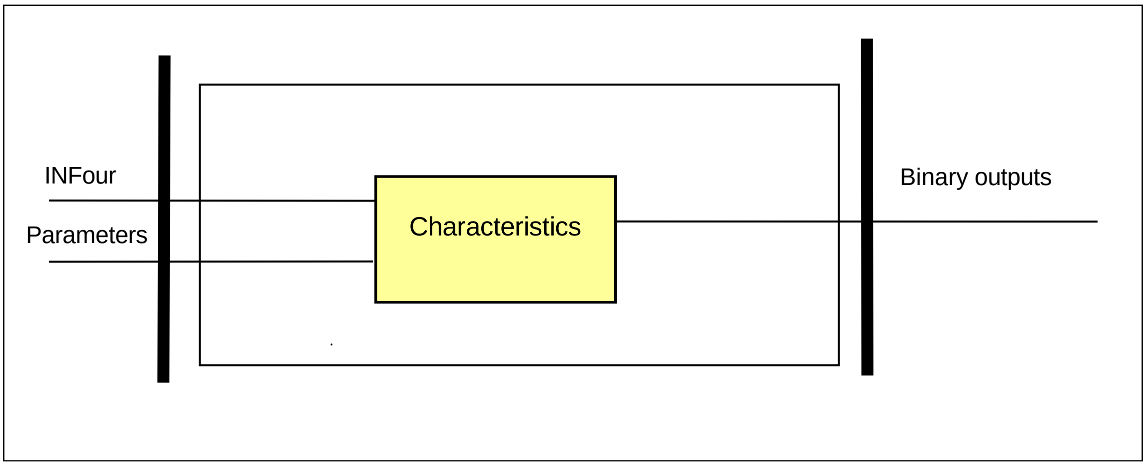


Figure 1-3 Schema of the characteristic calculation

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_GrI_	Start L1	Starting of the function
TOC51N_Tr_GrI_	Trip L1	Trip command of the function

Table 1-7 The binary output status signals of the residual overcurrent protection function

3.1.11.4. The decision logic (Decision logic)

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

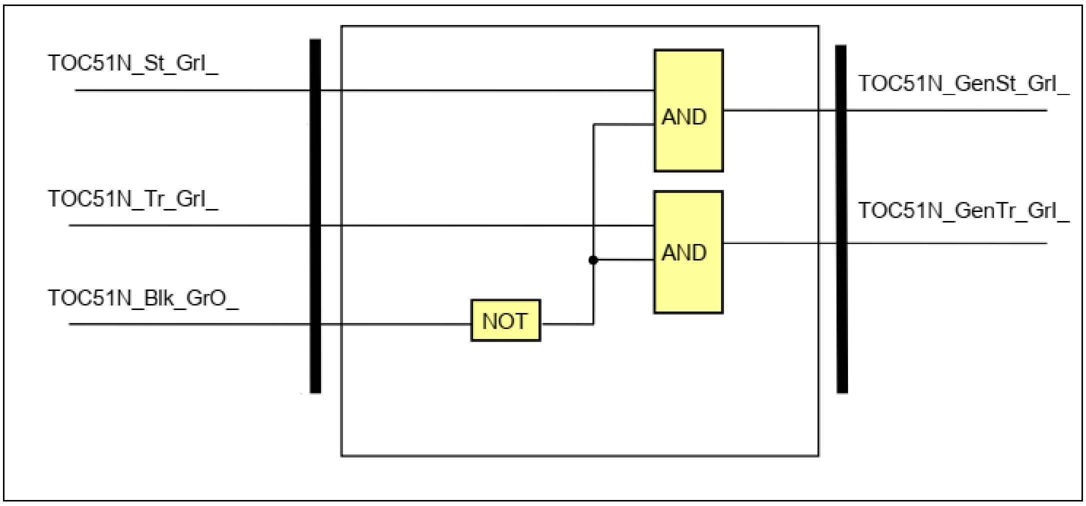


Figure 1-4 The (simplified) logic scheme of the residual overcurrent protection function

Binary input signals	Signal title	Explanation
TOC5N1_St_GrI_	Start	Starting of the function
TOC51N_Tr_GrI_	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_GrI_	General Start	General starting of the function
TOC51N_GenTr_GrI_	General Trip	General trip command of the function

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

3.1.11.5. Technical summary

3.1.11.5.1. Technical data

Function	Value	Accuracy
Operating accuracy *	$20 \le G_S \le 1000$	< 3 %
Operate time accuracy		±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	
Overshoot 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 In = 200 mA*

Table 1-11 Technical data of the residual overcurrent protection function

3.1.11.5.2. The parameters

The parameters are summarized in Chapter 1.3.

3.1.11.5.3. 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

3.1.11.5.4. 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_GrI_	General Start	General starting of the function
TOC51N_GenTr_GrI_	General Trip	General trip command of the function

Table 1-13 The binary output status signals of the residual overcurrent protection function

3.1.11.5.5. 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.

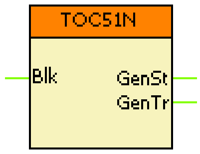


Figure 1-5 The function block of the residual overcurrent protection function

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3.1.12. Inrush current detection function

3.1.12.1. 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.

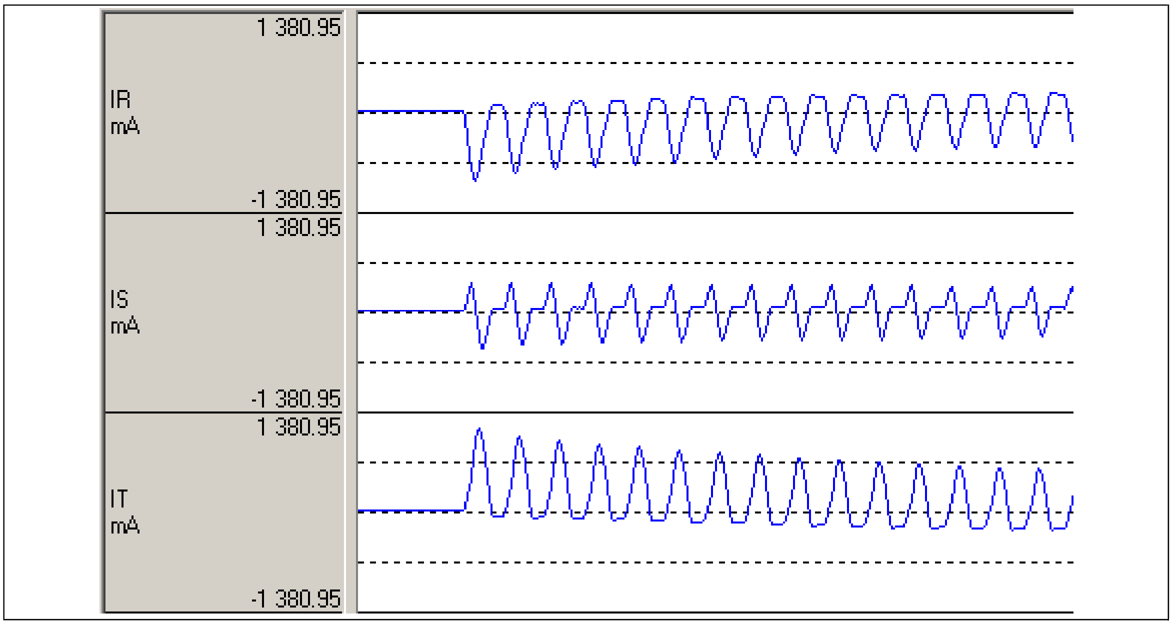

Figure 1-1 Example: A typical inrush current

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.

3.1.12.1.1. 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 (2^{nd}, 4^{th} 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.

3.1.12.2. 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.

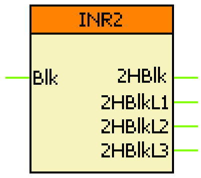

Figure 2-1 The function block of the inrush current detection function

3.1.12.2.1. Settings

3.1.12.2.1.1. 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

3.1.12.2.2. Function I/O

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

3.1.12.2.2.1. Analogue inputs

The basic and second Fourier components of three phase currents.

3.1.12.2.2.2. 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_**Blk**_GrO_	Blocking input of the function

3.1.12.2.2.3. 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_**2HBlk**_Grl_	Inrush	Inrush current detected in one of the three phases
INR2_**2HBlkL1**_Grl_	Inrush L1	Inrush current detected in phase L1
INR2_**2HBlkL2**_Grl_	Inrush L2	Inrush current detected in phase L2
INR2_**2HBlkL3**_Grl_	Inrush L3	Inrush current detected in phase L3

3.1.12.2.2.4. 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

3.1.12.2.2.5. 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

3.1.12.2.3. Technical data

Table 2-6 Technical data of the inrush current detection function

FUNCTION	VALUE	ACCURACY
Current accuracy	20 – 2000% of In	±1% of In

3.1.12.2.4. Notes for testing

The differential protection function block (DIF87) has its own, built-in 2^{nd} 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 2^{nd} harmonic content related to the fundamental component.

3.1.13. HV AutoReclosing

3.1.13.1. Application

The HV automatic reclosing function for high voltage networks can realize up to four shots of reclosing. The dead time can be set individually for each reclosing and separately for single- phase faults and for multi-phase faults.

The starting signal of the cycles can be generated by any combination of the protection functions or external signals of the binary inputs. The selection to generate the binary input REC79_**St**_GrO_ (Protection Start) is made by graphic equation programming.

The automatic reclosing function is triggered if as a consequence of a fault a protection function generates a trip command to the circuit breaker and the protection function resets because the fault current drops to zero or the circuit breaker's auxiliary contact signals open state. According to the preset parameter values, either of these two conditions starts counting the dead time, at the end of which the HV automatic reclosing function generates a close command automatically. If the fault still exists or reappears, then within the "**Reclaim time**" (according to parameter setting REC79_Rec_TPar_), started at the close command, the protection functions picks up again and the subsequent cycle is started. If no pickup is detected within this time, then the HV automatic reclosing cycle resets and a new fault will start the procedure with the first cycle again.

The sequence of the initial actions on starting the automatic reclosing function is as follows:

- Protection starting to the binary input REC79_**St**_GrO_ (Protection Start) starts the action time (REC79_Act_TPar_), during its running time, the protection trip should be got.
- Triggering signal of the HV automatic reclosing function to the binary input REC79_**Tr**_GrO_ (AutoReclosing Start) is the protection trip, it starts the „Run" state („In progress" state, REC79_**Run**_GrI_) and starts the Start Signal Max Time (REC79_MaxSt_TPar_) counter. During its running time, according to the preset parameter value, protection trip resetting or CB open signal (starting signal) should be got.
- Starting signal of the HV automatic reclosing function can be protection trip resetting or CB open signal which starts the dead time.
- Close command is generated at the dead time end, and it starts the reclaim time (REC79_Rec_TPar).

There are some additional requirements to perform automatic reclosing:

- The HV automatic reclosing function can be blocked by the variable REC79_Blk_GrO_, for which the user has to compose a graphic logical equation.
- After a pickup of the protection function, a timer starts to measure the "**Action time**" (the duration of which depends on parameter setting REC79_Act_TPar_ (Action time)). The trip command must be generated within this time to start reclosing cycles, or else the HV automatic function enters dynamic blocked state.
- At the moment of generating the close command, the circuit breaker must be ready for operation, which is signaled via binary input REC79_**CBRdy**_GrO_ (CB Ready). The preset parameter value REC79_CBTO_TPar_ (CB Supervision time) decides how long the HV automatic reclosing function is allowed to wait when the function is in "In Progress" state. If the signal is not received during this time, then the HV automatic reclosing function terminates and after a "**dynamic blocking time**" (depending on the preset parameter value REC79_DynBlk_TPar_ (Dynamic Blocking time)) the function resets.

Depending on the preset parameter value, the HV automatic reclosing function can influence the operation of the protection functions as well. The binary outputs of the HV automatic reclosing function, including the "In progress" (Run) state, can be applied for this purpose in the graphic equation editor. (See Chapter 1.3.5)

In case of a manual close command which is assigned to the logic variable REC79_**ManCl**_GrO_ (Maunal Close) using graphic equation programming, a preset parameter value decides how long the HV automatic reclosing function should be disabled **after the manual close** command.

The **duration of the close command** depends on preset parameter value REC79_Close_TPar_ (Close command time), but the close command terminates if any of the protection functions issues a trip command.

3.1.13.2. Mode of operation

The HV automatic reclosing function can control up to four reclosing cycles. Depending on the preset parameter value REC79_CycEn_EPar_ (Reclosing cycles), there are different modes of operation:

Disabled	No automatic reclosing is selected,
1. Enabled	Only one automatic reclosing cycle is selected,
1.2. Enabled	Two automatic reclosing cycles are activated,
1.2.3. Enabled	Three automatic reclosing cycles are activated,
1.2.3.4. Enabled	All automatic reclosing cycles are activated.

The function can be switched Off /On using the parameter REC79_Op_EPar_ (Operation).

The user can also block the HV automatic reclosing function applying the graphic equation editor. The binary status variable to be programmed is REC79_**Blk**_GrO_ (Block).

If the device is generally blocked, then the HV automatic reclosing function is also blocked.

3.1.13.2.1. Starting the HV automatic reclosing cycle

Depending on the present parameter value REC79_St_EPar_ (Reclosing started by), the HV automatic reclosing function can be started either by resetting of the TRIP command (setting: Trip reset) or by the binary signal indicating the open state of the circuit breaker (setting: CB open).

If the reset state of the TRIP command is selected to start the HV automatic reclosing function, then the binary status variable to be programmed is: REC79_**Tr**_GrO_ (AutoReclosing Start).

If the open state of the circuit breaker is selected to start the HV automatic reclosing function (CB open), then also the binary status variable REC79_**CBOpen**_GrO_ (CB OPEN single-pole) is additionally to be programmed. This signal should be TRUE if at least one of the poles is open

The HV automatic reclosing function gets the trip commands of the protection functions intended to trigger the reclosing function. The conditions for detecting the triggered state of the protection functions are defined by the user applying the graphic equation editor. The binary status variable to be programmed is: REC79_**Tr**_GrO_ (AutoReclosing Start). This signal starts a dedicated timer, the elapsed time of which is compared to the preset parameter value REC79_MaxSt_TPar_ (Start-signal Max.Tim).

The HV automatic reclosing function enters the dynamic blocking state:

- If the parameter selected for REC79_St_EPar_ (Reclosing started by) is “Trip reset”, and the trip impulse is too long
- If the parameter selected for REC79_St_EPar_ (Reclosing started by) is “CB open”, then during the runtime of the timer CB open signal is not received

For further information about the dynamic blocking state see Chapter 1.2.17.

3.1.13.2.2. Starting the dead time counter

In the base case, the dead time counter of any reclosing cycle is started by the starting signal (See Chapter 1.2.1) but starting can be delayed. The delay is activated while the value of the REC79_**DtDel**_GrO_ (Dead Time Start Delay) status signal is TRUE. The conditions are defined by the user applying the graphic equation editor. This delay is limited by the timer parameter REC79_DtDel_TPar_ (DeadTime Max.Delay).

3.1.13.2.3. The dead time

For all four reclosing cycles, separate dead times can be defined for single-phase trip commands (as a consequence of single-phase faults) and for three-phase trip commands (as a consequence of multi-phase faults).

The timer parameters for single-phase trip commands are:

REC79_1PhDT1_TPar_	1. Dead Time 1Ph
REC79_1PhDT2_TPar_	2. Dead Time 1Ph
REC79_1PhDT3_TPar_	3. Dead Time 1Ph
REC79_1PhDT4_TPar_	4. Dead Time 1Ph

The timer parameters for three-phase trip commands are:

REC79_3PhDT1_TPar_	1. Dead Time 3Ph
REC79_3PhDT2_TPar_	2. Dead Time 3Ph
REC79_3PhDT3_TPar_	3. Dead Time 3Ph
REC79_3PhDT4_TPar_	4. Dead Time 3Ph

The different dead time settings can be justified as follows: in case of a single-phase fault, only the circuit breakers of the faulty phase open. In this case, due to the capacitive and inductive coupling of the healthy phases, the extinction of the secondary electric arc at the fault location can be delayed. Consequently, a longer dead time is needed for the fault current to extinguish than in the case of a three-phase open state, when no coupled voltage can sustain the fault current.

From other point of view, in case of a transmission line connecting two power systems, only a shorter dead time is allowed for the three-phase open state because, due to the possible power unbalance between the interconnected systems, a large angle difference can be reached if the dead time is too long. If only a single phase is open, then the two connected healthy phases and the ground can sustain the synchronous operation of both power systems.

3.1.13.2.4. Special dead time for the first cycle

This special dead time can be necessary for the following reason:

Assume a line between substations A and B, and a protection system without tele-protection. In the event of a three-phase fault near substation B, the protection at A generates a trip command according to the second zone's time setting only, and starts measuring the dead time with considerable delay as compared to the protection at B, which generates a trip command immediately due to the close-in fault.

If the three-phase dead time is too short, the HV automatic reclosing at B may attempt to close the circuit breaker during the running time of the second zone trip at A, which means that the fault is not cleared yet. Consequently, a prolonged dead time is needed if the fault was detected in the first zone.

The preset timer parameter value is REC79_3PhDT1_TPar_2 (1. special DT 3Ph).
The special dead time is valid if the REC79_**1cyc3PhFlt**_GrO_ (3PhFault for Spec.DT1) status signal is TRUE. The conditions are defined by the user applying the graphic equation editor.

3.1.13.2.5. Reduced dead time

Dead time reduction may be applicable under the following circumstances:

If healthy voltage is measured in all three phases during the dead time, this means that no fault exists on the line. In this case, the expiry of the normal dead time need not be waited for, a reclosing attempt can be initiated immediately.

The dead time is terminated immediately if the REC79_**RDT**_GrO_ (Reduced DeadTime) status signal is TRUE. The conditions are defined by the user applying the graphic equation editor.

3.1.13.2.6. Three-phase trip

The HV automatic reclosing function is prepared to get the general trip command as programmed to the binary input status variable REC79_**Tr**_GrO_ (AutoReclosing Start) and the three-phase trip signal REC79_**3PhTr**_GrO_ (3Ph Trip). If no three-phase trip signal is received, then it performs automatic reclosing cycles with the dead times according to the setting for single phase cycles. The three-phase cycles are controlled by the status variable REC79_**3PhTr**_GrO_ (3Ph Trip). If this is TRUE, three-phase cycles are performed. The conditions are defined by the user applying the graphic equation editor.

If, during the cycles, the three-phase dead time is applied once, then all subsequent cycles will consider the three-phase dead time settings, too.

Three-phase reclosing can be disabled by the preset parameter value REC79_3PhRecBlk_BPar_ (Disable 3Ph Rec.). If the value of this parameter is TRUE, then if a three-phase trip command is received, the HV automatic reclosing function enters “Dynamic blocked” state.

For further information about the dynamic blocked state, see Chapter 1.2.17.

3.1.13.2.7. Checking the ready state of the circuit breaker

At the end of the dead time, reclosing is possible only if the circuit breaker can perform the command.
The binary variable REC79_**CBRdy**_GrO_ (CB Ready) indicates this state. The conditions are defined by the user applying the graphic equation editor.

If the circuit breaker is not ready, the controller functions wait for a pre-programmed time for this state. The waiting time is defined by the user as parameter value REC79_CBTO_TPar_ (CB Supervision time). If this condition is not fulfilled during the waiting time, then the HV automatic reclosing function enters “Dynamic blocked” state.

For further information about the dynamic blocked state, see Chapter 1.2.17.

3.1.13.2.8. Reclosing with synchronous state supervision

Reclosing is possible only if the conditions required by the *Synchro-check, synchro-switch* function are fulfilled. This state is signaled by the binary variable REC79_**SynRel**_GrO_ (SYNC Release) from the *Synchro-check, synchro-switch* function. The conditions are defined by the user applying the graphic equation editor. The HV automatic reclosing function waits for a pre- programmed time for this signal. This time is defined by the user as parameter value REC79_SYN1_TPar_ (SynCheck Max Time). If the “SynRel” signal is not received during the running time of this timer, then the “synchronous switch” operation is started (See Chapter

1.2.9) and the binary output signal REC79_**ClReq**_GrI_ (ClReq) is generated which is connected to the *Synchro-check, synchro-switch* function.

3.1.13.2.9. Reclosing with synchronous switching

If the conditions of the synchronous state are not fulfilled, another timer starts. This waiting time is defined by the user as parameter value REC79_SYN2_TPar_ (SynSW Max Time).

The separate *Synchro-check, synchro-switch* function controls the generation of the close command in case of relatively rotating voltage vectors on both sides of the circuit breaker to make contact at the synchronous state of the rotating vectors. For this calculation, the closing time of the circuit breaker must be defined in that function.

This mode of operation is indicated by the output variable REC79_**ClReq**_GrI_ (ClReq).

If no switching is possible during the running time of this timer, then the HV automatic reclosing function enters “Dynamic blocked” state and resets.

For further information about the dynamic blocked state, see Chapter 1.2.17.

3.1.13.2.10. Impulse duration of the CLOSE command

The “Close” impulse is generated as one of the output status signals of the HV automatic reclosing function REC79_**Close**_GrI_ (Close). This signal is common to all three phases. The impulse duration is defined by the user setting the timer parameter REC79_Close_TPar_ (Close command time).

3.1.13.2.11. Behavior after reclosing

When the close command is generated, a timer is started to measure the “Reclaim time”. The duration is defined by the parameter value REC79_Rec_TPar_ (Reclaim time), but it is prolonged up to the reset of the close command (if the close command duration is longer then the reclaim time set). If the fault is detected again during this time, then the sequence of the HV automatic reclosing cycles continues. If no fault is detected, then at the expiry of the reclaim time the reclosing is evaluated as successful and the function resets. If fault is detected after the expiry of this timer, then the cycles restart with the first reclosing cycle.

If the user programmed the status variable REC79_**St**_GrO_ (Protection Start) and it gets TRUE during the Reclaim time, then the HV automatic reclosing function continues even if the trip command is received after the expiry of the Reclaim time.

3.1.13.2.12. Behavior after manual close command

This state of manual close command is signaled by the binary variable REC79_**ManCl**_GrO_ (Maunal Close). The conditions are defined by the user applying the graphic equation editor.

After a manual close command, the HV automatic reclosing function enters “Not Ready” state for the time period defined by parameter REC79_MC_TPar_ (Block after Man.Close). For “Not Ready” state, see Chapter 1.2.18.

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If the manual close command is received during the running time of any of the cycles, then the HV automatic reclosing function enters “Dynamic blocked” state and resets. For dynamic blocked state, see Chapter 1.2.17.

3.1.13.2.13. Behavior in case of evolving fault

In case of evolving faults (when a single-phase fault detected changes to multi-phase fault), the behavior of the automatic reclosing function is controlled by the preset parameter value REC79_EvoFlt_EPar_ (Evolving fault). The options are

- “Block Reclosing” or
- “Start 3Ph Rec.” .

If “Block Reclosing” is selected, the HV automatic reclosing function enters dynamic blocked state (See Chapter 1.2.17.), and the subsequent reclosing command is not generated.

If “Start 3Ph Rec.” is selected, the HV automatic reclosing function goes on performing the subsequent cycle according to the three-phase parameters.

