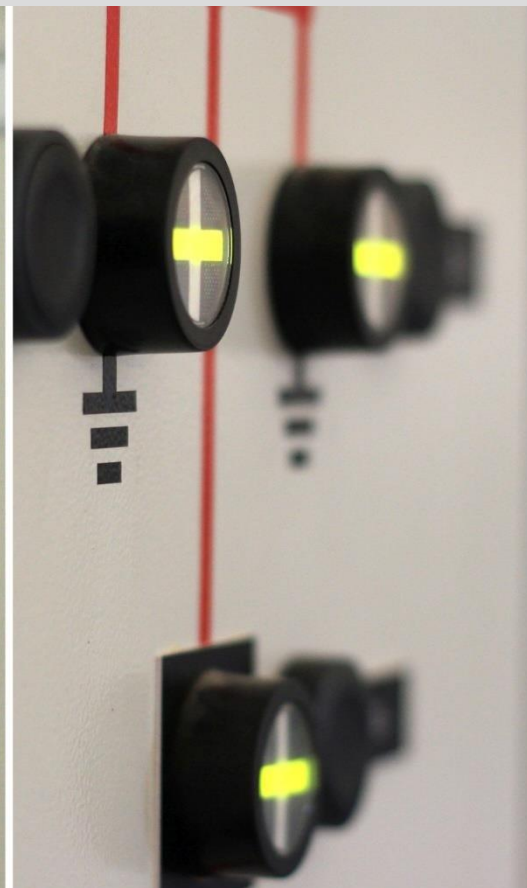
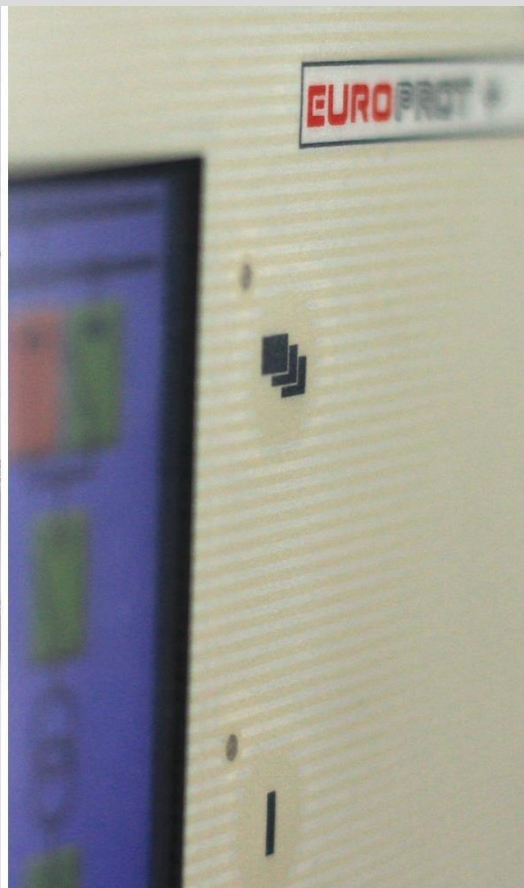
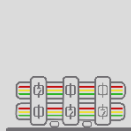
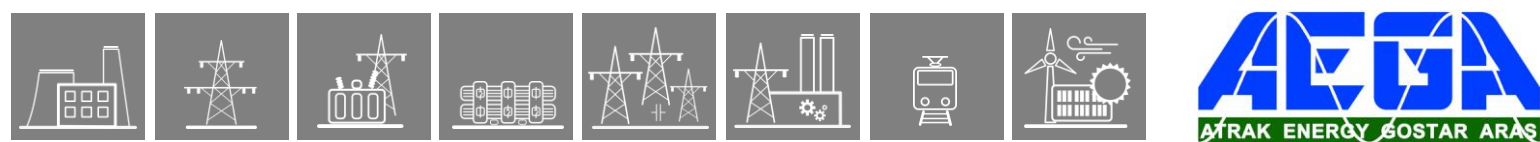




Manual

Transformer Protection & control
EuroProt+/DTRV

E1-TR



VERSION INFORMATION

NAME	DOCUMENT ID	VERSION	DATE
EuroProt+ DTRV type	PP-13-21886	1.0	2019-04-04
EuroProt+ Hardware description	PP-13-19958	2.1	2024-09-17
Negative sequence overcurrent protection	PP-13-20319	1.3	2022-08-09
Line thermal protection	VERSION 1.0	1.0	2011-10-25
Three-phase Instantaneous Overcurrent Protection	PP-13-22489	2.0	2022-03-04
Residual Instantaneous Overcurrent Protection	PP-13-22488	2.1	2022-11-28
Breaker failure protection	PP-13- 22253	2.1	2022-10-03
Three-phase overcurrent protection	PP-13-21408	2.4	2022-08-22
Residual overcurrent protection	PP-13-20320	1.3	2022-08-22
Current unbalance protection	PP-13-22163	2.0	2020-06-25
Restricted earth-fault protection	VERSION 1.0	1.0	2011-06-27
Differential protection	PP-13-21650	3.5	2023-07-17
Phase-Selective Trip Logic	PP-13-21531	2.0	2019-03-12
Circuit breaker wear monitoring	PP-13-21310	1.1	2016-09-06
Circuit Breaker control	PP-13-21877	2.0	2019-04-01
Disconnecter control	PP-13-20396	2.0	2019-04-01
Ethernet Links function	PP-13-21870	1.0	2019-02-19
Trip Circuit Supervision (TCS)	PP-13-21875	1.2	2019-08-09
Dead Line Detection Function	PP-13-22522	2.0	2022-03-04
Voltage transformer supervision and dead line detection	VERSION 1.1	1.1	2011-10-25
Current input function block setting guide	VERSION 1.1	1.0	2015-01-29
Voltage input function block setting guide	VERSION 1.0	1.0	2015-01-29
Line measurement Frequency measurement Voltage measurement Current measurement	PP-13-21168	2.3	2021-09-02
Disturbance recorder	PP-13-20368	3.2	2023-10-09
Average and maximum measurement function	PP-11-20109	1.0	2013-09-27
Metering function	PP-13-22238	2.1	2022-10-19
Trip value recorder function	PP-13-20947	2.1	2020-12-10
Voltage measurement selection function	VERSION 1.0	1.0	2013-02-06
Application guide to the differential protection and restricted earth-fault protection functions for autotransformers	-	1.1	2016-05-19
Differential protection function setting guide	-	1.0	2015-11-19
AIC current input function	PP-13-21392	1.0	2017-01-03
Remote I/O (RIO) server description	PP-13-22346	1.0	2021-06-02
Technical notes on EOB interoperability	-	1.0	2011-06-27
Maintenance guide	PP-13-226045	2.0	2022-11-18
RTD temperature input function	PP-13-21394	1.0	2017-01-03
Inrush current detection function	PP-13-22394	2.0	2021-08-10



EP+ Installation manual	PP-06-22516	1.0	2022-03-09
Application of high-speed TRIP contacts	PP-13-21592	1.1	2017-10-02

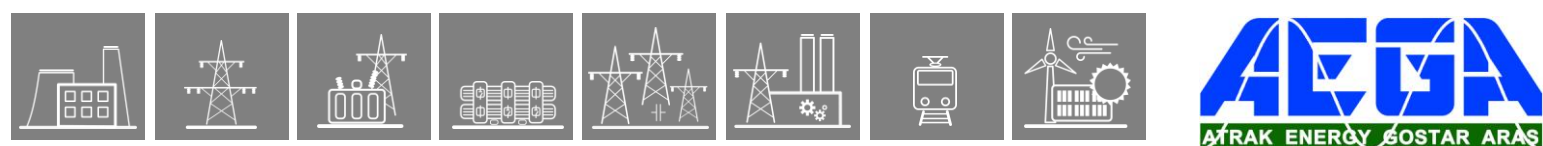
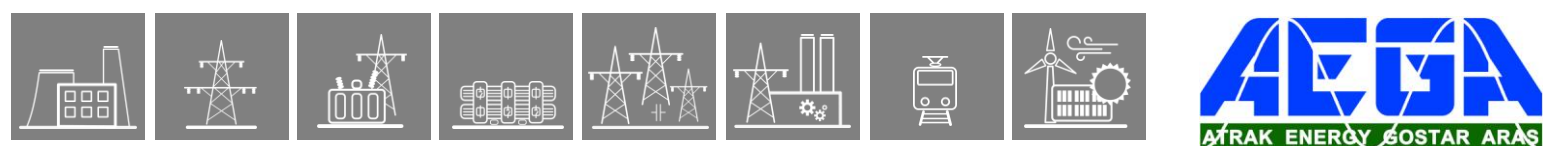


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1. Introduction

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

1.1. Application

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

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

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

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

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

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

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

1.1.1. General features

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



- Built-in self-monitoring to detect internal hardware or software errors
- Different time sources available: NTP server; Minute pulse; Legacy protocol master; IRIG-B000 or IRIG-B12X

1.2. Pre-defined configuration variants

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

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

Table 1-1 The members of the DTRV type

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

1.3. Hardware configuration

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

Hardware configuration	ANSI	E1-TR
Mounting		Op.
Panel instrument case		
Current inputs (4th channel can be sensitive)		8
Voltage inputs		-
Digital inputs		12
Digital outputs		8
Fast trip outputs		4
Temperature monitoring (RTDs) *	38 / 49T	Op.

Table 1-2 The basic hardware configuration of the E1-TR configuration

The basic module arrangement of the E1-TR configuration is shown below.

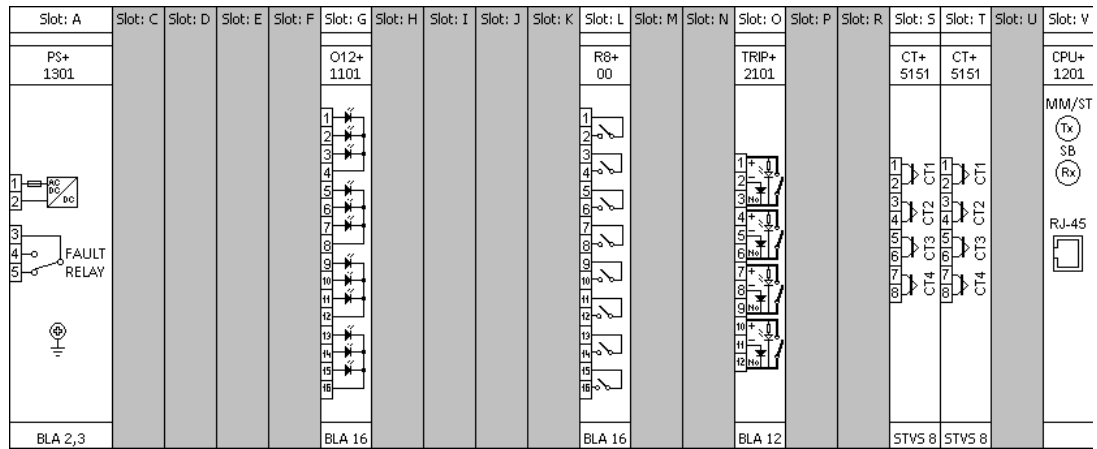


Figure 1 Basic module arrangement of the E1-TR configuration (84TE, rear view)

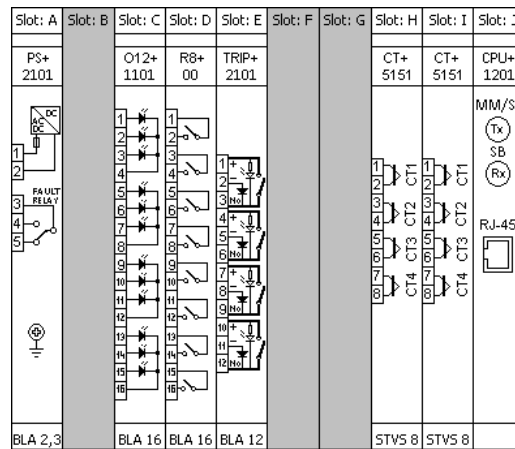


Figure 2 Basic module arrangement of the E1-TR configuration (42TE, rear view)

1.3.1. The applied hardware modules

The applied modules are listed in Table 1-3.

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

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

Table 1-3 The applied modules of the E1-TR configuration

1.3.2. Meeting the device

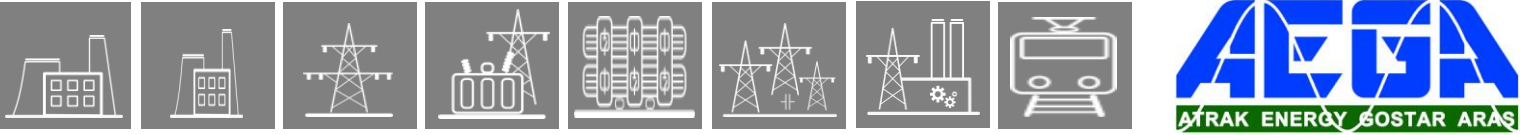
The basic information for working with the **EuroProt+** devices are described in the document “**Quick start guide to the devices of the EuroProt+ product line**”.



*Figure 4 The 84 inch rack of **EuroProt+** family*



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



1.4. Hardware description

1.4.1. 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.

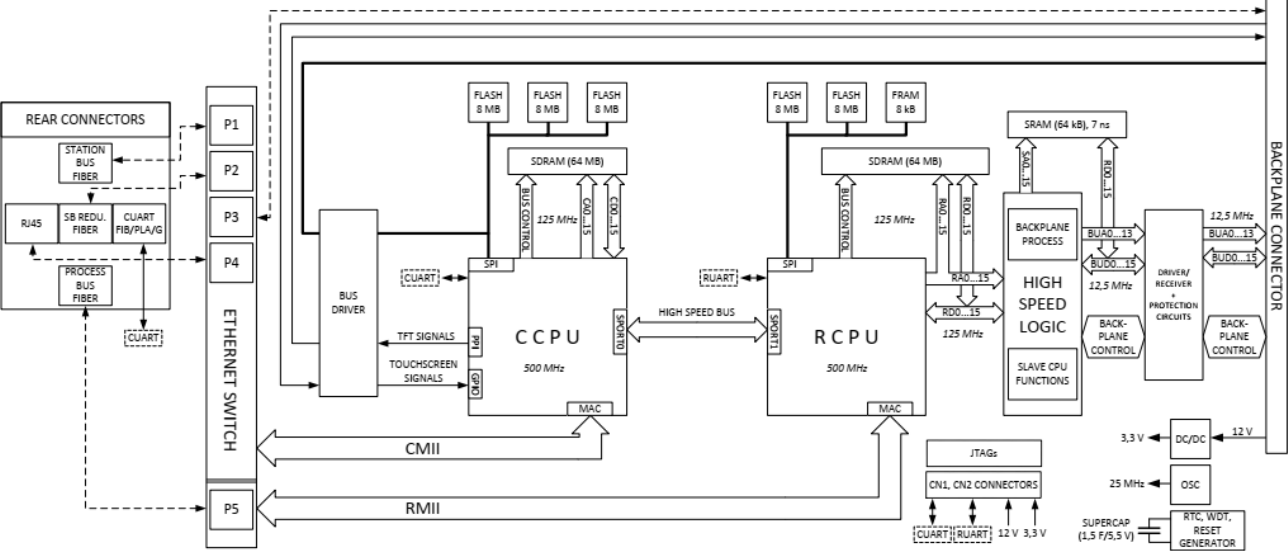


figure 1-1 CPU block diagram

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.



1.4.2. CPU and COM module

1.4.2.1. CPU+ module

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

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

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

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



1.4.2.1.1. 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.

1.4.2.1.2. 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)
- IEEE802.1w (RSTP, STP) standard supported by onboard Ethernet chipset (only on marked modules, see the table below).
- 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	PORT 1		PORT 2		PORT 3		SERVICE PORT ON FRONT PANEL EOB/ RJ45
	A	B	A	B	A	B	
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+/1211	+ MM		+ RJ45		+ MM		+
CPU+/1281*	+ MM		+ RJ45		+ SM LH		+
CPU+/1291*	+ 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 VERSION	PORT 1		PORT 2		PORT 3		SERVICE PORT ON FRONT PANEL EOB/ RJ45
	A	B	A	B	A	B	
CPU+/1511	+ MM		+ Galv. RS485/422**		+ MM		+
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+/6201*	+ MM/LC		+ RJ45		-		+
CPU+/6501T	+ MM/LC		+ Galv. RS485/422**		-		+
CPU+/6601*	+ MM/LC		+ MM/LC		-		+
CPU+/6691	+ MM/LC		+ MM/LC		+ SM SH		+
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.*

***Legacy port/protocol*

The CPU+/xxx4 cards are for special use.

CPU VERSION	PORT 1		PORT 2		PORT 3		SERVICE PORT ON FRONT PANEL EOB/ RJ45
	A	B	A	B	A	B	
CPU+/0202	-		+ RJ45		-		+
CPU+/1202	+ MM		+ RJ45		-		+
CPU+/1292	+ MM		+ RJ45		+ SM SH		+
CPU+/1302	+ MM		+ POF**		-		+
CPU+/1502	+ MM		+ Galv. RS485/422 ***		-		+
CPU+/2202	+ RJ45		+ RJ45		-		+
CPU+/2292	+ RJ45		+ RJ45		+ SM SH		+
CPU+/22F2S**	+ RJ45		+ RJ45		SFP		+
CPU+/6002S**	+ MM/LC		-		-		+
CPU+/6092S	+ MM/LC		-		+ SM SH		+
CPU+/9202	+ SM SH		+ RJ45		-		+
CPU+/A002*	+ MM/LC PRP/HSR		-		-		+
CPU+/A092	+ MM/LC PRP/HSR		-		+ SM SH		+
CPU+/A202	+ MM/LC PRP/HSR		+ RJ45		-		+
CPU+/A212	+ MM/LC PRP/HSR		+ RJ45		+ MM		+
CPU+/A292	+ MM/LC PRP/HSR		+ RJ45		+ SM SH		+
CPU+/F202	+ double SFP		+ RJ45		-		+
CPU+/F292	+ double SFP		+ RJ45		+ SM SH		+
CPU+/F2F2S**	+ double SFP		+ RJ45		SFP (2X)		+

*IEEE802.1w (**RSTP**, **STP**) standard supported by onboard Ethernet chipset

**Secure boot capability

***Legacy port/protocol

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 software 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

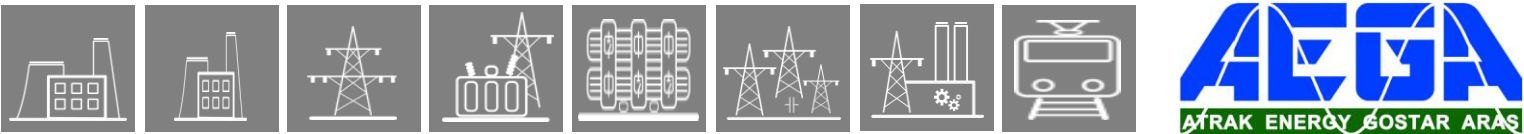
CPU+ 0007										
CPU+ 0091										
CPU+ 0201		RJ-45 								
CPU+ 0211		RJ-45 	MM/ST PB 							
CPU+ 0281		RJ-45 	SM LH FCPC PB 							
CPU+ 0291		RJ-45 	SM SH FCPC PB 							
CPU+ 0301		Tx Rx 								
CPU+ 0401		GS/ST ASIF 								
CPU+ 0501		Tx+ Tx- GND Rx- Rx+	 							
CPU+ 1001		MM/ST SB 								
CPU+ 1004		MM/ST SB 								
CPU+ 1011	MM/ST SB 									
CPU+ 1091	MM/ST SB 									
CPU+ 1101	MM/ST SBVW 	MM/ST SBR 								
CPU+ 1111	MM/ST SBVW 	MM/ST SBR 								
CPU+ 1181	MM/ST SBVW 	MM/ST SBR 	SM LH FCPC PB 							
CPU+ 1191	MM/ST SBVW 	MM/ST SBR 	SM SH FCPC PB 							
CPU+ 1201	MM/ST SB 	RJ-45 								
CPU+ 1211	MM/ST SB 	RJ-45 								
CPU+ 1281	MM/ST SB 	RJ-45 	SM LH FCPC PB 							
CPU+ 1291	MM/ST SB 	RJ-45 	SM SH FCPC PB 							
CPU+ 1301	MM/ST SB 	Pof Tx Rx 								

CPU+ 1311	CPU+ 1331	CPU+ 1381	CPU+ 1391	CPU+ 1401	CPU+ 1411	CPU+ 1481	CPU+ 1491	CPU+ 1501	CPU+ 1511	CPU+ 1581
MM/ST Tx SB Rx POF Tx Rx MM/ST Tx PB Rx	MM/ST Tx SB Rx POF1 Tx Rx POF2 Tx Rx MM/ST Tx PB Rx	MM/ST Tx SB Rx POF Tx Rx SM LH FCPC Tx PB Rx	MM/ST Tx SB Rx POF Tx Rx SM SH FCPC Tx PB Rx	MM/ST Tx SB Rx GS/ST Tx ASIF Rx MM/ST Tx PB Rx	MM/ST Tx SB Rx GS/ST Tx ASIF Rx MM/ST Tx PB Rx	MM/ST Tx SB Rx GS/ST Tx ASIF Rx SM LH FCPC Tx PB Rx	MM/ST Tx SB Rx GS/ST Tx ASIF Rx SM SH FCPC Tx PB Rx	MM/ST Tx SB Rx Tx+ 1 Tx- 2 GND 3 Rx- 4 Rx+ 5 MM/ST Tx PB Rx	MM/ST Tx SB Rx Tx+ 1 Tx- 2 GND 3 Rx- 4 Rx+ 5 MM/ST Tx PB Rx	MM/ST Tx SB Rx Tx+ 1 Tx- 2 GND 3 Rx- 4 Rx+ 5 SM LH FCPC Tx PB Rx
CPU+ 1611	CPU+ 1681	CPU+ 6001	CPU+ 6004	CPU+ 6093	CPU+ 6094	CPU+ 6201	CPU+ 6501T	CPU+ 6601	CPU+ 6691	CPU+ 9201
MM/ST Tx SB Rx - 1 - 2 GND 3 Sy- 4 Sy+ 5 MM/ST Tx PB Rx	MM/ST Tx SB Rx - 1 - 2 GND 3 Sy- 4 Sy+ 5 SM LH FCPC Tx PB Rx	MM/LC Rx Tx LAN - 1 - 2 GND 3 Sy- 4 Sy+ 5 MM/ST Tx PB Rx	MM/LC Rx Tx LAN - 1 - 2 GND 3 Sy- 4 Sy+ 5 SM SH FCPC Tx PB Rx	MM/LC Rx Tx LAN - 1 - 2 GND 3 Sy- 4 Sy+ 5 SM SH FCPC Tx PB Rx	MM/LC Rx Tx LAN - 1 - 2 GND 3 Sy- 4 Sy+ 5 SM SH FCPC Tx PB Rx	MM/LC Rx Tx LAN RJ-45 - 1 - 2 GND 3 Sy- 4 Sy+ 5 SM SH FCPC Tx PB Rx	MM/LC Rx Tx LAN Tx+ 1 Tx- 2 GND 3 Rx- 4 Rx+ 5 SM SH FCPC Tx PB Rx	MM/LC Rx Tx LAN MM/LC Rx Tx LAN SM SH FCPC Tx PB Rx	MM/LC Rx Tx LAN MM/LC Rx Tx LAN SM SH FCPC Tx PB Rx	SM SH FCPC Tx SB Rx RJ-45 SM SH FCPC Tx PB Rx
CPU+ 9291	CPU+ 9501	CPU+ 9901	CPU+ A001	CPU+ A004	CPU+ A011	CPU+ A081	CPU+ A091	CPU+ A094		
SM SH FCPC Tx SB Rx RJ-45 SM SH FCPC Tx PB Rx	SM SH FCPC Tx SB Rx Tx+ 1 Tx- 2 GND 3 Rx- 4 Rx+ 5 SM SH FCPC Tx PB Rx	SM SH FCPC Tx SB Rx SM SH FCPC Tx PB Rx	PRP/HSR MM/LC Rx Tx LAN A LAN B Rx Tx LAN A LAN B A B I LINK/ACT SM SH FCPC Tx PB Rx	PRP/HSR MM/LC Rx Tx LAN A LAN B Rx Tx LAN A LAN B A B I LINK/ACT SM SH FCPC Tx PB Rx	PRP/HSR MM/LC Rx Tx LAN A LAN B Rx Tx LAN A LAN B A B I LINK/ACT MM/ST Tx PB Rx	PRP/HSR MM/LC Rx Tx LAN A LAN B Rx Tx LAN A LAN B A B I LINK/ACT SM LH FCPC Tx PB Rx	PRP/HSR MM/LC Rx Tx LAN A LAN B Rx Tx LAN A LAN B A B I LINK/ACT SM SH FCPC Tx PB Rx	PRP/HSR MM/LC Rx Tx LAN A LAN B Rx Tx LAN A LAN B A B I LINK/ACT SM SH FCPC Tx PB Rx		



Interface types:

- 100Base-FX Ethernet:
 - MM/ST 1300 nm, 50/62.5/125 μ m connector, (up to 2 km) fiber
 - SM/FC 1550 nm, 9/125 μ m connector, (LH: long haul, up to 120 km)
 - SM/FC 1550 nm, 9/125 μ m connector, (SH: short haul, up to 50 km)
 - MM/LC 1300 nm, 50/62.5/125 μ m connector, (up to 2 km) fiber
 - SFP
 - MM/LC 1300nm
 - RAD E1 (G703, 2 Mbit/s)
 - SM/LC 1550nm, -12dBm to -6dBm, short haul use
 - SM/LC 1550nm, -5dBm to 0dBm, long haul use
 - RJ45
- 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)



1.4.2.2. 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

1.4.2.2.1. 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.*

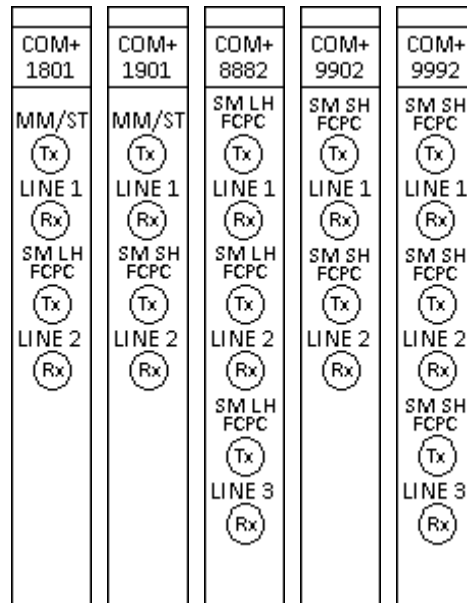


Figure 2-2 COM modules for binary signal transmission

1.4.2.2.2. 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.

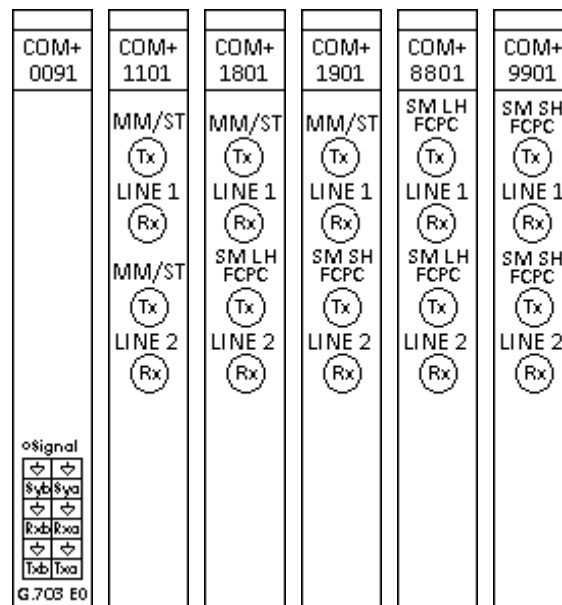


Figure 2-3 COM modules for line differential applications

1.4.2.2.3. 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 μ m 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 μ m connector, 100Base-FX Ethernet	3	4 HP	Busbar protection for 3x2 bay units (dual) up to 2 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.*

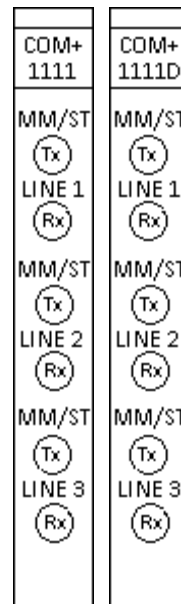


Figure 2-4 COM modules for busbar differential protections

1.4.2.2.4. 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

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.*

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

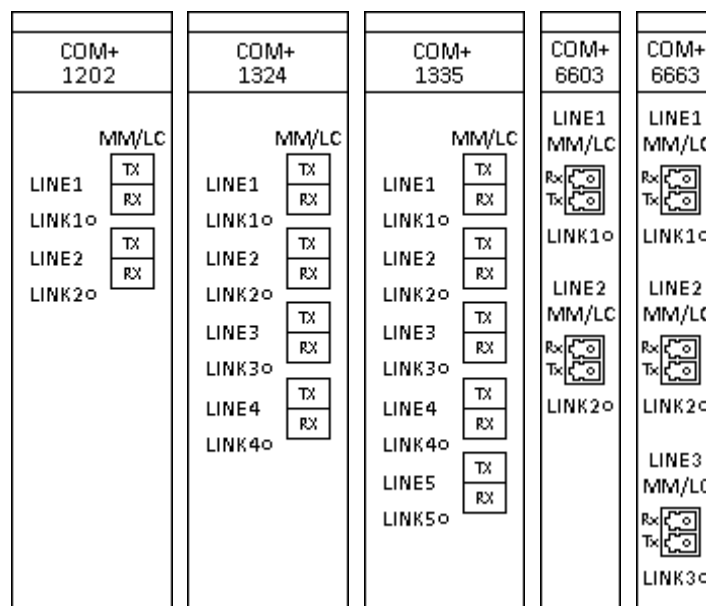


Figure 2-5 COM modules for RIO servers



1.4.2.3. Communication interface characteristics

1.4.2.3.1. Ethernet multi-mode transmitter and receiver

1.4.2.3.1.1. 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 $\text{BER} = 2.5 \times 10^{-10}$

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

1.4.2.3.1.2. MM/LC connector

Up to approximately 2

km. **Transmitter**

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

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

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

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

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



1.4.2.3.2. Ethernet single mode transmitter and receiver

1.4.2.3.2.1. 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 223 – 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



1.4.2.3.2.2. Short haul single mode transceiver

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

Transmitter

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

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

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

1.4.2.3.3. Small Form-factor Pluggable connector (SFP)

1.4.2.3.3.1. MM/LC connector Transmitter

Transmitter

PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNIT
OPTICAL OUTPUT POWER 62.5/125 μm , NA = 0.275 FIBER	P_O	-20.0	-17.0	-14.0	dBm avg.
OPTICAL OUTPUT POWER 50/125 μm , NA = 0.20 FIBER	P_O	-23.5	-20.0	-14.0	dBm avg.
OPTICAL EXTINCTION RATIO	ER	10	-	-	dB
CENTER WAVELENGTH	λ_C	1270	1308	1380	nm

Receiver

PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNIT
OPTICAL INPUT POWER	P_{IN}	-31.0	-	-14.0	dBm
OPERATING WAVELENGTH	λ_R	1270	-	1380	nm
SIGNAL DETECT - ASSERTED	P_A	-45	-	-	dBm avg.
SIGNAL DETECT – DE-ASSERTED	P_D	-	-	-32.0	dBm avg.
SIGNAL DETECT - HYSTERESIS	$P_A - P_D$	0.5	1.8	-	dB



1.4.2.3.3.2. RAD E1 (G703, 2 Mbit/s)

PARAMETER	VALUE
FRAME FORMAT	E1 G.732N CRC
COMPLIANCE	G.704, G.775, G.823
DATA RATE	2.048 Mbps
LINE CODE	HDB3
FRAMING	Framed, Unframed (HDLC, cHDLC)
LINE IMPEDANCE	120Ω, balanced
TRANSMIT CLOCK	Receive clock
CONNECTOR	RJ-45
CABLE LENGTH (MAX)	Up to 2500 m (8202 ft) for the AWG 22 cable
E1 RJ45 CONNECTOR PINOUT	The E1/T1 interface terminates in an 8-pin RJ-45 connector, wired as shown in the following table.

E1/T1 Connector Pinout

PIN	FUNCTION
1	Rx Ring
2	Rx Tip
3, 6, 7, 8	-
4	Tx Ring
5	Tx Tip
S=CONN. BODY	FGND/GND



1.4.2.3.3.3. Long haul, single mode transceiver - SM/LC

Up to approximately 104 km, with max. 29 dB link attenuation.

Transmitter

PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNIT
OPTICAL OUTPUT POWER 9/125 μm , NA = 0.275 FIBER	P_O	-5	-	0	dBm avg.
OPTICAL EXTINCTION RATIO	ER	10	-	-	dB
CENTER WAVELENGTH	λ_C	1530	1550	1570	nm

Receiver

PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNIT
OPTICAL INPUT SENSITIVITY 9/125 μm , NA = 0.275 FIBER	P_{IN}	-	-38	-34	dBm avg.
SATURATION	P_{SAT}	-3	0	-	dBm
CENTER WAVELENGTH	λ	1100	-	1600	nm
SIGNAL DETECT - ASSERTED	P_A	-	-	-34	dBm avg.
SIGNAL DETECT - DEASSERTED	P_D	-48	-	-	dBm avg.
HYSTERESIS	P_{HYS}	-	2	-	dB



1.4.2.3.3.4. Short haul, single mode transceiver – SM/LC

Up to approximately 50 km, with max. 28 dB link attenuation.

Transmitter

PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNIT
OPTICAL OUTPUT POWER 9/125 μm , NA = 0.275 FIBER	P_O	-12	-	-6	dBm avg.
OPTICAL EXTINCTION RATIO	ER	10	-	-	dB
CENTER WAVELENGTH	λ_C	1530	1550	1570	nm

Receiver

PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNIT
OPTICAL INPUT SENSITIVITY 9/125 μm , NA = 0.275 FIBER	P_{IN}	-	-38	-34	dBm avg.
SATURATION	P_{SAT}	-3	-	-	dBm
CENTER WAVELENGTH	λ_C	1100	-	1600	nm
SIGNAL DETECT - ASSERTED	P_A	-	-	-34	dBm avg.
SIGNAL DETECT - DEASSERTED	P_D	-48	-	-	dBm avg.
HYSTERESIS	P_{HYS}	-	2	-	dB

1.4.2.3.3.5. GE-FB-P2RT - RJ45 Small Form-factor Pluggable connector

+3.3V Volt Electrical Power interface

PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNIT
SUPPLY CURRENT	I_s	-	320	375	mA
INPUT VOLTAGE	V_{CC}	3.13	3.3	3.47	V
MAXIMUM VOLTAGE	V_{max}	-	-	3.6	V

Low-speed signals, electronic characteristics

PARAMETER	SYMBOL	MIN.	MAX.	UNIT
SFP OUTPUT LOW (MEASURED AT HOST SIDE OF THE CONNECTOR)	VOL	0	0.5	V
SFP OUTPUT HIGH (MEASURED AT HOST SIDE OF THE CONNECTOR)	VOH	host_ V_{CC} - 0.5	Host_ V_{CC} + 0.3	V
SFP INPUT LOW (MEASURED AT SFP SIDE OF THE CONNECTOR)	VIL	0	0.8	V
SFP INPUT HIGH (MEASURED AT SFP SIDE OF THE CONNECTOR)	VIH	2	$V_{CC} + 0.3$	V

High-speed electrical interface, transmission line-SFP

PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNIT
LINE FREQUENCY	f_L	-	125	-	MHz
TX OUTPUT IMPEDANCE	$Z_{out, TX}$	-	100	-	Ohm
RX INPUT IMPEDANCE	$Z_{in, RX}$	-	100	-	Ohm

High-speed electrical interface, host-SFP

PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNIT
SINGLE ENDED DATA INPUT SWING	V_{insing}	250	-	1200	mV
SINGLE ENDED DATA OUTPUT SWING	$V_{outsing}$	350	-	800	mV
RISE/FALL TIME (20% - 80%)	T_r, T_f	-	175	-	psec
TX INPUT IMPEDANCE	Z_{in}	-	50	-	Ohm
RX OUTPUT IMPEDANCE	Z_{out}	-	50	-	Ohm

1.4.2.3.3.6. FLD-S155-T - RJ45 Small Form-factor Pluggable connector

+3.3V Volt Electrical Power Interface

PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNIT
SUPPLY CURRENT	I_s	-	320	375	mA
INPUT VOLTAGE	V_{CC}	3.13	3.3	3.47	V
MAXIMUM VOLTAGE	V_{max}	-	-	4	V
SURGE CURRENT	I_{surge}	-	-	30	mA

Low-Speed Signals

PARAMETER	SYMBOL	MIN.	MAX.	UNIT
SFP OUTPUT LOW (MEASURED AT HOST SIDE OF THE CONNECTOR)	VOL	0	0.5	V
SFP OUTPUT HIGH (MEASURED AT HOST SIDE OF THE CONNECTOR)	VOH	host_ V_{CC} - 0.5	Host_ V_{CC} + 0.3	V
SFP INPUT LOW (MEASURED AT SFP SIDE OF THE CONNECTOR)	VIL	0	0.8	V
SFP INPUT HIGH (MEASURED AT SFP SIDE OF THE CONNECTOR)	VIH	2	$V_{CC} + 0.3$	V

High-Speed Electrical Interface

PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNIT
LINE FREQUENCY	fL	-	125	-	MHz
TX OUTPUT IMPEDANCE	$Z_{out, TX}$	-	100	--	Ohm
RX INPUT IMPEDANCE	$Z_{in, RX}$	-	100	-	Ohm

PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNIT
SINGLE ENDED DATA INPUT SWING	V_{insing}	250	-	1200	mV
SINGLE ENDED DATA OUTPUT SWING	$V_{outsing}$	350	-	800	mV
RISE/FALL TIME	T_r, T_f	-	175	-	psec
TX INPUT IMPEDANCE	Z_{in}	-	50	-	Ohm
RX OUTPUT IMPEDANCE	Z_{out}	-	50	-	Ohm

1.4.2.3.4. ASIF-O transmitter and receiver

1.4.2.3.4.1. 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.

1.4.2.3.4.2. ASIF-O GLASS

Transmitter (Output measured out of 1 meter of cable)

PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNIT	JUMPER SETTINGS
TRANSMITTER OUTPUT OPTICAL POWER 50/125 μ m 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
TRANSMITTER OUTPUT OPTICAL POWER 62.5/125 μ m FIBER CABLE NA = 0.275	P_o	-15.6	-12.6	-10.6	dBm peak	JP1 2-3
		-22.9	-19.9	-17.9		JP1 1-2

Receiver

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

1.4.2.3.5. ASIF-G transmitter and receiver

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

Transmitter

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

Receiver

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

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

The EuroProt+ device also supports line differential communication via telecom networks using G.703.1 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	One symmetric pair
TEST LOAD IMPEDANCE	120 Ω resistive
NOMINAL PEAK VOLTAGE OF A “MARK” (PULSE)	1.0 V
PEAK VOLTAGE OF A “SPACE” (NO PULSE)	0 V ± 0.10 V
NOMINAL PULSE WIDTH	3.9 ms
RATIO OF THE AMPLITUDES OF POSITIVE AND NEGATIVE PULSES AT THE CENTRE OF THE PULSES INTERVAL	0.95 to 1.05
RATIO OF THE WIDTHS OF POSITIVE AND NEGATIVE PULSES 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

1.4.2.3.7. 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.

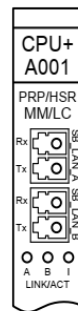


Figure 2-6 PRP/HSR connectors on a CPU+A001 module

1.4.2.3.7.1. 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.

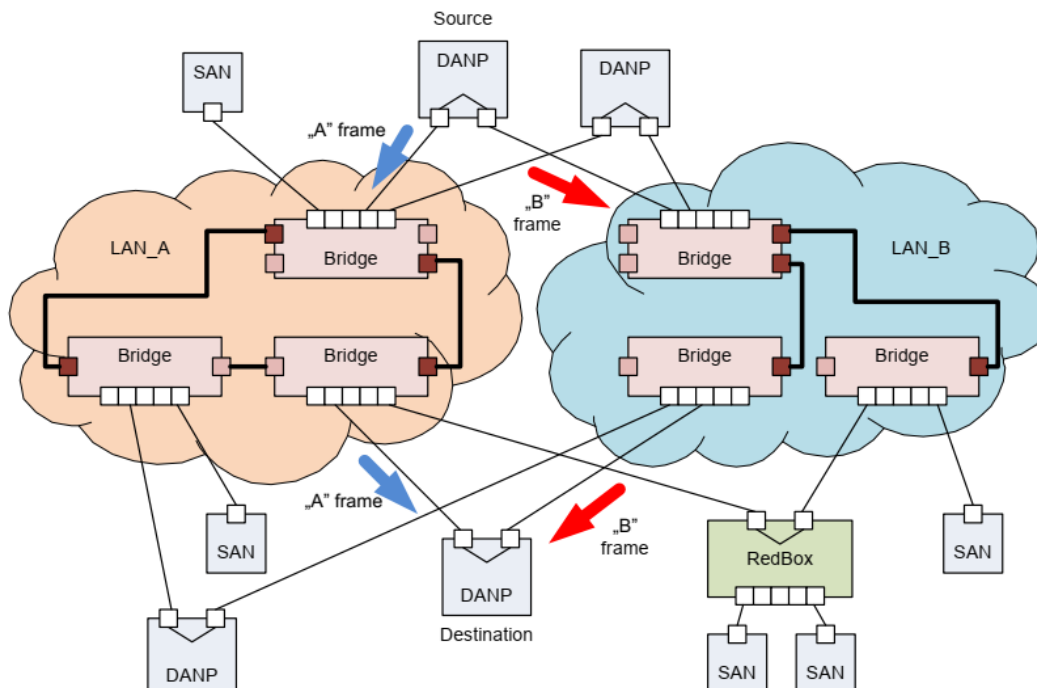


Figure 2-7 Example of a PRP redundant network

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.

1.4.2.3.7.2. 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 copies of a frame to both directions 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.

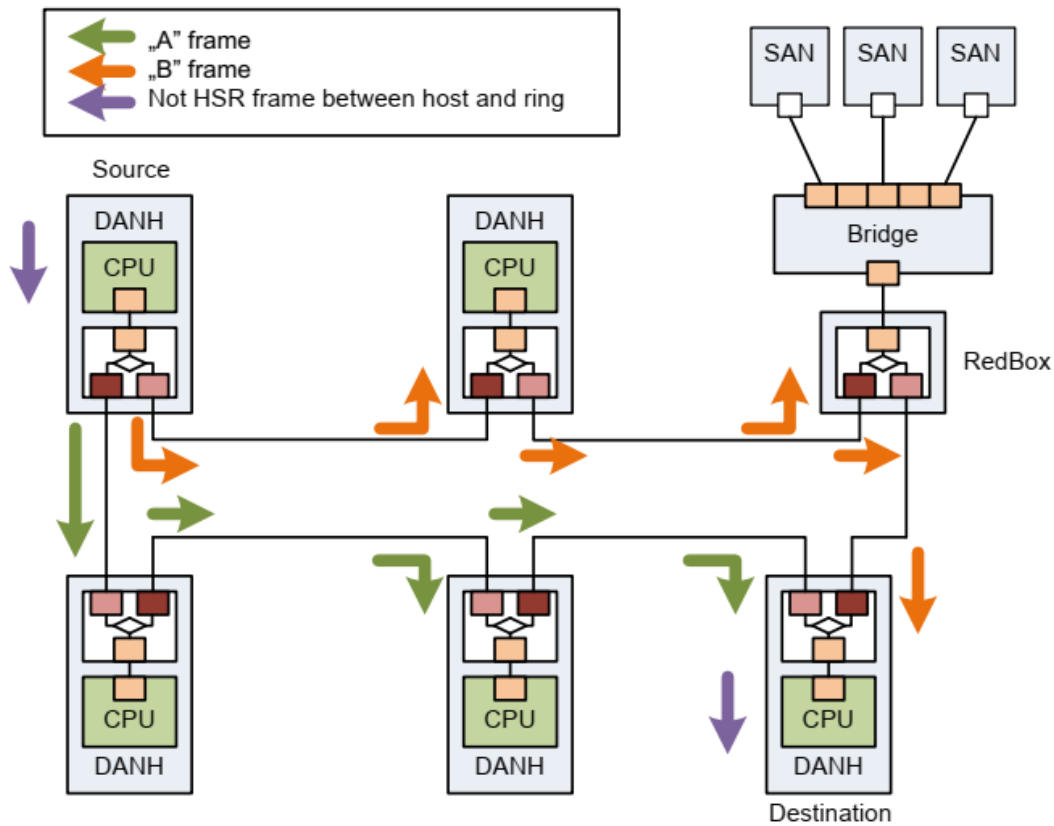


Figure 2-8 Example of an HSR redundant network

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.



1.4.3. 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 0.

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

1.4.4. Human-Machine Interface (HMI) module

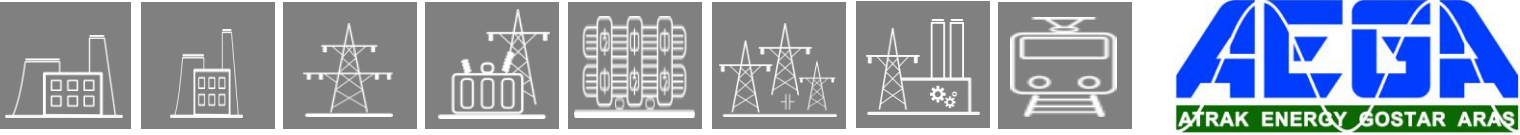
The EuroProt+ device HMI consists of the following two main parts:

- 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).

1.4.4.1. 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 0), 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	

1.4.4.2. 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.



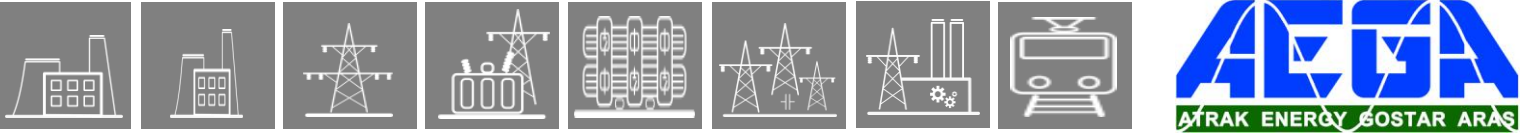
Figure 4-1 42 HP Remote HMI

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 0), 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	

1.4.4.3. S24 HMI

The S24 Smart Line devices have a different HMI family:

Module Type	Display	Service Port	Rack Size	Mounting	Illustration
HMI+/2604* HMI+/2404 HMI+/2304**	3,5" TFT	RJ-45	24 HP	Normal	
HMI+/2606* HMI+/2406 HMI+/2306**	3,5" TFT	RJ-45	24 HP	DIN-rail	
HMI+/2704* HMI+/2504	B&W LCD	RJ-45	24 HP	Normal	
HMI+/2706* HMI+/2506	B&W LCD	RJ-45	24 HP	DIN-rail	

*For newer, modular-type S24 devices.
 **New display hardware requires CDSP firmware version 1560-H5 or higher!

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

Module Type	Display	Service Port	Rack Size	Mounting	Illustration
HMI+/2401*	3,5" TFT	EOB	24 HP	Normal	

1.4.4.4. Parts of the HMI modules

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

FUNCTION	DESCRIPTION
16 PIECES USER LEDs	Three-color, 3 mm circular LEDs
COM LED	Yellow, 3 mm circular LED indicating EOB/RJ-45 (on the front panel) communication link and activity
CAPACITIVE TOUCH KEY LEDs	4 pcs yellow, 3 mm circular LEDs indicating touch key actions
DEVICE STATUS LED	1 piece three-color, 3 mm circular LED Green: normal device operation Yellow: device is in warning state Red: device is in error state
DEVICE KEYS (I, O, X, PAGE)	Capacitive touch keys
	Tactile push buttons
BUZZER	Audible touch key pressure feedback
CHANGEABLE LED DESCRIPTION LABEL	Describes user LED functionality
DISPLAY	320 × 240 pixel TFT color display with resistive touchscreen interface (3.5" or optional 5.7")
	128 × 64 LCD black & white display
OPTICAL INTERFACE FOR FACTORY USAGE	For debugging and software development purposes <i>Only for 42 HP and 84 HP devices.</i>
EOB CONNECTOR	Ethernet Over Board: communication interface accomplishes isolated, non-galvanic Ethernet connection with the help of a magnetically attached EOB device. The EOB device has an RJ-45 type connector supporting Ethernet connection to the user computer. This is a proprietary and patented solution from Protecta Ltd. 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.)