3.1.13.2.14. The final trip

If the fault still exists at the end of the last cycle, the HV automatic reclosing function generates the signal for final trip: REC79_**FinTr**_GrI_ (FinTr). The same final trip signal is generated in case of an evolving fault if “Block Reclosing” is selected (see Chapter 1.2.13). After final trip, the HV automatic reclosing function enters “Dynamic blocked” state.

A final trip command is also generated if, after a multi-phase fault, a fault is detected again during the dead time.

For further information about the dynamic blocked state, see Chapter 1.2.17.

3.1.13.2.15. Action time

The user can compose the binary status variable REC79_**St**_GrO_ (Protection Start) to indicate the start of the protection functions, whose operations are related to the HV automatic reclosing function. See Chapter 1.1This signal starts the “Action time”, the duration of which is defined by the preset parameter value REC79_Act_TPar_ (Action time). During the running time, the HV automatic reclosing function waits for the trip command. If no trip command is received, then the HV automatic reclosing function enters “Dynamic blocked” state.

For further information about the dynamic blocked state, see Chapter 1.2.17.

3.1.13.2.16. Accelerating trip commands

Depending on the Boolean parameter settings, the automatic reclosing function block can accelerate trip commands of the individual reclosing cycles. This means that the output REC79_**TrAcc**_GrI_ (TrAcc) of the function block gets active for the first starting state of the protection function or at the end of the dead time of the running cycle, if the dedicated parameter enables acceleration. This signal “TrAcc” needs user-programmed graphic equations to generate the accelerated trip command.

3.1.13.2.17. Dynamic blocking conditions

There are several conditions to result dynamic blocked state of the HV automatic reclosing function. This state becomes valid if any of the conditions of the dynamic blocking get TRUE during the running time of any of the reclosing cycles.

At the time of the change to start the dynamic blocked state a timer is started, the running duration of which is defined by the time parameter REC79_DynBlk_TPar_ (Dynamic Blocking time). During its running time the function is blocked, no reclosing command is generated.

The conditions to start the dynamic blocked state are:

- There is no trip command during the "Action time" (See Chapter 1.2.15).
- The duration of the starting impulse for the HV automatic reclosing function is too long (See Chapter 1.2.1).
- If no "CB ready" signal is received at the intended time of reclosing command (See Chapter 1.2.7)
- The dead time is prolonged further then the preset parameter value REC79_DtDel_TPar_ (DeadTime Max.Delay) (See Chapter 1.2.2).
- The waiting time for the "SYNC Release" signal is too long (See Chapter 1.2.9)
- After the final trip command (See Chapter 1.2.14).
- Automatic reclosing is started during the blocking time after a manual close command (See Chapter 1.2.12)
- While *CB State Monitoring* is on, a manual open command (the status variable REC79_**CBOpen**_GrO_ (CB OPEN single-pole) gets TRUE without REC79_**Tr**_GrO_ (AutoReclosing Start).
- In case of a three-phase trip command if the preset parameter REC79_3PhRecBlk_BPar_ (Disable 3Ph Rec.) is set to TRUE. (See Chapter 1.2.6)
- In case of evolving faults, if the parameter setting for REC79_EvoFlt_EPar_ (Evolving fault) is "Block Reclosing" (See Chapter 1.2.13)
- Automatic reclosing is started during a general block (the device is blocked, see Chapter 1.2).

In a dynamic blocked state, the REC79_**Blocked**_GrI_ (Blocked) status signal is TRUE (similar to "Not ready" conditions).

3.1.13.2.18. "Not Ready" conditions

There are several conditions to result "Not Ready" state of the HV automatic reclosing function. This state becomes valid if any of the conditions of the blocking get TRUE outside the running time of the reclosing cycles.

- Reclosing is disabled by the parameter REC79_Op_EPar_ (Operation) if it is selected to "Off". (See Chapter 1.2)
- No reclosing cycles are selected by the parameter REC79_CycEn_EPar_ (Reclosing cycles) if it is set to "Disabled" (See Chapter 1.2)
- The circuit breaker is not ready for operation: the result of the graphic programming of the binary variable REC79_**CBRdy**_GrO_ (CB Ready) is FALSE. (See Chapter 1.2.7)
- After a manual close command (See Chapter 1.2.12)
- If the parameter REC79_CBState_BPar_ (CB State Monitoring) is set to TRUE and the circuit breaker is in Open state, i.e., the value of the REC79_**CBOpen**_GrO_ (CB OPEN single-pole) status variable gets TRUE.
- The starting signal for automatic reclosing is selected by parameter REC79_St_EPar_ (Reclosing started by) to be "CB open" and the circuit breaker is in Open state.
- In case of a general block (the device is blocked, see Chapter 1.2).

In a "Not ready" state, the REC79_**Blocked**_GrI_ (Blocked) status signal is TRUE (similar to "Dynamic blocking" conditions).

3.1.13.3. Technical summary

3.1.13.3.1. Technical data

Function	Accuracy
Operating time	±1% of setting value or ±30 ms

Table 1-1 *Technical data of the HV automatic reclosing function*

3.1.13.3.2. Summary of the parameters

Enumerated parameters

Parameter name	Title	Selection range	Default
Switching ON/OFF the HV automatic reclosing function (See Chapter 1.2)			
REC79_Op_EPar_	Operation	Off, On	On
Selection of the number of reclosing sequences (See Chapter 1.2)			
REC79_CycEn_EPar_	Reclosing Cycles	Disabled, 1. Enabled, 1.2. Enabled, 1.2.3. Enabled, 1.2.3.4. Enabled	1. Enabled
Selection of triggering the dead time counter (trip signal reset or circuit breaker open position, see Chapter 1.2.1)			
REC79_St_EPar_	Reclosing Started by	Trip reset, CB open	Trip reset
Selection of behavior in case of evolving fault (block reclosing or perform three-phase automatic reclosing cycle, see Chapter 1.2.13)			
REC79_EvoFlt_EPar_	Evolving Fault	Block Reclosing, Start 3Ph Rec.	Block Reclosing

Tables 1-2 *The enumerated parameters of the HV automatic reclosing function*

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Dead time setting for the first reclosing cycle for single-phase fault (See Chapter 1.2.3)						
REC79_1PhDT1_TPar_	1. Dead Time 1Ph	msec	0	100000	10	500
Dead time setting for the second reclosing cycle for single-phase fault (See Chapter 1.2.3)						
REC79_1PhDT2_TPar_	2. Dead Time 1Ph	msec	10	100000	10	600
Dead time setting for the third reclosing cycle for single-phase fault (See Chapter 1.2.3)						
REC79_1PhDT3_TPar_	3. Dead Time 1Ph	msec	10	100000	10	700
Dead time setting for the fourth reclosing cycle for single-phase fault (See Chapter 1.2.3)						
REC79_1PhDT4_TPar_	4. Dead Time 1Ph	msec	10	100000	10	800
Dead time setting for the first reclosing cycle for multi-phase fault (See Chapter 1.2.3)						
REC79_3PhDT1_TPar_1	1. Dead Time 3Ph	msec	0	100000	10	1000
Special dead time setting for the first reclosing cycle for multi-phase fault (See Chapter 1.2.4)						
REC79_3PhDT1_TPar_2	1. Special DT 3Ph	msec	0	100000	10	1350
Dead time setting for the second reclosing cycle for multi-phase fault (See Chapter 1.2.3)						
REC79_3PhDT2_TPar_	2. Dead Time 3Ph	msec	10	100000	10	2000
Dead time setting for the third reclosing cycle for multi-phase fault (See Chapter 1.2.3)						
REC79_3PhDT3_TPar_	3. Dead Time 3Ph	msec	10	100000	10	3000
Dead time setting for the fourth reclosing cycle for multi-phase fault (See Chapter 1.2.3)						
REC79_3PhDT4_TPar_	4. Dead Time 3Ph	msec	10	100000	10	4000
Reclaim time setting (See Chapter 1.2.11)						
REC79_Rec_TPar_	Reclaim Time	msec	100	100000	10	2000
Impulse duration setting for the CLOSE command (See Chapter 1.2.10)						
REC79_Close_TPar_	Close Command Time	msec	10	10000	10	100
Setting of the dynamic blocking time (See Chapter 1.2.17)						
REC79_DynBlk_TPar_	Dynamic Blocking Time	msec	10	100000	10	1500
Setting of the blocking time after manual close command						
REC79_MC_TPar_	Block after Man.Close	msec	0	100000	10	1000
Setting of the action time (See Chapter 1.2.15)						
REC79_Act_TPar_	Action Time	msec	0	20000	10	1000
Limitation of the starting signal (See Chapter 1.2.1)						
REC79_MaxSt_TPar_	Start Signal Max Time	msec	0	10000	10	1000
Maximum delaying the start of the dead-time counter (See Chapter 1.2.2)						
REC79_DtDel_TPar_	DeadTime Max Delay	msec	0	100000	10	3000
Waiting time for circuit breaker ready signal (See Chapter 1.2.7)						
REC79_CBTO_TPar_	CB Supervision Time	msec	10	100000	10	1000
Waiting time for synchronous state signal (See Chapter 1.2.8)						
REC79_SYN1_TPar_	SynCheck Max Time	msec	500	100000	10	10000
Waiting time for synchronous switching (See Chapter 1.2.9)						
REC79_SYN2_TPar_	SynSw Max Time	msec	500	100000	10	10000

Table 1-3 *Timer parameters of the HV automatic reclosing function*

Boolean parameters

Parameter name	Title	Default	Explanation
REC79_CBState_BPar_	CB State Monitoring	0	Enable CB state monitoring for "Not Ready" state (See Chapter 1.2.18)
REC79_3PhRecBlk_BPar_	Disable 3Ph Rec.	0	Disable three-phase reclosing (See Chapter 1.2.6)
REC79_Acc1_BPar_	Accelerate 1.Trip	0	Accelerate trip command starting cycle 1 (See Chapter 1.2.16)
REC79_Acc2_BPar_	Accelerate 2.Trip	0	Accelerate trip command starting cycle 2 (See Chapter 1.2.16)
REC79_Acc3_BPar_	Accelerate 3.Trip	0	Accelerate trip command starting cycle 3 (See Chapter 1.2.16)
REC79_Acc4_BPar_	Accelerate 4.Trip	0	Accelerate trip command starting cycle 4 (See Chapter 1.2.16)
REC79_Acc5_BPar_	Accelerate FinTrip	0	Accelerate final trip command (See Chapter 1.2.16)

Table 1-4 *Boolean parameters of the HV automatic reclosing function*

3.1.13.3.3. Summary of the generated output signals

The **binary output status signals** of the HV automatic reclosing function are listed in Table *1-5*.

Binary output status signal	Title	Explanation
REC79_**Blocked**_Grl_	Blocked	The HV automatic reclosing function is in blocked state. (See Chapters 1.2.17 and 1.2.18)
REC79_**Close**_Grl_	Close command	Close command of the HV automatic reclosing function. (See Chapter 1.2.10)
REC79_**ClReq**_Grl_	CloseRequ. SynSwitch	The closing requests synchronous switching. (See Chapter 1.2.9)
REC79_**FinTr**_Grl_	Final Trip	Indication of final trip state. (See Chapter 1.2.14)
REC79_**TrAcc**_Grl_	Acceleration	Trip command acceleration. (See Chapter 1.2.16)
REC79_**Run**_Grl_	AR in progress	The automatic reclosing is running ("In progress" state).

Table 1-5 *The binary output status signals of the HV automatic reclosing function*

3.1.13.3.4. Summary of the input signals

The HV automatic reclosing function has binary input status signals. The conditions are defined by the user applying the graphic equation editor.
The **binary input status signals** of the HV automatic reclosing function are listed in Table *1-6*.

Binary input status signal	Title	Explanation
REC79_**Blk**_GrO_	Block	Signal for blocking the automatic reclosing function externally (See Chapter 1.2)
REC79_**St**_GrO_	Protection Start	Start signal of a protection function. (See Chapter 1.2.1)
REC79_**Tr**_GrO_	AutoReclosing Start	Signal to start the automatic reclosing function. (See Chapter 1.2.1)
REC79_**3PhTr**_GrO_	3Ph Trip	Signal of three-phase trip (See Chapter 1.2.6)
REC79_**1cyc3PhFlt**_GrO_	3PhFault for Spec.DT1	Signal for special 1st dead time (See Chapter 1.2.4)
REC79_**CBOpen**_GrO_	CB OPEN single-pole	Circuit breaker is opened at least in one phase (See Chapter 1.2.1)
REC79_**SynRel**_GrO_	SYNC Release	Release signal from synchro-check function (See Chapter 1.2.8)
REC79_**ManCl**_GrO_	Manual Close	Signal of manual close command (See Chapter 1.2.12)
REC79_**CBRdy**_GrO_	CB Ready	Circuit breaker is ready for operation (See Chapter 1.2.7)
REC79_**DtDel**_GrO_	Dead Time Start Delay	Signal for delaying the start of the dead time counter (See Chapter 1.2.2)
REC79_**RDT**_GrO_	Reduced DeadTime	Signal for reducing the dead time (See Chapter 1.2.5)

Table 1-6 *The binary input signal of the HV automatic reclosing function*

3.1.13.3.5. The symbol of the function block

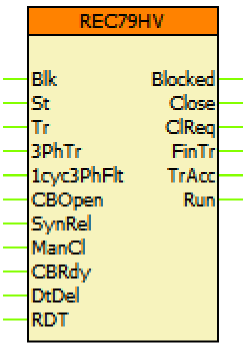


Figure 1-1 *The function block of the HV automatic reclosing function*

The names of the input and output signals are parts of the “Binary status signal” names listed in Table *1-5* and Table *1-6*.

3.1.13.4. Examples

3.1.13.4.1. Logic connections of the REC79HV function block

Basic example for the application of the REC79HV function block in a logic diagram is shown in Figure 3-1. This connection is used for the examples below.

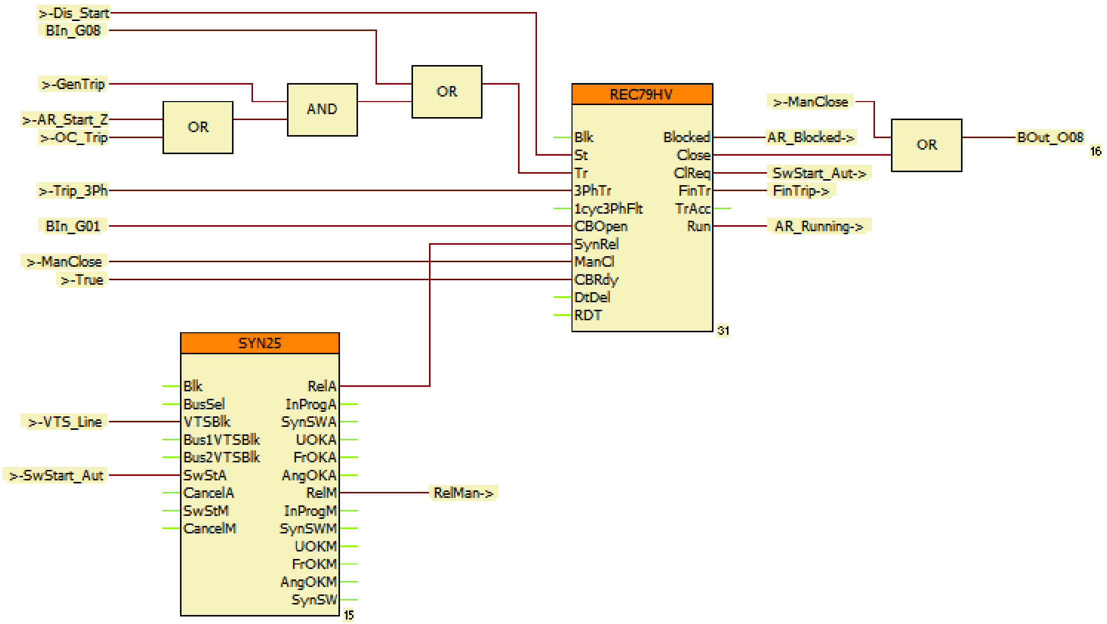


Figure 3-1 Example: The connections of the function block of the AR function

The “**Blk**” input is not connected. The function cannot be disabled externally.

The “**St**” input is connected the general start signal from the distance protection. This means that if the distance protection starts in any zone, the automatic reclosing function will wait for the trip signal to come on the “**Tr**” input (see Chapter 1.2.6).

The “**Tr**” input is connected to a binary input (e.g. external AR start signal) and to the trip signals of the distance and overcurrent protections. The AND connection of the “GenTrip” command prevents the starting if the “Trip Logic” function block (not shown here) disables the operation of the trip contacts.

The “**3PhTr**” input is connected to the three-phase trip command indicator of the “Trip Logic” function block.

The “**1cyc3PhFlt**” input is not connected. No special dead time is used in this configuration. The

“**CBOpen**” input is connected to the open state signal from the circuit breaker.

The “**SynRel**” input is connected to the release output of the synchro-check/synchro-switch function. This input disables the reclosing in case of asynchronous state of the voltage vectors.

The “**ManCl**” input is connected to a signal that indicates the manual close command.

The “**CBRdy**” input is connected to fix TRUE signal. The ready state of the circuit breaker is out of consideration.

The “**DtDel**” input is not connected. The dead time is not intended to be delayed externally. The

“**RDT**” input is not connected. The dead time is not intended to be reduced externally.

3.1.13.4.2. Example1: Time diagram with two reclosing shots (first unsuccessful, second successful)

The following timing diagram shows two reclosing cycles. The first cycle is unsuccessful, the second one is successful. The relevant parameter set of the HV autoreclosing operation are listed in the Table 3-1 below. The effect of this parameter set is shown in the first time diagram of Figure 3-2.

HV AutoReclosing	
Operation	On
Reclosing Cycles	1.2. Enabled
Reclosing Started by	CB open
CB State Monitoring	0

Table 3-1 Example 1, parameter setting

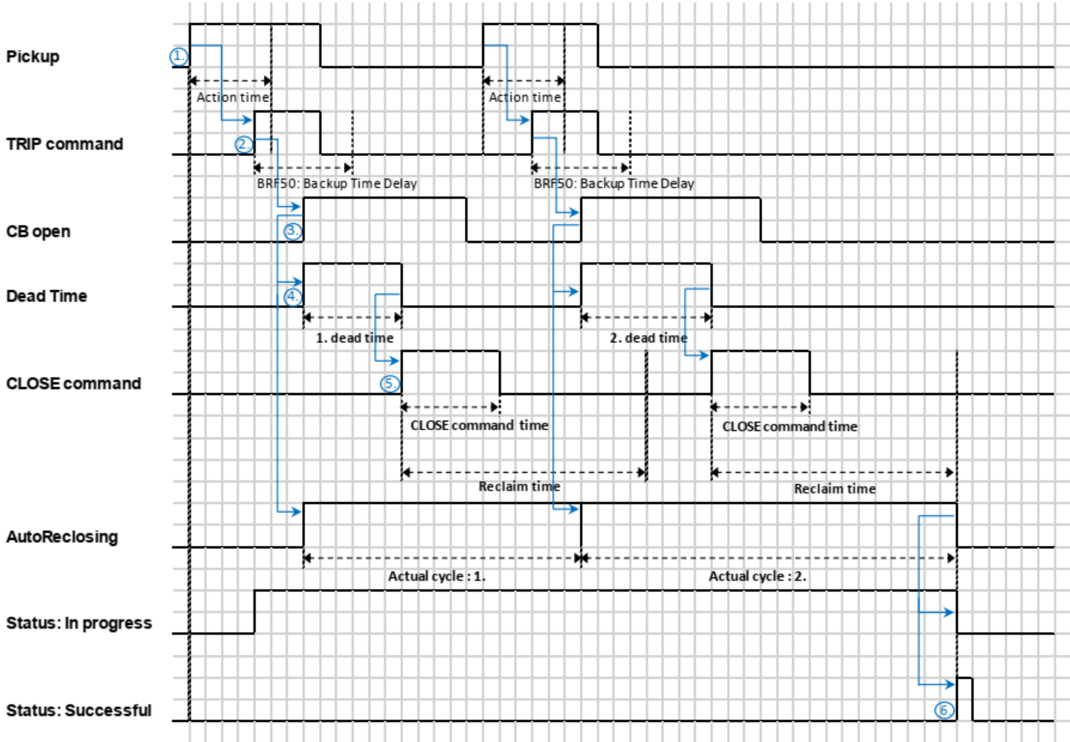


Figure 3-2 Example 1 time diagram

After a pickup of the protection function (No. 1), a timer starts to measure the “**Action time**” (the duration of which depends on parameter setting REC79_Act_TPar_ (Action time)). The trip command must be generated (No. 2) within this time to start reclosing cycles, or else the HV automatic function enters dynamic blocked state.

The automatic reclosing function is triggered if a protection function generates a trip command to the circuit breaker and the protection function resets because the fault current drops to zero and/or the auxiliary contact of the circuit breaker signals open state. Depending on the preset parameter value REC79_St_EPar_ (Reclosing started by), the HV automatic reclosing function can be started either by resetting of the TRIP command (setting: Trip reset) or by the binary signal indicating the open state of the circuit breaker (No. 3) (setting: CB open) – in the above example, the “Reclosing started by” parameter is set: “CB Open”.

According to the preset parameter values, either of these two conditions starts the timer for counting the „**Dead time**" (No. 4). For all four reclosing cycles, separate dead times can be defined for line-to-line faults and for earth faults.

At the end of the dead time the HV automatic reclosing function generates a close command automatically (No. 5). The "**Close command**" impulse is generated as one of the output status signals of the HV automatic reclosing function REC79_**Close**_GrI_ (Close command). This signal is common to all three phases. The impulse duration is defined by the user setting the timer parameter REC79_Close_TPar_ (Close command time).

When the close command is generated, a timer is started to measure the "**Reclaim time**". The duration is defined by the parameter value REC79_Rec_TPar_ (Reclaim time), but it is prolonged up to the reset of the close command (if the close command duration is longer than the reclaim time set).

If the fault is detected again during this time, then the sequence of the HV automatic reclosing cycles continues, the above example showing this case. If no fault is detected, then at the expiry of the reclaim time the reclosing is evaluated as successful and the function resets. If a fault is detected after the expiry of this timer, then the cycles restart with the first reclosing cycle. (If the user programmed the status variable REC79_**St**_GrO_ (Protection Start) and it gets TRUE during the Reclaim time, then the HV automatic reclosing function continues even if the trip command is received after the expiry of the Reclaim time.)

After the second reclosing cycle no pickup is detected within the reclaim time, the HV auto reclosing function enters "**Successful**" state (No. 6). The HV automatic reclosing cycle resets and a new fault will start the procedure with the first cycle again.

3.1.13.4.3. Example2: Timing diagram with two reclosing shots (both unsuccessful)

The following timing diagram shows two unsuccessful reclosing cycles. The relevant parameter set of the HV autoreclosing is same like the previous case.