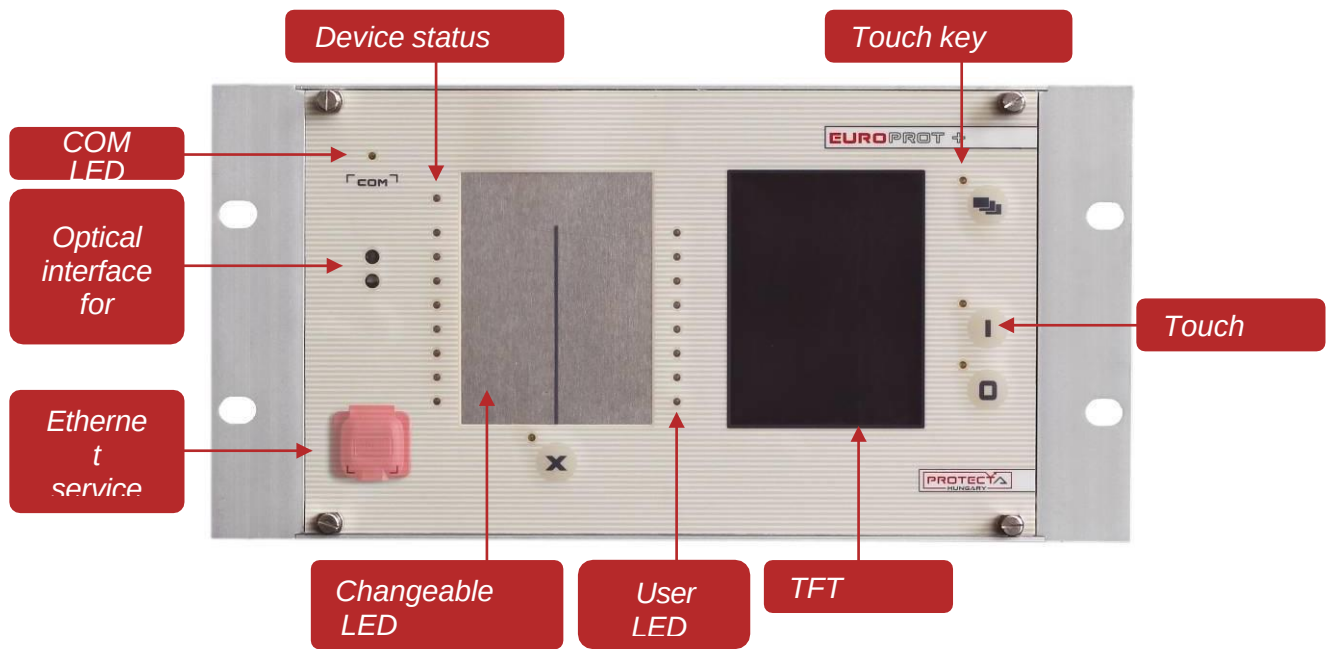


Figure 4–3 HMI signals and controls

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)



1.4.5. Current input module

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

Main features:

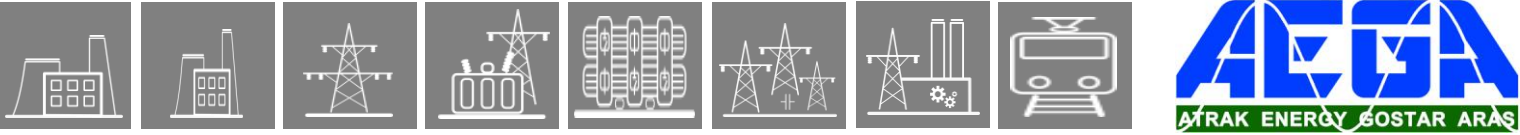
- Rated frequency: 50 Hz, 60 Hz
- *Electronic* iron-core flux compensation

Connector types:

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

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

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

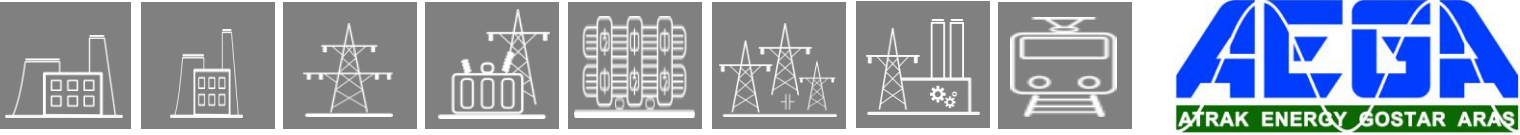


MODULE TYPE	CT+/0101		CT+/1111*		CT+/1155		CT+/1500	
CHANNEL NUMBER	1 – 4		1 – 4		1 – 4		1 – 3	
SELECTABLE RATED CURRENT, I_N [A]	0.04	0.2	1	5	1	5	1	5
MAX. MEASURED CURRENT ($\pm 10\%$)	$8 \times I_N$		$50 \times I_N$		$12.5 \times I_N$		$2 \times I_N$	
POWER CONSUMPTION AT RATED CURRENT [VA]	0.005	0.1	0.01	0.25	0.02	0.45	0.1	1.55
THERMAL WITHSTAND [A]								
CONTINUOUSLY	7		20		20		7	
10 s	50		175		120		50	
1 s	150		500		380		150	
10 ms	330		1200		850		330	
CONNECTOR TYPE	Default: STVS Options: T		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 cannot exceed $10 \times I_N$		General three-phase measurement	

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

MODULE TYPE	CT+/1515*		CT+/2500*		CT+/5101			
CHANNEL NUMBER	1 – 4		1 – 3		1 – 3			
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	<u>Default:</u> STVS <u>Options:</u> -		<u>Default:</u> STVS <u>Options:</u> -		<u>Default:</u> STVS <u>Options:</u> -			
RECOMMENDED APPLICATION	Special disturbance recorder application		Generator protections		Extremely sensitive earth-fault applications			

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



MODULE TYPE	CT+5115		CT+5116		CT+/5151		CT+/5152	
CHANNEL NUMBER	1 – 4		1 – 3		1 – 4		1 – 4	
SELECTABLE RATED CURRENT, I_N [A]	1	5	1	5	1	5	1	5
MAX. MEASURED CURRENT ($\pm 10\%$)	$50 \times I_N$		$50 \times I_N$		$50 I_N$		$50 I_N$	
POWER CONSUMPTION AT RATED CURRENT [VA]	0.01	0.25	0.01	0.25	0.01	0.25	0.01	0.25
THERMAL WITHSTAND [A]								
CONTINUOUSLY	20		20		20		20	
10 s	175		175		175		175	
1 s	500		500		500		500	
10 ms	1200		1200		1200		1200	
CONNECTOR TYPE	<u>Default:</u> STVS <u>Options:</u> R, T		<u>Default:</u> STVS <u>Options:</u> R		<u>Default:</u> STVS <u>Options:</u> R, T		<u>Default:</u> STVS <u>Options:</u> R	
RECOMMENDED APPLICATION	- General protection application* - 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	<u>Default:</u> STVS <u>Options:</u> R, T**					<u>Default:</u> STVS <u>Options:</u> R				
RECOMMENDED APPLICATION	General protection application, extremely sensitive transient earth-fault protections					General protection application, sensitive transient earth-fault protections				

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

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

Module type	CT+/5155*					CT+/5253**				
Channel number	1 – 3		4			1 – 3		4		
Selectable rated current, I _N [A]	1	5	0.25	0.05	0.05 sens	5	1	0.01	0.05	0.25
M _{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	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**

CT+ 0101	CT+ 1111	CT+ 1155	CT+ 1500	CT+ 1515	CT+ 2500	CT+ 5101	CT+ 5102	CT+ 5110	CT+ 5111	CT+ 5115
1 CT1 2 CT1 3 CT2 4 CT2 5 CT3 6 CT3 7 CT4 8 CT4	1 CT1 2 CT1 3 CT2 4 CT2 5 CT3 6 CT3 7 CT4 8 CT4	1 CT1 2 CT1 3 CT2 4 CT2 5 CT3 6 CT3 7 CT4 8 CT4	1 CT1 2 CT1 3 CT2 4 CT2 5 CT3 6 CT3 7 CT4 8 CT4	1 CT1 2 CT1 3 CT2 4 CT2 5 CT3 6 CT3 7 CT4 8 CT4	1 CT1 2 CT1 3 CT2 4 CT2 5 CT3 6 CT3 7 CT4 8 CT4	1 CT1 2 CT1 3 CT2 4 CT2 5 CT3 6 CT3 7 CT4 8 CT4	1 CT1 2 CT1 3 CT2 4 CT2 5 CT3 6 CT3 7 CT4 8 CT4	1 CT1 2 CT1 3 CT2 4 CT2 5 CT3 6 CT3 7 CT4 8 CT4	1 CT1 2 CT1 3 CT2 4 CT2 5 CT3 6 CT3 7 CT4 8 CT4	1 CT1 2 CT1 3 CT2 4 CT2 5 CT3 6 CT3 7 CT4 8 CT4

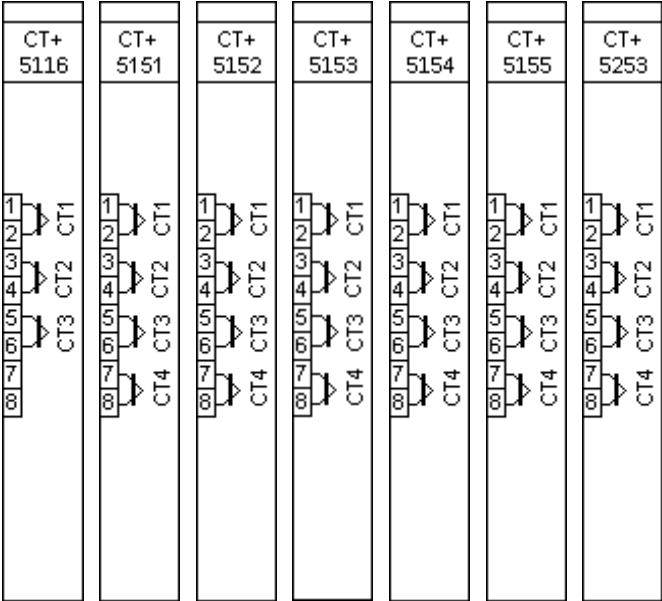


Figure 5-1 CT modules



1.4.6. Voltage input module

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

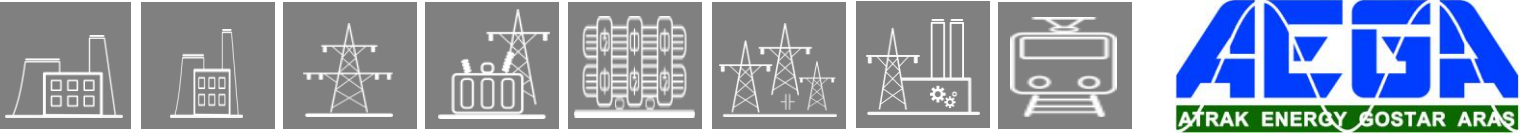
Connector types:

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

MODULE TYPE	VT+/2211	VT+/2212*	VT+/2215**
CHANNEL NUMBER	4	4	4
SELECTABLE VOLTAGE RANGE	<u>Type 100:</u> $\frac{100}{\sqrt{3}}$, 100 V <u>Type 200:</u> $\frac{200}{\sqrt{3}}$, 200 V	<u>Type 100:</u> $\frac{100}{\sqrt{3}}$, 100 V <u>Type 200:</u> $\frac{200}{\sqrt{3}}$, 200 V	<u>Type 100:</u> $\frac{100}{\sqrt{3}}$, 100 V <u>Type 200:</u> $\frac{200}{\sqrt{3}}$, 200 V
CONTINUOUS VOLTAGE WITHSTAND	200 V	200 V	200 V
SHORT TIME OVERLOAD (1 s)	275 V (10s)	275 V	275 V
VOLTAGE MEASURING RANGE ($\pm 10\%$)	$0.05 U_N - 1.3 U_N$	$0.05 U_N - 1.3 U_N$	$0.05 U_N - 1.3 U_N$
POWER CONSUMPTION OF VOLTAGE INPUT	1.22 VA at 200 V 0.4 VA at 100 V	0.61 VA at 200 V 0.2 VA at 100 V	<u>ch. 1-3:</u> 0.61 VA at 200 V 0.2 VA at 100 V <u>ch. 4:</u> 50 mVA at 100 V
CONNECTOR TYPE	<u>Default:</u> BLA <u>Options:</u> T, R	<u>Default:</u> BLA <u>Options:</u> -	<u>Default:</u> BLA <u>Options:</u> -
RECOMMENDED APPLICATION	General protection applications.	Special disturbance recorder application in wider frequency range	Special protection applications with voltage transformers that require low power consumption on the 4 th channel.

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

****Special module**



MODULE TYPE	VT+/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 ($\pm 10\%$)	$0.05 U_N - 1.3 U_N$	$0.05 U_N - 1.3 U_N$	$0.05 U_N - 1.3 U_N$
POWER CONSUMPTION OF VOLTAGE INPUT	1.22 VA at 200 V 0.4 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	<u>Default:</u> BLA <u>Options:</u> T, R	<u>Default:</u> BLA <u>Options:</u> -	<u>Default:</u> BLA <u>Options:</u> -
RECOMMENDED APPLICATION	General protection applications.	Special disturbance recorder application in wider frequency range	Special protection applications with voltage transformers that require low power consumption on the 4 th channel.

*Special module

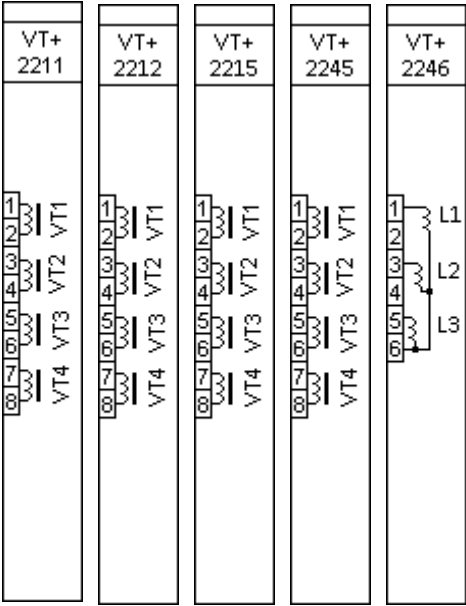


Figure 6-1 VT modules



1.4.7. 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:

- 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+/1101	O8+/2201	O8+/2401	O8+/4801
CHANNEL NUMBER	8	8	8	8
TIME SYNCHRONIZATION	configured by EuroCAP	configured by EuroCAP	configured by EuroCAP	configured by EuroCAP
RATED VOLTAGE	110 V*	220 V	24 V	48 V
WITHSTAND VOLTAGE	250 V	320 V	72 V	100 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

*Cards with a 110 V rated voltage can also be used with 125 V DC, but the clamp voltage values still refer to 110 V.

MODULE TYPE	O12+/1101	O12+/2201	O12+/2401	O12+/4801
CHANNEL NUMBER	12	12	12	12
TIME SYNCHRONIZATION	configured by EuroCAP	configured by EuroCAP	configured by EuroCAP	configured by EuroCAP
RATED VOLTAGE	110 V*	220 V	24 V	48 V
WITHSTAND VOLTAGE	250 V	320 V	72 V	72 V
CLAMP VOLTAGE	falling $0.64 U_N$ rising $0.8 U_N$	falling $0.64 U_N$ rising $0.8 U_N$	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: T	Default: BLA Options: T	Default: BLA Options: T

*Cards with a 110 V rated voltage can also be used with 125 V DC, but the clamp voltage values still refer to 110 V.



MODULE TYPE	O12+/2101*	O12+/2102	O12+/4201*	O15+/1101T
CHANNEL NUMBER	12	12	12	15
TIME SYNCHRONIZATION	configured by EuroCAP	configured by EuroCAP	configured by EuroCAP	configured by EuroCAP
RATED VOLTAGE	110 V DC / 220 V DC user selectable on channel basis by jumpers**	110 V DC / 220 V DC	24 V DC / 48 V DC user selectable on channel basis by jumpers	110 V**
WITHSTAND VOLTAGE	320 V	264 V	72 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	4 × 3 common	1 × 15 common
CONNECTOR TYPE	<u>Default:</u> BLA <u>Options:</u> T	BLT	<u>Default:</u> BLA <u>Options:</u> -	BLT

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

**Cards with a 110 V rated voltage can also be used with 125 V DC, but the clamp voltage values still refer to 110 V.

MODULE TYPE	O15+/2201T	O15+/2401T	O15+/4801T	O16+/1101*
CHANNEL NUMBER	15	15	15	16
TIME SYNCHRONIZATION	configured by EuroCAP	configured by EuroCAP	configured by EuroCAP	-
RATED VOLTAGE	220 V	24 V	48 V	110 V**
WITHSTAND VOLTAGE	250 V	100 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	1 × 15 common	1 × 15 common	1 × 15 common	2 × 8 common
CONNECTOR TYPE	BLT	BLT	BLT	<u>Default:</u> BL 3.5 <u>Options:</u> -

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

**Cards with a 110 V rated voltage can also be used with 125 V DC, but the clamp voltage values still refer to 110 V.

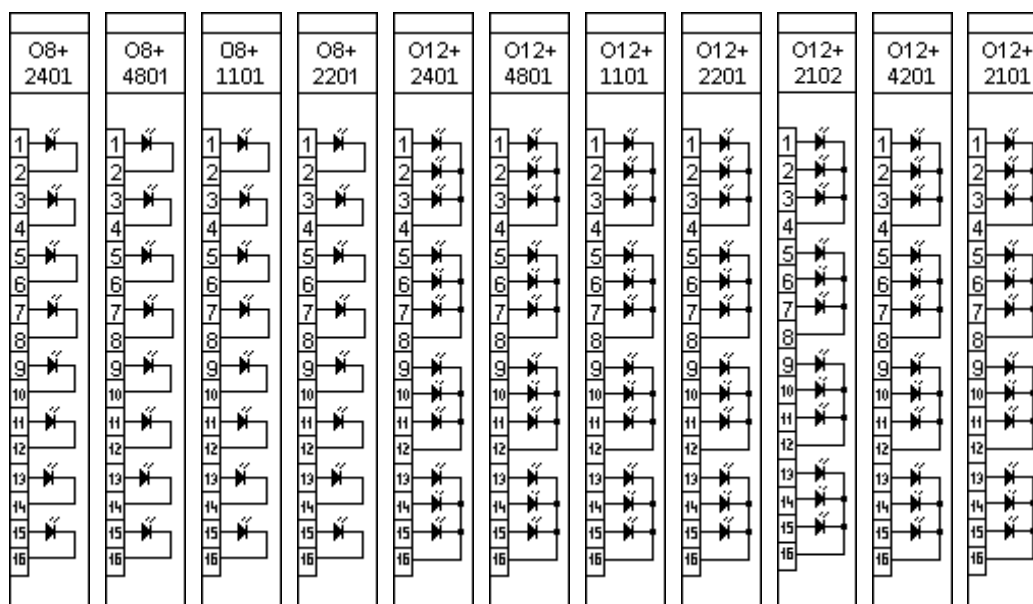
MODULE TYPE	O16+/2201*	O16+/2401*	O16+/4801*
CHANNEL NUMBER	16	16	16
TIME SYNCHRONIZATION	-	-	-
RATED VOLTAGE	220 V	24 V	48 V
WITHSTAND VOLTAGE	320 V	72 V	100 V
CLAMP VOLTAGE	falling 0.64 U _N rising 0.8 U _N	falling 0.64 U _N rising 0.8 U _N	falling 0.64 U _N rising 0.8 U _N
COMMON GROUPS	2 × 8 common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

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

Though the states of the inputs are refreshed with 2 kHz frequency, there is a 1 ms built-in analog filtering in them. Additional digital filtering is set in the EuroCAP tool (default: 4 ms).

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.



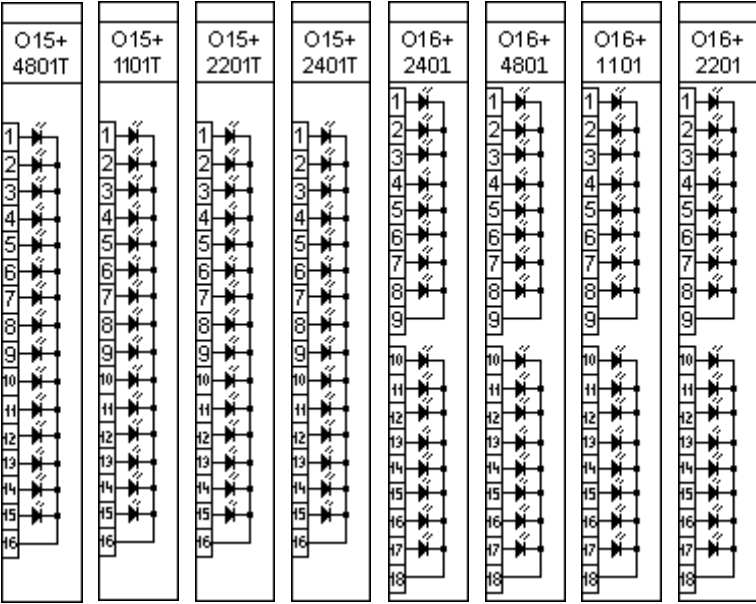


Figure 7-1 Binary input modules



1.4.8. 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	R6+/0012	R8+/00	R8+/01
RATED VOLTAGE	250 V AC/DC	390 V AC	250 V AC/DC	250 V AC/DC
CONTINUOUS CARRY	8 A	8 A	8 A	8 A
CONTACT VERSIONS	4 CO	CH5 and CH6 NO others CO	8 NO	CH1 NC others NO
GROUP ISOLATION	4 independent	6	8 independent	8 independent
CONNECTOR TYPE	<u>Default:</u> BLA <u>Options:</u> T	BLT	<u>Default:</u> BLA <u>Options:</u> T	<u>Default:</u> BLA <u>Options:</u> -

MODULE TYPE	R8+/80	R8+/0002	R8+/C0	R8+/FF
RATED VOLTAGE	250 V AC/DC	390 AC	250 V AC/DC	250 V AC/DC
CONTINUOUS CARRY	8 A	8 A	8 A	8 A
CONTACT VERSIONS	CH8 NC others NO	8 NO	CH7 and CH8 NC others NO	8 NC
GROUP ISOLATION	8 independent	8 independent	8 independent	8 independent
CONNECTOR TYPE	<u>Default:</u> BLA <u>Options:</u> T	BLT	<u>Default:</u> BLA <u>Options:</u> T	<u>Default:</u> BLA <u>Options:</u> -

MODULE TYPE	R12+/0000	R12+/4000	R12+/4400
RATED VOLTAGE	250 V AC/DC	250 V AC/DC	250 V AC/DC
CONTINUOUS CARRY	8 A	8 A	8 A
CONTACT VERSIONS	12 NO	CH12 NC others NO	CH9 and CH12 NC others NO
GROUP ISOLATION	4 × 3 common	4 × 3 common	4 × 3 common
CONNECTOR TYPE	<u>Default:</u> BLA <u>Options:</u> T	<u>Default:</u> BLA <u>Options:</u> T	<u>Default:</u> BLA <u>Options:</u> 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	<u>Default:</u> BL 3.5 <u>Options:</u> -	<u>Default:</u> BL 3.5 <u>Options:</u> -	<u>Default:</u> BL 3.5 <u>Options:</u> -

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	<u>Default:</u> BLA <u>Options:</u> T	<u>Default:</u> BLA <u>Options:</u> -	STVS

*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 × 10⁶ 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

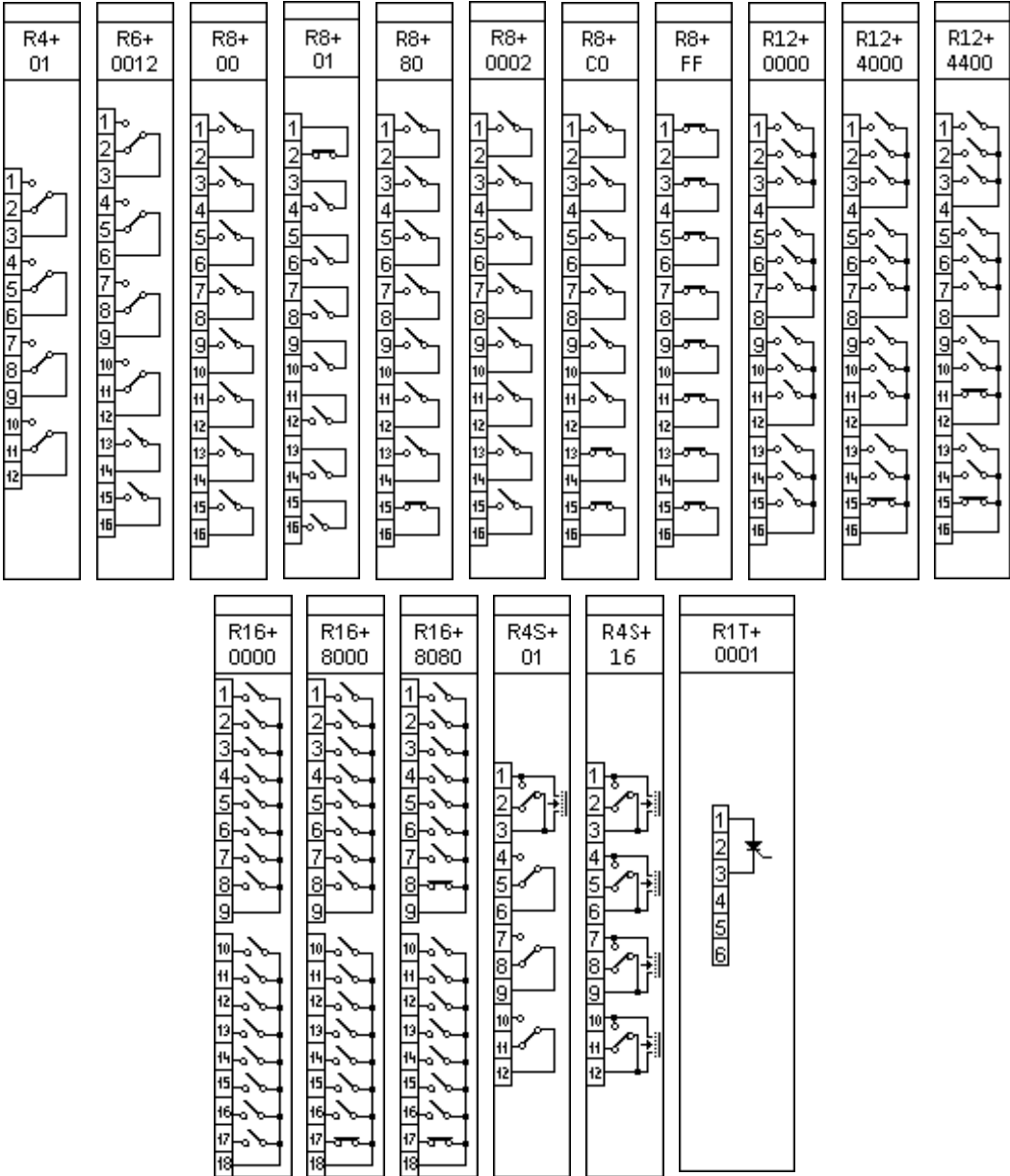


Figure 8-1 Signaling modules

1.4.9. Tripping module

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

Connector types:

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

MODULE TYPE	TRIP+/4201	TRIP+/1101*	TRIP+/2101	TRIP+/2102
CHANNEL NUMBER	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
WITHSTAND VOLTAGE	72 V DC	242 V DC	150 V DC	264 V DC
CONTINUOUS CARRY	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
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
CONNECTOR TYPE	<u>Default:</u> BLA <u>Options:</u> T	<u>Default:</u> BLA <u>Options:</u> -	<u>Default:</u> BLA <u>Options:</u> T	BLT

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

MODULE TYPE	TRIP+/21F1*	TRIP+/2201	TRIP+/2201/C
CHANNEL NUMBER	4	4	4
RATED VOLTAGE	110 V DC	220 V DC	220 V
WITHSTAND VOLTAGE	150 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	<u>Default:</u> BLA <u>Options:</u> T	<u>Default:</u> BLA <u>Options:</u> T	<u>Default:</u> BLA <u>Options:</u> -

**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

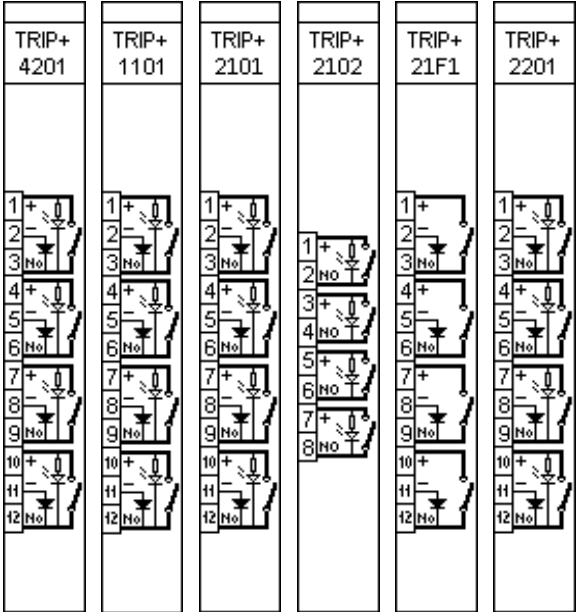


Figure 9-1 Tripping modules

1.4.9.1. 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 damage the internal circuits. Improper wiring might cause improper operation!**

1.4.9.1.1. 3-wire TRIP+ wiring methods

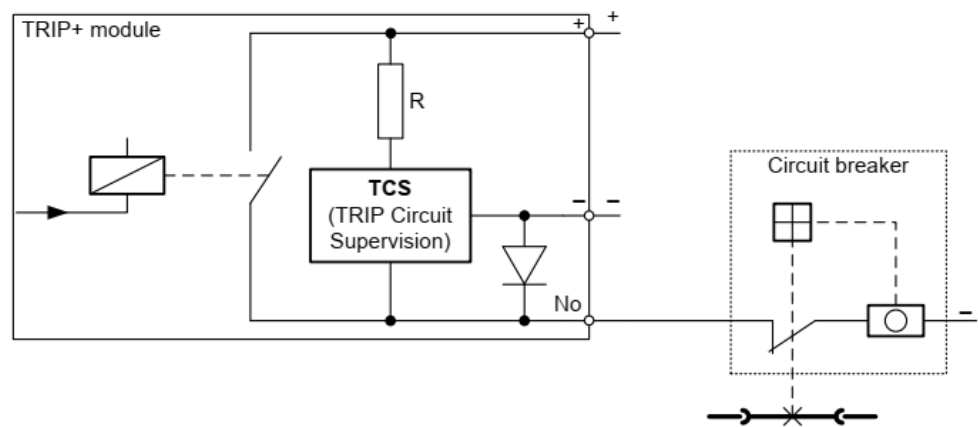


Figure 9-2 3-wire TRIP+ wiring

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

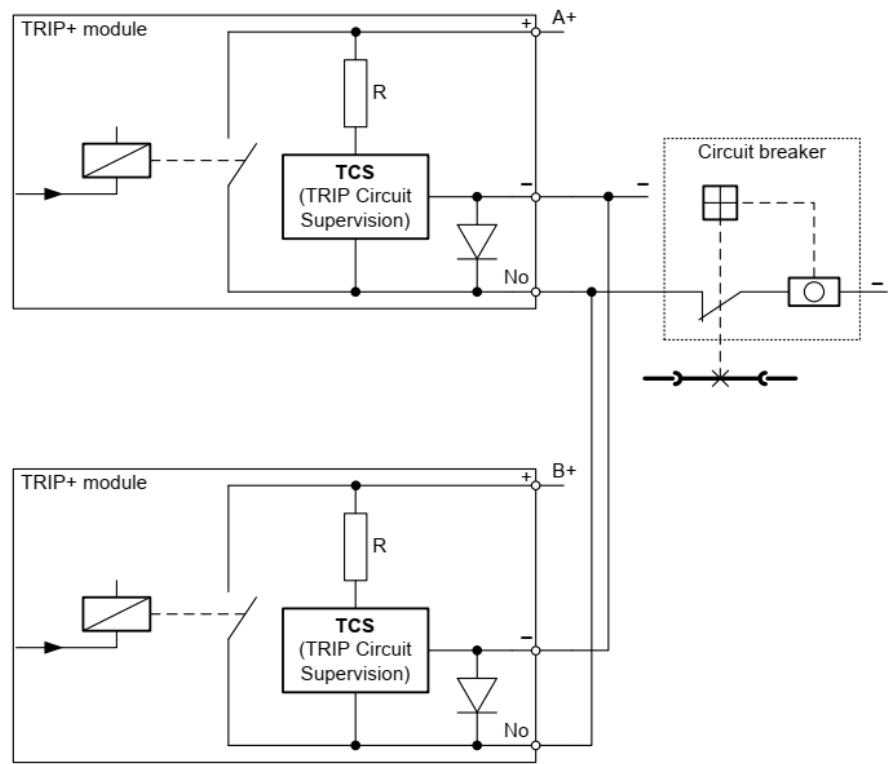


Figure 9-3 3-wire TRIP+ wiring using parallel connected TRIP+ modules

1.4.9.1.2. **2-wire TRIP+ wiring methods**

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

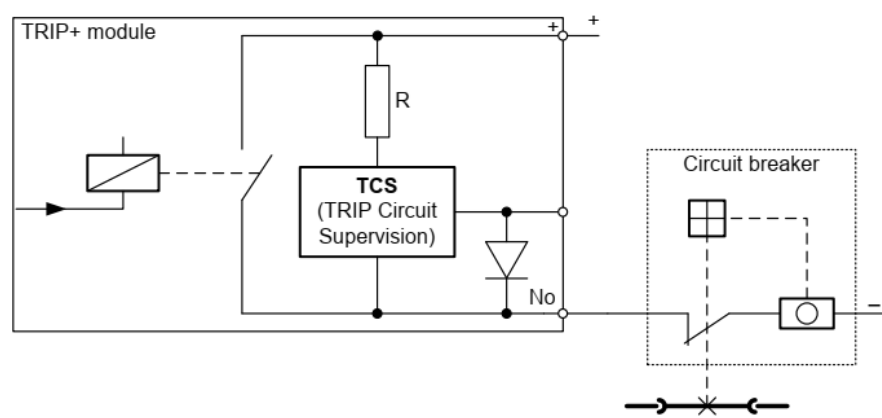


Figure 9-4 2-wire TRIP+ wiring

It is possible to use parallel connected TRIP+ modules.

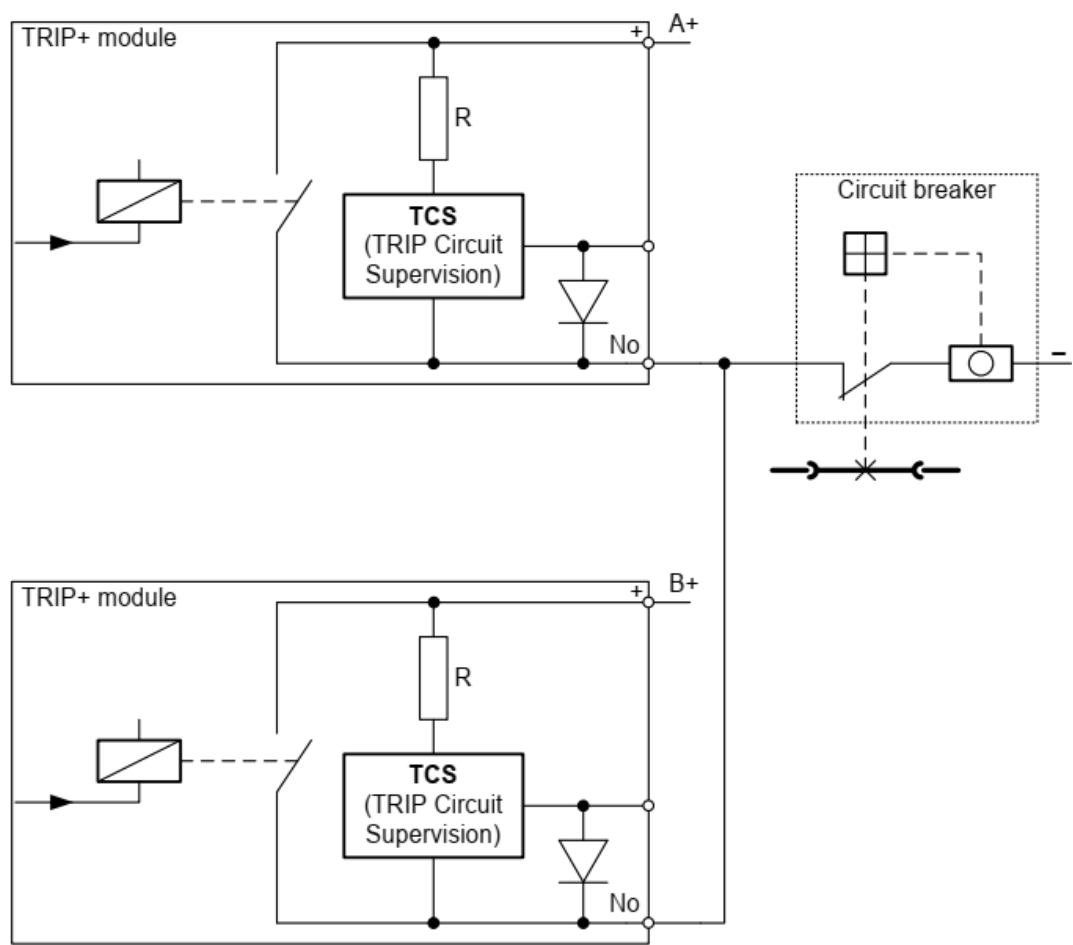


Figure 9-5 2-wire TRIP+ wiring using parallel connected TRIP+ modules

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

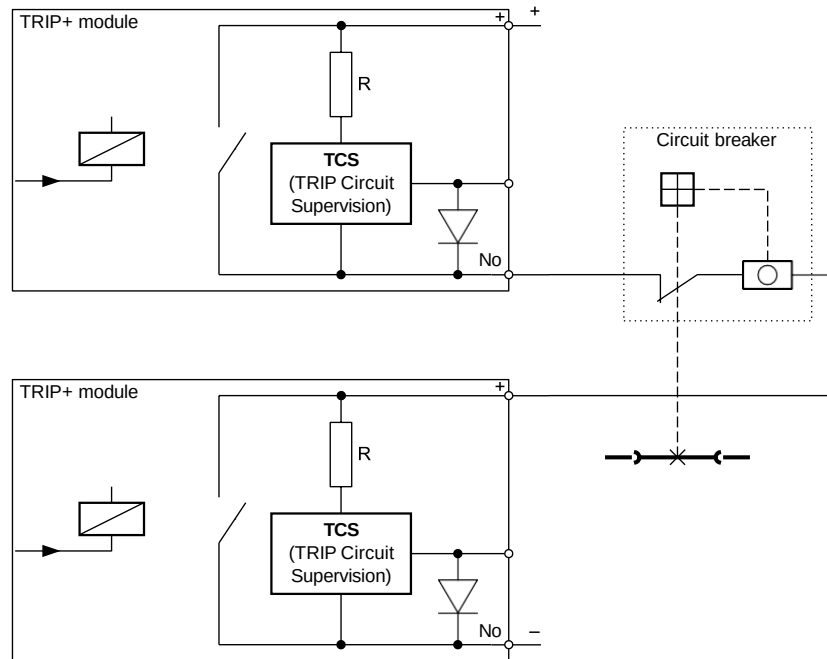


Figure 9-6 2-wire TRIP+ wiring using series connected TRIP+ modules

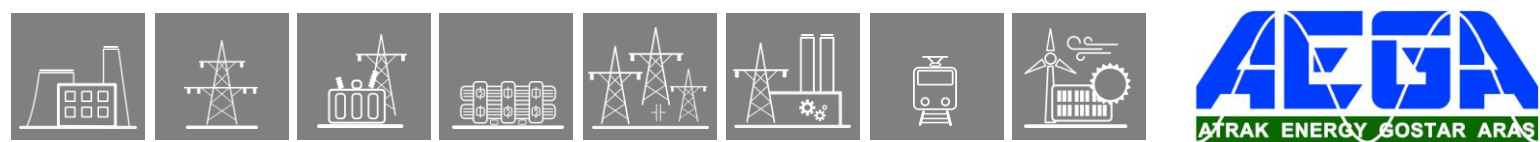
1.4.9.2. Trip Circuit Supervision (TCS)

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 ($\pm 10\%$)		10 k Ω	73 k Ω	130 k Ω
INJECTED CURRENT AT "NO" CONTACT		2.4 mA @ 24 V DC 4.8 mA @ 48 V DC	1.5 mA @ 110 V DC	1.7 mA @ 220 V DC
MAXIMUM RESISTANCE OF THE TRIP COIL	3-WIRE WIRING (MAX. 10 V)	11.8 k Ω @ 24 V DC 3.7 k Ω @ 48 V DC	9.7 k Ω @ 110 V DC 8.4 k Ω @ 125 V DC	8.1 k Ω @ 220 V DC
	3-WIRE WIRING WITH IN PARALLEL (MAX. 10 V)	5.9 k Ω @ 24 V DC 1.8 k Ω @ 48 V DC	4.8 k Ω @ 110 V DC 4.2 k Ω @ 125 V DC	4 k Ω @ 220 V DC
	2-WIRE METHOD (1 mA MIN. CURRENT)	14 k Ω @ 24 V DC 38 k Ω @ 48 V DC	37 k Ω @ 110 V DC 52 k Ω @ 125 V DC	90 k Ω @ 220 V DC



1.4.9.3. Relay output modules of the EuroProt+ system

1.4.9.3.1. 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

1.4.9.3.2. 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.

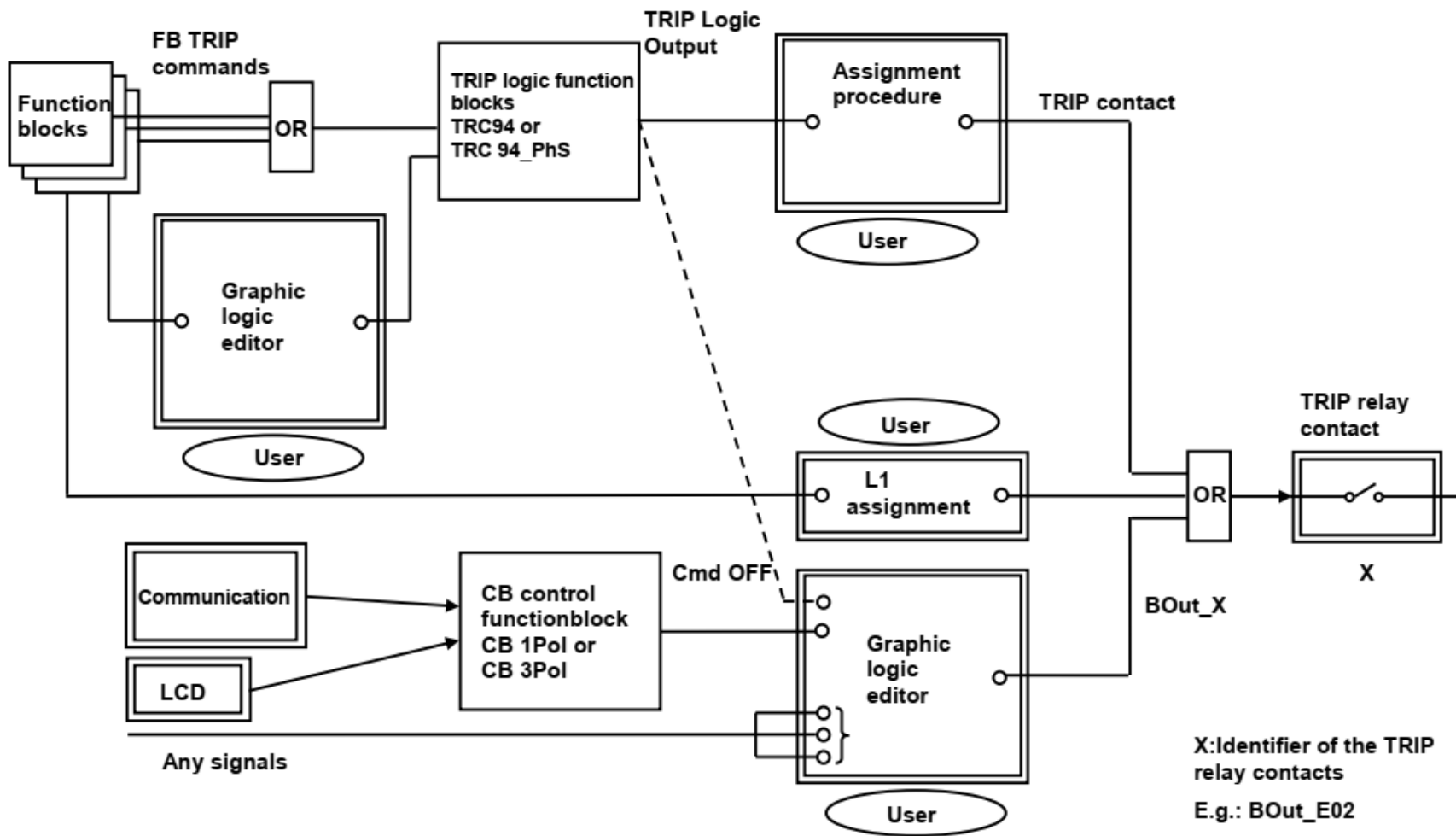
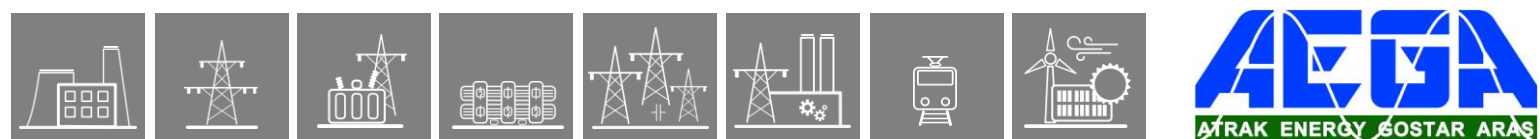


Figure 1-1 Principle of TRIP command processing



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

1.4.9.3.3.1. 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.

1.4.9.3.3.2. 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

1.4.9.3.3.2.1. 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.

1.4.9.3.3.2.2. 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!

1.4.9.3.3.3. 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).

1.4.9.3.3.4. 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](#).

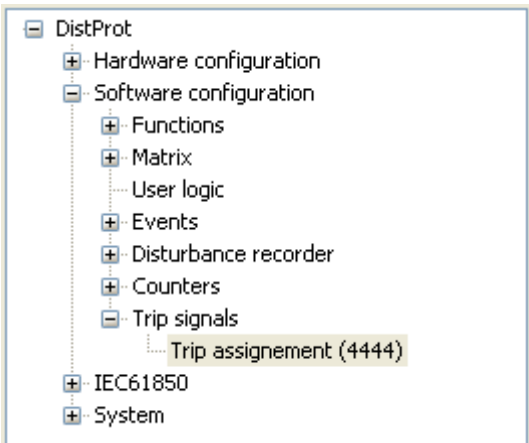


Figure 2-1 Menu item for TRIP command assignment

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.

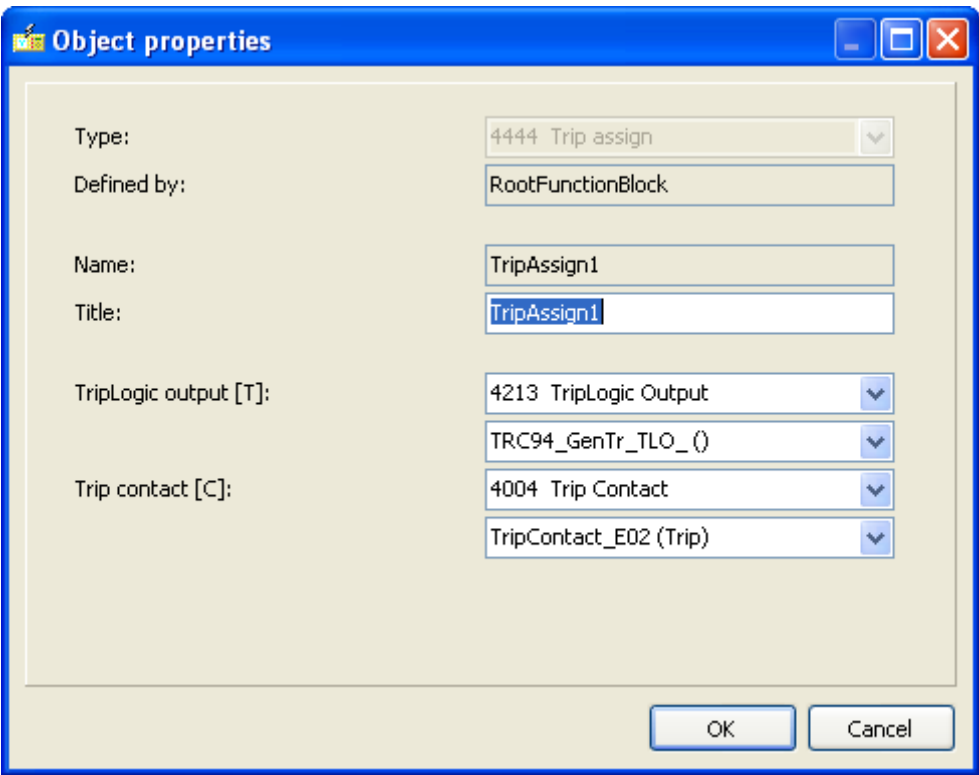


Figure 2-2 Changing the TRIP command assignment

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.

1.4.9.3.3.5. 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”.

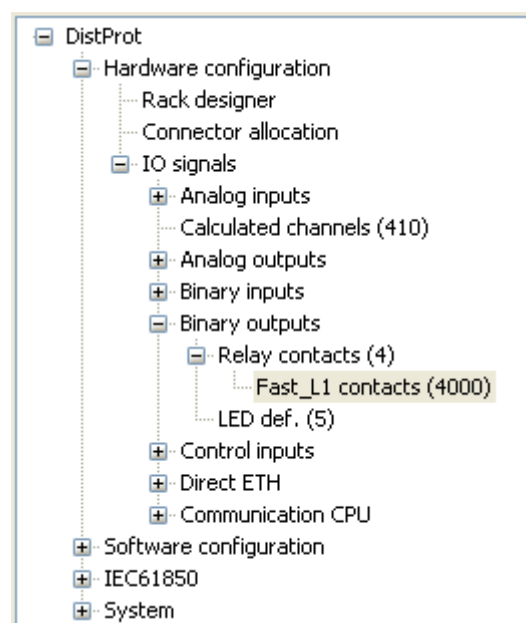


Figure 2-3 Configuring Fast L1 contacts

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.