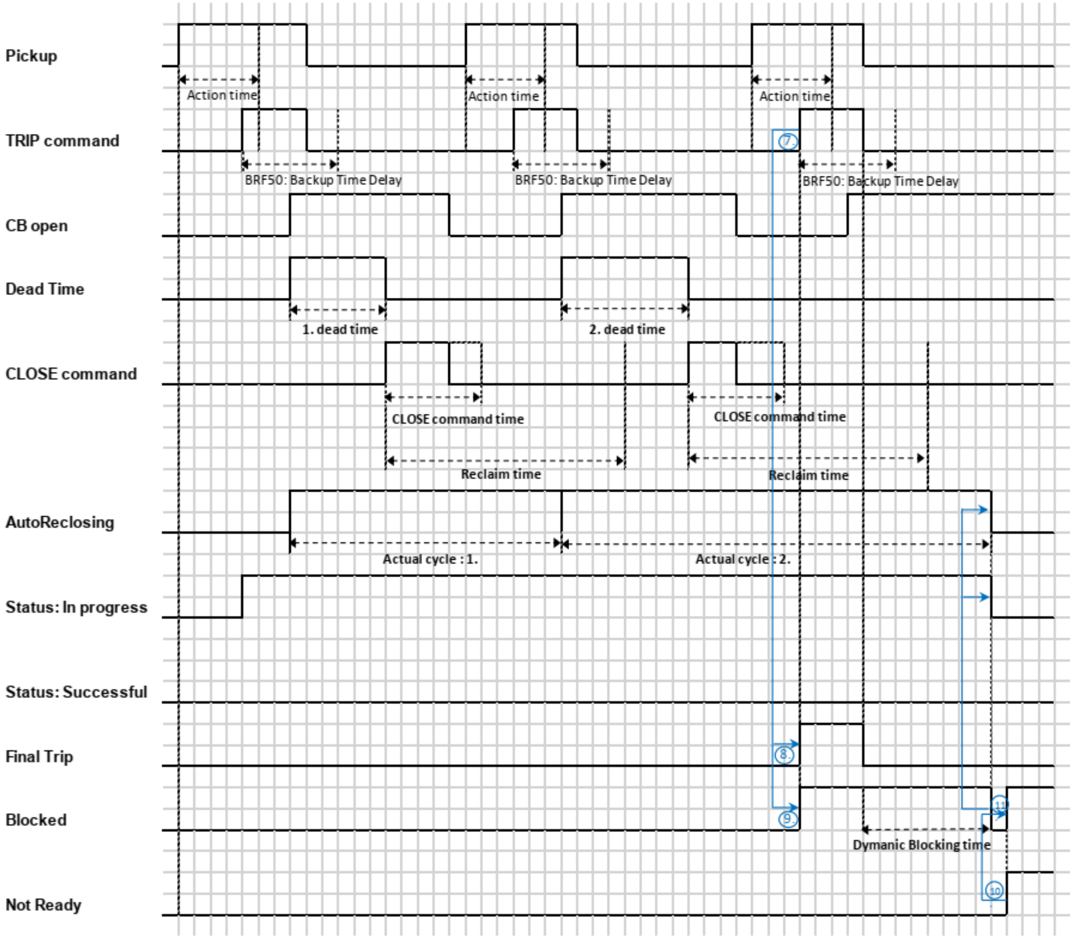


Figure 3-3 Example 2 time diagram

These events are similar to those of the previous case, but there are differences after the second reclosing attempt. The differences are written in the next Chapter.

The fault still exists at the end of the last cycle, therefore the protection function trips again (No. 7), and the HV automatic reclosing function trips and generates the signal for final trip: REC79_**FinTr**_GrI_ (Final Trip) (No. 8). After final trip, the HV automatic reclosing function enters "Dynamic blocked" state (No. 9). (A final trip command is also generated if a fault is detected again during the dead time.)

After the dynamic blocking, the HV automatic reclosing function gets "Not Ready" condition (No. 10), because the starting signal for automatic reclosing is selected by parameter REC79_St_EPar_ (Reclosing started by) to be "CB open" and the circuit breaker is in Open state and the "In progress" state of the function is not TRUE.

In a "Not ready" state, the REC79_**Blocked**_GrI_ (Blocked) status signal is TRUE, so the HV automatic reclosing function is blocked (No. 11).

3.1.13.4.4. Example3 Timing diagram with two reclosing shots (both unsuccessful)

The following timing diagram shows two unsuccessful reclosing cycles. The parameter setting of Table 3-2 are applied for the following timing diagram.

HV AutoReclosing	
Operation	On
Reclosing Cycles	1.2. Enabled
Reclosing Started by	Trip reset
CB State Monitoring	1
	⋮

Table 3-2 Example 3, parameter setting

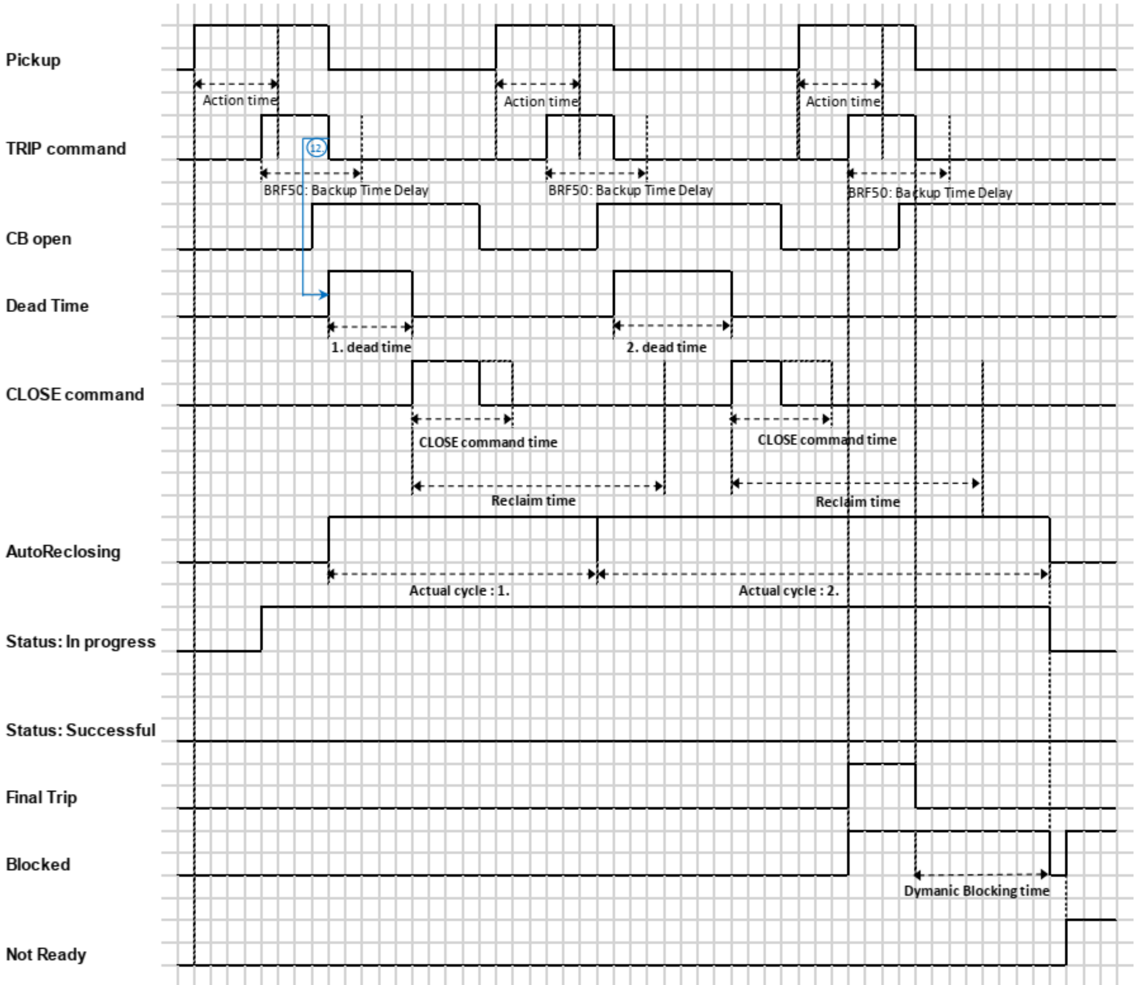


Figure 3-4 Example 3 time diagram

The timing diagram is similar to that of the previous case (Example2), the difference is caused by the starting of the HV automatic reclosing function. Here it is started by resetting of the TRIP command (setting: Trip reset) (No. 12).

3.1.13.4.5. Example4 Timing diagram with two reclosing shots (both unsuccessful)

The following timing diagram shows two unsuccessful reclosing cycles. The actual parameter set can be seen in the table below.

HV AutoReclosing	
Operation	On
Reclosing Cycles	1.2. Enabled
Reclosing Started by	Trip reset
CB State Monitoring	0
⋮	

Table 3-3 Example 4, parameter setting

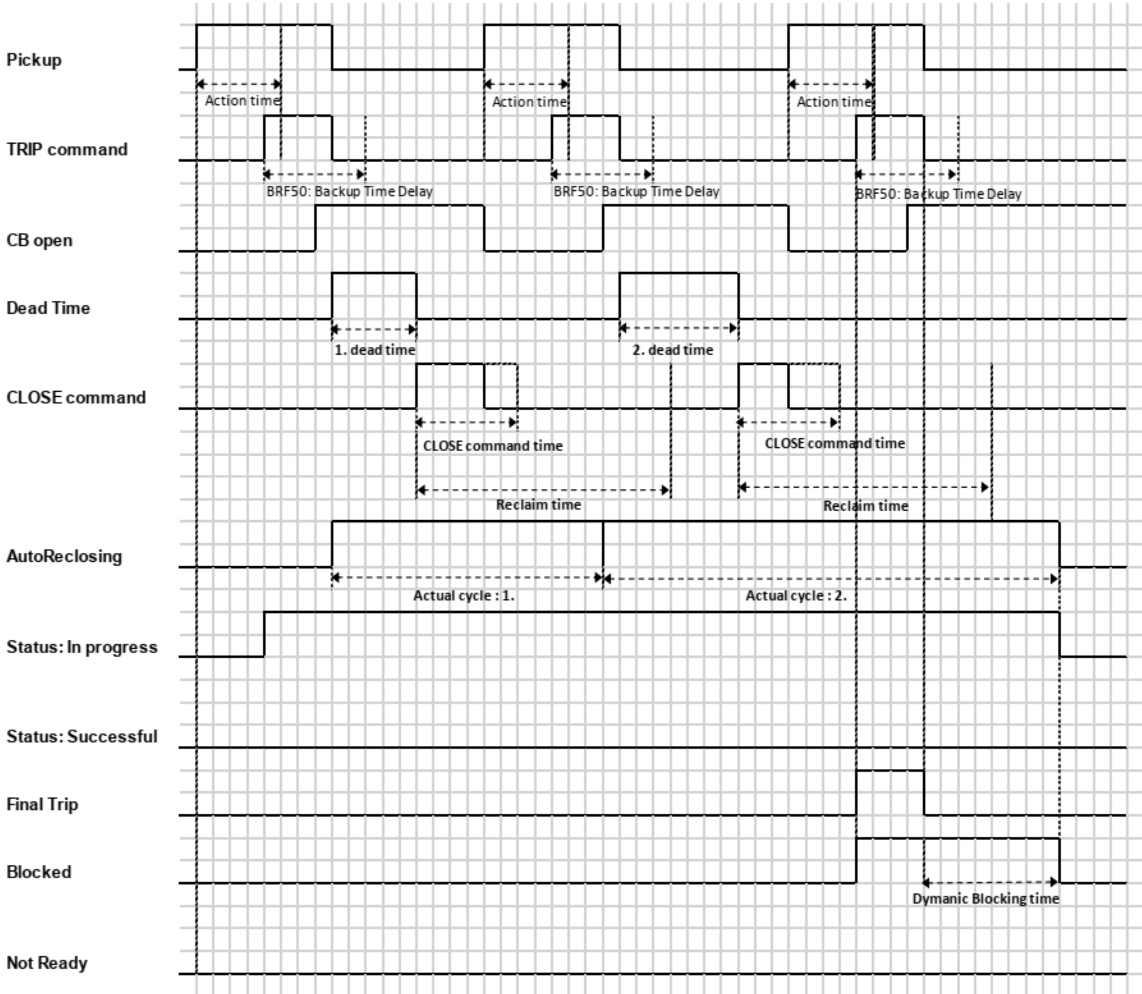


Figure 3-5 Example 4 time diagram

One difference can be seen if it is compared to the previous one.

After the "Dynamic Blocking" state the HV automatic reclosing function does not enter "Not Ready" state, because the "Not Ready" condition is not satisfied due to the parameter REC79_CBState_BPar_ (CB State Monitoring) is set to FALSE.

3.1.14. Capacitor overvoltage protection function

3.1.14.1. Application

The power frequency voltage of a network can be high due to voltage fluctuation and regulation or due to the voltage rise at light load. The shunt capacitors connected to the network need protection against high steady state voltage, because the voltage over the rated level accelerates the aging of the material inside the capacitor.

A moderated overvoltage can be tolerated for a relatively long time; the high overvoltages however need fast disconnection. The characteristic of this overvoltage protection function is a certain kind of inverse type characteristics, defined in international standards (IEC 60871-1 Shunt capacitors for a.c. power systems having a rated voltage above 1000 V – Part 1: General, or ANSI/IEEE C37.99 Capacitor Banks, Guide for Protection of Shunt).

The function has additionally a definite time warning stage, the setting of which is independent of that of the inverse type tripping stage.

The capacitors on a network in most cases have no dedicated voltage measurement, the voltage transformers on the busbar measure voltage even in disconnected state of the capacitors. To avoid these kinds of problems, this protection function measures the currents in the phases of the capacitor, and calculates the voltages in the phases independently. The warning and trip decision is based on the calculated voltage values.

3.1.14.2. Mode of operation

The capacitor overvoltage protection function measures phase currents. The phase voltages as a function of the time can be calculated by integration of the current time function of the phases:

$$u(t) = \frac{1}{C}\int i(t)dt$$

This integral, which is evaluated using a simple numerical method, considers also the higher harmonic contents of the current up to the 10^{th} harmonic. All harmonics with higher ordinal number are filtered out.

The function does not consider the transient values caused by switching procedures, these values are filtered out. The decision is based on the steady state values, since the time delay can be several minutes, and only the symmetrical peak values are considered. The calculated and found peak values are related to the rated power frequency peak voltage. If the voltage is above the setting value then the time is weighted according to the inverse type characteristic, and based on the time multiplier setting (K). These values are added (accumulated). If this accumulated time exceeds the limit, the function generates the trip command.

3.1.14.3. Operating characteristics

3.1.14.3.1. Inverse type tripping characteristic

The international standards (IEC 60871-1 or ANSI/IEEE C37.99) define the operate time, as the maximum duration for some values of the power frequency voltage. Based on these standards the characteristic is defined on the following discrete values: (shown in Table 1-1.)

Voltage factor * U_N V R.M.S.	Maximum duration defined in the standards	Maximum duration in seconds
1	Continuous	
1.15	30 min in every 24 h	1800 s
1.2	5 min	300 s
1.3	1 min	60 s
1.4	15 s	15 s
1.7	1 s	1 s
2.0	0.3 s	0.3 s
2.2	0.12 s	0.12 s

Table 1-1 Admissible voltage levels in service

Additionally the characteristic can be modified by the time multiplier setting (K).

According to the standards, the amplitudes of the overvoltages that may be tolerated without significant deterioration of the capacitor depend on:

- their total duration,
- their total number and
- the capacitor temperature.

The *total duration* of the overvoltage is covered by the accumulation.

The *number of the overvoltages* is considered in this protection function as follows:
If the voltage peak is above 1.1 * U_{Npeak} then additionally to the accumulation, a reset time measurement is started. Then

- If the accumulated value reaches the trip value then the trip command is generated.
- If the voltage peak drops below 1 * U_{Npeak} then both the integral and the reset time measurement reset to zero.
- If the voltage peak drops below 1.1 * U_{Npeak} but above 1 * U_{Npeak} then the integral is "frozen", and the reset time keeps on counting. In this state
  - If the voltage peak is above 1.1 * U_{Npeak} again then the accumulation is going on starting with the "frozen" value.
  - If the reset time measurement gets above the reset time setting without trip generation then both the integral and the reset time measurement reset to zero.

Concerning the effect of the *ambient temperature*, this simple protection function does not include direct ambient temperature measurement. It is the task of the user to set the appropriate time multiplier value (K), to accelerate the trip command for the worst case expected temperature (or delay the trip command if the ambient temperature is continuously below the rated temperature of the capacitor type test).

3.1.14.3.2. Definite time warning characteristic

This protection function has additionally a definite time warning stage, the setting of which is independent of that of the inverse type tripping stage.

3.1.14.4. Technical summary

3.1.14.4.1. Technical data

Function	Value	Accuracy
Pick-up starting accuracy		< 1%
Operate time accuracy	at In=100 %	< 5%

Table 1-2 Technical data of the overvoltage protection function

3.1.14.4.2. Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Enabling or disabling the capacitor overvoltage protection function			
CapOV_Oper_EPar_	Operation	Off, On	On

Table 1-3 The enumerated parameter of the capacitor overvoltage protection function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Capacitor nominal current, related to the rated current of the current transformer. The integral of this current defines the nominal basic harmonic voltage, the peak value of which is the reference for overvoltage detection.						
CapOV_NomCurr_IPar_	Rated current	%	15	120	1	100
Value of the overvoltage, related to the rated voltage of the capacitor, to start the warning stage of the function						
CapOV_I2Start_IPar_	Warning Start	%	80	120	1	100
Reset time setting for Stage 1						
CapOV_Reset_IPar_	Reset Time	sec	1	60000	1	3600
Definite time delay for Stage 2						
CapOV_Delay2_IPar_	Warning Delay	sec	1	3600	1	60

Table 1-4 The integer parameters of the capacitor overvoltage protection function

Floating point parameter

Parameter name	Title	Dim.	Min	Max	Step	Default
Time multiplier for the inverse type characteristic						
CapOV_K_FPar_	Time Multiplier	-	0.20	2.00	0.01	1.00

Table 1-5 The floating point parameter of the capacitor overvoltage protection function

3.1.14.4.3. Binary status signals

The **binary output status signals** of the capacitor overvoltage protection function are listed in *Table 1-6* below.

Binary output signals	Signal title	Explanation
CapOV_Str1L1_GrI_	Start1 L1	Start of Stage 1 in phase L1
CapOV_Str1L2_GrI_	Start1 L2	Start of Stage 1 in phase L2
CapOV_Str1L3_GrI_	Start1 L3	Start of Stage 1 in phase L3
CapOV_Str2L1_GrI_	Start2 L1	Start of Stage 2 in phase L1
CapOV_Str2L2_GrI_	Start2 L2	Start of Stage 2 in phase L2
CapOV_Str2L3_GrI_	Start2 L3	Start of Stage 2 in phase L3
CapOV_Trip1_GrI_	Trip1	Trip command of Stage 1
CapOV_Trip2_GrI_	Trip2	Trip command of Stage 2 (usually assigned as Warning)

Table 1-6 The binary output status signals of the capacitor overvoltage protection function

The **binary input status signal** of the capacitor overvoltage protection function is shown in Table 1-7 below.

The capacitor 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 logic editor.**

Binary input status signal	Title	Explanation
CapOV_Blk_GrO_	Block	Output status of a graphic equation defined by the user to disable the capacitor overvoltage protection function.

Table 1-7 The binary input status signal of the capacitor overvoltage protection function

3.1.14.4.4. The function block

The function block of the capacitor overvoltage protection 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.

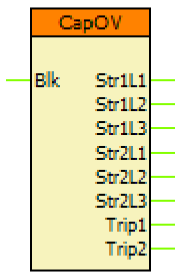


Figure 1-1 *The function block of the capacitor overvoltage protection function*

3.1.15. Capacitor unbalance protection for blocks in double star connection

3.1.15.1. Application

The shunt capacitor banks are usually constructed of capacitor units, and the units contain capacitor elements.

There are constructions of the bank where fuses are connected inside a capacitor unit, in series with an element or a group of elements. The fuse is connected in series with the element that the fuse is designed to isolate if the element becomes faulty. After the breakdown of an element, the fuse connected to it will blow and isolate it from the remaining part of the capacitor, which allows the unit to continue in service. The blowing of one or more fuses decreases the capacitance value and additionally it will cause voltage changes within the bank.

If no internal fuses are applied then the breakdown of an element will short-circuit a “layer” of capacitors. The capacitance value increases and additionally it will also cause voltage changes within the bank.

Each time an internal capacitor element fails, a slight change of voltage distribution and current flow within the capacitor bank is encountered. The magnitude of these changes depends upon the number of failed elements and their location within the bank.

The main purpose of the capacitor unbalance protection is to give an alarm or to disconnect the entire capacitor bank when unbalances across healthy capacitors, adjacent to a failed capacitor, are excessive. Normally not more than 10 % unbalance should be allowed (unbalance limit according to IEC 60871-1 Shunt capacitors for a.c. power systems having a rated voltage above 1000 V – Part 1: General).

If an externally fused capacitor is disconnected by its fuse, a larger voltage and current change is obtained than if single elements are disconnected by internal fuses.

This kind of protection prevents steady-state overvoltage and accelerated aging of the capacitor elements.

Another function of the unbalance protection is to remove the bank from service for a fault not isolated by a fuse or to protect banks that are not internally or externally fused. Unbalance protection is not a replacement for short-circuit protection.

3.1.15.2. Mode of operation

3.1.15.2.1. Construction of the capacitor bank

This version of the capacitor unbalance protection can be applied if the capacitors are arranged in two parallel stars (ungrounded) with a current transformer between the neutrals. The stars do not have to be equal in size. An unbalance in the bank will cause current to flow in the neutral.

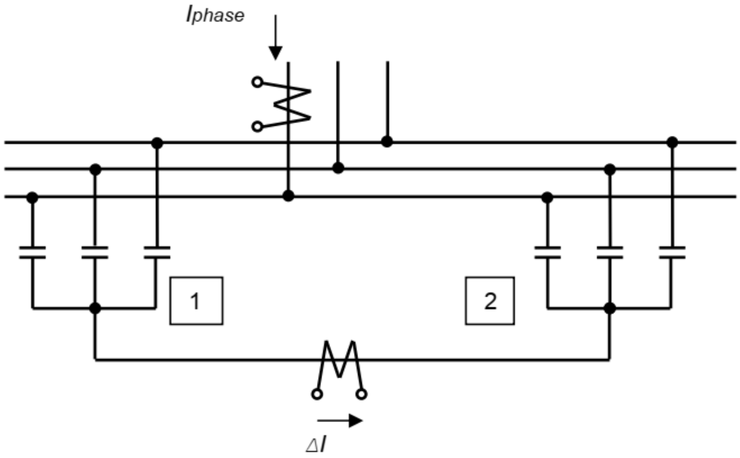


Figure 1-1 *Current unbalance between neutrals*

The scheme may be used for both internal and external fuses and also in capacitor configurations without fuses. As the sensitivity performance is good, the method is especially useful for internal fuses. The current transformer between the neutral points should be rated for full system voltage.

3.1.15.2.2. Effect of the “natural” asymmetry of the capacitor bank

The related standard permits a considerable amount of asymmetry, which can be up to 10%, consequently in healthy state a relatively high current can flow between the star points. At commissioning the unbalance protection function stores the vector position and the value of the “natural” unbalance current as the reference current $\Delta Iref$ and additionally those of one phase current $Iphase\_ref$

The reference current is corrected according to the actually measured phase current $Iphase$ and the stored $Iphase\_ref$ reference phase current.

$$\Delta Iref\_corr = \Delta Iref\ \frac{Iphase}{Iphase\_ref}$$

where all current values are complex Fourier base harmonic vectors:

$\Delta Iref$	reference current measured between the neutral points at commissioning,
$\Delta Iref\_corr$	corrected reference current,
$Iphase$	measured phase current,
$Iphase\_ref$	phase current measured at commissioning.

3.1.15.2.3. The energizing quantity (G)

If there are no changes inside the capacitor then no change can be detected in the actually measured unbalance current related to the corrected reference current.

Accordingly the energizing quantity for evaluation is the difference of the measured current between the neutral points and the corrected reference current:

$$G = dI = \Delta I - \Delta Iref\_corr$$

where all current values are complex Fourier base harmonic vectors:

ΔI	current measured between the neutral points,
$\Delta Iref\_corr$	corrected reference current (see above).

NOTE: This approach using a single phase current supposes that the asymmetry of the network itself does not change, or the changes are cleared with high speed by other protection functions. If considerable steady-state changes in the symmetry of the network are expected, then the measurement and correction based a single phase current is not sufficient. In this case please consult Protecta Co. Ltd. for solution.

3.1.15.3. Calibration at commissioning

This is the task of the commissioning to store the reference values for the neutral point current Δ*Iref*, and that of the phase current *Iphase_ref* in the memory.

For this purpose the function block has a dedicated binary input: *Calibr*. This input must be activated for the calibration. For the physical means for activation see the description of the configuration. This input may be programmed by the user using the graphic logic editor.

The calibration at the moment of activation can be performed only if the conditions for calibration are fulfilled. The conditions for calibration are:

- The phase current has to be less than 2*In of the current input,
- The phase current has to be above 70% of the rated capacitor current,
- The neutral current has to be less than the value set by the dedicated parameter.

The calibrated state is indicated by the dedicated binary output of the function *Calibrated*.

The calibration values are stored in non-volatile memory, separately for each parameter set.

The *Reset* binary input resets the calibrated state.

Among the “on-line” information the function continuously displays the magnitude and the angle of the Δ*I* current measured between the neutral points. At the moment of calibration this vector resets to zero vector. See *Figure 1-2*. At the same time the “Calibrated” field on the screen displays a check-mark. If however after calibration any changes happen within the capacitor bank then the displayed values change.

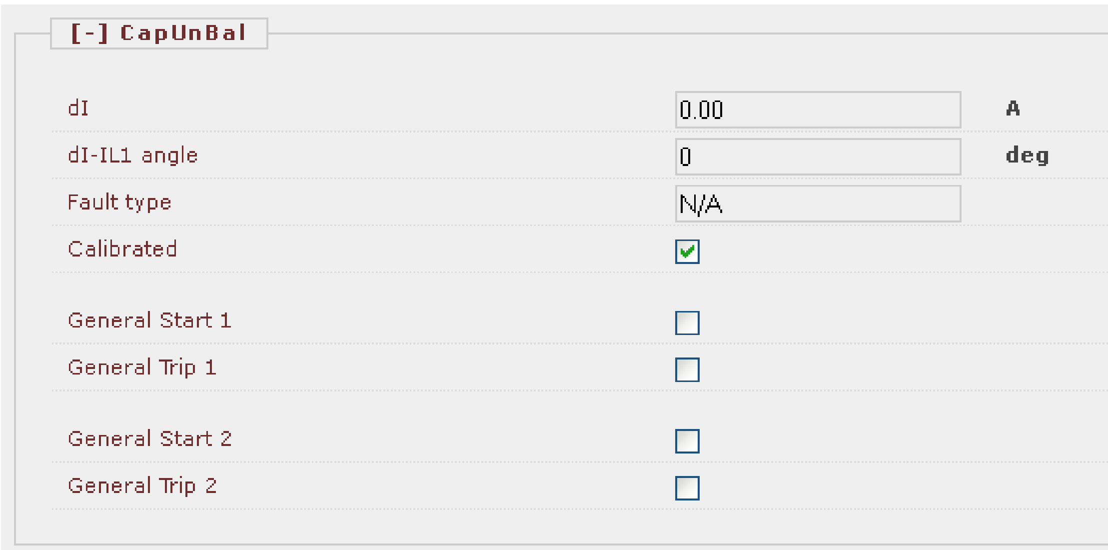


Figure 1-2 On-line display of the “dI=ΔI” neutral current, referred to the reference current

3.1.15.4. Operating characteristics

The capacitor unbalance protection function is configured with two independent stages.

For the first stage definite time characteristic and several types of inverse characteristics can be selected.

The second stage is definite time characteristic.

3.1.15.4.1. Definite time characteristic

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

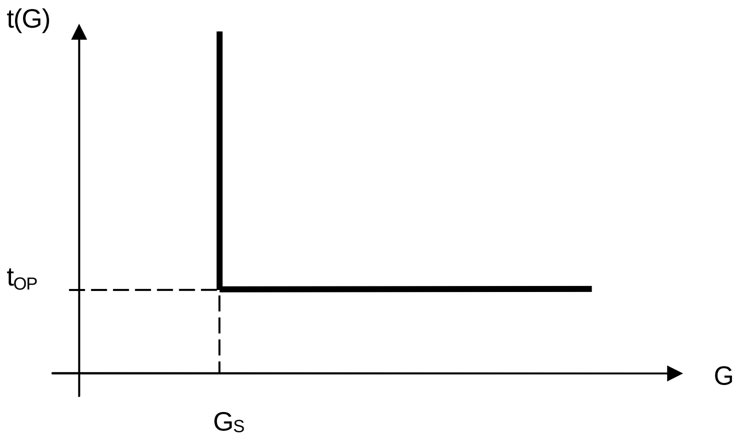


Figure 1-3 Overcurrent definite time characteristic

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 value, (see section 1.2.3),
G_S	preset value of the characteristic quantity.

3.1.15.4.2. Standard inverse time characteristics

Operating characteristics:

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

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 value, (see section 1.2.3),
G_S	preset starting value of the characteristic quantity,
TMS	preset time multiplier (no dimension).

	IEC ref	Title	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 inverse 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 setting. This delay is valid if it is longer than t(G), defined by the formula of the operating characteristics 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 the parameter CapUnB1_Reset_TPar_ (Reset Time),
- 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

$t_r(G)$(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 (CapUnB1_StCurr1_IPar_, Start current 1),
TMS	preset time multiplier (no dimension).

	IEC ref	Title	k_r	α
1	A	IEC Inv	Resetting after fix time delay, according to preset parameter CapUnB1_Reset_TPar_ "Reset Time"	
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*

3.1.15.5. Fault location

The vector measurement enables identification of the faulty capacitor unit. For the explanation of the principle of fault location consider the positive direction of the current as indicated in Figure 1-1: the current flows from capacitor unit 1 to capacitor unit 2.

Now consider a fault inside unit 1 in the phase L1, which increases the capacitance value. This event can be modelled by an additional capacitor connected parallel to the capacitor in unit 1 phase L1. It is obvious that this current is in phase of the current of the original phase capacitor "*IL1*", as it is indicated in Figure 1-4. Consequently the ΔI current measured in the neutral point is in phase with the current of the original phase capacitor. To permit some asymmetry changes in the network and some measuring error, this current is inside the shaded area between -15 ° and +15 °. The on-line m easurement will display the increased "*dI*" value with "*dI-IL1 angle*" in this range. The related event indicates "L1-1".

Similarly if an additional capacitor is added to phase L2, then the ΔI current measured in the neutral point is in phase with the current IL2. The phase angle related to phase IL1 is -120°, and it is in the range of -105 °and -135 °. The re lated event indicates "L2-1".

If for example the added capacitor is in unit 2 in phase L2 then the vector is in the range of +45 °and +75°. The related event indicates "L2-2" .

If the capacitor elements are not fused then the breakdown of a capacitor element will short-circuit a "layer" of capacitors. The resultant capacitance, consequently the capacitive current increases, as in the explanation above.

If however the capacitor elements are individually fused then the breakdown of a capacitor element is disconnected from the "layer" of capacitors. The resultant capacitance decreases, and the result is opposite to the explanation in Figure 1-4.

For correct evaluation the information is needed: whether internal fuses are applied or not. This is to be set by the Boolean parameter "Internal fuse".

The event list related to the capacitor faults can contain the following messages:

Message	Explanation
L1-1	Fault in phase L1, unit 1
L2-1	Fault in phase L2, unit 1
L3-1	Fault in phase L3, unit 1
L1-2	Fault in phase L1, unit 2
L2-2	Fault in phase L2, unit 2
L3-2	Fault in phase L3, unit 2

Table 1-3 Capacitor fault location

NOTE: The fault location is active in "*Calibrated*" state only. The event is registered at the moment of trip command generation.

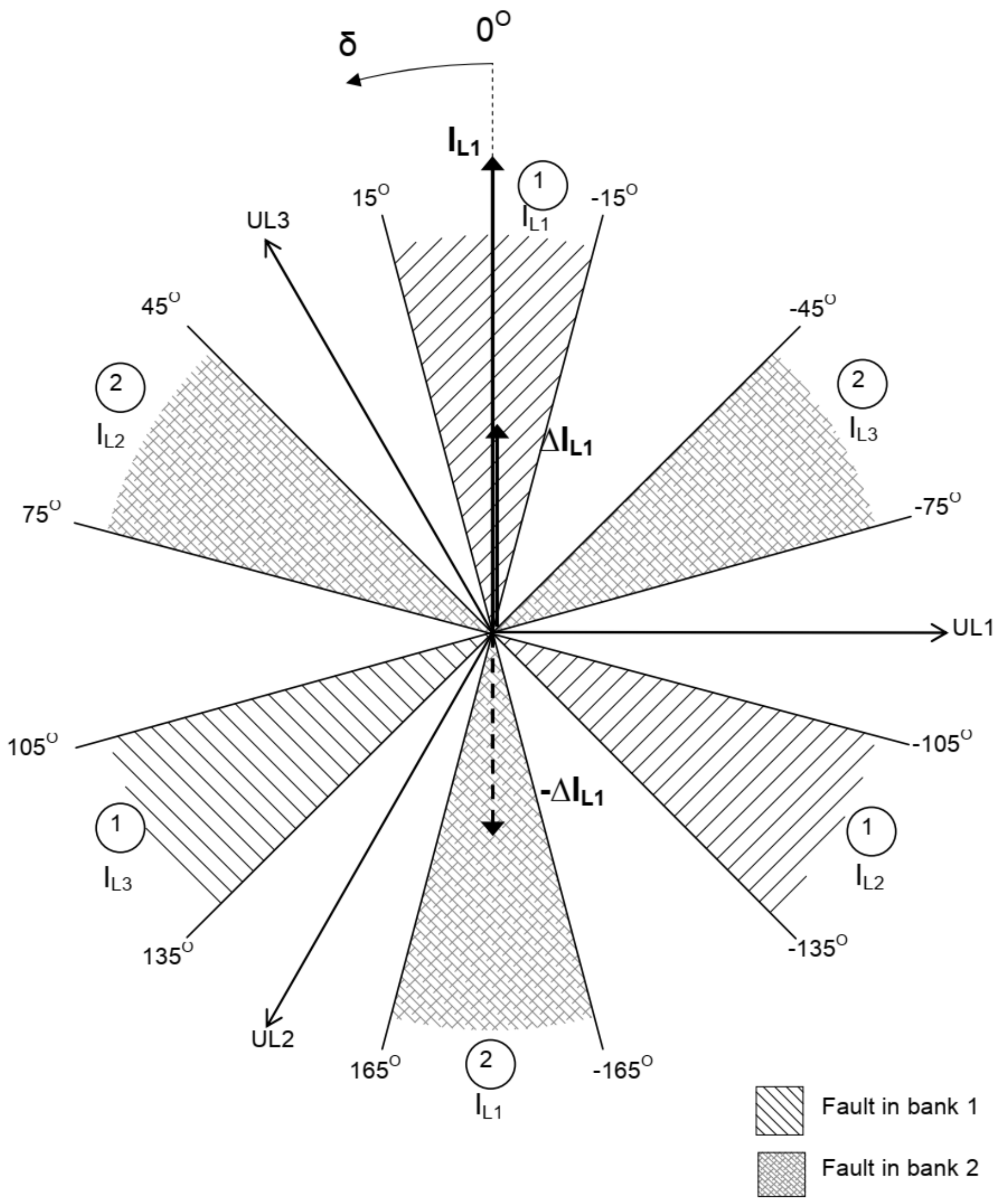


Figure 1-4 Scheme of the fault location

3.1.15.6. Technical summary

3.1.15.6.1. Technical data

Function	Value	Accuracy
Pick-up starting accuracy	$20 \le G_S \le 1000$	< 5 %
Pickup time	< 40 ms	
Angle accuracy		<1 degree*
Reset ratio	0,9	
Reset time Dependent time char. Definite time char.	Approx 60 ms	< 2% or ±35 ms, whichever is greater
Operate time accuracy		±5% or ±15 ms, whichever is greater

** Valid if the negative sequence component of the network voltage is < 5%*

Table 1-4 Technical data of the unbalance protection function

3.1.15.6.2. Parameters

Enumerated parameters

Parameter name	Title	Selection range	Default
Enabling or disabling the capacitor unbalance protection function			
CapUnB1_Oper1_EPar_	Operation Stage 1	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
CapUnB1_Oper2_EPar_	Operation Stage2	Off,On	Off

Table 1-5 The enumerated parameters of the capacitor unbalance protection function

Boolean parameter

Parameter name	Title	Default	Explanation
CapUnB_IntFuse_BPar_	Internal fuse	0	0 means no internal fuse 1means capacitor units with internal fuse

Table 1-6 The Boolean parameters of the capacitor unbalance protection function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Current setting for the capacitor unbalance protection function, first stage						
CapUnB1_StCurr1_IPar_	Start Current 1	%	10	100	1	10
Current setting for the capacitor unbalance protection function, second stage						
CapUnB1_StCurr2_IPar_	Start Current 2	%	5	100	1	10
Nominal current of the capacitor, as percent of the rated input current						
CapUnB1_NomCurr_IPar_	Inom capacitor	%	15	120	1	100
ΔI setting, at calibration the current between the neutral points must be below this level						
CapUnB1_dIMax_IPar_	dI maxcalib	%	5	50	1	10

Table 1-7 The integer parameters of the capacitor unbalance protection function

Floating point parameter

Parameter name	Title	Dim.	Min	Max	Default
Time multiplier setting for the inverse type characteristics, first stage					
CapUnB1_Multip_FPar_	Time Multiplier	sec	0.05	999	1.0

Table 1-8 The floating point parameter of the capacitor unbalance protection function

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Minimum time delay for the inverse type characteristics, first stage (valid, if this characteristic is selected)						
CapUnB1_MinDel_TPar_	Min Time Delay	msec	0	60000	1	100
Definite time delay for the first stage (valid, if this characteristic is selected)						
CapUnB1_DefDel_TPar_	Definite Time Delay	msec	0	60000	1	1000
Reset time setting, first stage						
CapUnB1_Reset_TPar_	Reset Time	msec	0	60000	1	100
Definite time delay for the second stage						
CapUnB1_Delay2_TPar_	Delay Stage 2	msec	0	60000	1	1000

Table 1-9 The timer parameters of the capacitor unbalance protection function

3.1.15.6.3. Binary status signals

The **binary output status signals** of the capacitor unbalance protection function are listed in *Table 1-10* below.

Binary output signals	Signal title	Explanation
CapUnB1_GenSt1_Grl_	General Start 1	General start signal for stage 1
CapUnB1_GenTr1_Grl_	General Trip 1	General trip command for stage 1
CapUnB1_GenSt2_Grl_	General Start 2	General start signal for stage 2
CapUnB1_GenTr2_Grl_	General Trip 2	General trip command for stage 2
CapUnB1_Calib_Grl_	Calibrated	True, if the function has been calibrated

Table 1-10 The binary output status signals of the capacitor unbalance protection function

The **binary input status signals** of the capacitor unbalance protection function are shown in Table 1-11 below.

The capacitor unbalance protection function has binary input signals. **The conditions of these status signals are defined by the user, applying the graphic logic editor.**

Binary input signals	Signal title	Explanation
CapUnB1_Reset_GrO_	Reset	Resetting the calibrated state
CapUnB1_Calibr_GrO_	Calibr	Binary input for calibration
CapUnB1_Blk_GrO_	Blk	Blocking input

Table 1-11 The binary input status signal of the capacitor unbalance protection function

3.1.15.6.4. The function block

The function block of the capacitor unbalance protection function is shown in Figure 1-5. This block shows all binary input and output status signals that are applicable in the graphic logic editor.

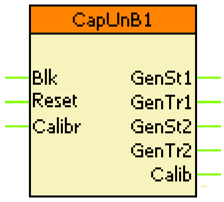


Figure 1-5 The function block of the capacitor unbalance protection function

3.1.16. Capacitor unbalance protection for blocks in bridge connection

3.1.16.1. Application

The shunt capacitor banks are usually constructed of capacitor units, and the units contain capacitor elements.

There are constructions of the bank where fuses are connected inside a capacitor unit, in series with an element or a group of elements. The fuse is connected in series with the element that the fuse is designed to isolate if the element becomes faulty. After the breakdown of an element, the fuse connected to it will blow and isolate it from the remaining part of the capacitor, which allows the unit to continue in service. The blowing of one or more fuses decreases the capacitance value and additionally it will cause voltage changes within the bank.

If no internal fuses are applied then the breakdown of an element increases the capacitance value and additionally it will cause voltage changes within the bank.

Each time an internal capacitor element fails, a slight change of voltage distribution and current flow within the capacitor bank is encountered. The magnitude of these changes depends upon the number of failed elements and their location within the bank.

The main purpose of the capacitor unbalance protection is to give an alarm or to disconnect the entire capacitor bank when unbalances across healthy capacitors, adjacent to a failed capacitor, are excessive. Normally not more than 10 % unbalance should be allowed (unbalance limit according to IEC 871-1 Shunt capacitors for a.c. power systems having a rated voltage above 1000V – Part 1: General).

If an externally fused capacitor is disconnected by its fuse, a larger voltage and current change is obtained than if single elements are disconnected by internal fuses.

This kind of protection prevents steady-state overvoltage and accelerated aging of the capacitor elements.

Another function of the unbalance protection is to remove the bank from service for a fault not isolated by a fuse or to protect banks that are not internally or externally fused. Unbalance protection is not a replacement for short-circuit protection.

3.1.16.2. Mode of operation

3.1.16.2.1. Construction of the capacitor bank

This version of the capacitor unbalance protection can be applied if the capacitors in the phases are arranged in bridge connection (“H configuration”), according to Figure 1-1.

The capacitors in each phase are arranged in two branches with a current transformer connected between midpoints or close to midpoints of the two branches. Failures anywhere in the branches will cause an unbalance current to flow through the current transformer.

This method is suitable for large capacitor banks since the total bank will be divided into separate protection zones. The method is not influenced by phase voltage unbalances. It may be used in delta- or star-connected banks with the neutral grounded or ungrounded.

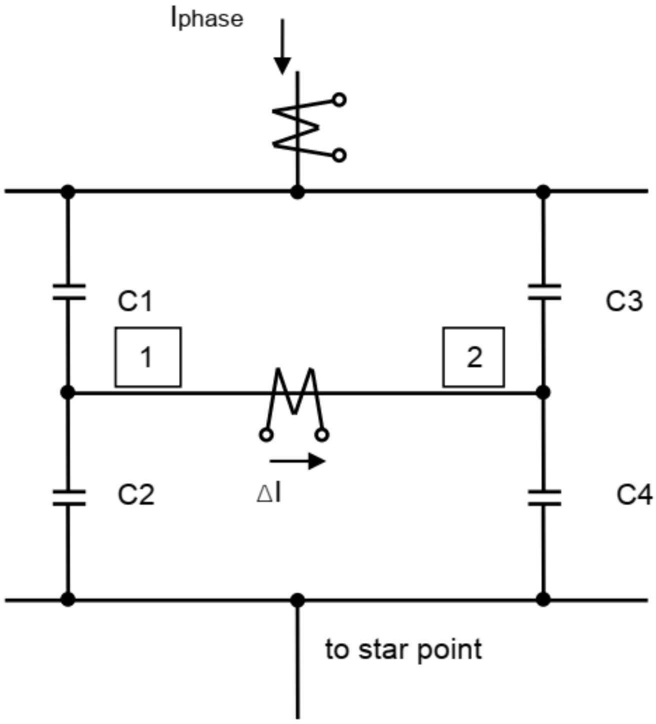


Figure 1-1 Current unbalance in bridge connection ("H configuration") (drawing in one phase only)

3.1.16.2.2. Effect of the "natural" asymmetry of the capacitor bank

The related standard permits a considerable amount of asymmetry, which can be up to 10%, consequently in healthy state a relatively high current can flow through the current transformer. At commissioning the unbalance protection function stores the vector position and the value of the "natural" unbalance currents as three reference currents $\Delta Iref$ and additionally those of one of the phase currents $Iphase\_ref$ $(= IL1)$.

The reference currents are corrected according to the actually measured phase current $Iphase$ and the stored $Iphase\_ref$ reference phase current.

$$\Delta Iref\_corr = \Delta Iref \ \frac{Iphase}{Iphase\_ref}$$

where all current values are complex Fourier base harmonic vectors:

$\Delta Iref$	reference current measured in the bridge of all three phases at commissioning,
$\Delta Iref\_corr$	corrected reference currents of all three phases,
$Iphase$	measured phase current of one of the three phases ($IL1$),
$Iphase\_ref$	phase current of one of the three phases measured at commissioning ($IL1$).

The correction is performed with one phase current in all three phases separately.

NOTE: This approach using a single phase current supposes that the asymmetry of the network itself does not change, or the changes are cleared with high speed by other protection functions. If considerable steady-state changes in the symmetry of the network are expected, then the measurement and correction based a single phase current is not sufficient. In this case please consult Protecta Co. Ltd. for solution.

3.1.16.2.3. The energizing quantity (G)

If there are no changes inside the capacitor then no change can be detected in the actually measured unbalance current related to the corrected reference current.

Accordingly the energizing quantity for evaluation is the difference of the measured currents in the bridges and the corrected reference current:

$$G = dI = \Delta I - \Delta Iref\_corr$$

where all current values are complex Fourier base harmonic vectors:

ΔI	currents measured in the bridge,
$\Delta Iref\_corr$	corrected reference currents (see above).

NOTE: The correction is performed in all three phases separately with one phase current.

3.1.16.3. Calibration at commissioning

This is the task of the commissioning to store the reference values for the bridge currents $\Delta Iref$, and that of one of the phase currents $Iphase\_ref$ in the memory.

For this purpose the function block has a dedicated binary input: *Calibr*. This input must be activated for the calibration. For the physical means for activation see the description of the configuration. This input may be programmed by the user using the graphic logic editor.

The calibration at the moment of activation can be performed only if the conditions for calibration are fulfilled. The conditions for calibration are:

- The phase currents have to be less than 2*In of the current input,
- The phase currents have to be above 70% of the rated capacitor current,
- The bridge currents have to be less than the value set by the dedicated parameter.