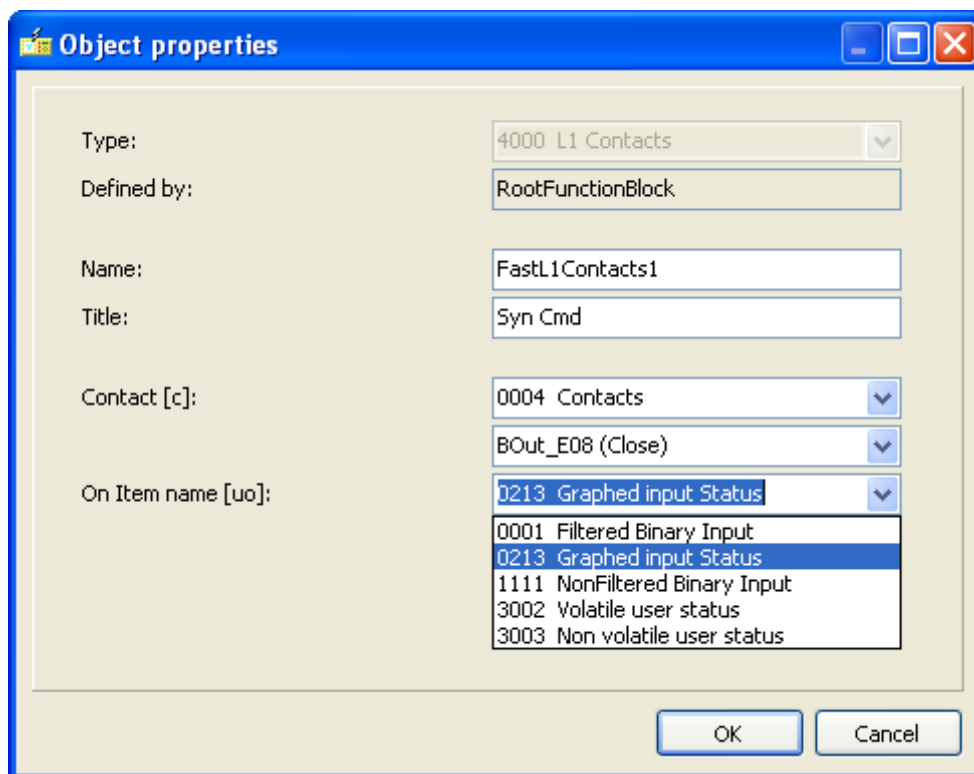


Figure 2-4 Fast L1 contact assignment

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!

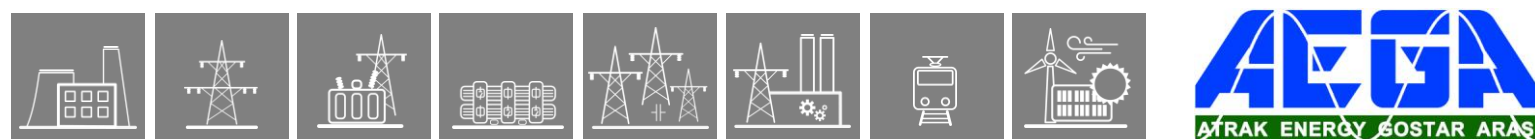
1.4.9.3.4. User application of the TRIP relays

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.

1.4.9.3.4.1. 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.

1.4.9.3.4.2. 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).

1.4.9.3.5. 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.

1.4.9.4. Examples

1.4.9.4.1. Application of the TRIP logic

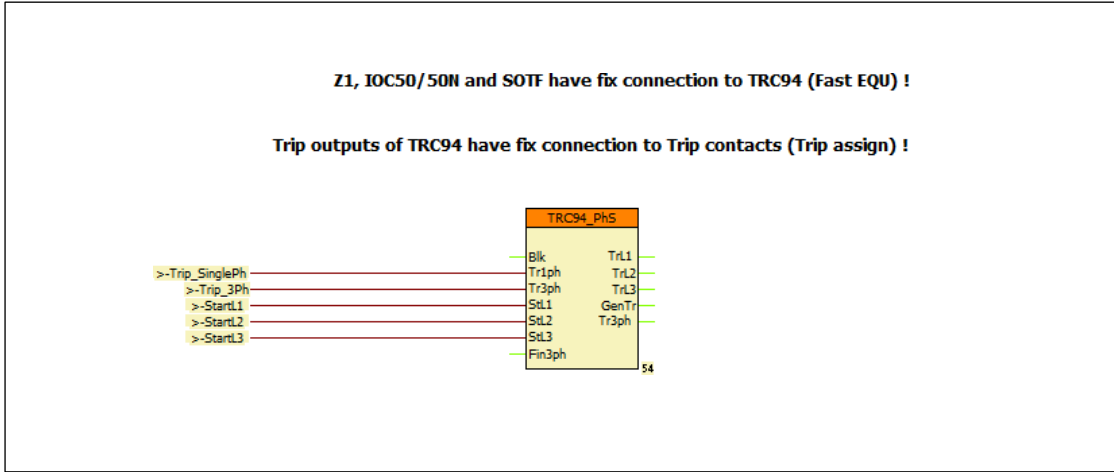


Figure 5-1 Example: A simple configuration to trip the circuit breaker

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.

1.4.9.4.2. Application of circuit breaker control block

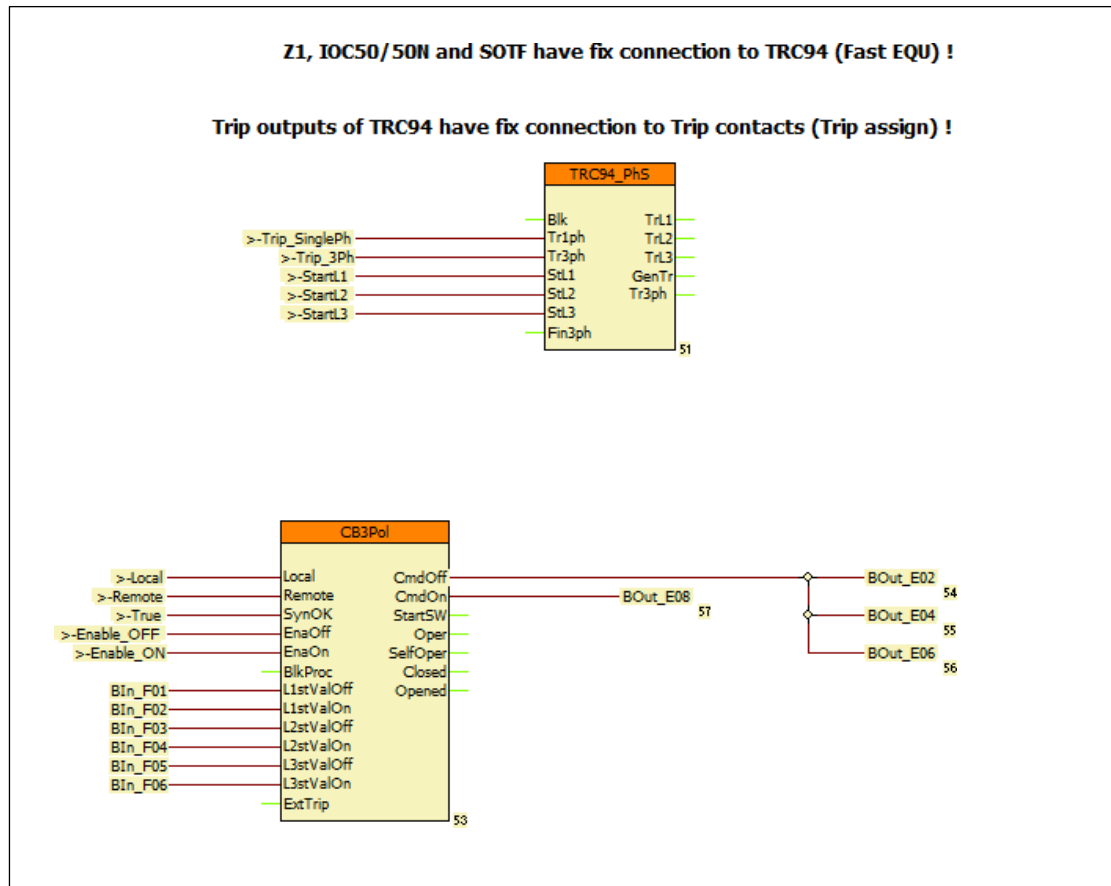


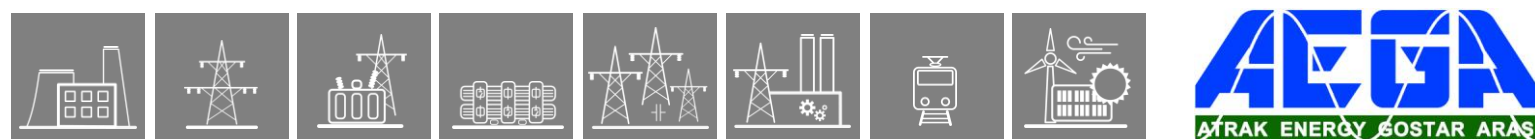
Figure 5-2 Example: Application of circuit breaker control block

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.

1.4.9.4.3. Automatic reclosing and circuit breaker control

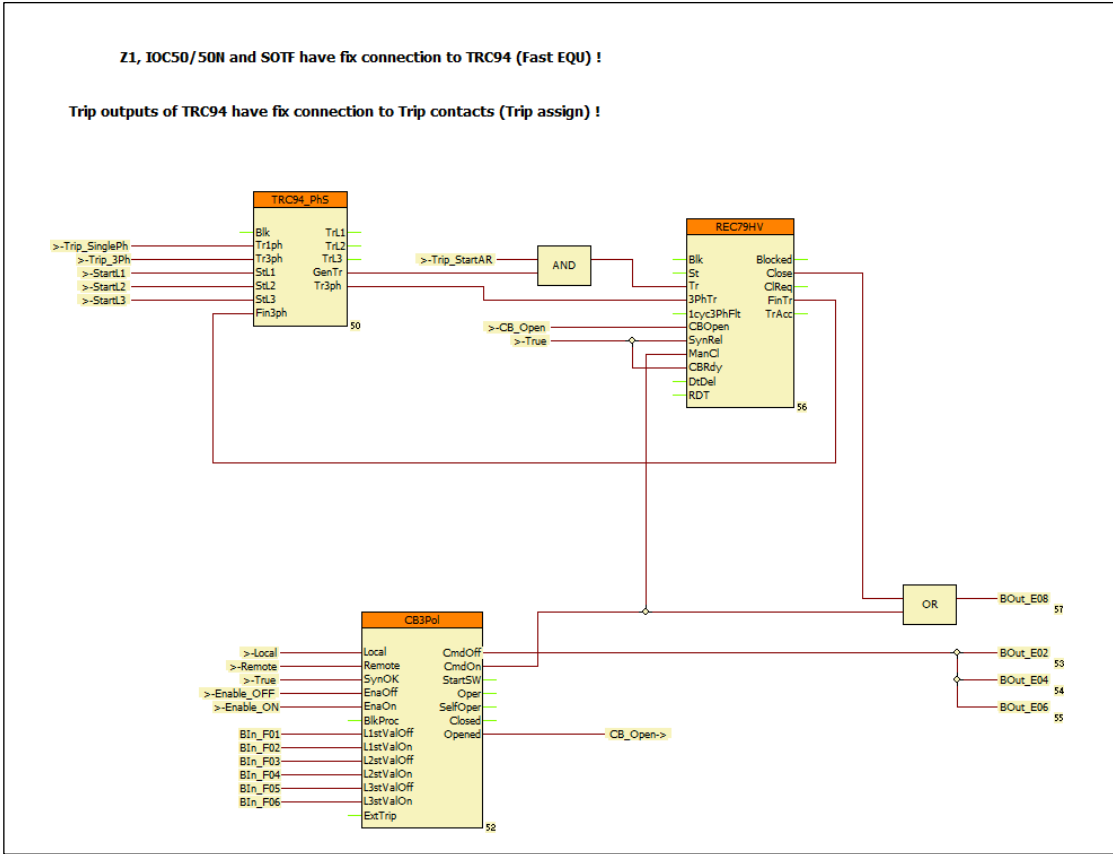


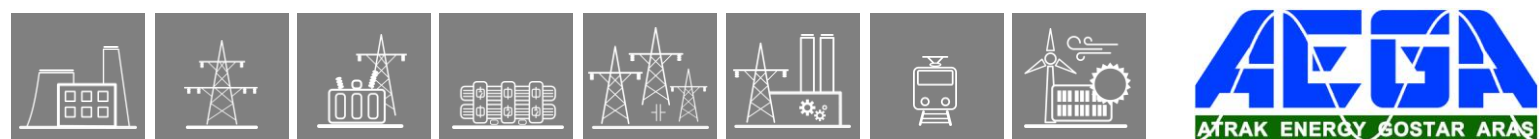
Figure 5-3 Example: Automatic reclosing and circuit breaker control

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

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

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

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



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

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

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

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

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

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

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

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

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

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

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

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

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

1.4.9.4.4. Closing the circuit breaker with synchro-check

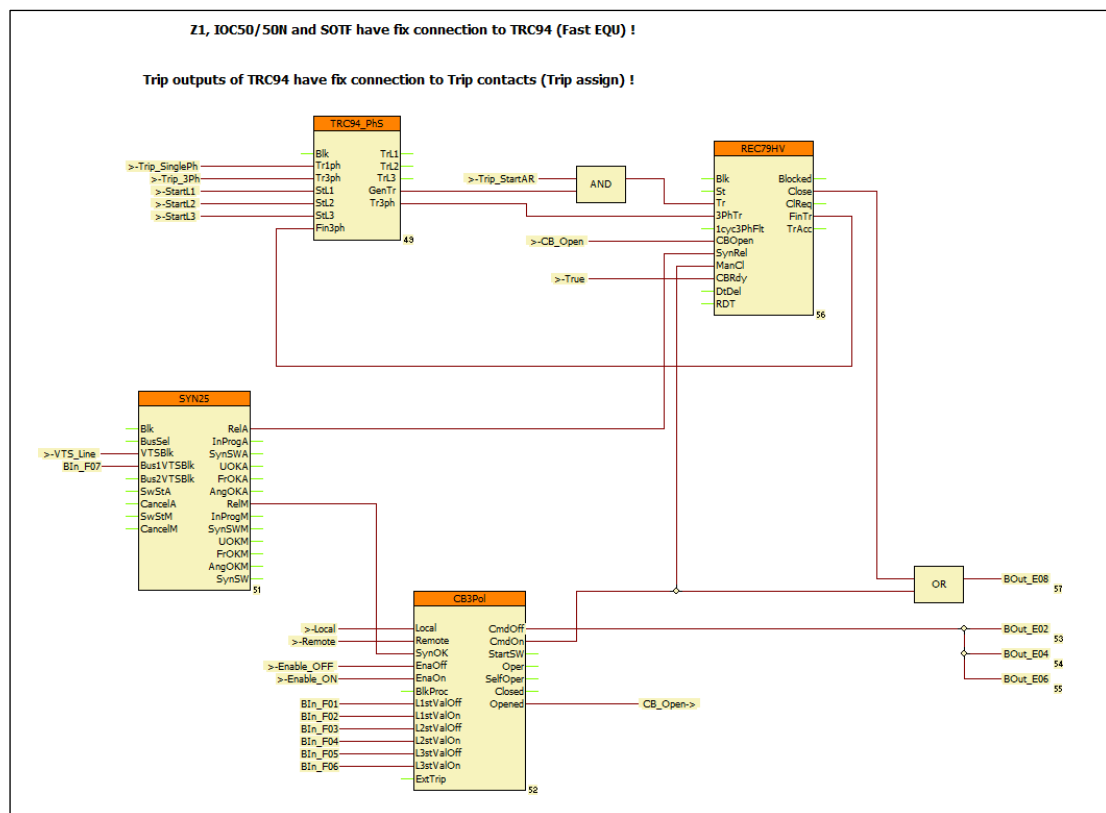


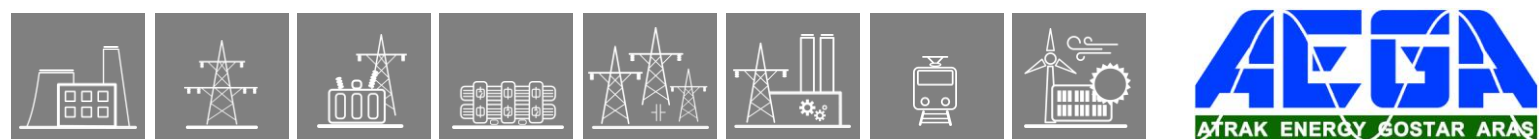
Figure 5-4 Example: closing the circuit breaker with synchro-check

Figure 5-4 shows an example for the application of “SYN25” synchro-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 „ManCI” 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.

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

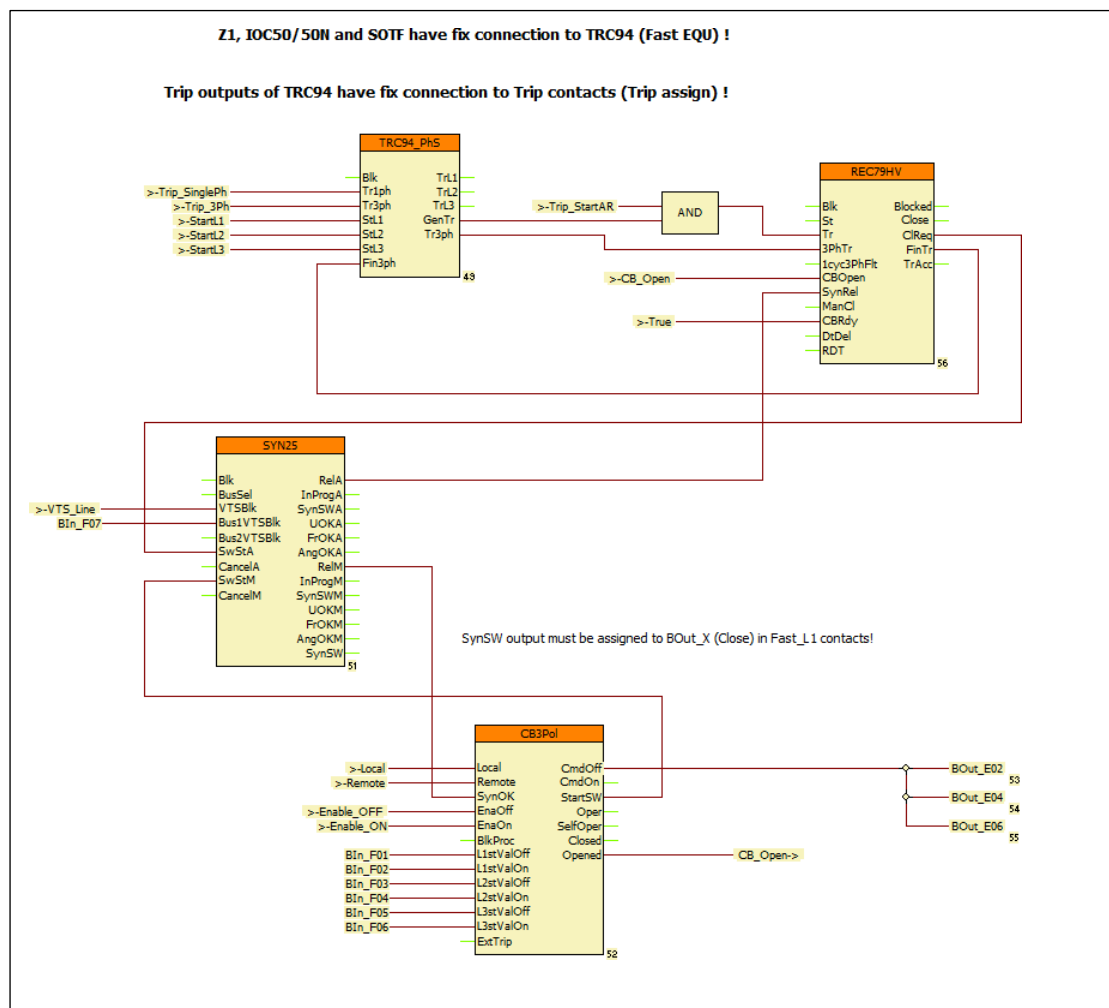
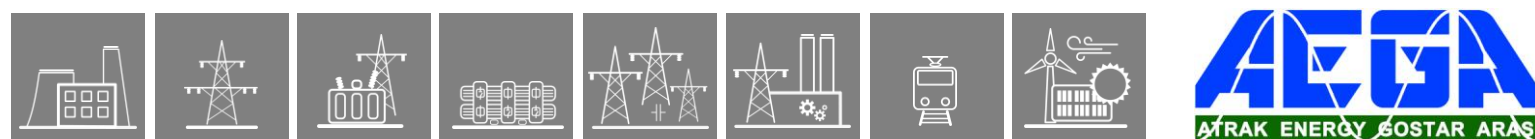


Figure 5-5 Example: closing the circuit breaker with synchro-check and synchro- switch

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”.

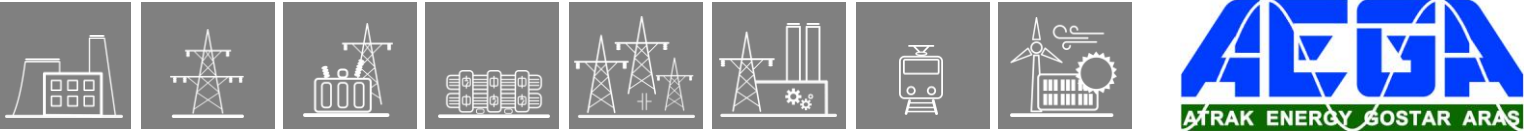
If the automatic reclosing is to be disabled after a fault caused by a manual close command, then the „CmdOn” output of the „CB3Pol” module must be connected to the „ManCl” input of the „REC79_HV” automatic reclosing function.

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.

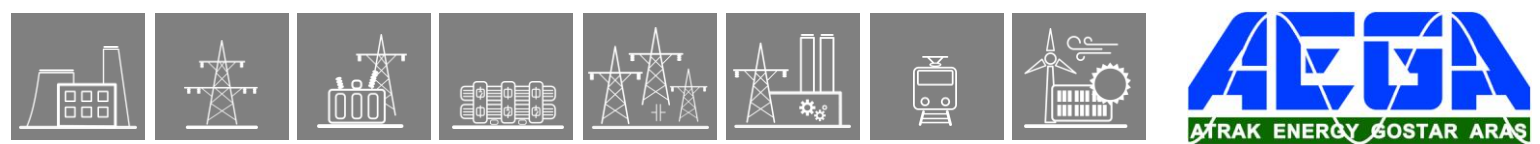
The evaluation of the status signals indicating the open state of the circuit breaker poles in OR gate is needed for the operation of the automatic reclosing function. According to the scheme of *Figure 5-5* the open state is indicated by at least one pole open state of the circuit breaker. (For simplicity, 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 „StartSW” output of the „CB3Pol” functionblock must be connected here.

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

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

1.4.10. 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	$\pm 0.5 \% \pm 1$ digit	$\pm 0.5 \% \pm 1$ digit	$\pm 0.5 \% \pm 1$ digit
SENSOR TYPE	Service-Ohm	Pt100/Ni100 Ni120/Ni120US Pt250/Ni250 Pt1000/Ni1000 Cu10 Service-Ohm (60 Ω ... 1.6 k Ω)	Service-Ohm
MEASUREMENT RANGES	2 Ω ... 200 Ω	- 50 $^{\circ}\text{C}$ – +150 $^{\circ}\text{C}$	10 Ω ... 1000 Ω
CONNECTOR TYPE	Default: BLA Options: T	Default: BLA Options: T	Default: BLA Options: T
RECOMMENDED APPLICATION	Arc suppression coil controller	General resistance-based temperature measurement	Arc suppression coil controller

*Special module

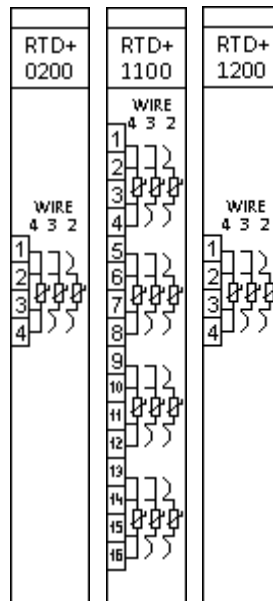


Figure 10-1 RTD input modules

1.4.10.1. 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.