The calibrated state is indicated by the dedicated binary output of the function *Calibrated*. This output gets in “true” state only if the calibration procedure in all three phases was successful.

The calibration values are stored in non-volatile memory, separately for each parameter set.

The *Reset* binary input resets the calibrated state.

Among the “on-line” information the function continuously displays the ΔI currents measured in the bridges. At the moment of calibration this vectors reset to zero vector. See *Figure 1-2*. At the same time the “*Calibrated*” field on the screen displays a check-mark. If however after calibration any changes happen within the capacitor bank then the displayed values change.

Figure 1-2 On-line display of the "dI=ΔI" neutral current, referred to the reference current

3.1.16.4. Operating characteristics

The capacitor unbalance protection function is configured with two independent stages.

For the first stage definite time characteristic and several types of inverse characteristics can be selected.

The second stage has a definite time characteristic.

3.1.16.4.1. Definite time characteristic

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

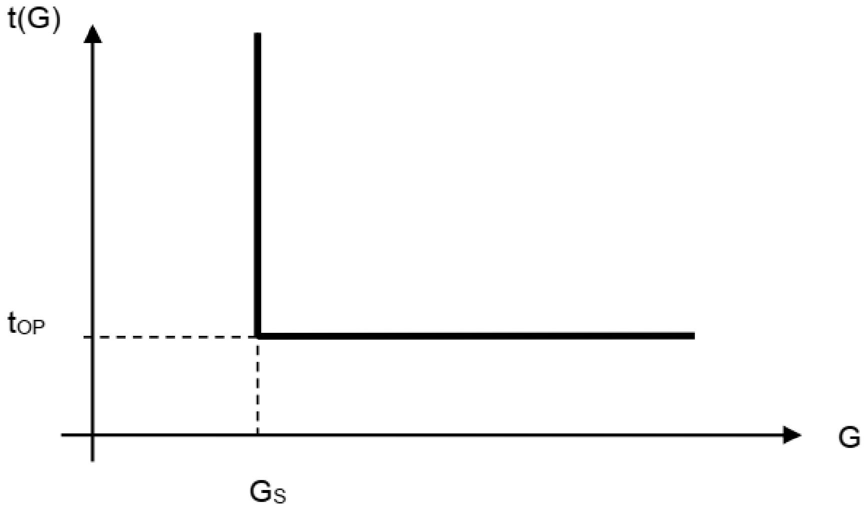


Figure 1-3 Overcurrent definite time characteristic

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 value, see section 1.2.3,
G_S	preset starting value of the characteristic quantity.

3.1.16.4.2. Standard inverse time characteristics

Operating characteristics:

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

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 value, see section 1.2.3,
G_S	preset starting value of the characteristic quantity,
TMS	preset time multiplier (no dimension).

	IEC ref	Title	k	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 inverse 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 setting. This delay is valid if it is longer than $t(G)$, defined by the formula of the operating characteristics 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 the parameter CapUnB3_Reset_TPar_ (Reset Time),
- 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

$t_r(G)$(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, see section 1.2.3,
G_S	preset value of the characteristic quantity (CapUnB3_StCurr1_IPar_, Start current 1),
TMS	preset time multiplier (no dimension).

	IEC ref	Title	k_r	α
1	A	IEC Inv	Resetting after fix time delay, according to preset parameter CapUnB3_Reset_TPar_ "Reset Time"	
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*

3.1.16.5. Fault location

The vector measurement enables identification of the faulty capacitor unit. For the explanation of the principle of fault location consider the positive direction of the current *Iphase* and Δ*I* as indicated in Figure 1-1: the current flows from capacitor unit 1 to capacitor unit 2.

Now consider a fault in phase L1, inside unit 1 in the capacitor C1, which increases the capacitance value, consequently decreases the impedance related to the impedance of C3. The current in C1 increases related to the current of C3, consequently the current flows in the bridge from the unit 1 towards the unit 2. It is obvious that this current is in phase with the current of the original phase capacitor "*IL1*", as it is indicated in Figure 1-4. Consequently the Δ*I* current measured in the bridge is in phase with the current of the original phase capacitor. To permit some asymmetry changes in the network and some measuring error, this current is inside the shaded area between -15 ° and +15 °. The on-line measurement will display the increased "*dI*" value with "*dI-IL1 angle*" in this range. The related event indicates "L1-1". The same current vector flows in the bridge if the value of the capacitor 4 increases, here the event should be "L1-4". Based on the current measurement these two events cannot be separated so the common fault identification is: " L1-1 or L1-4"

If the capacitor elements are not fused then the breakdown of a capacitor element will short-circuit a "layer" of capacitors. The capacitance increases and consequently also the capacitive current increases. This case was described in the explanation above.

If however the capacitor elements are individually fused then the breakdown of a capacitor element is disconnected from the "layer" of capacitors. The resultant capacitance decreases, and the result is opposite to the explanation in Figure 1-4.

For correct evaluation the information is needed: whether internal fuses are applied or not. This is to be set by the Boolean parameter "Internal fuse".

The event list related to the capacitor faults can contain the following messages:

Message	Explanation
L1-1 or L1-4	Fault in phase L1, C1 or C4
L2-1 or L2-4	Fault in phase L2, C1 or C4
L3-1 or L3-4	Fault in phase L3, C1 or C4
L1-2 or L1-3	Fault in phase L1, C2 or C3
L2-2 or L2-3	Fault in phase L2, C2 or C3
L3-2 or L3-3	Fault in phase L3, C2 or C3

Table 1-3 Capacitor fault location

NOTE: The fault location is active in "*Calibrated*" state only. The event is registered at the moment of trip command generation.

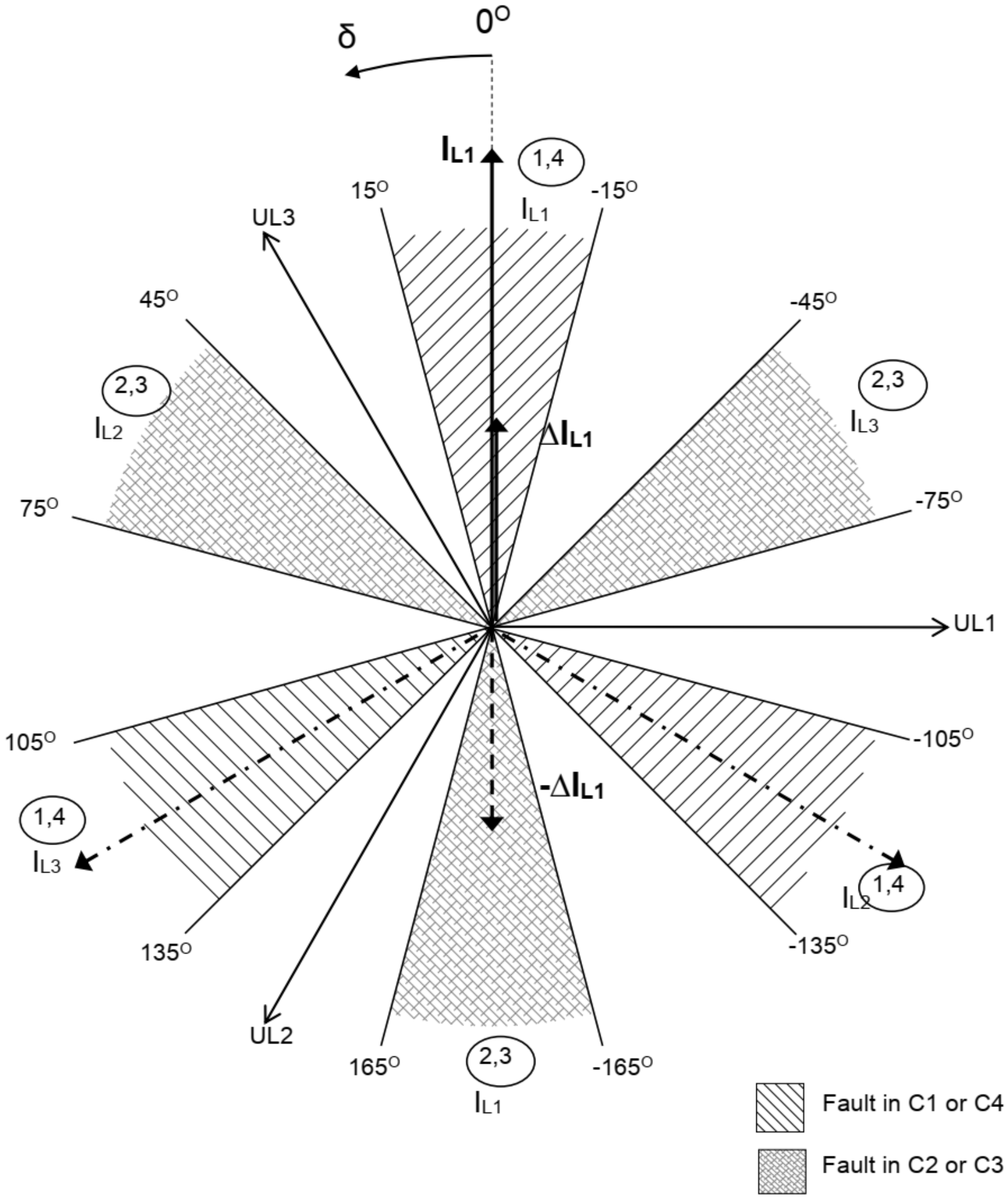


Figure 1-4 Scheme of the fault location

3.1.16.6. Technical summary

3.1.16.6.1. Technical data

Function	Value	Accuracy
Pick-up starting accuracy	20 ≤ G_S ≤ 1000	< 5 %
Pickup time	< 40 ms	
Angle accuracy		<1 degree
Reset ratio	0,9	
Reset time Dependent time char. Definite time char.	Approx 60 ms	< 2% or ±35 ms, whichever is greater
Operate time accuracy		±5% or ±15 ms, whichever is greater

Table 1-4 Technical data of the unbalance protection function

3.1.16.6.2. Parameters

Enumerated parameters

Parameter name	Title	Selection range	Default
Enabling or disabling the capacitor unbalance protection function			
CapUnB3_Oper1_EPar_	Operation Stage 1	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
CapUnB3_Oper2_EPar_	Operation Stage2	Off,On	Off

Table 1-5 The enumerated parameters of the capacitor unbalance protection function

Boolean parameter

Parameter name	Title	Default	Explanation
CapUnB3_IntFuse_BPar_	Internal fuse	0	0 means no internal fuse 1means capacitor units with internal fuse

Table 1-6 The Boolean parameters of the capacitor unbalance protection function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Current setting for the capacitor unbalance protection function, first stage						
CapUnB3_StCurr1_IPar_	Start Current 1	%	10	100	1	10
Current setting for the capacitor unbalance protection function, second stage						
CapUnB3_StCurr2_IPar_	Start Current 2	%	5	100	1	10
Nominal current of the capacitor, as percent of the rated input current						
CapUnB3_NomCurr_IPar_	Inom capacitor	%	15	120	1	100
ΔI setting, at calibration the current in the bridge must be below this level						
CapUnB3_dIMax_IPar_	dI maxcalib	%	5	50	1	10

Table 1-7 The integer parameters of the capacitor unbalance protection function

Floating point parameter

Parameter name	Title	Dim.	Min	Max	Default
Time multiplier setting for the inverse type characteristics					
CapUnB3_Multip_FPar_	Time Multiplier	Sec	0.05	999	1.0

Table 1-8 The floating point parameter of the capacitor unbalance protection function

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Minimum time delay for the inverse type characteristics (valid, if this characteristic is selected)						
CapUnB3_MinDel_TPar_	Min Time Delay	msec	0	60000	1	100
Definite time delay for the first stage (valid, if this characteristic is selected)						
CapUnB3_DefDel_TPar_	Definite Time Delay	msec	0	60000	1	1000
Reset time setting						
CapUnB3_Reset_TPar_	Reset Time	msec	0	60000	1	100
Definite time delay for the second stage						
CapUnB3_Delay2_TPar_	Delay Stage 2	msec	0	60000	1	1000

Table 1-9 The timer parameters of the capacitor unbalance protection function

3.1.16.6.3. Binary status signals

The **binary output status signals** of the capacitor unbalance protection function are listed in *Table 1-10* below.

Binary output signals	Signal title	Explanation
CapUnB3_GenSt1L1_Grl_	General Start 1 L1	General start signal for stage 1 phase L1
CapUnB3_GenTr1L1_Grl_	General Trip 1 L1	General trip command for stage 1 phase L1
CapUnB3_GenSt2L1_Grl_	General Start 2 L1	General start signal for stage 2 phase L1
CapUnB3_GenTr2L1_Grl_	General Trip 2 L1	General trip command for stage 2 phase L1
CapUnB3_GenSt1L2_Grl_	General Start 1 L2	General start signal for stage 1 phase L2
CapUnB3_GenTr1L2_Grl_	General Trip 1 L2	General trip command for stage 1 phase L2
CapUnB3_GenSt2L2_Grl_	General Start 2 L2	General start signal for stage 2 phase L2
CapUnB3_GenTr2L2_Grl_	General Trip 2 L2	General trip command for stage 2 phase L2
CapUnB3_GenSt1L3_Grl_	General Start 1 L3	General start signal for stage 1 phase L3
CapUnB3_GenTr1L3_Grl_	General Trip 1 L3	General trip command for stage 1 phase L3
CapUnB3_GenSt2L3_Grl_	General Start 2 L3	General start signal for stage 2 phase L3
CapUnB3_GenTr2L3_Grl_	General Trip 2 L3	General trip command for stage 2 phase L3
CapUnB1_Calib_Grl_	Calibrated	True, if the function has been calibrated

Table 1-10 The binary output status signals of the capacitor unbalance protection function

The **binary input status signals** of the capacitor unbalance protection function are shown in Table 1-11 below.

The capacitor unbalance protection function has binary input signals. **The conditions of these status signals are defined by the user, applying the graphic logic editor.**

Binary input signals	Signal title	Explanation
CapUnB3_Reset_GrO_	Reset	Resetting the calibrated state
CapUnB3_Calibr_GrO_	Calibr	Binary input for calibration
CapUnB3_Blk_GrO_	Blk	Blocking input

Table 1-11 The binary input status signal of the capacitor unbalance protection function

3.1.16.6.4. The function block

The function block of the capacitor unbalance protection function is shown in Figure 1-5. This block shows all binary input and output status signals that are applicable in the graphic logic editor.

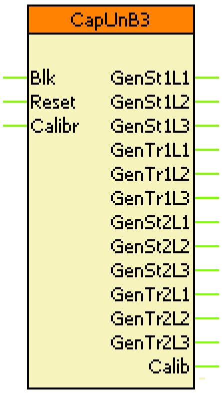


Figure 1-5 The function block of the capacitor unbalance protection function

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.

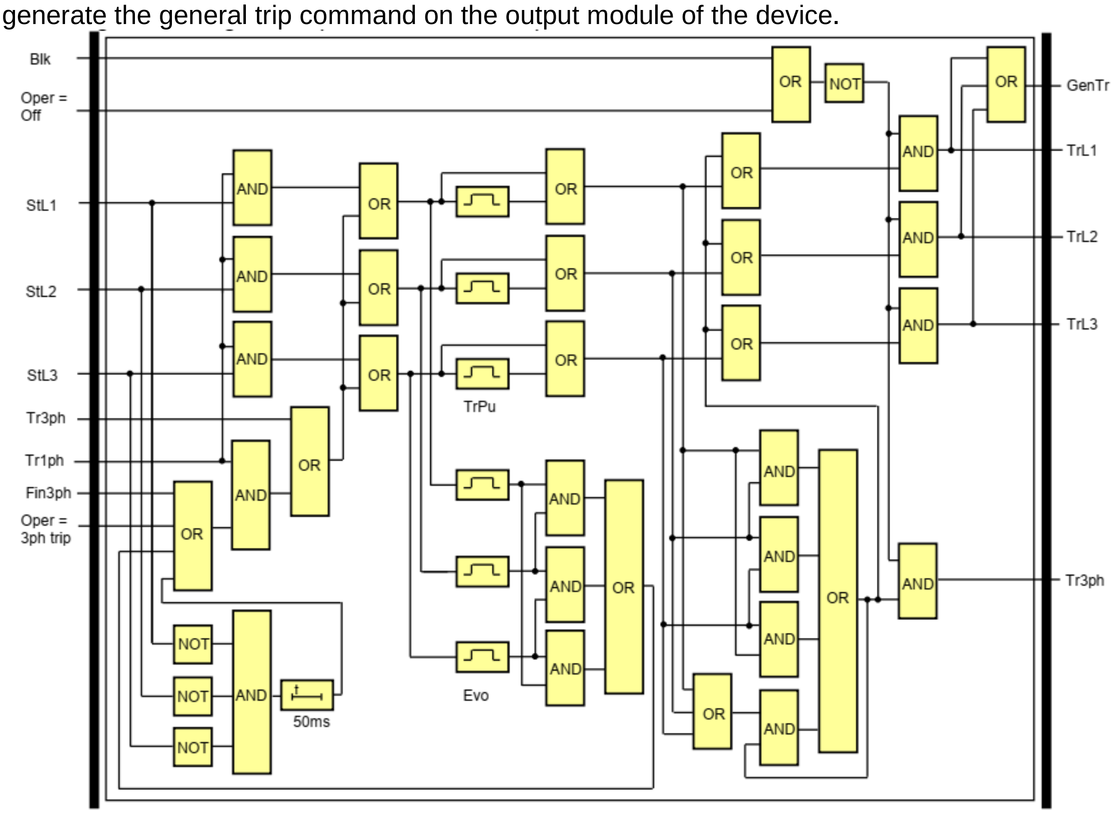


Figure 1-1 Logic scheme of the decision logic

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.

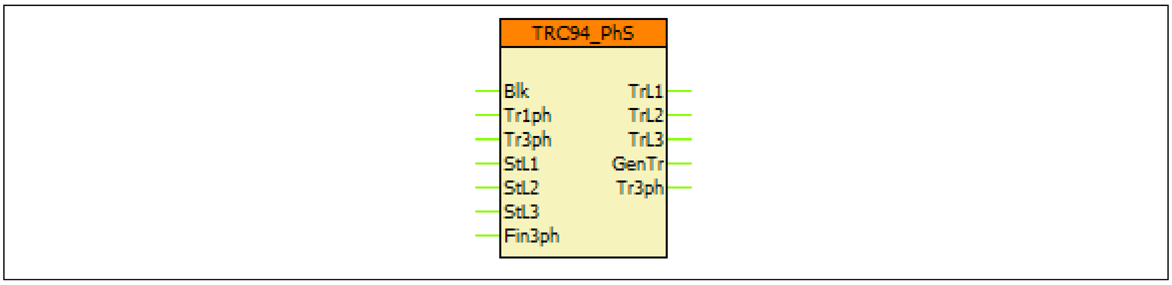


Figure 2-1 Graphic appearance of the function block of the phase-selective trip logic function

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).

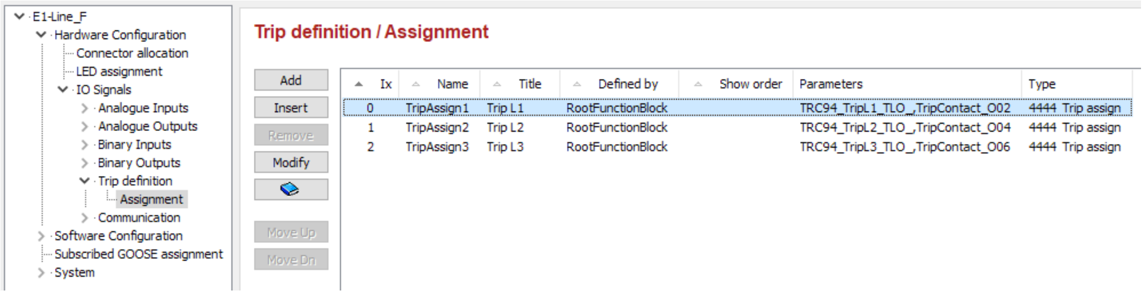


Figure 2-2 Trip assignment in EuroCAP

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.

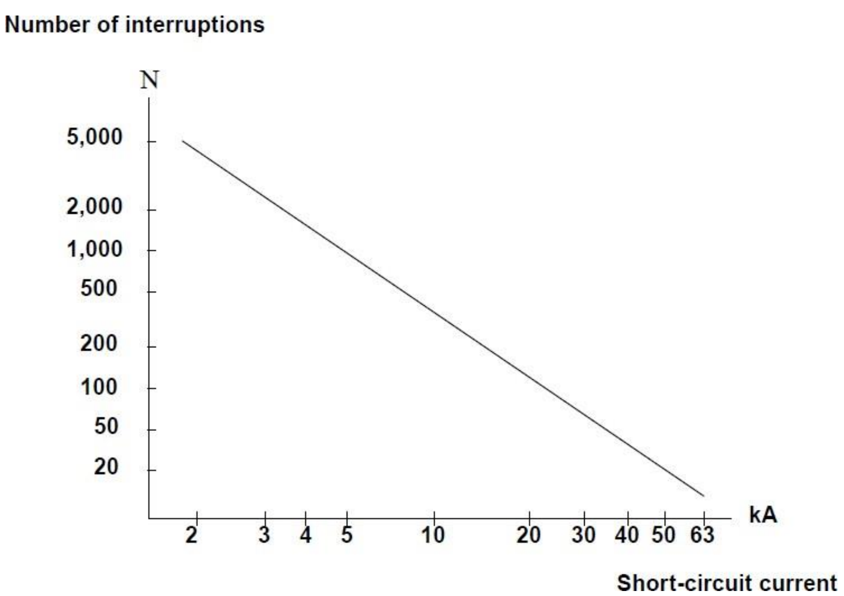


Figure 1-1 Example: Number of permitted interruptions as the function of the interrupted current

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 In	±1% of In
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_Imin_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.

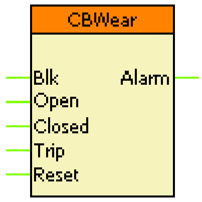


Figure 1-3 The function block of the circuit breaker wear monitoring function

3.2.3. Circuit breaker control function block

3.2.3.1. Application

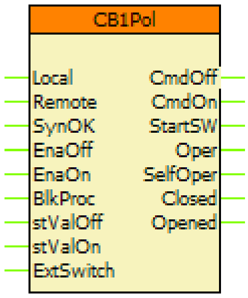
The circuit breaker control block can be used to integrate the circuit breaker control of the EuroProt+ device into the station control system and to apply active scheme screens of the local LCD of the device.

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 *interlocking conditions defined graphically by the user*.
CB1Pol_**EnaOn**_GrO_	The active state of this input enables the closing of the circuit breaker. The state is usually generated by the *interlocking conditions defined graphically by the user*.
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 (**INT**CILO# and **SBw**CSWI# 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)

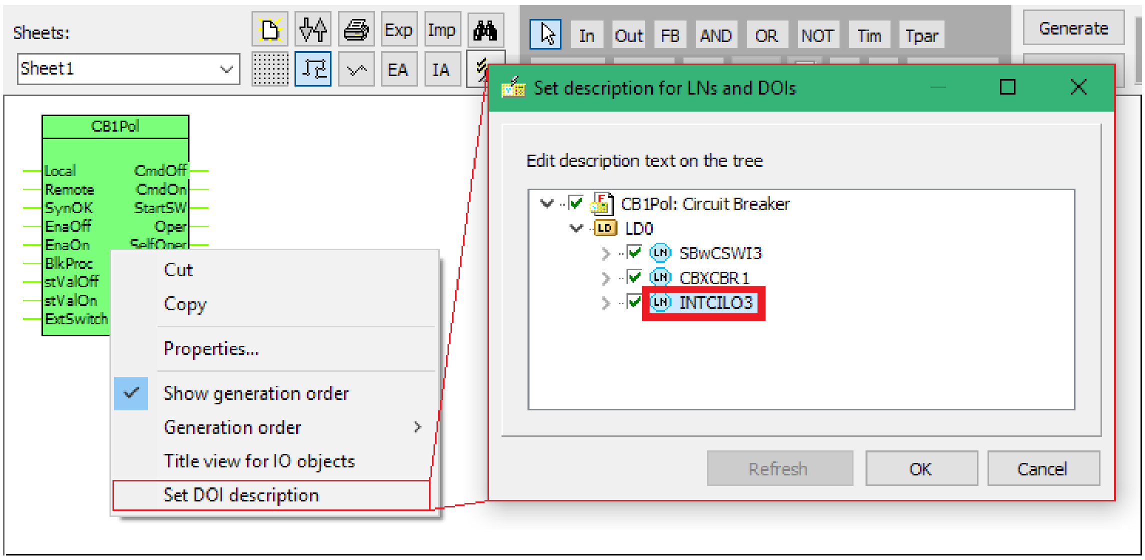


Figure 2-2 Checking the description of the Interlocking LN of the function block

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. Disconnector 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. Disconnector control function overview

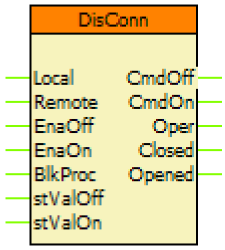


Figure 2-1 Graphic appearance of the function block of the disconnector control function

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 disconnector node according to the IEC 61850 standard
Type of Switch	-	N/A, Load Break, Disconnector, Earthing Switch, HS Earthing Switch	-	Disconnector	
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 disconnector 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 *interlocking conditions defined graphically by the user*.
DisConn_**EnaOn**_GrO_	The active state of this input enables the closing of the disconnector. The state is usually generated by the *interlocking conditions defined graphically by the user*.
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**_GrI_	Off Command	Off command impulse, the duration of which is defined by the parameter "Pulse duration"
DisConn_**CmdOn**_GrI_	On Command	On command impulse, the duration of which is defined by the parameter "Pulse duration"
DisConn_**Oper**_GrI_	Operation	An impulse with a duration of 150 ms at any operation of the disconnector
DisConn_**Closed**_GrI_	Closed	The filtered status signal for closed state of the disconnector
DisConn_**Opened**_GrI_	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 disconnector
Opened	-	The filtered status signal for opened state of the disconnector
Closed	-	The filtered status signal for closed state of the disconnector
Operation counter	-	Resettable* counter that increments every time the Operation (see above) output gets active

Table 2-4 On-line data of the disconnector 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 disconnector 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 disconnector 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 disconnector. 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 disconnector 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 disconnector 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 (**INT**CILO# and **SBw**CSWI# 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)

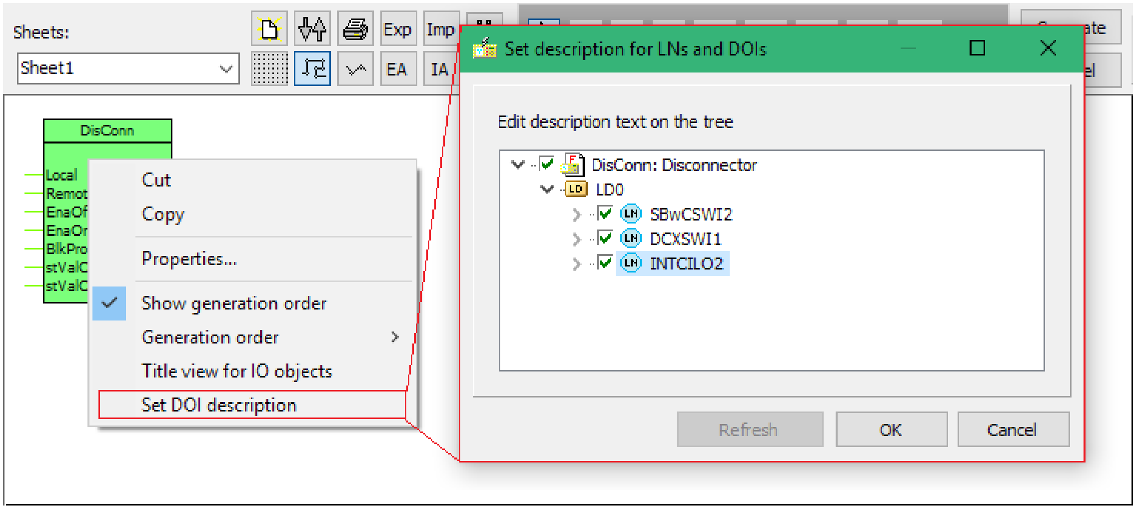


Figure 2-2 Checking the description of the Interlocking LN of the function block

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 disconnector 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.

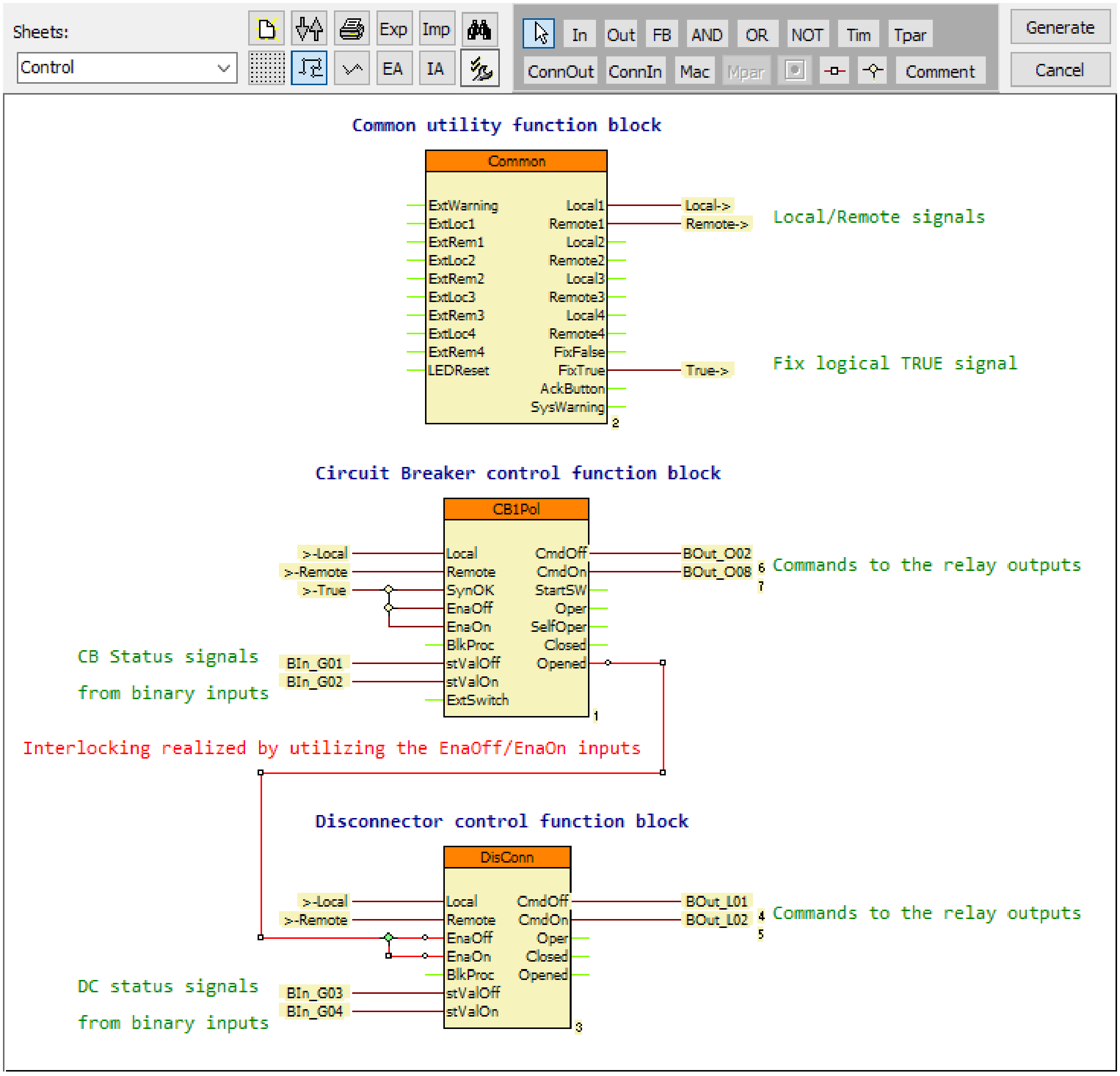


Figure 3-1 Inserting the disconnector function block into the logic (example)

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.

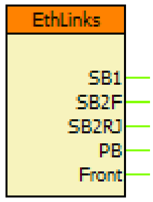


Figure 2-1 Graphic appearance of the function block of the ethernet links function

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

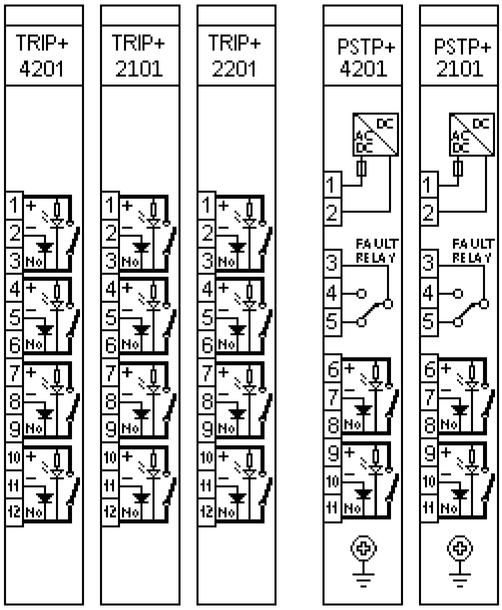


Figure 1-1 I/O arrangement of the modules with TCS

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 – **T**rip **C**ircuit **S**upervision 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

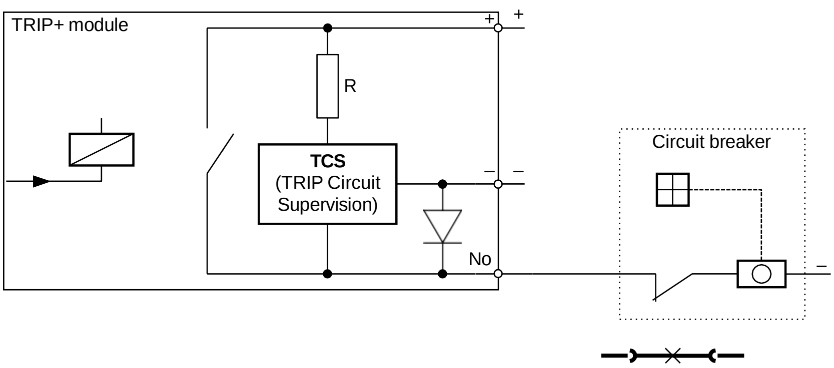


Figure 2-1 3-wire TRIP+ wiring

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

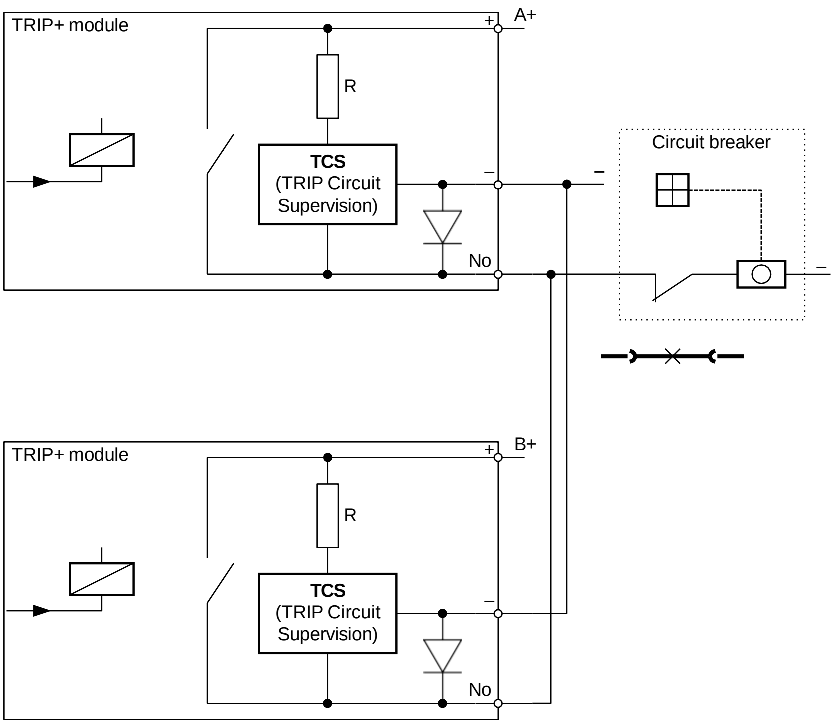


Figure 2-2 3-wire TRIP+ wiring using parallel connected TRIP+ modules

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.

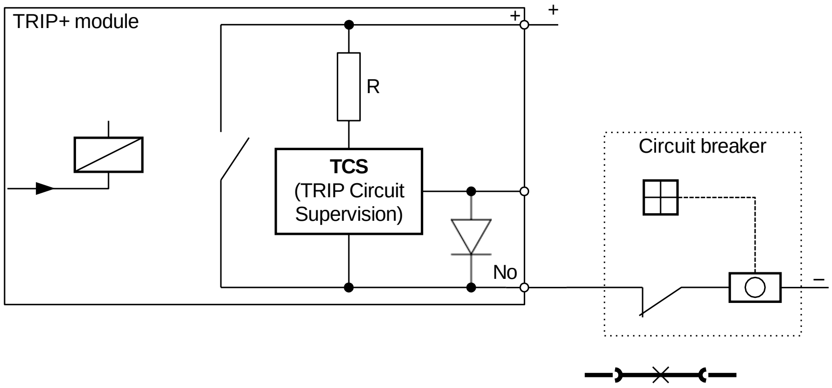


Figure 2-3 2-wire TRIP+ wiring

It is possible to use parallel connected TRIP+ modules.

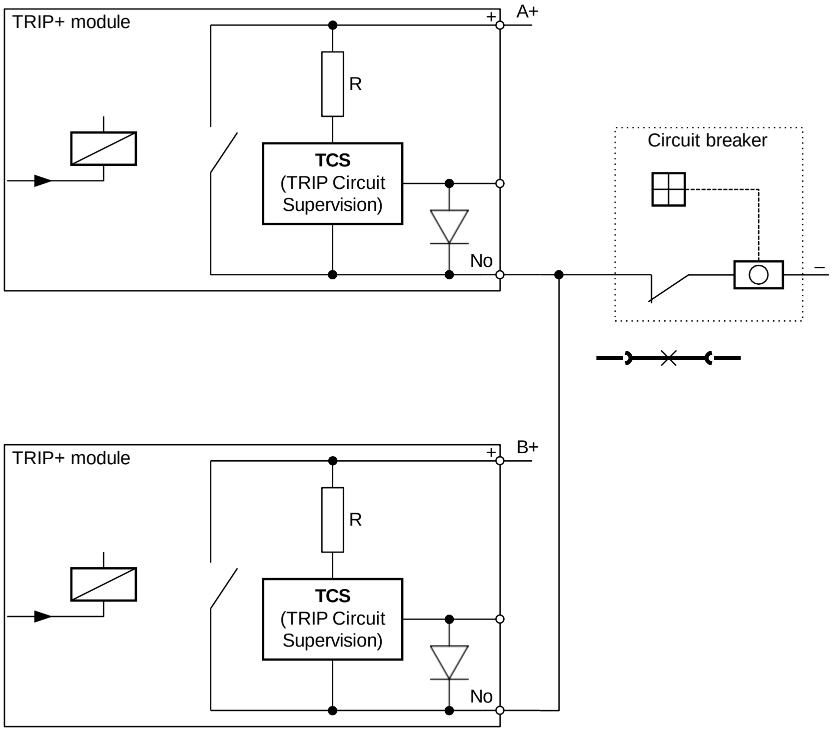


Figure 2-4 2-wire TRIP+ wiring using parallel connected TRIP+ modules

If the circuit breaker needs two-pole switching, TRIP+ modules can be connected series as you can see in Figure 2-5.

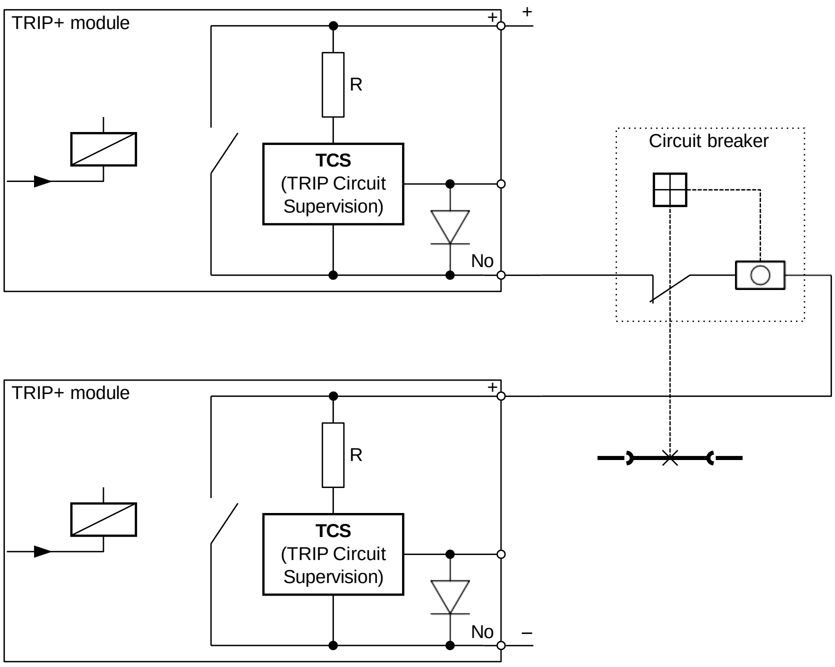


Figure 2-5 2-wire TRIP+ wiring using series connected TRIP+ modules

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:

a) **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.

b) **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 (± 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	**8.1 kΩ** @ 220 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	**4 kΩ** @ 220 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	**90 kΩ** @ 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 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

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.

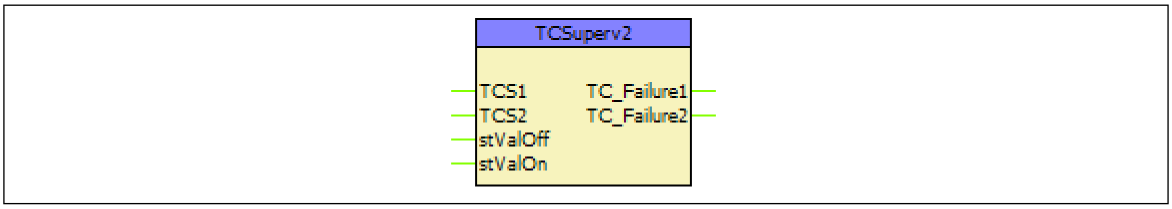


Figure 3-1 Graphic appearance of the Trip Circuit Supervision macro

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).

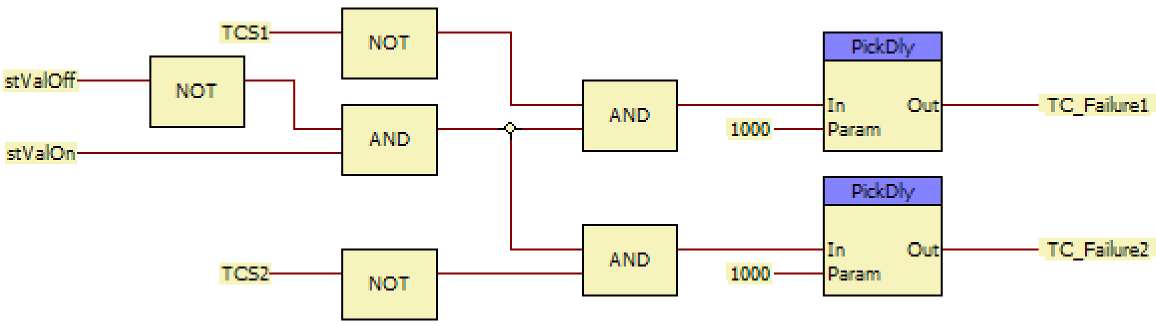


Figure 3-2 Internal logic of the Trip Circuit Supervision macro

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. Current unbalance function

3.2.7.1. Application

The current unbalance protection function can be applied to detect unexpected asymmetry in current measurement.

3.2.7.1.1. 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.

3.2.7.1.2. Operation principles

Figure ***1-1*** shows the structure of the current unbalance protection algorithm.

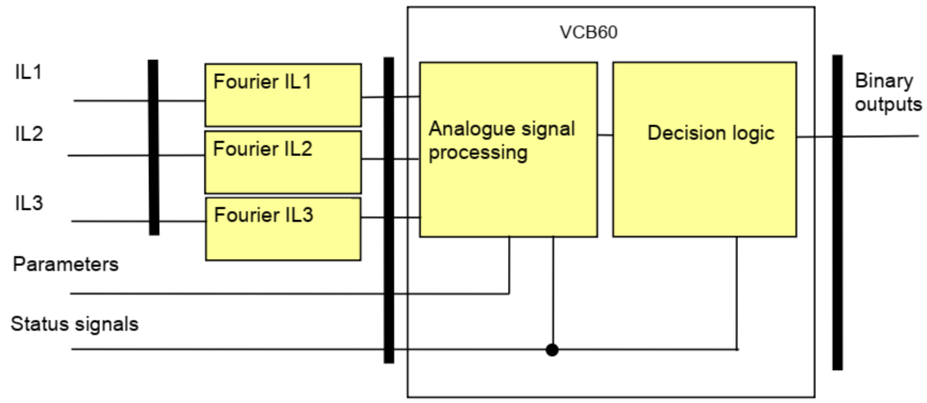


Figure 1-1 Structure of the current unbalance protection algorithm

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.

3.2.7.1.3. 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.