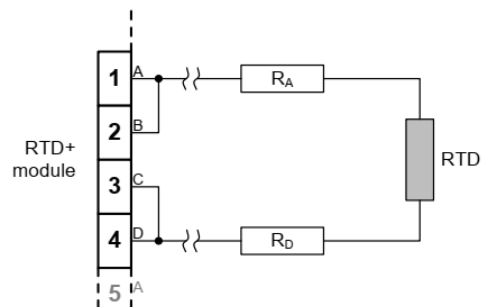


Figure 10-2 2-wire RTD wiring

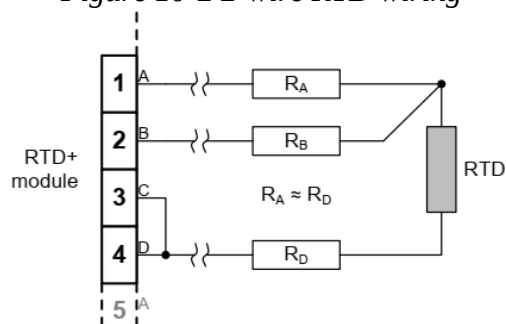


Figure 10-3 3-wire RTD wiring

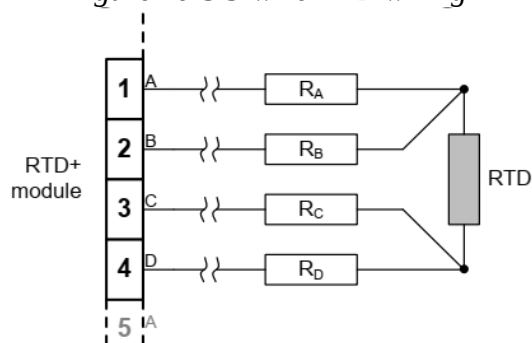


Figure 10-4 4-wire RTD wiring

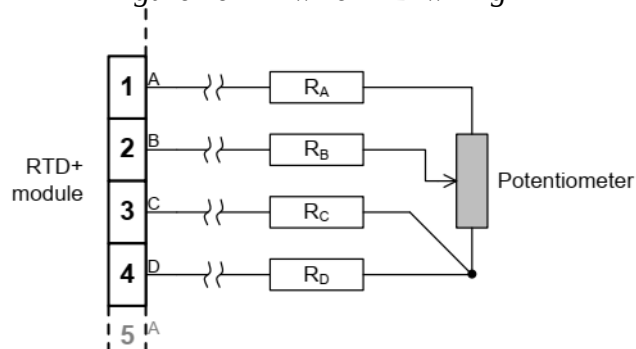


Figure 10-5 4-wire RTD wiring of potentiometer

1.4.11. Analog input module (AI)

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

Connector types:

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

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

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

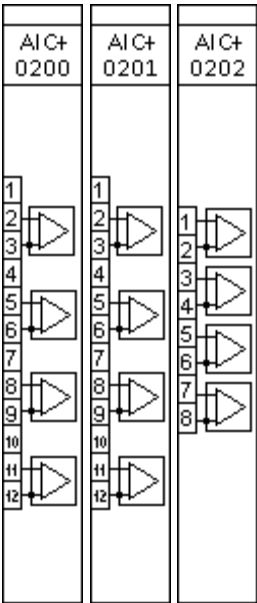


Figure 11-1 Analog input modules

1.4.11.1. **AI module wiring**

The following wiring method can be applied.

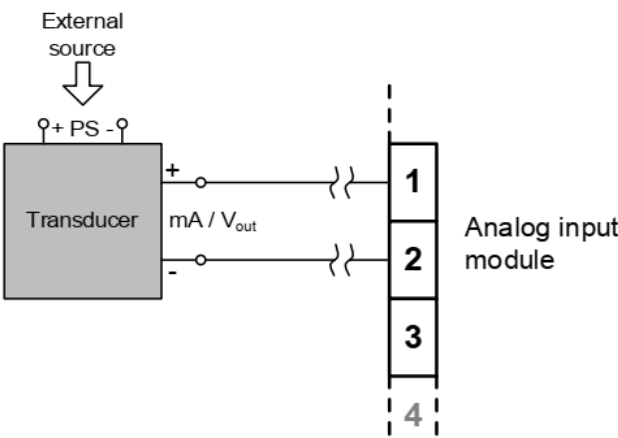


Figure 11-2 AI wiring

1.4.12. Analog output module (ATO)

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

Connector types:

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

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

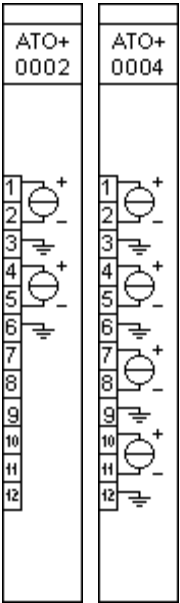


Figure 12-1 Analog output modules

1.4.12.1. **ATO module wiring**

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

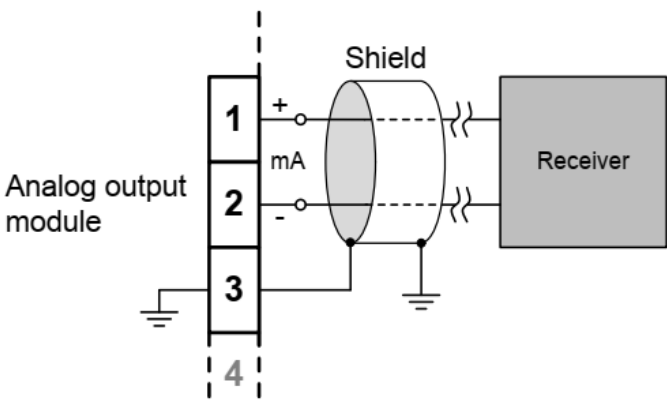


Figure 12-2 Analog output module wiring diagram

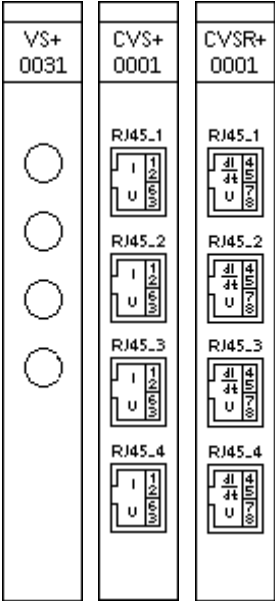
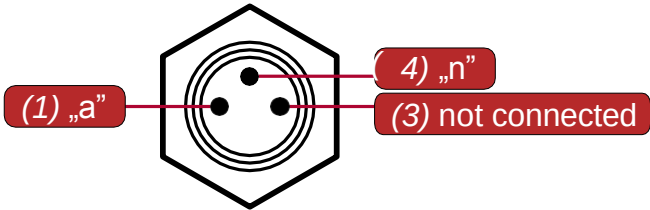


Figure 13-1 Voltage sensor modules

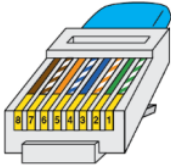


(FRONT VIEW)
Figure 13-2 M8 connector pinout



- 1.: S1
- 2.: S2
- 3.: “a”
- 6.: “n”

Figure 13-3 CVS module connector pinout



- 4.: S1
- 5.: S2
- 8.: “n”
- 7.: “a”

Figure 13-4 CVSR module connector pinout

1.4.14. INJ module

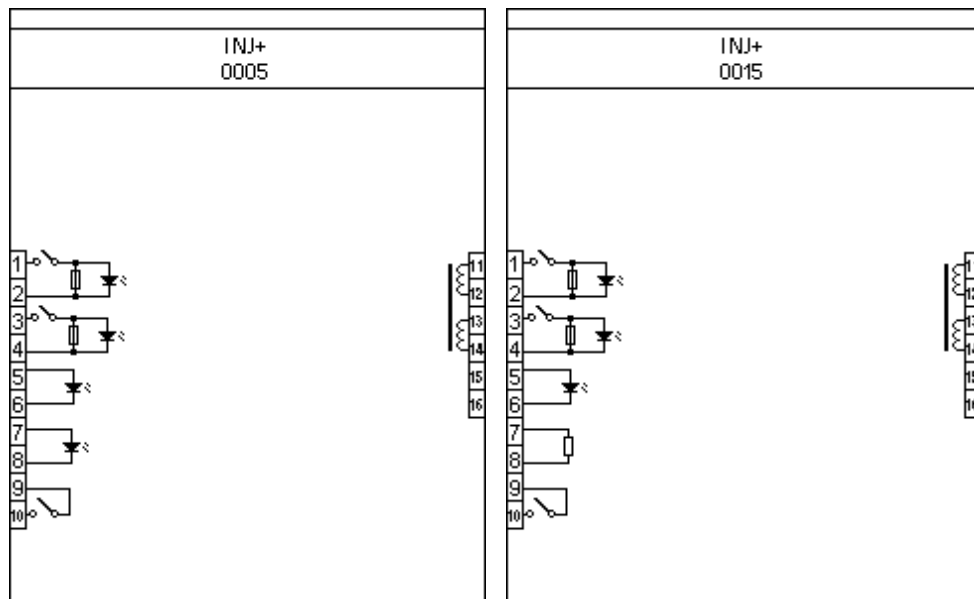
Complex module for controlling the Petersen coil, which contains an injector function for the measurements, an enabling and a blocking input, and a fault relay indicating if there is any fault in the injection circuit.

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*	INJ+/0025
INJECTED CURRENT	2 A	4 A	2 A
ENABLING INPUT CLAMP VOLTAGE	85 V AC	Not available function	18 V AC
BLOCKING INPUT CLAMP VOLTAGE	200 V AC	200 V AC	200 V AC
ADDITIONAL RESISTANCE FOR VOLTAGE INPUT	Not available function	265 k Ω $\pm$ 1%	Not available function
CONNECTOR TYPE	Default: STVS6, BLA10 Options: T	Default: STVS6, BLA10 Options: -	Default: STVS6, BLA10 Options: T
RECOMMENDED APPLICATION	Arc suppression coil controller	Network compensation level measurement on resonant grounded networks	Arc suppression coil controller

*Special module



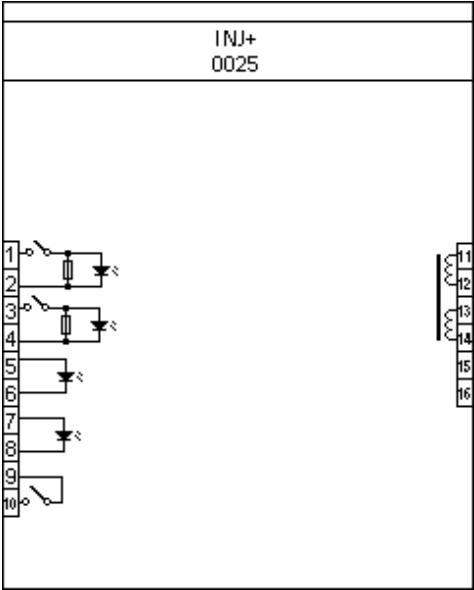


Figure 14-1 INJ modules

1.4.15. Generator protection modules

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

Connector types:

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

MODULE TYPE	RAI+/01	RAI+/11	RINJ+/21
NOMINAL VOLTAGE	-	-	110 V / 220 V
INPUT VOLTAGE RANGE	-	-	88 - 264 V DC 80 - 250 V AC
OUTPUT VOLTAGE	-	-	100V DC $\pm$ 2 %
MEASUREMENT RANGE	$\pm$ 20 mA	$\pm$ 20 mA	-
THERMAL WITHSTAND CONTINUOUS: 30 SEC:	15 mA 20 mA	10 mA 20 mA	20 mA
CONNECTOR TYPE	Default: STVS8 Options: T	Default: STVS8 Options: T*	Default: STVS8 Options: 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.

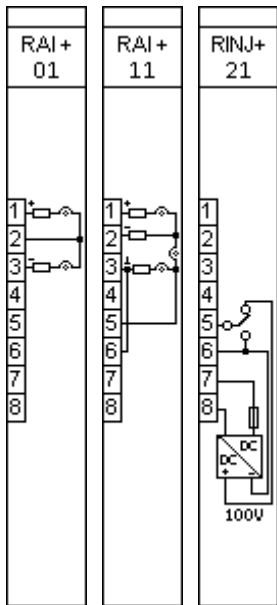


Figure 15-1 Generator protection modules

1.4.15.1. 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	<u>Default:</u> STVS6 <u>Options:</u> -	<u>Default:</u> STVS6 <u>Options:</u> -	<u>Default:</u> STVS6 <u>Options:</u> -
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.

1.4.15.1.1. 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.

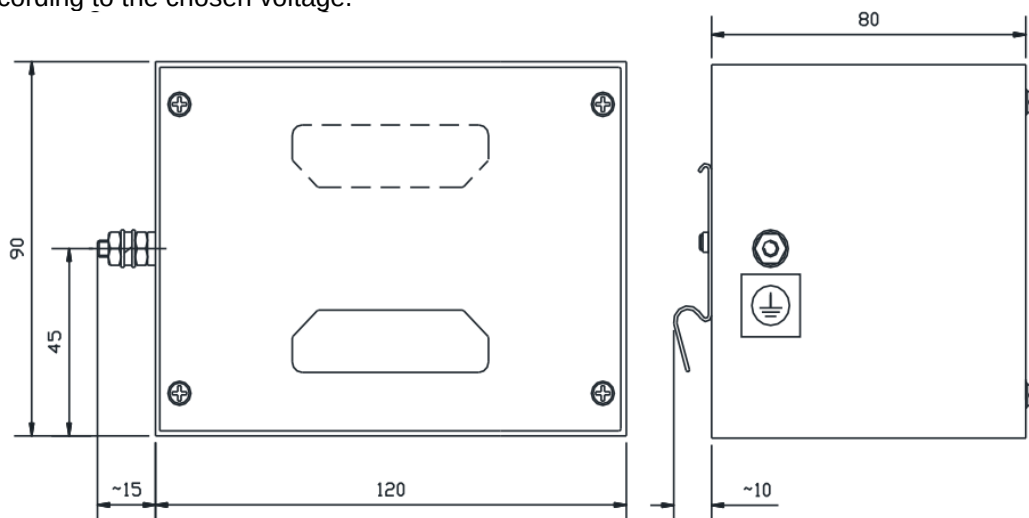


Figure 15-2 Size of the auxiliary boxes

1.4.15.2. Wiring of the rotor earth fault protection modules

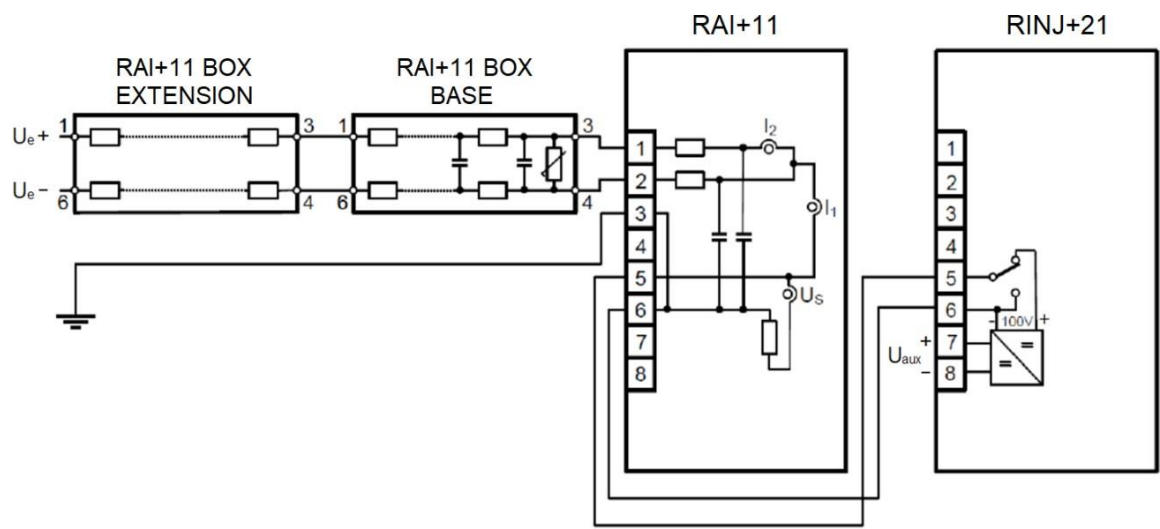


Figure 15-3 Wiring for ungrounded (isolated) rotors

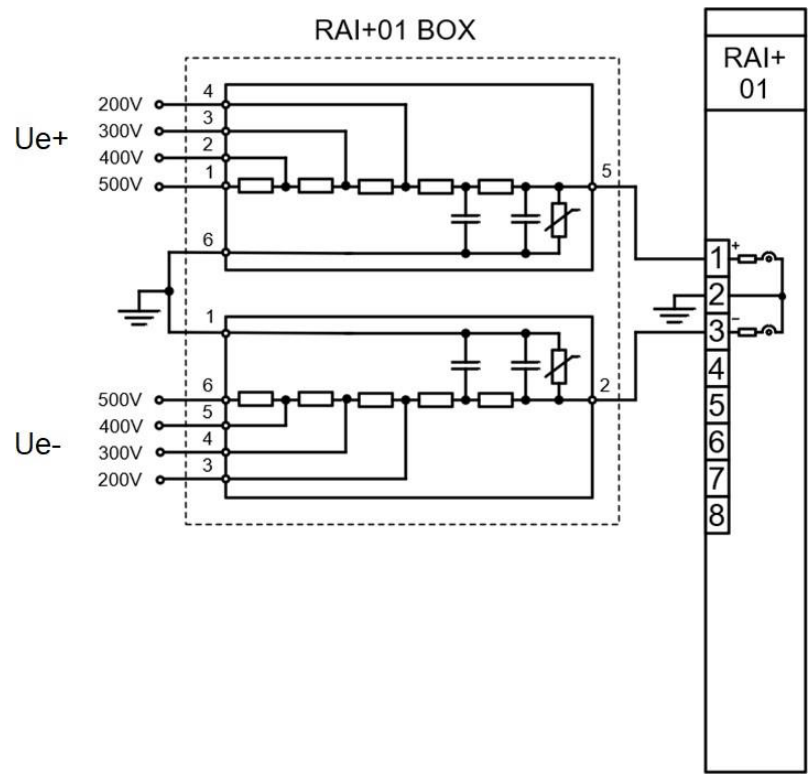
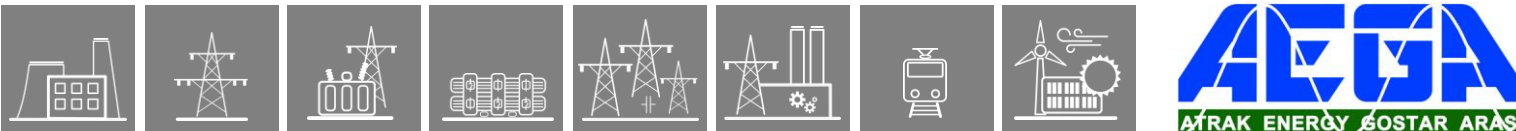


Figure 15-4 Wiring for middle-grounded rotors



1.4.16. 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 - 253 V AC
NOMINAL POWER	20 W	20 W
VOLTAGE DIP WITHSTAND AT 80% UN → 0% INPUT VOLTAGE CHANGE (IEC 60255-26)	50 ms on the rated input voltage, minimum 40 ms on the specified input voltage operative range	100 ms on the specified input voltage operative range
INTERNAL FUSE	3.15A/250V	3.15A/250V
CONNECTOR TYPE	<u>Default:</u> BLA <u>Options:</u> T	<u>Default:</u> BLA <u>Options:</u> T

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 80 - 130 V AC	88 - 132 V DC 80 - 130 V AC	176 - 264 V DC 160 - 253 V AC	176 - 264 V DC 160 - 253 V AC	88 - 264 V DC 80 - 264 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: T	Default: BLA Options: -	Default: BLA Options: T	Default: BLA Options: -	Default: BLA Options: 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 - 253 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: T	Default: BLA Options: T	Default: BLA Options: -	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+/2162	PS+/2164**	PS+/4261*	PS+/4264**
RATED VOLTAGE	110 V DC / 220 V DC/ 230 V AC	110 V DC / 220 V DC/ 230 V AC	110 V DC / 220 V DC/ 230 V AC	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 184 - 253 V AC	184 - 253 V AC, 88 - 264 V DC	88 - 264 V DC 184 - 253 V AC	19.2 - 72 V DC	19.2 - 72 V DC
MAX. CONTINUOUS POWER OUTPUT	60 W	60 W	60 W	60 W	60 W
VOLTAGE DIP WITHSTAND AT 80% UN → 0% INPUT VOLTAGE CHANGE (IEC 60255-26)	50 ms	50 ms	40 ms	40 ms	40 ms
INTERNAL FUSE	3.15A/250V	3.15A/250V	3.15A/250V	8A/250V	8A/250V
CONNECTOR TYPE	<u>Default:</u> BLT <u>Options:</u> -	<u>Default:</u> BLT <u>Options:</u> -	<u>Default:</u> BLT <u>Options:</u> -	<u>Default:</u> BLT <u>Options:</u> -	<u>Default:</u> BLT <u>Options:</u> -

**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)	40 ms	50 ms 100 ms at 100%Un → 0%
INTERNAL FUSE	3.15A/250V	2.5A/250V
CONNECTOR TYPE	<u>Default:</u> BLA <u>Options:</u> T	<u>Default:</u> BLA <u>Options:</u> -

**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 supplying 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.)

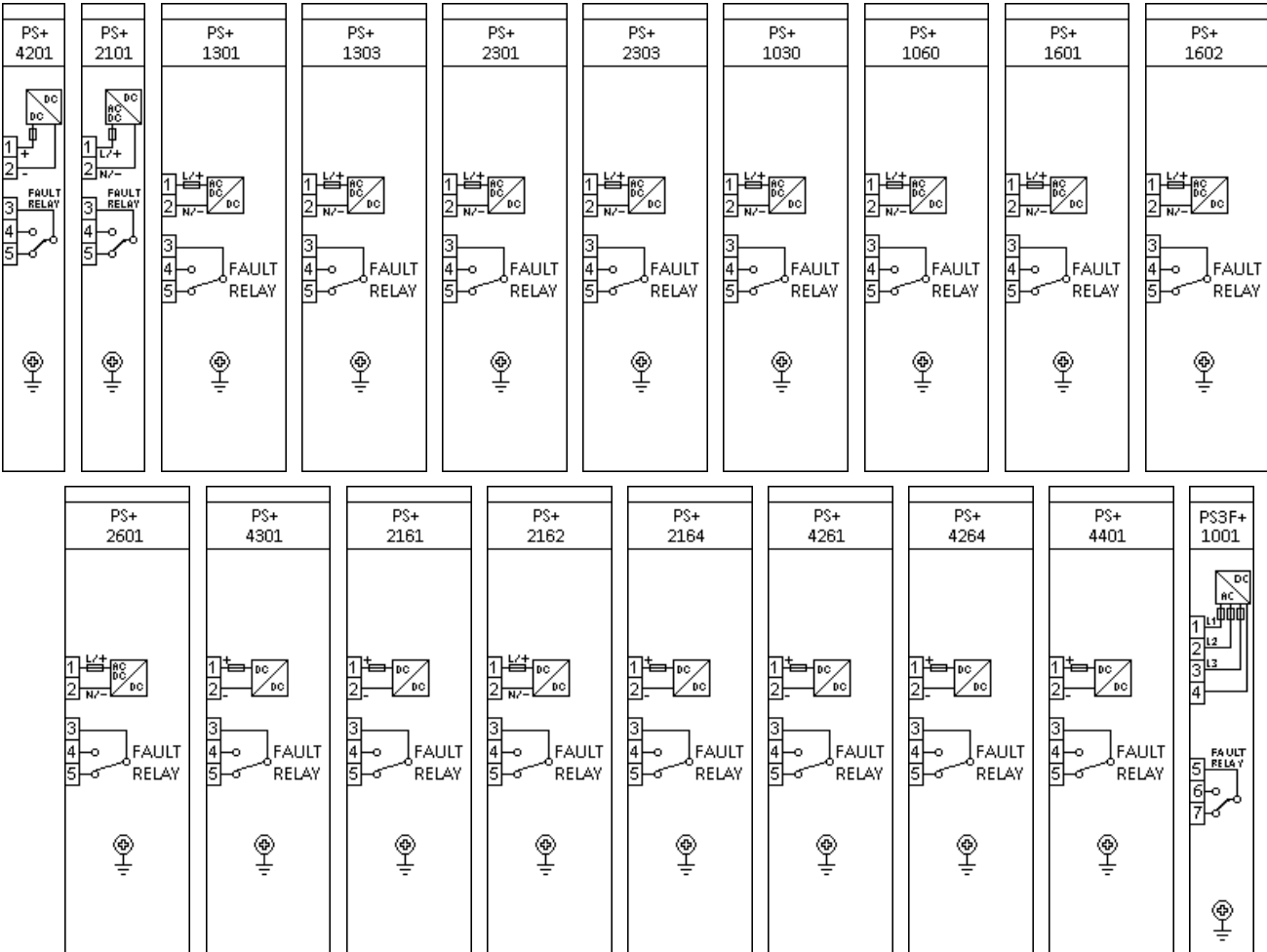


Figure 16-1 Power supply modules

1.4.17. 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

MODULE TYPE	PSTP+/2131**	PSTP+/4201	PSTP+/4202*
	POWER SUPPLY CHARACTERISTICS		
RATED VOLTAGE	110 V / 220 V	24 V / 48 V / 60 V	24 V / 48 V / 60 V
INPUT VOLTAGE OPERATIVE RANGE	88 - 264 V DC 80 - 250 V AC	19.2 - 72 V DC	19.2 - 72 V DC
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	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	3.15A/250V
CONNECTOR TYPE	<u>Default:</u> BLA <u>Options:</u> T	<u>Default:</u> BLA <u>Options:</u> T	<u>Default:</u> BLA <u>Options:</u> -
	TRIPPING CHARACTERISTICS		
CHANNEL NUMBER	2	2	2
RATED VOLTAGE	110 V DC and 220 V DC or dry contacts	24 V DC and 48 V DC or dry contacts	24 V DC and 48 V DC or dry contacts
WITHSTAND VOLTAGE	242 V DC	72 V DC	72 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	<u>Default:</u> BLA <u>Options:</u> T	<u>Default:</u> BLA <u>Options:</u> T	<u>Default:</u> BLA <u>Options:</u> -

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

****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
- 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.)

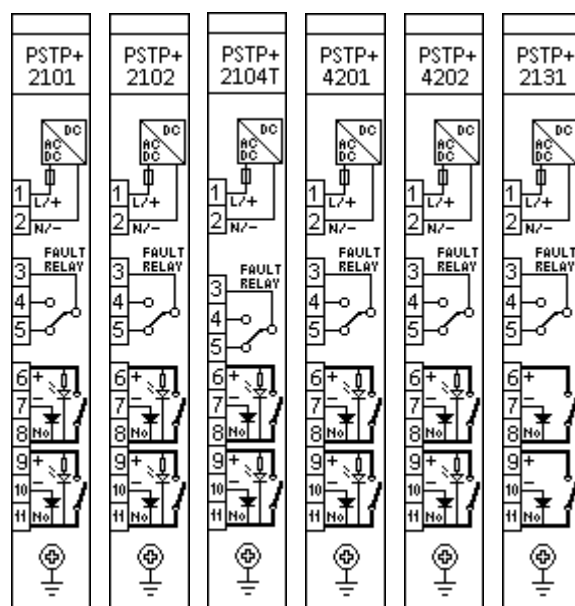


Figure 18-1 Power supply with 2 Ch. TRIP modules

1.4.18.1.1. Trip Circuit Supervision (TCS) in PSTP modules

Apart from the PSTP+/2131, all PSTP 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 in PSTP modules:

MODULE TYPE		PSTP+/4201 PSTP+/4202	PSTP+/2101 PSTP+/2102
MAXIMUM RESISTANCE OF THE TRIP COIL	INJECTED CURRENT AT "NO" CONTACT	1.5 mA	1.5 mA
	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

1.4.18.2. PSR2+ module

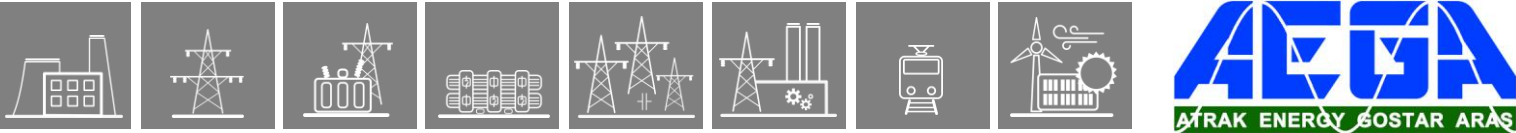
IMPORTANT

PSR2+ modules can be used only if the power consumption of the device does not reach 20 W and a maximum of 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.