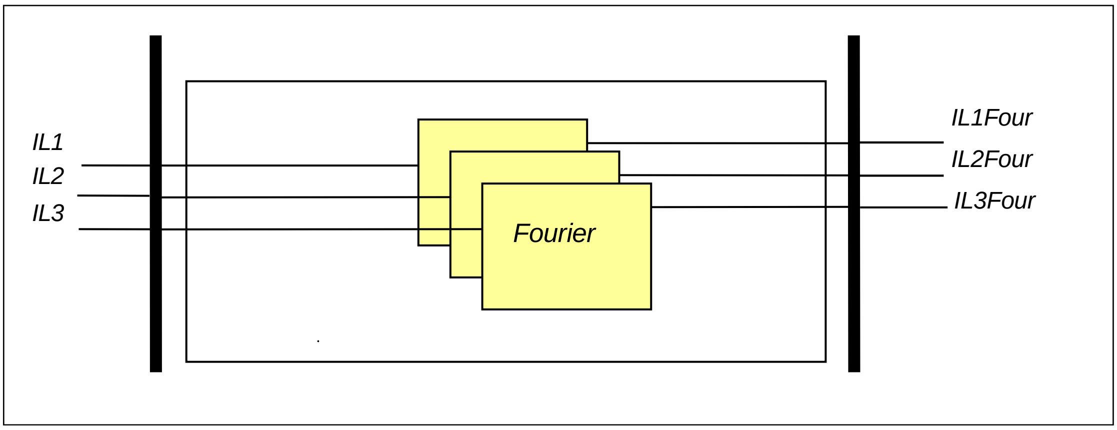


Figure 1-2 Principal scheme of the Fourier calculation

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).

3.2.7.1.4. The Analogue signal processing

This module processes the Fourier components of the phase currents to prepare the signals for the decision.

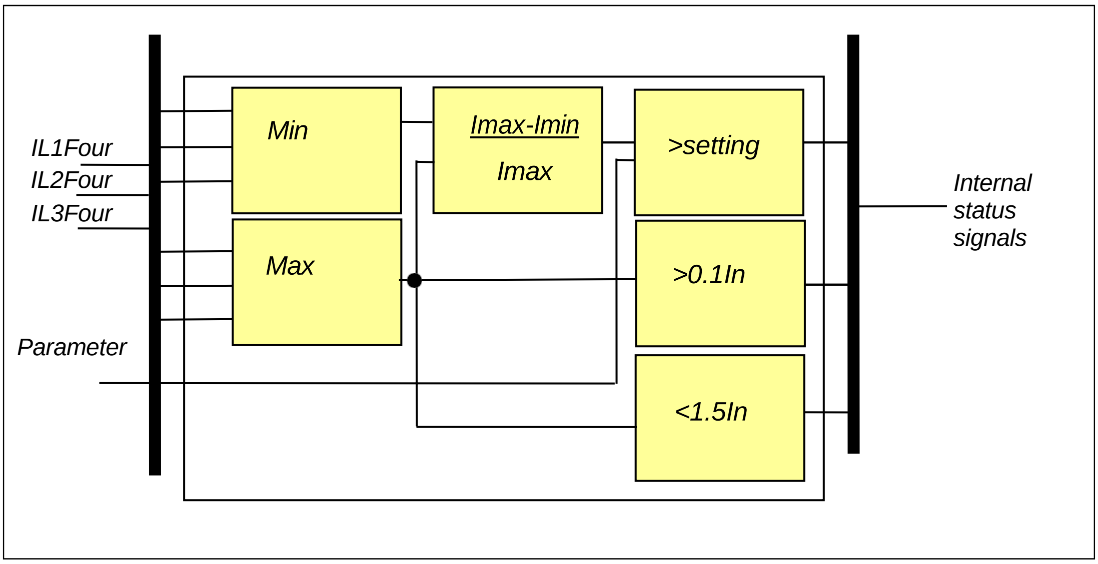


Figure 1-3 Principal scheme of the analogue signal processing

The **inputs** are the fundamental Fourier components of the analyzed currents (IL1Four, IL2Four, IL3Four)

The **outputs** are internal binary signals:

- ΔI> 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”;
- Imax>0.1In The maximum of the RMS values of the fundamental Fourier components of the phase currents is sufficient for evaluation;
- Imax<1.5In The maximum of the RMS values of the fundamental Fourier components of the phase currents is not considered as a fault current.

3.2.7.1.5. 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.

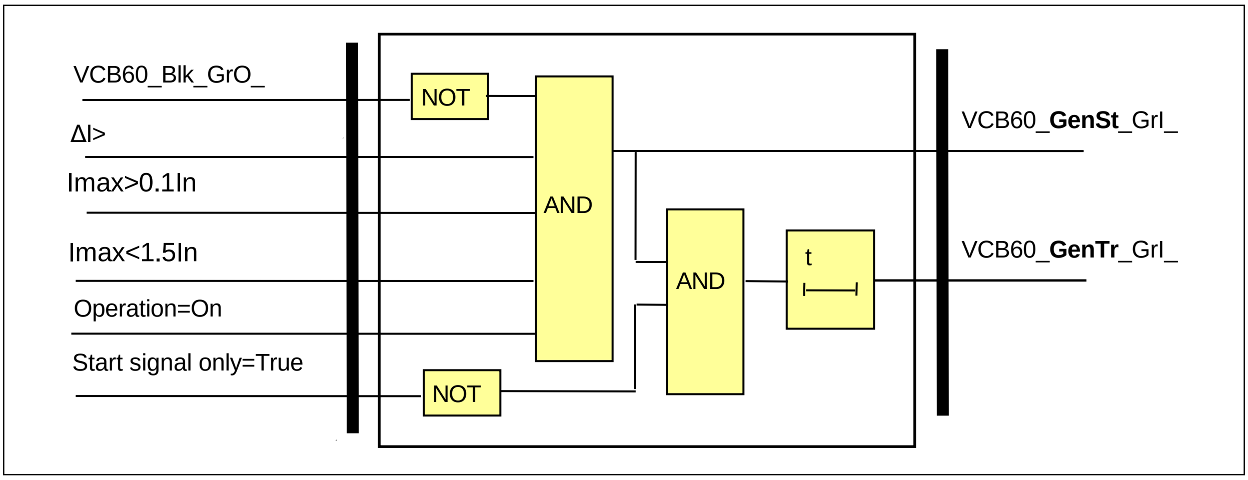


Figure 1-4 The logic scheme of the current unbalance function

The **inputs** are internal binary signals:

- ΔI> 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”;
- Imax>0.1In the maximum of the RMS values of the fundamental Fourier components of the phase currents is sufficient for evaluation;
- Imax<1.5In the maximum of the RMS values of the fundamental Fourier components of the phase currents is not considered as a fault current.

3.2.7.2. 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.

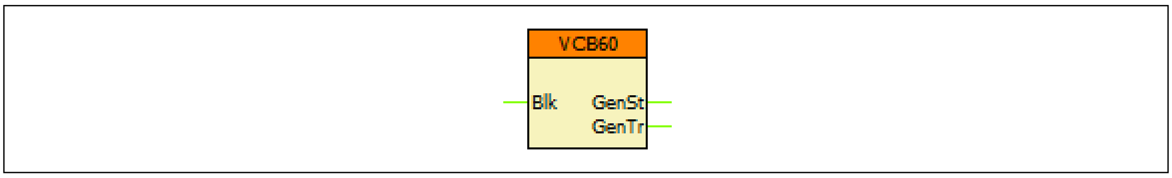


Figure 2-1 Graphic appearance of the function block of the current unbalance protection function

3.2.7.2.1. 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 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)

3.2.7.2.2. Function I/O

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

3.2.7.2.2.1. Analogue inputs

The function uses the sampled values of a current input. This is defined in the configuration.

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 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

3.2.7.2.2.3. 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 current unbalance protection function

BINARY OUTPUT SIGNAL	SIGNAL TITLE	EXPLANATION
VCB60_**GenSt**_GrI_	General Start	General start signal of the function
VCB60_**GenTr**_GrI_	General Trip	General trip command of the function

3.2.7.2.2.4. 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

3.2.7.2.2.5. Events

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

Table 2-5 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

3.2.7.2.3. 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	

3.2.7.2.4. 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.

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.

3.3. 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

Synchrocheck function (SYN25)	
Voltage Diff	Voltage different value
Frequency Diff	Frequency different value
Angle Diff	Angle different value
Line measurement (MXU_L) (here the displayed information means primary value)	
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
Metering (MTR)	
Forward MWh	Forward MWh
Backward MWh	Backward MWh
Forward MVArh	Forward MVArh
Backward MVArh	Backward MVArh
Line thermal protection (TTR49L)	
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_PriI13_FPar_	Rated Primary I1-3	A	100	4000	1000
Rated primary current of channel4					
CT4_PriI4_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 I4
Angle Ch – I4	degree	Vector position of the current in channel I4

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 3Io 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.

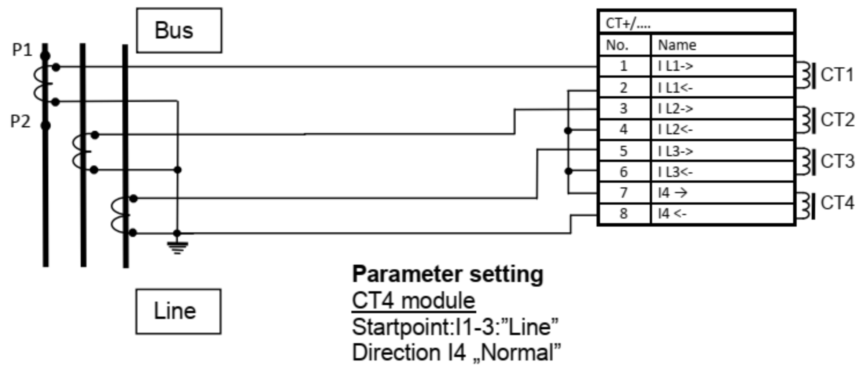


Figure 1-1 Example: CT connection with 3Io measurement

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).

[-] CT4 Primary2 "P"

	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 3Io 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-cicuit, 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).

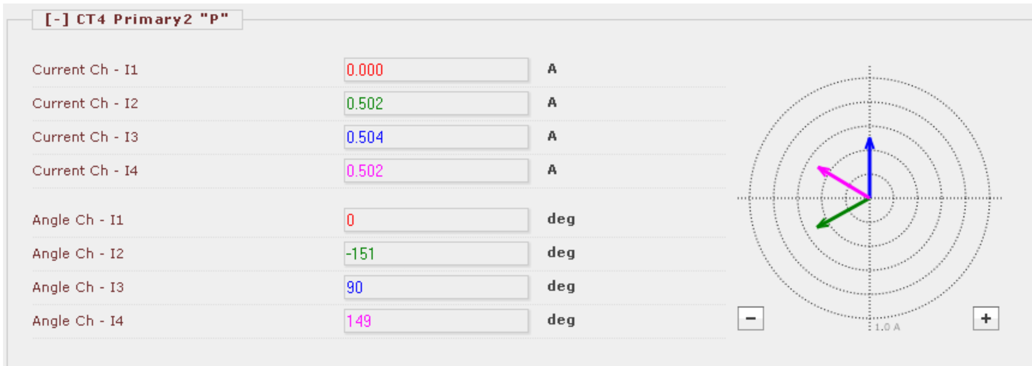


Figure 1-3 Example: Checking the current connection

3.3.1.1.3.2. Application of core-balanced CT

Figure *1-4* shows a connection example with 3Io 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.

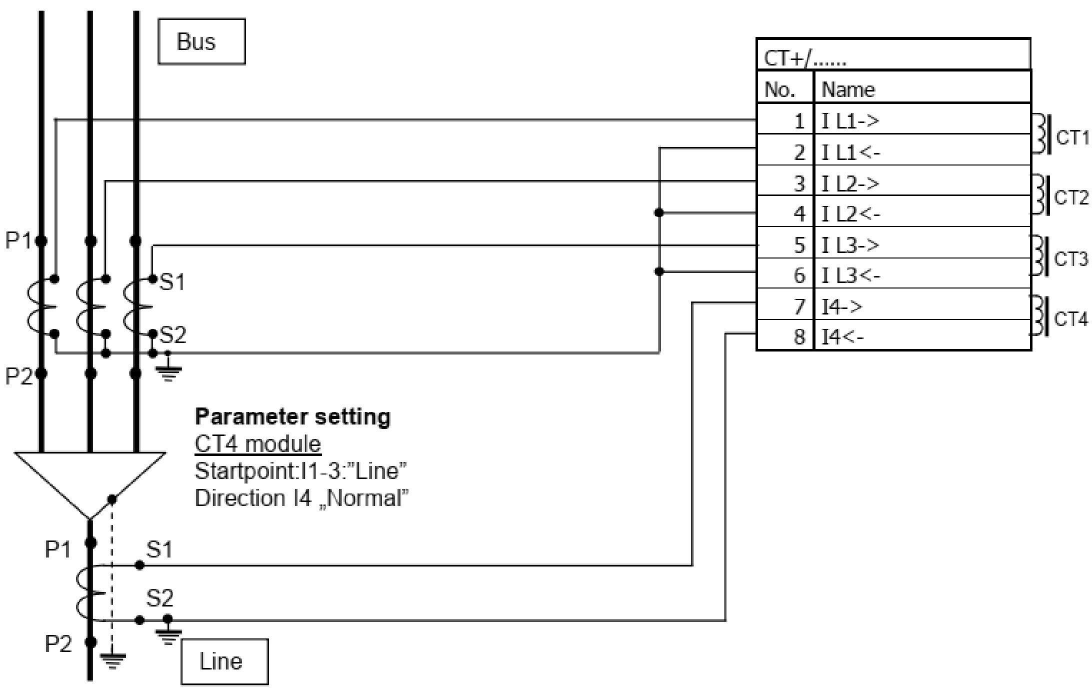


Figure 1-4 Example: CT connection with core-balance CT application

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.

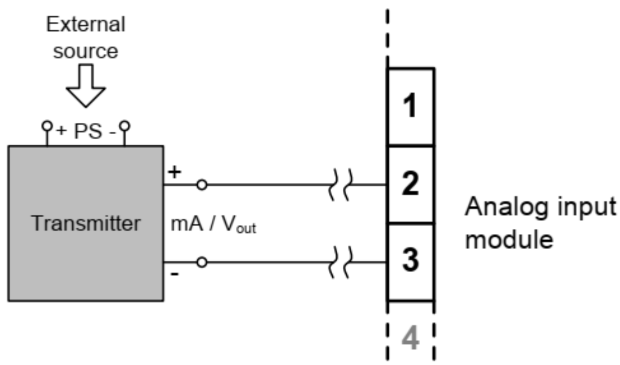


Figure 1–1 2-wire AIC wiring without 12 V excitation

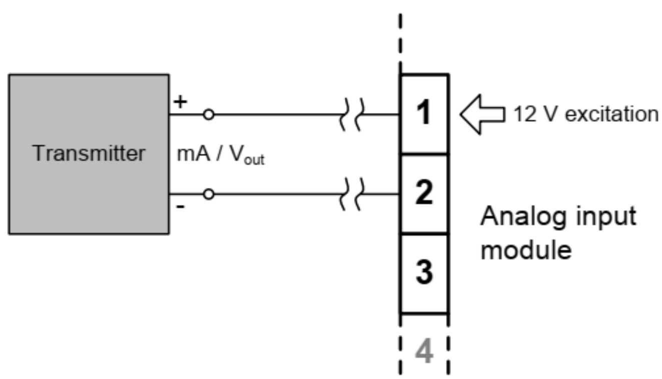


Figure 1–2 2-wire AIC wiring with 12 V excitation

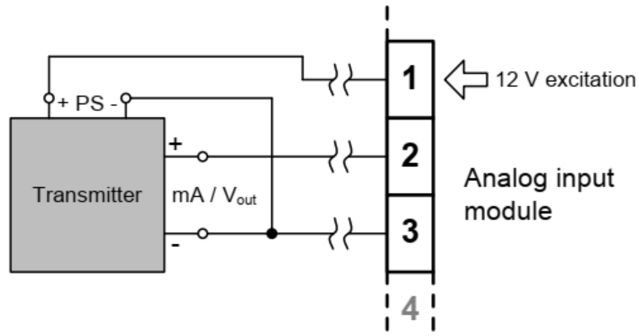


Figure 1–3 3-wire AIC wiring with 12 V excitation

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. Line and frequency measurement functions

3.3.3.1. 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.

3.3.3.2. 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.

3.3.3.3. The measurement

3.3.3.3.1. 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			

3.3.3.3.2. 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).

3.3.3.4. 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.

3.3.3.4.1. “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”.

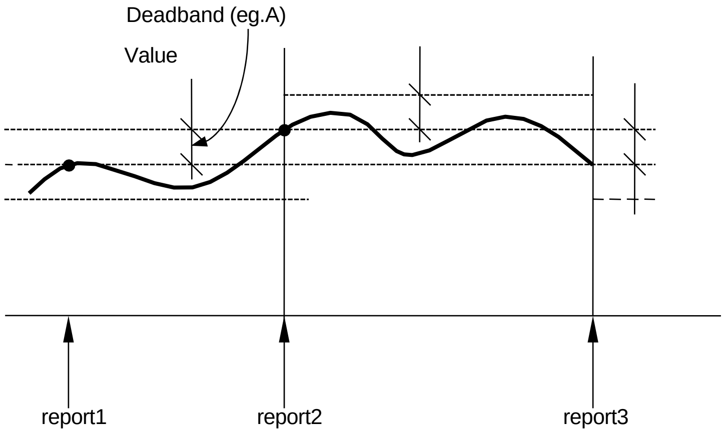


Figure 1-1 Reporting if “Amplitude” mode is selected

3.3.3.4.2. “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.

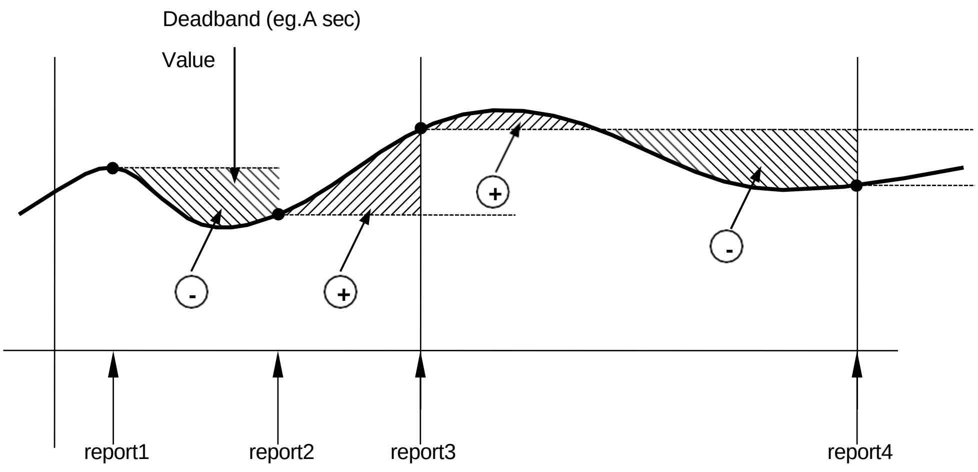


Figure 1-2 Reporting if “Integrated” mode is selected

3.3.3.4.3. 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.

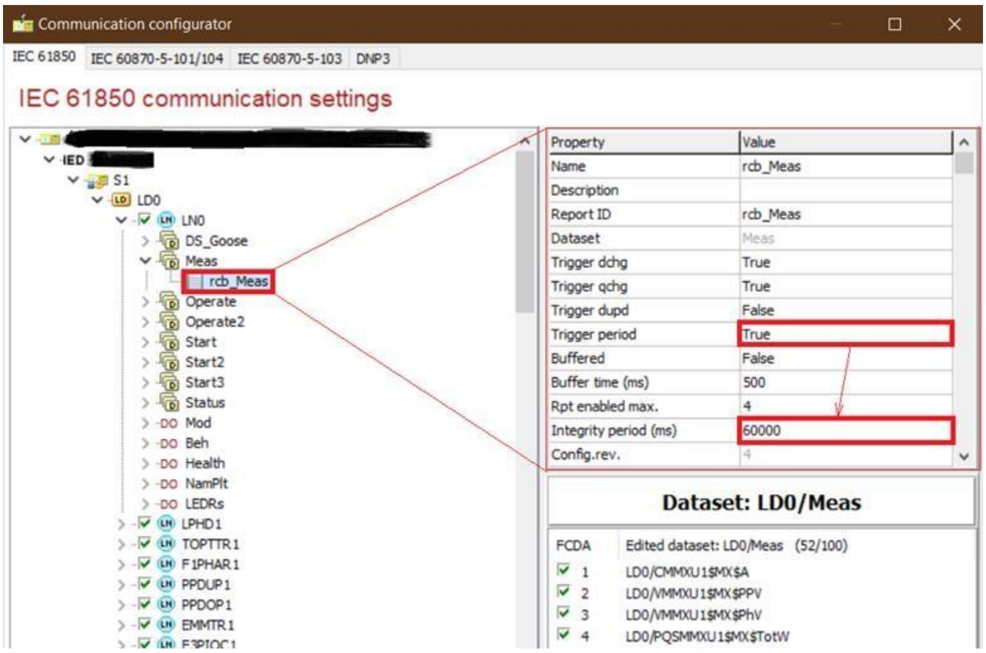


Figure 1-3 Setting up periodic reporting in EuroCAP

3.3.3.4.4. 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 (In)
- Three-phase voltage measurement *2%* of nominal (Un)
- Residual current measurement *0.2%* of nominal (In)
- Residual voltage measurement *2%* of nominal (Un)
- Phase sequence current measurement *0.2%* of the nominal (In)
- Phase sequence voltage measurement *2%* of the nominal (Un)
- Three-phase power and energy measurement *0.23%* of the nominal (Sn)

3.3.3.5. Line and frequency measurement functions overview

3.3.3.5.1. Settings

3.3.3.5.1.1. 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*

3.3.3.5.2. Function I/O

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

3.3.3.5.2.1. 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,

3.3.3.5.2.2. 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

3.3.3.5.2.3. 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 3Io	A	Calculated 3Io 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 3Uo	kV*	Calculated 3Uo 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*

3.3.3.5.3. Technical data

Table 2-3 Technical data of the line measurement function (power)

POWER MEASUREMENT (P, Q, S)* HW MODULES	RANGE	ACCURACY
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) HW MODULES	RANGE	ACCURACY
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) HW MODULES	RANGE	ACCURACY
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

3.3.3.5.3.1. 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

3.3.4. RTD temperature input function

3.3.4.1. 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.

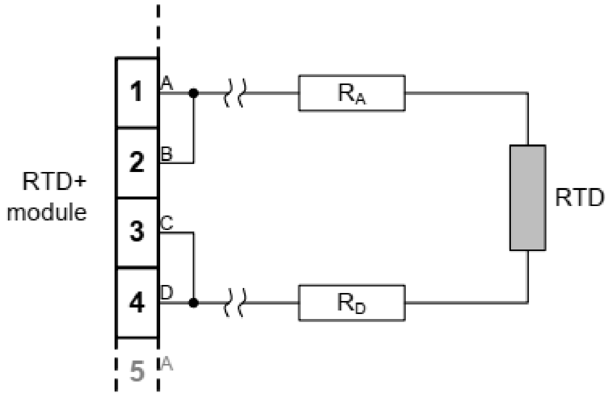


Figure 1–1 2-wire RTD wiring

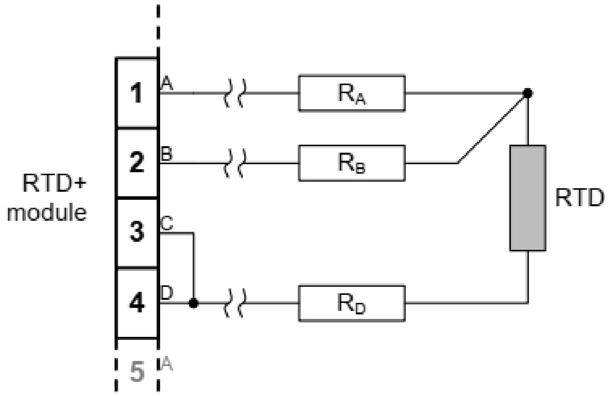


Figure 1–2 3-wire RTD wiring

When 3-wire connection is applied, it is supposed that R_A=R_D.

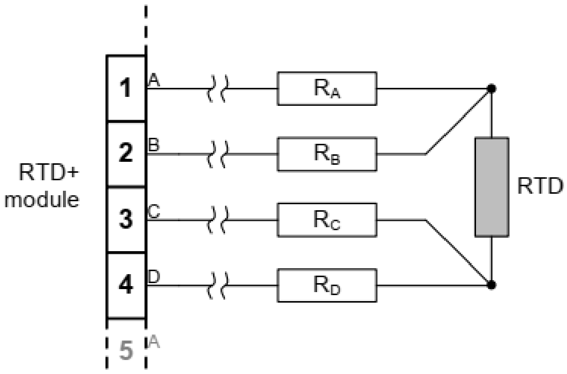


Figure 1–3 4-wire RTD wiring

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 kΩ)

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***".

3.3.4.2. Technical summary

3.3.4.2.1. 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".

3.3.4.2.2. 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.

3.3.5. Metering

3.3.5.1. 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.

3.3.5.1.1. 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.

3.3.5.1.2. 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.

3.3.5.1.3. 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.

3.3.5.1.4. 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 (**k**ilo- or **M**ega) 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.

3.3.5.1.5. The measurement

3.3.5.1.5.1. Reference direction

"Reference direction" parameter setting defines the direction when voltage and current vectors are in phase. Setting can be "Demand" or "Supply".

3.3.5.1.5.2. The measured values

Unit prefix of the **measured values** of the metering function depends on the configuration: it can be **k**ilo or **M**ega. 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.

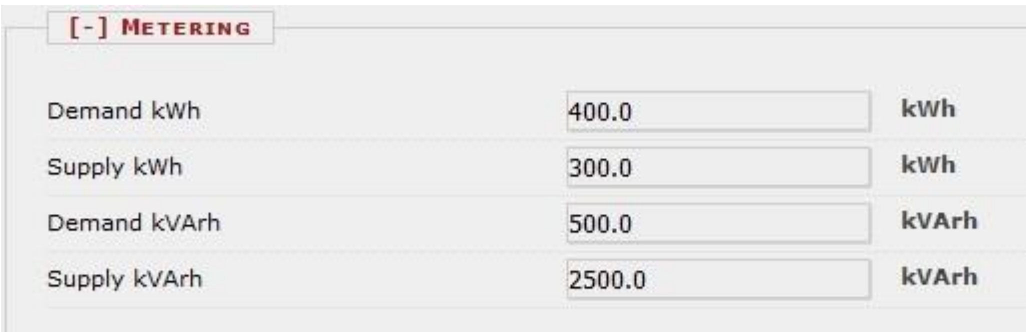


Figure 1-1 Measured values of the metering function

3.3.5.1.6. 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

3.3.5.2. 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.

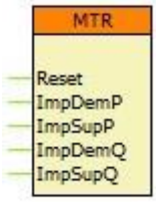


Figure 2-1 Graphic appearance of the function block of the metering function

3.3.5.2.1. Settings

3.3.5.2.1.1. 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

3.3.5.2.2. Function I/O

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

3.3.5.2.2.1. Analogue inputs

The function uses the sampled values of a voltage and current inputs. This is defined in the configuration.

3.3.5.2.2.2. 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	*Demand P. Unit prefix can be kilo- or mega-, depends on the configuration*
Supply P	kWh	*Supply P. Unit prefix can be kilo- or mega-, depends on the configuration*
Demand Q	kVArh	*Demand Q. Unit prefix can be kilo- or mega-, depends on the configuration*
Supply Q	kVArh	*Supply Q. Unit prefix can be kilo- or mega-, depends on the configuration*

3.3.5.2.2.3. 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

3.3.5.2.2.4. 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	*Demand P value*
Supply P	Wh	*Supply P value*
Demand Q	VArh	*Demand Q value*
Supply Q	VArh	*Supply Q value*

3.3.5.2.3. Technical data

Table 2-5 Technical data of the metering function

FUNCTION	RANGE	ACCURACY
Power accuracy	I > 15%In	±3%

3.3.5.2.4. 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.

3.3.5.2.5. 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*

3.3.6. Voltage selection function block

3.3.6.1. Application

In several substation configurations with double busbar, the 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.

3.3.6.2. 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.

3.3.6.3. 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.

3.3.6.4. The parameters

The voltage selection function block has no parameters.

3.3.6.5. The symbol of the function block in the graphic editor

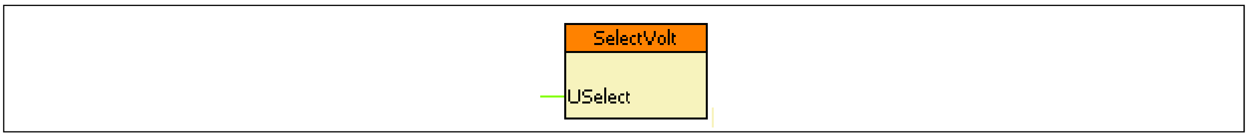


Figure 1-1 The function block of the voltage selection function block

The name of the input signal is a part of the “Binary status signal” name shown in Table 1-1.

3.3.6.6. 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.

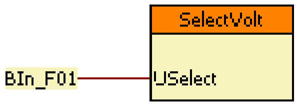


Figure 2-1 Example The simple application of the voltage selection function block

3.3.7. Trip Value Recorder

3.3.7.1. 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).

3.3.7.1.1. 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.

3.3.7.1.2. 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 prefault 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 prefault 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 prefault 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:

- prefault 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.

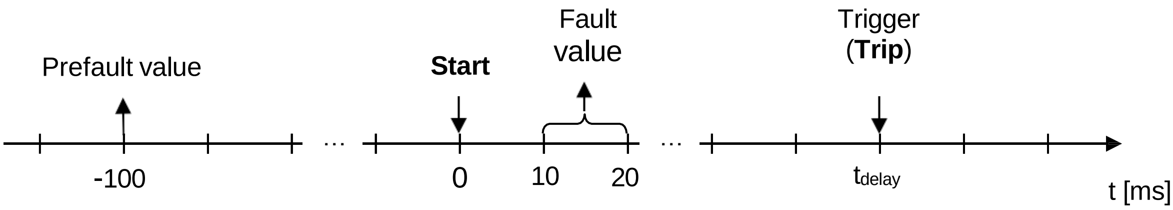


Figure 1-1 Time diagram of the trip recording behaviour

3.3.7.2. 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.

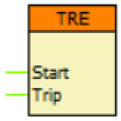


Figure 2-1 Graphic appearance of the function block of the trip value recorder function

3.3.7.2.1. Settings

3.3.7.2.1.1. Parameters

The Trip value recorder function does not have any parameters.

3.3.7.2.2. Function I/O

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

3.3.7.2.2.1. 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.

3.3.7.2.2.2. 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 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

3.3.7.2.2.3. Binary output signals (graphed input statuses)

The Trip value recorder function does not have any binary output signals.

3.3.7.2.2.4. Online data

No default visible values on the *online data* page.

3.3.7.2.2.5. Events

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

Table 2-3 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)*

3.3.8. Average and maximum measurement function

3.3.8.1. 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.

3.3.8.2. 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.

3.3.8.3. 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.

3.3.8.4. 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

3.3.8.5. 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**.

3.3.8.6. 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.

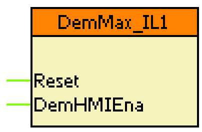


Figure 1-1 The function block of the average and maximum measurement function block

3.4. 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:

Memory size of a record = (n*7 kB+ m*2 kB)*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."

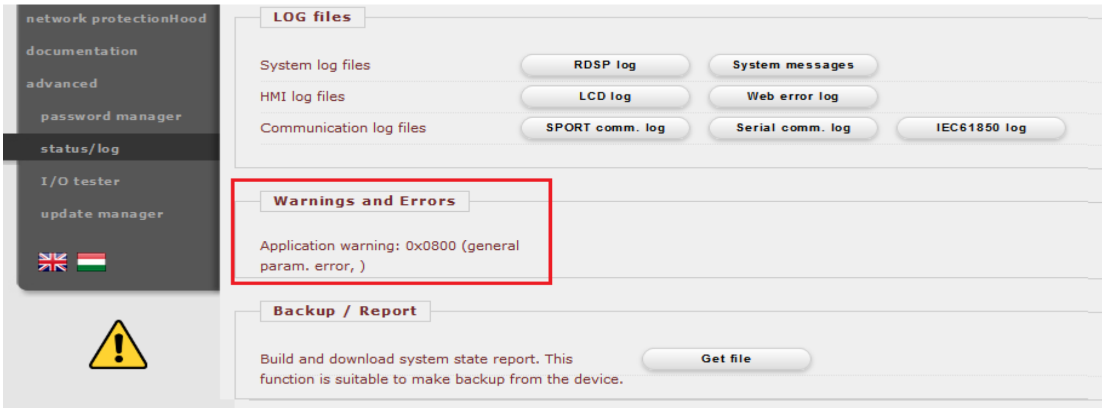


Figure 1-1 Warning message if the settings are invalid

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.

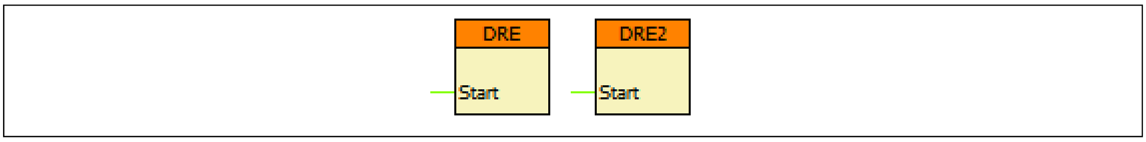


Figure 1-2 The function blocks of the disturbance recorder functions

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

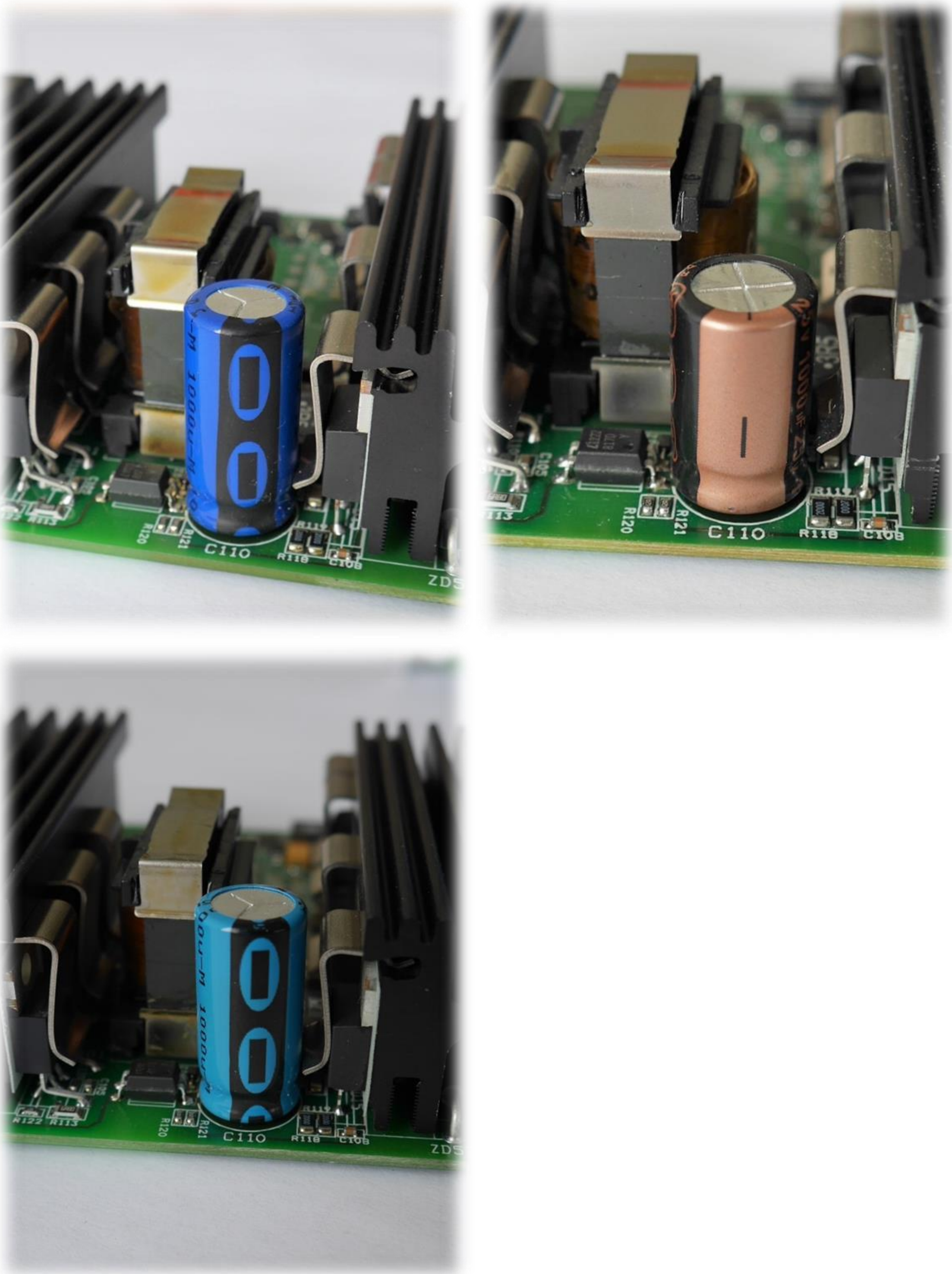


Figure 4-2 Healthy capacitors on visual inspection

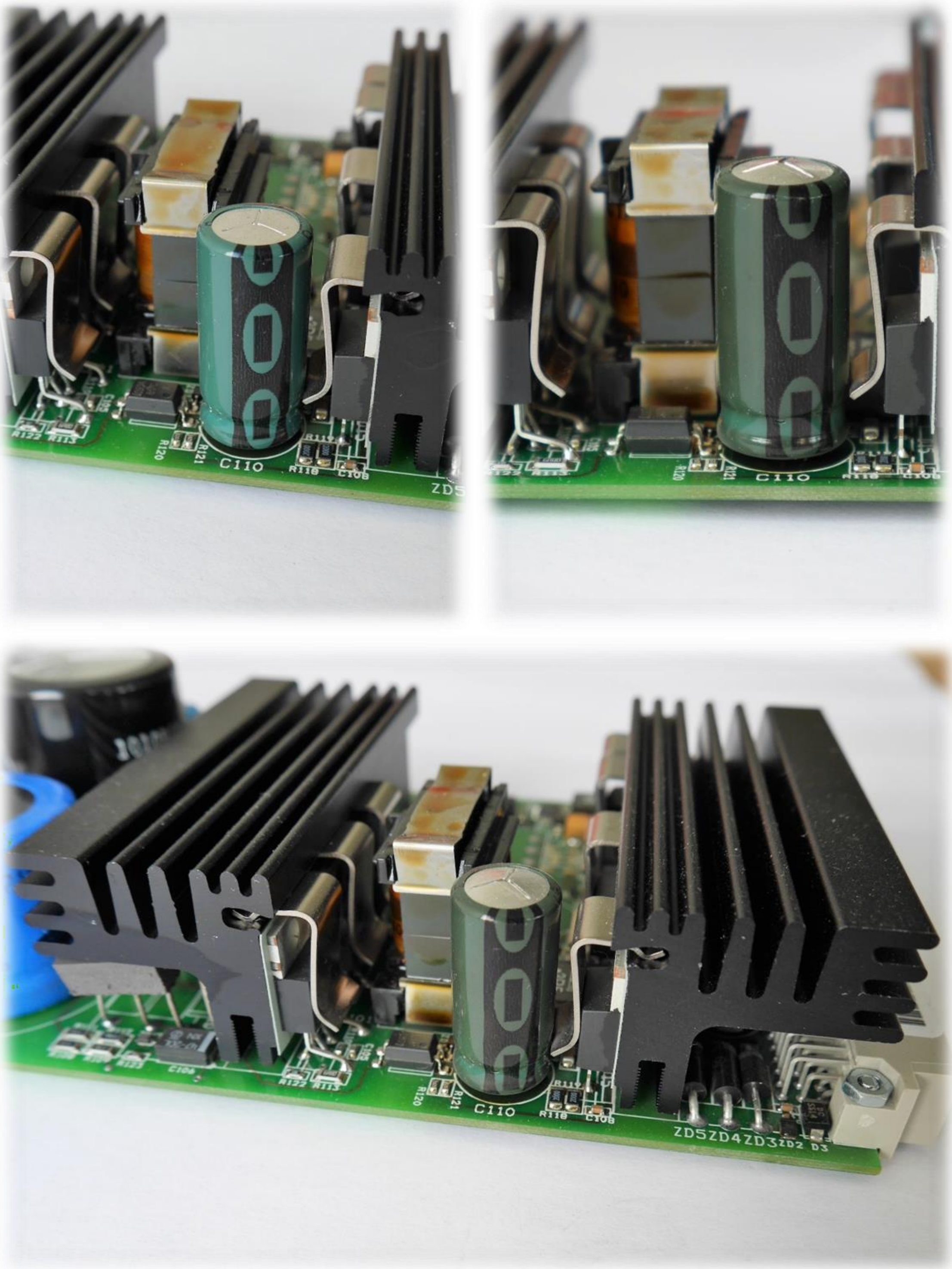


Figure 4-3 Faulty capacitances on visual inspection. The discoloration compared to the original blue color is clearly visible, bloating can be seen on 2 of them

4.4. Elements and Batteries

Az EuroProt+ protection family devices do not contain either a single-use battery or a rechargeable battery.

5. TRIP contact assignment

The procedures of command processing are shown in the following symbolical figure.

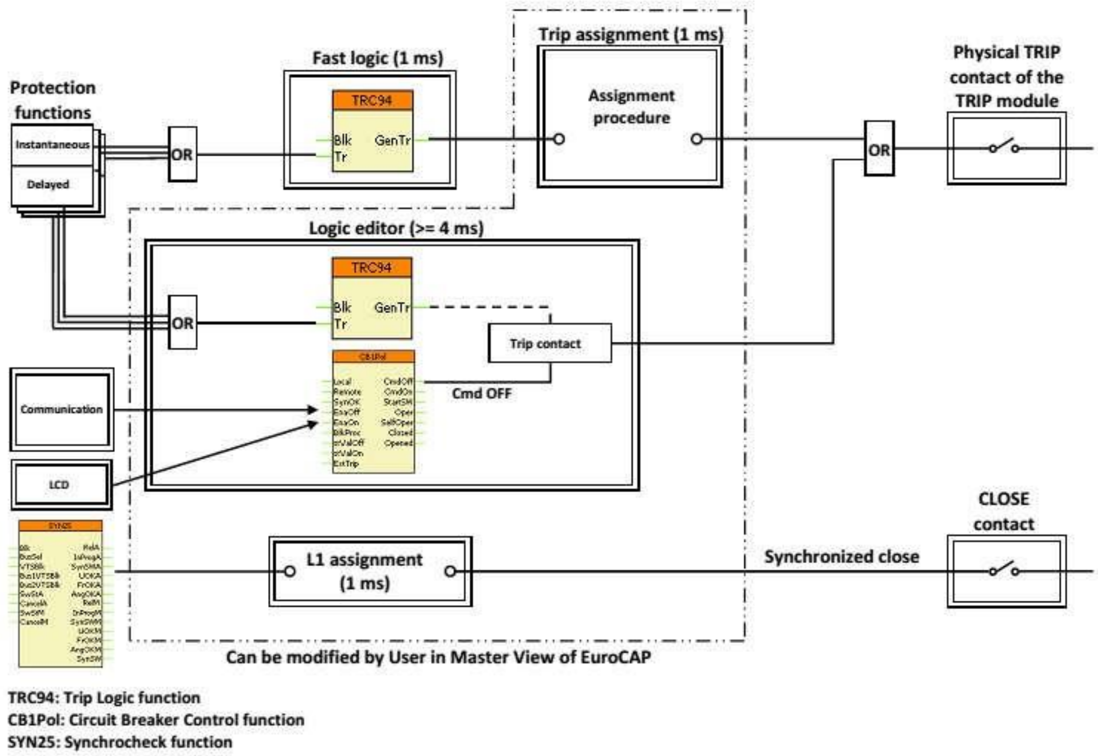


Figure 6 Principle of TRIP command processing

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

- The function blocks, 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. The detailed description of the TRIP command processing can be found on the website in the following document: “**Application of high – speed TRIP contacts”**.

The outputs of the “Simplified trip logic function” are connected directly to the contacts of the trip module (PSTP+/2101 module in position “A”).

Binary status signal	**Title**	Connected to the contact PSTP+/2101 module in position “A”
TRC94_GenTr_GrI_	General Trip	Trip

Table 72 The connected signals of the phase-selective trip logic function

To the inputs of the “phase-selective trip logic function” some signals are assigned during factory configuration, some signals however depend on the programming by the user**. The conditions are defined by the user applying the graphic equation editor.** The factory defined inputs and the user defined inputs are in “**OR**” relationship.

Input	Binary status signal	Explanation
3Ph Trip	IOC50_GenTr_GrI_ OR IOC50N_GenTr_GrI_	Trip command of the instantaneous overcurrent protection function OR Trip command of the residual instantaneous overcurrent protection function
Block	n.a.	Blocking the outputs of the phase-selective trip logic function

Table 73 The factory defined binary input signals of the trip logic function

The user defined signals are listed in Table *74*.

Input	Binary status signal	Explanation
3ph Trip	TRC94 GrO_	Request for three-phase trip command
Block	TRC94_Blk_GrO_	Blocking the outputs of the phase-selective trip logic function

Table 74 The user defined binary input signals of the trip logic function

6. LED assignment

On the front panel of the device there are “User LED”-s with the “Changeable LED description label” (See the document “***Quick start guide to the devices of the EuroProt+ product line***”). Some LED-s are factory assigned, some are free to be defined by the user.

LED	Explanation
General Trip	Trip command generated by the trip logic function
OC Trip	Trip command generated by the phase OC protection functions
Res OC Trip	Trip command generated by the residual OC protection functions
LED3104	Free LED, it can be configured by the costumer
LED3105	Free LED, it can be configured by the costumer
LED3106	Free LED, it can be configured by the costumer
LED3107	Free LED, it can be configured by the costumer
AR Blocked	Blocked state of the automatic reclosing function
Therm alarm	Thermal prot. alarm signal
LED3110	Free LED, it can be configured by the costumer
LED3111	Free LED, it can be configured by the costumer
LED3112	Free LED, it can be configured by the costumer
LED3111	Free LED, it can be configured by the costumer
LED3112	Free LED, it can be configured by the costumer
LED3113	Free LED, it can be configured by the costumer
LED3115	Free LED, it can be configured by the costumer
LED3116	Free LED, it can be configured by the costumer
AutoReclose	Close command of auto-reclosing function

Table 75 LED assignment

7. External Connections