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	<u>Default:</u> BLA <u>Options:</u> 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	<u>Default:</u> BLA <u>Options:</u> 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 × 10⁶ cycles
- Circuit closing capability: typically 10 ms, maximally 22 ms.
- Bounce time: typically 6,5 ms, maximally 10 ms.
- Minimal switching requirement: 5 V

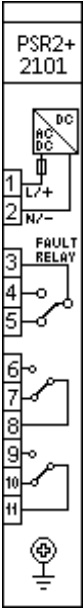


Figure 18-2 Power supply with 2 Ch. signaling modules

1.4.18.3. PSTO+ module

IMPORTANT

PSTO+ modules can be used only if the power consumption of the device does not reach 20 W and a maximum of 1 TRIP contact is 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.

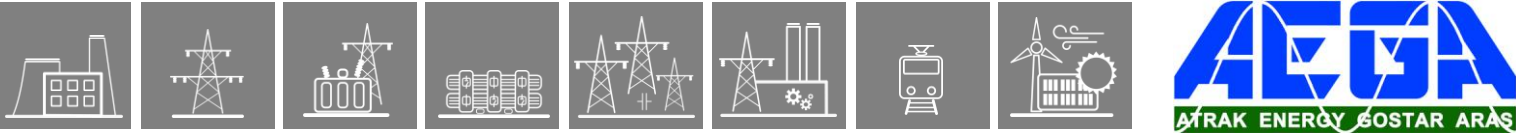
Connector types:

- 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:

- 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	PSTO+/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	<u>Default:</u> BLT <u>Options:</u> -
	TRIPPING CHARACTERISTICS
CHANNEL NUMBER	1
RATED VOLTAGE	110 V DC and 220 V DC or dry contacts
WITHSTAND VOLTAGE	242 V DC
CONTINUOUS CARRY	8 A
MAKING CAPACITY	0.5 s, 30 A
BREAKING CAPACITY	L/R = 40 ms: 4 A DC
CONNECTOR TYPE	<u>Default:</u> BLT <u>Options:</u> -



MODULE TYPE	PSTO+/2101
	BINARY INPUT CHARACTERISTICS
CHANNEL NUMBER	3
RATED VOLTAGE	110 V / 220 V user selectable on channel basis by jumpers
TIME SYNCHRONIZATION	configured by EuroCAP
WITHSTAND VOLTAGE	320 V
CLAMP VOLTAGE	falling 0.64 U_N rising 0.8 U_N
COMMON GROUPS	1 × 3 common
CONNECTOR TYPE	<u>Default:</u> BLT <u>Options:</u> -

Main features:

- High-speed operation: with pre-trip 0.5 ms, without pre-trip typically 10 ms, maximally 22 ms.
- Trip circuit supervision
- 1 unit wide (4 HP) module
- 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.)
- 3x binary inputs

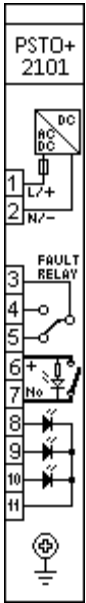
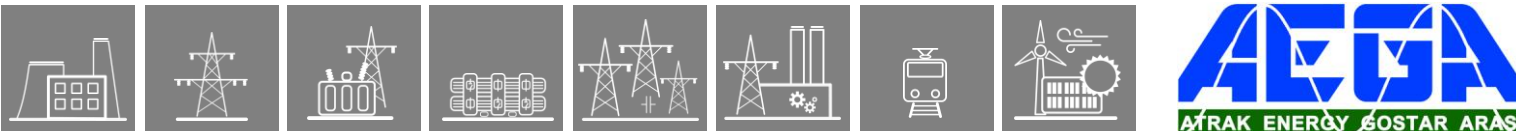


Figure 18-3 Power supply with 1 Ch. Trip module and 3 Ch. Binary Input module



1.4.18.4. O6R5+ module

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

Connector types:

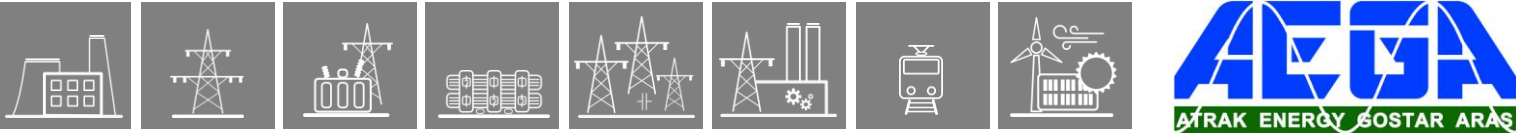
- The default and optionally available connector types are indicated for each module in the tables below. See Chapter 20.2 for details about each type.

Notes for the following table:

- **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
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	Rated Voltage	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

Though the states of the inputs are refreshed with 2 kHz frequency, there is a 1 ms built-in analog filtering in them. Additional digital filtering is set in the EuroCAP tool (default: 4 ms).



Main features for binary inputs:

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

Main features for signaling outputs:

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

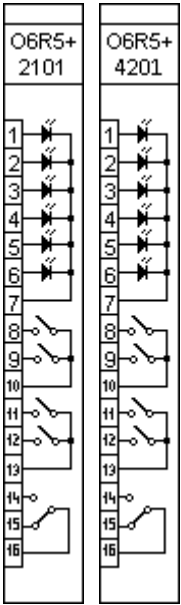


Figure 18-4 Binary input/output modules

1.4.18.5. 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:

- 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+/4221T
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
WITHSTAND VOLTAGE	320 V	320 V	72 V
WITHSTAND VOLTAGE FOR SYNC. INPUT	35 V _{PEAK}	-	-
CLAMP VOLTAGE	falling $0.64 U_N$ rising $0.8 U_N$	falling $0.64 U_N$ rising $0.8 U_N$	falling $0.64 U_N$ rising $0.8 U_N$
COMMON GROUPS	9 (3 × 3 common)	9 (3 × 3 common)	9 (3 × 3 common)
CONNECTOR TYPE	<u>Default:</u> BLA <u>Options:</u> T	<u>Default:</u> BLA <u>Options:</u> T	<u>Default:</u> BLT <u>Options:</u> -

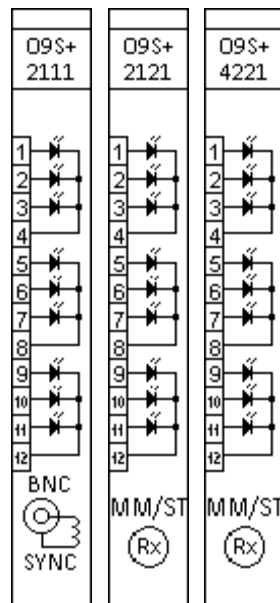
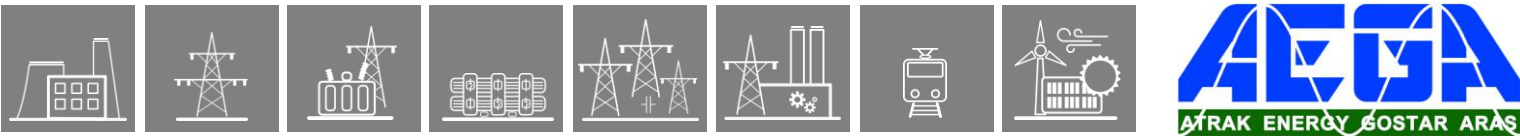


Figure 18-5 Binary input modules with time synchronization



1.4.18.6. 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:

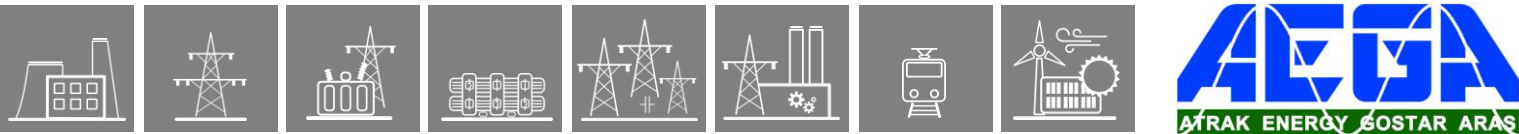
- The default and optionally available connector types are indicated for each module in the tables below. See Chapter 20.2 for details about each type.

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

**Special module*



Figure 18-6 Externally driven TRIP module



1.4.19. General data

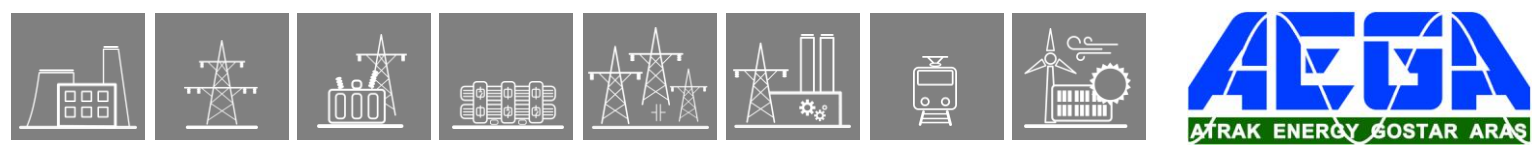
- Storage temperature: - 40 °C ... + 70 °C
- Operation temperature: - 20 °C ... + 55 °C
- Humidity: 10 % ... 93 %
- Altitude: up to 2000 m
- Atmospheric pressure: 86 ... 106 kPa

1.4.19.1. 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, Level 4
 - 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, Level 3
 - Test frequency: 1 MHz
 - Test voltage: 2.5 kV in common mode, 1 kV in differential mode
- Voltage dips, short interruptions and voltage variations immunity, IEC-EN 60255-26:2013
 - Voltage dips: 40 % (200 ms), 70 % (500 ms), 80 % (5000 ms)
- Ripple on d.c. input power port immunity, IEC-EN 60255-26:2013
 - Level 4, 15 % of rated d.c. value
- Power frequency magnetic field immunity test, IEC-EN 60255-26:2013, Level 5
 - Test field strength: 100 A/m continuous, 1000 A/m for 3 s
- Power frequency immunity test on the binary inputs, IEC-EN 60255-26:2013, Class A
 - Test voltages: 300 V in common mode, 150 V in differential mode
- Insulation tests, IEC-EN 60255-27:2013
 - Impulse voltage test
 - Test levels: 5 kV (1 kV for transducer and temperature measuring inputs)
 - Dielectric test
 - Test levels: 2 kV AC 50 Hz (0.705 kV DC for transducer inputs)
 - Insulation resistance
 - Insulation resistance > 15 GΩ
- Radiated emission, IEC-EN 60255-26:2013 Limits:

▪ 30 MHz to 230 MHz:	50 dB(μV/m) quasi peak, 3 m
▪ 230 MHz to 1 000 MHz:	57 dB(μV/m) quasi peak, 3 m
▪ 1 GHz to 3 GHz:	76 dB(μV/m) peak, 3 m
▪ 3 GHz to 6 GHz:	80 dB(μV/m) peak, 3 m
- Conducted emission, IEC-EN 60255-26:2013 Limits:

▪ 0,15 MHz to 0,50 MHz:	79 dB(μV) quasi peak, 66 dB(μV) average
▪ 0,5 MHz - 30 MHz:	73 dB(μV) quasi peak, 60 dB(μV) average
- Vibration, shock, bump and seismic tests on measuring relays and protection equipment
 - Vibration tests (sinusoidal), Class I, IEC 60255-21-1:1988
 - Shock and bump tests, Class I, IEC 60255-21-2:1988
 - Seismic tests, Class I, IEC 60255-21-3:1993

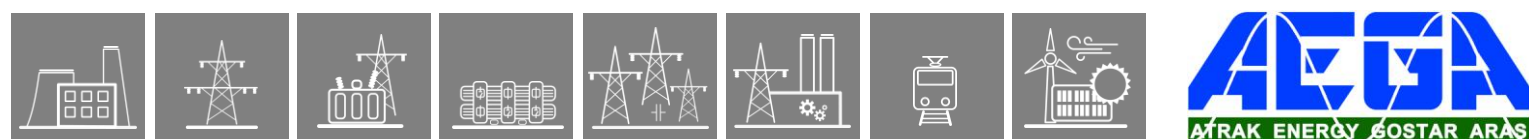


1.4.20. Mechanical data

1.4.20.1. General mechanical data

- Construction: chromate aluminum surface with built-in EMC accessories

- If the power consumption of an 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
 - 1½ 19" (42 HP), 3 U, single rack
 - 1½ 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



1.4.20.2. 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.

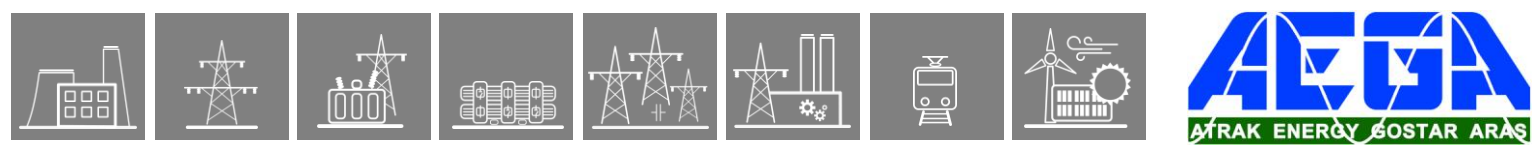
Example: the VT+/2211 module may have four types of connectors. In its description (Chapter 6), these are indicated with their ID:

- 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+/2211**F**", if it is equipped with this terminal (BLA 8B/180)
- Top-screw terminal: **T**, the label becomes "VT+/2211**T**" (BLT 5.08HC/08/180F)
- Ring-lug terminal: **R**, so the module's label shall be "VT+/2211**R**"

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.



1.4.21. 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.

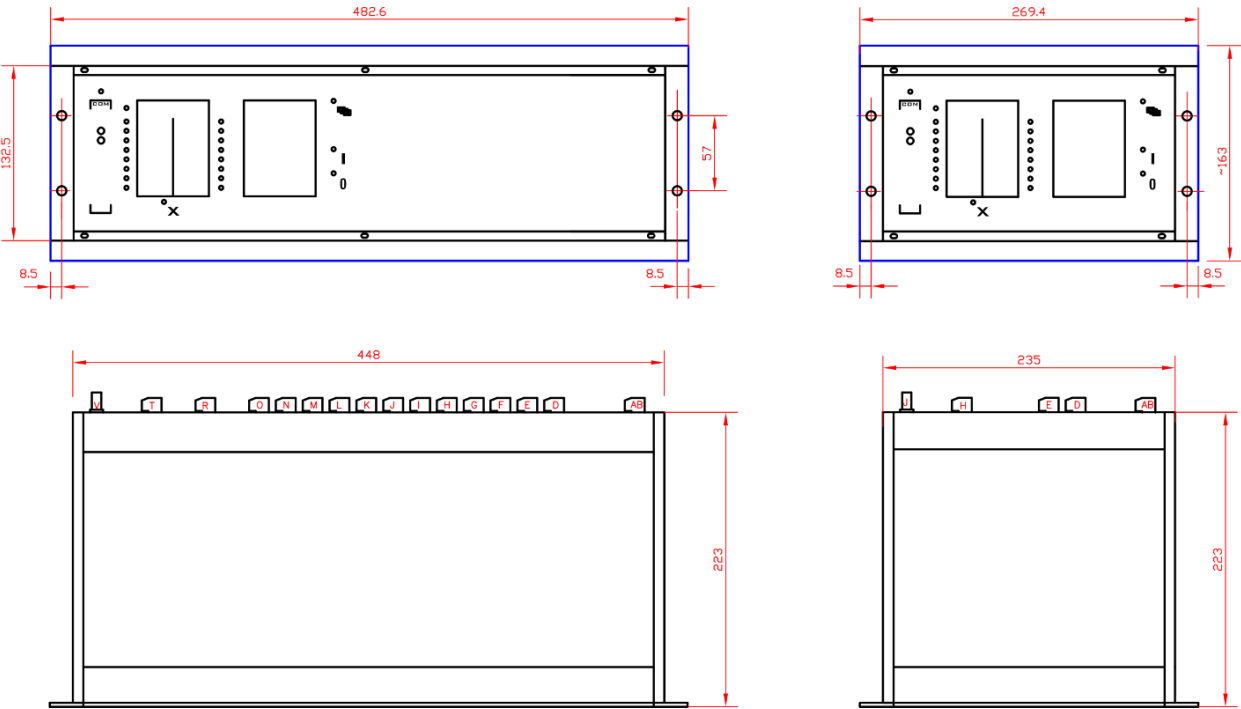


1.4.21.1. Flush mounting

Flush mounting can be used for all sizes 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.

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



PANEL CUT-OUT

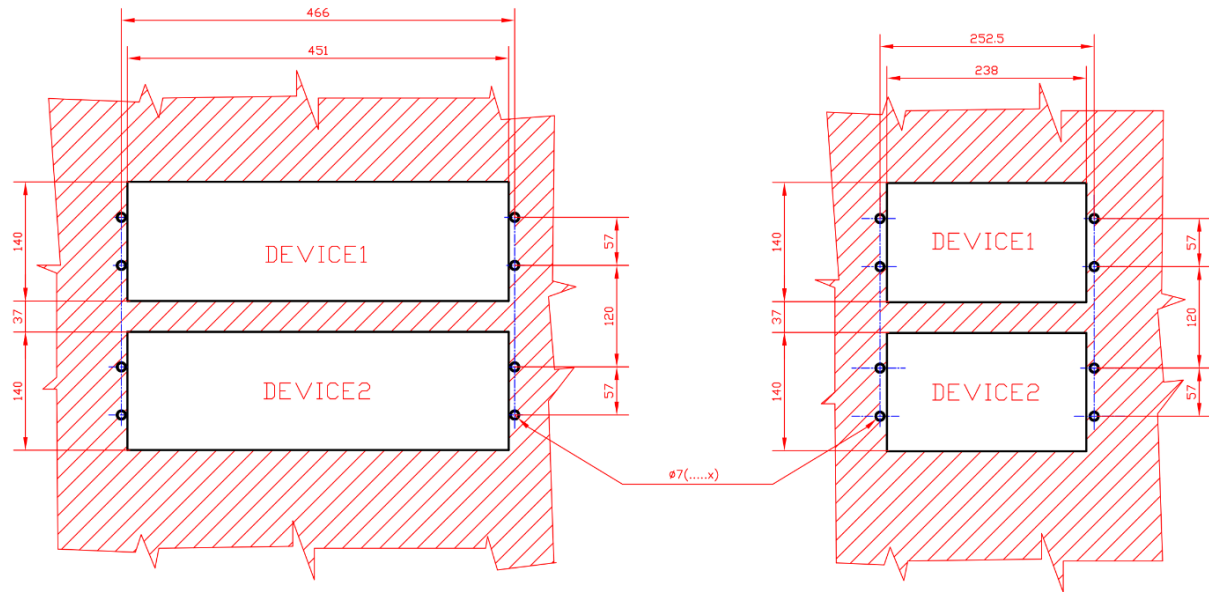


Figure 21-1 Dimensions for flush mounting of 84 HP and 42 HP single rack

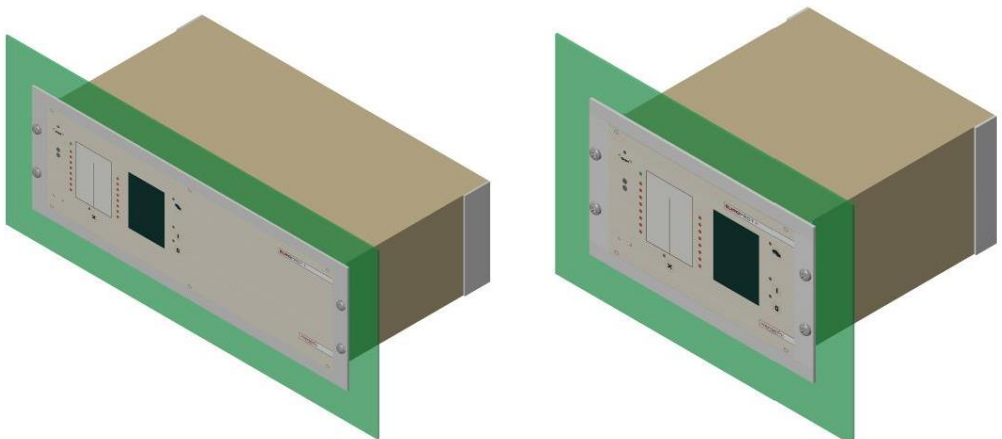


Figure 21-2 3D illustration for flush mounting of 84 HP and 42 HP devices

1.4.21.1.2. Flush mounting of 42 HP double rack

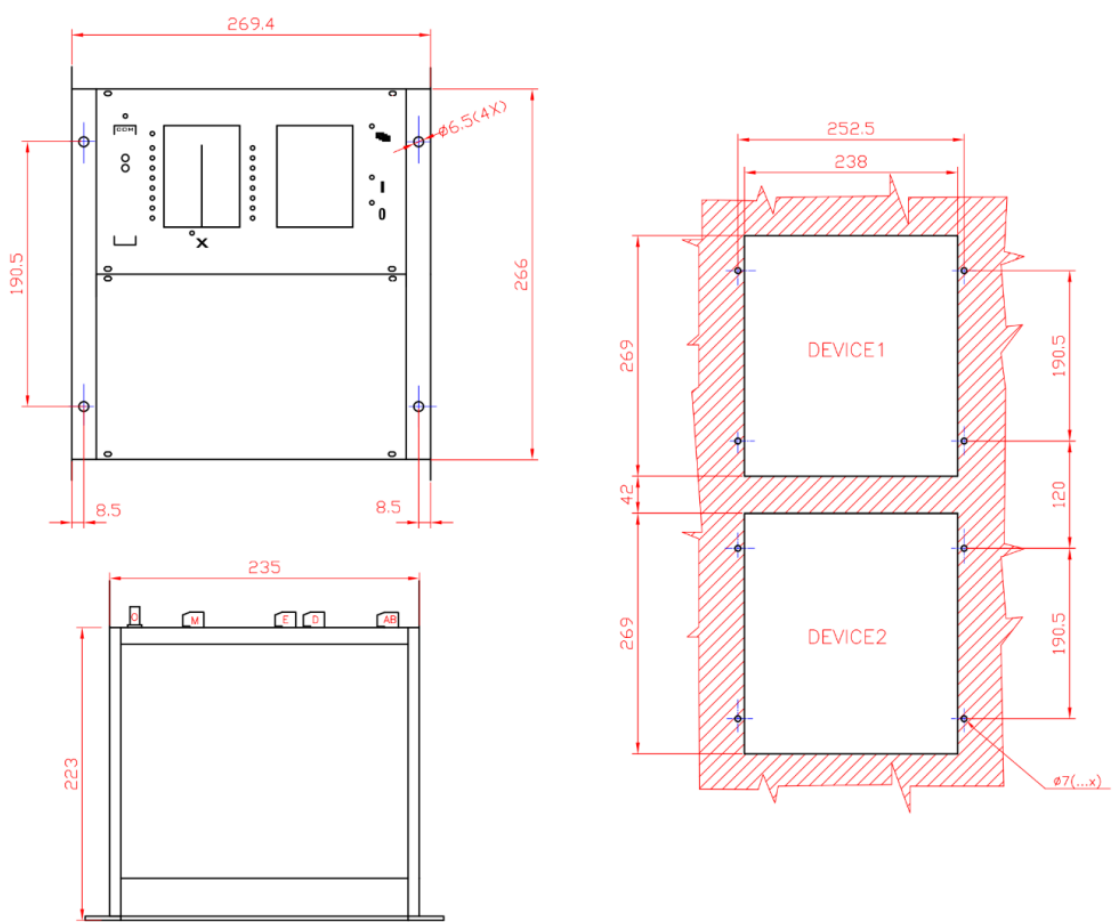


Figure 21-3 Dimensions for flush mounting of 42 HP double rack

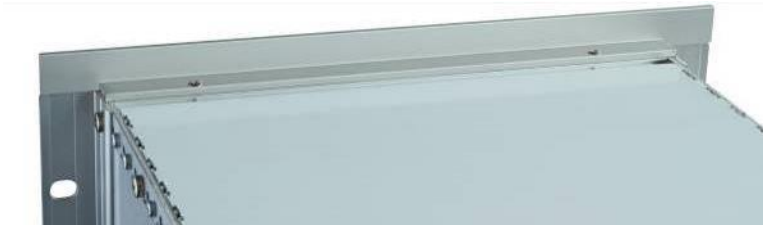


Figure 21-4 42 HP wide cover profile

1.4.21.1.3. Flush mounting of 24 HP panel instrument case

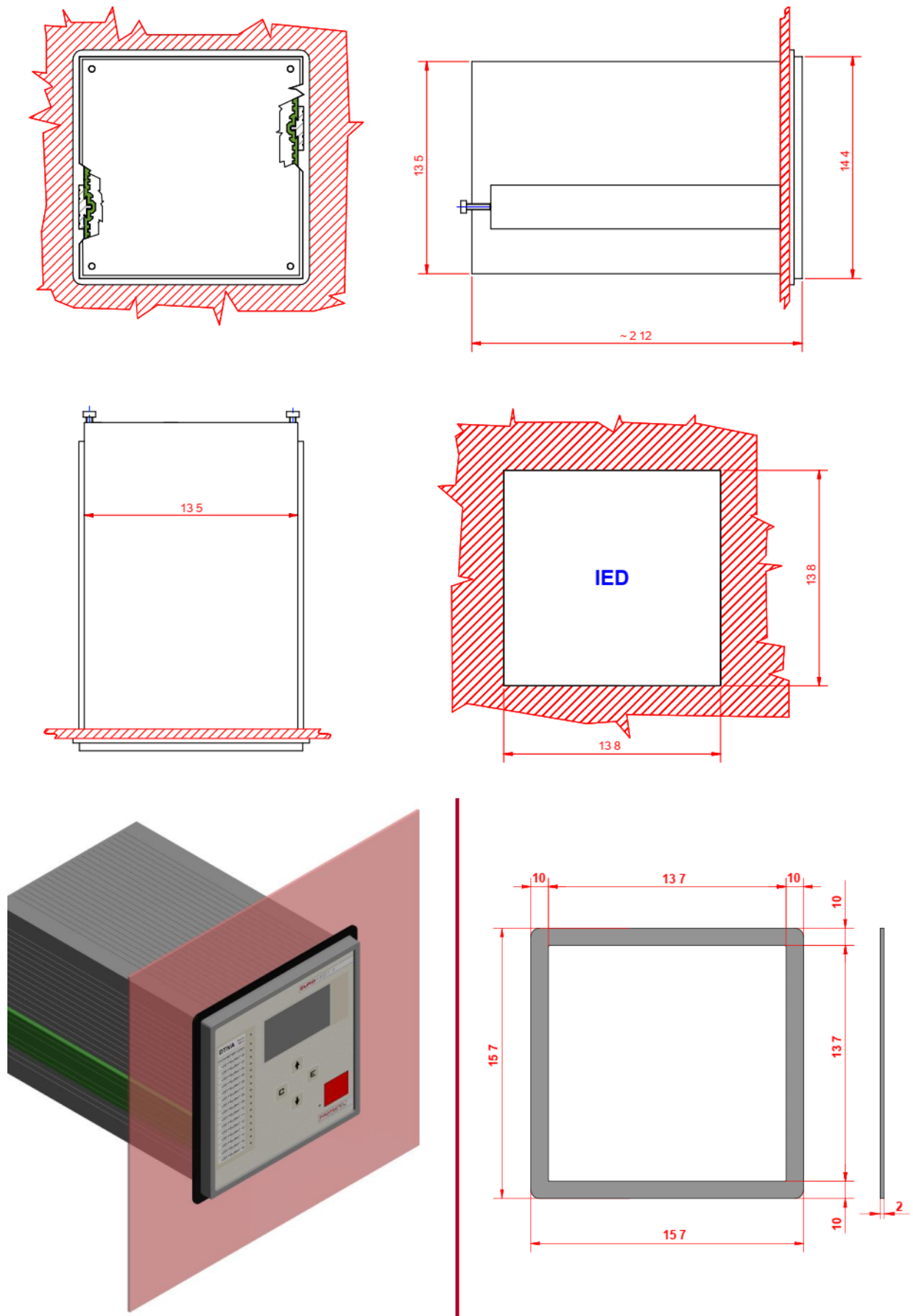


Figure 21-5 Dimensions for flush mounting of 24 HP panel instrument case with 3D illustration

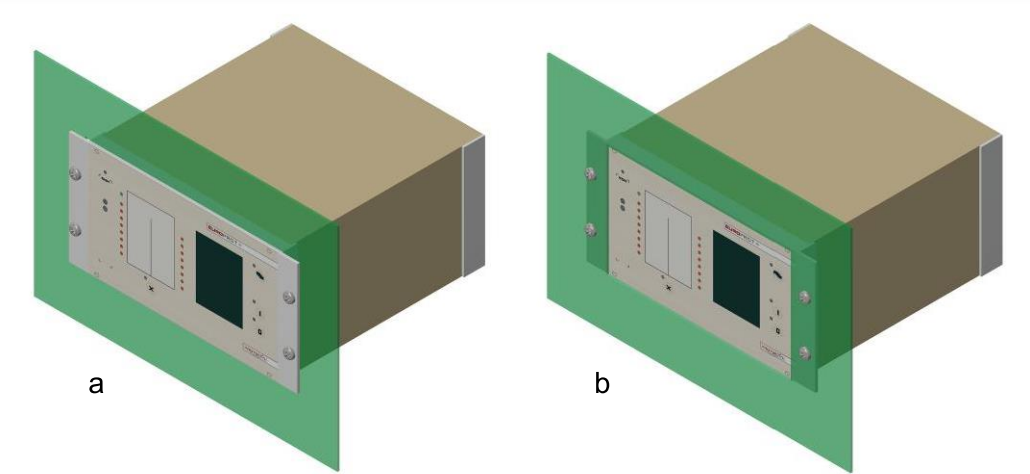


Figure 21-8 3D illustration for rack mounting of 42 HP device (a - from the front; b - from the back)

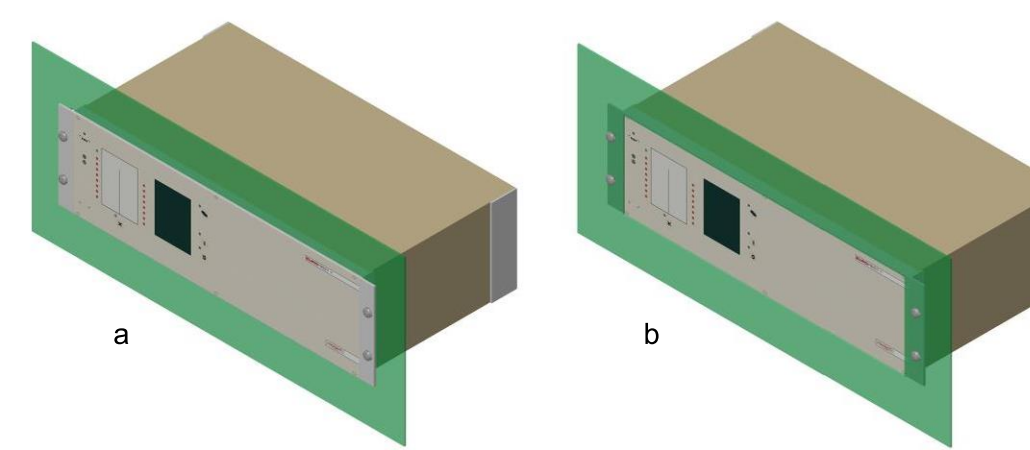


Figure 21-9 3D illustration for rack mounting of 84 HP device (a - from the front; b - from the back)

1.4.21.2.2. Rack mounting of 42 HP double rack

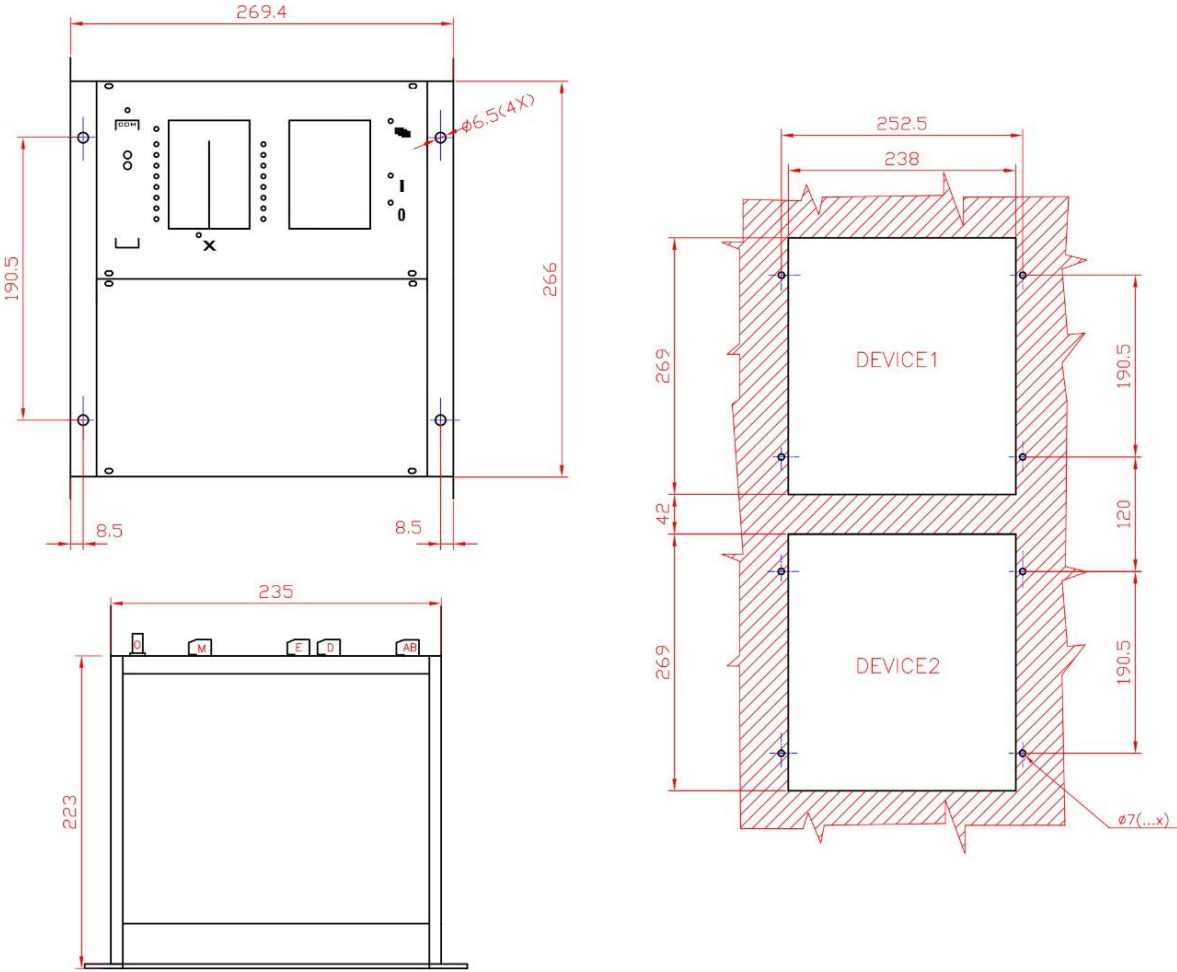


Figure 21-10 Dimensions for rack mounting of 42 HP double rack

1.4.21.3. 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.

1.4.21.3.1. Semi-flush mounting of 84 HP single rack

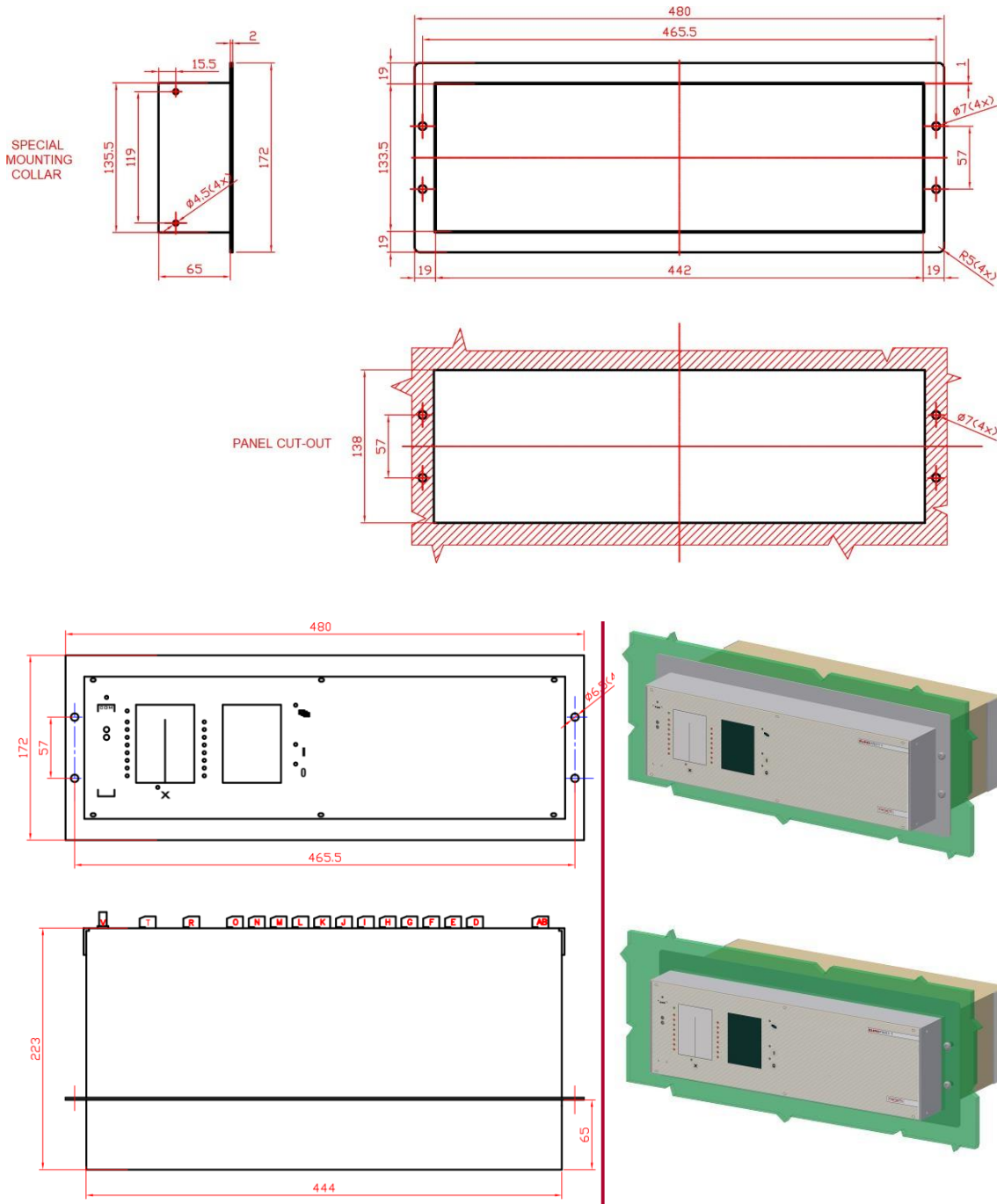


Figure 21-11 Dimensions for semi-flush mounting of 84 HP single rack with 3D illustration

1.4.21.3.2. Semi-flush mounting of 42 HP single rack

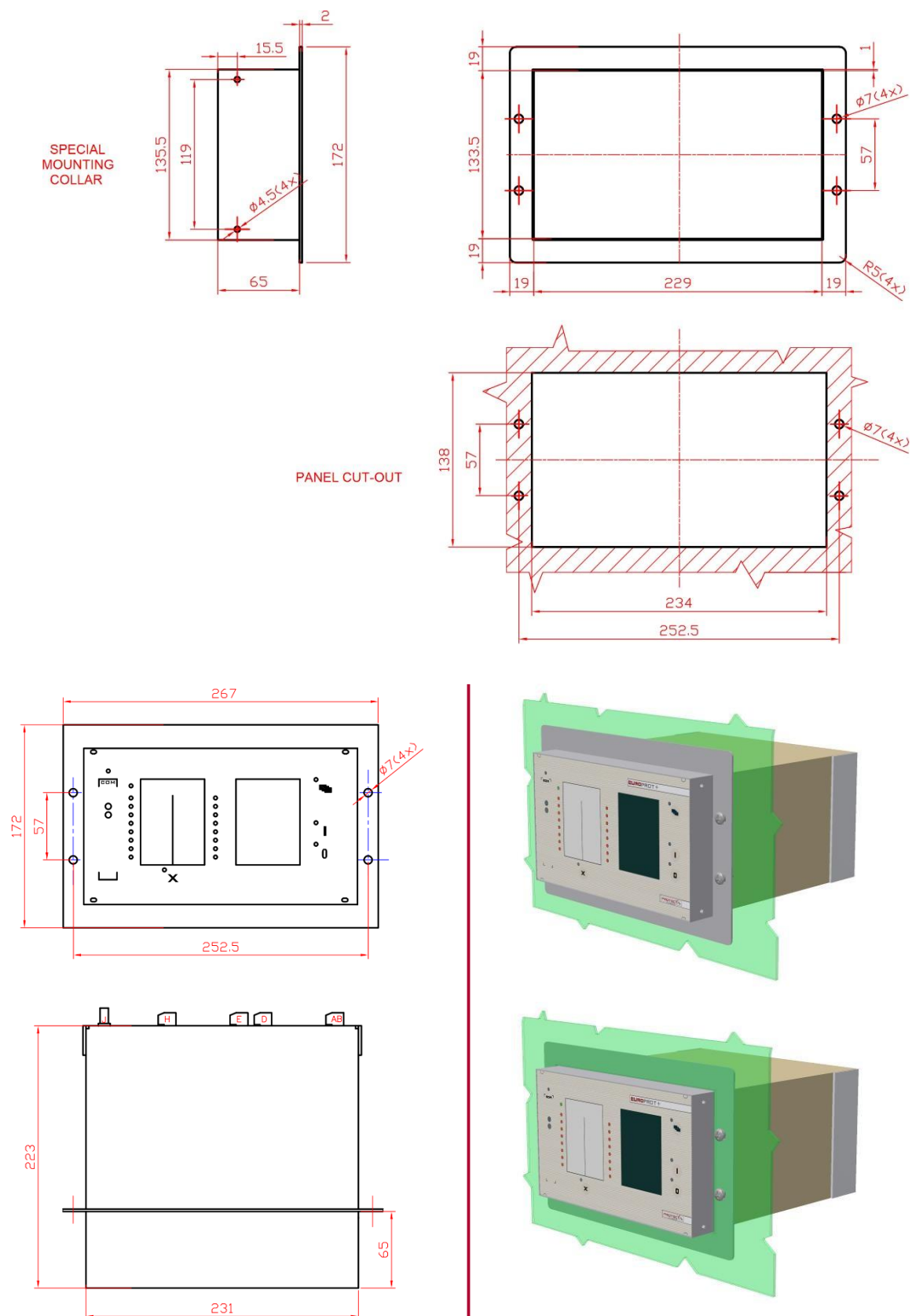
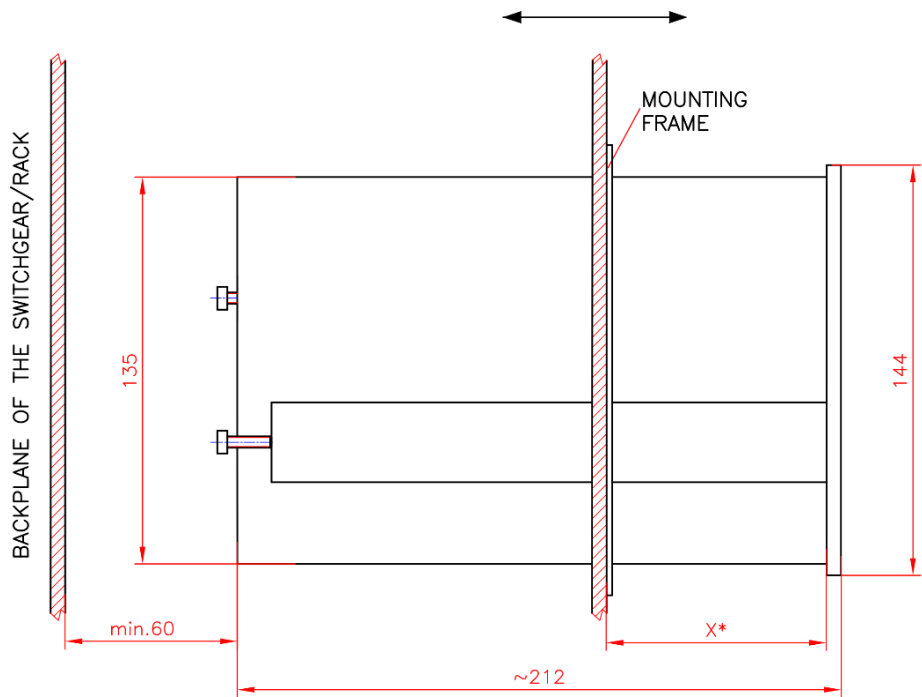


Figure 21-12 Dimensions for semi-flush mounting of 42 HP single rack with 3D illustration

1.4.21.3.3. 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 color in the 3D illustration below) and to make the assembly as shown in the pictures below.

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



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

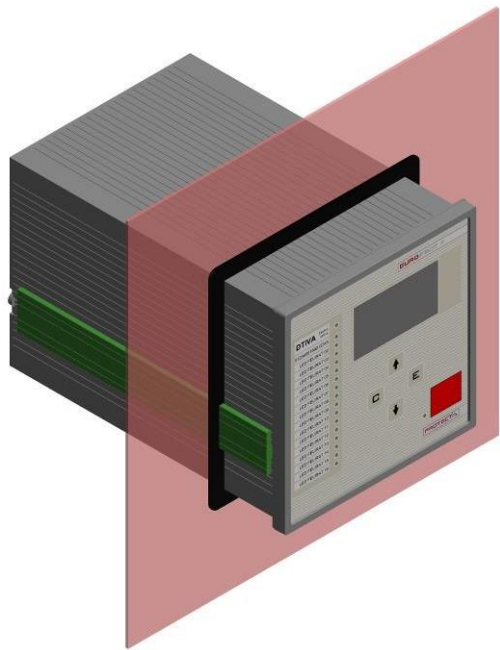


Figure 21-13 Dimensions for semi-flush mounting of 24 HP panel instrument case with 3D illustration

1.4.21.4. Wall mounting of 42 HP and 84 HP devices

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

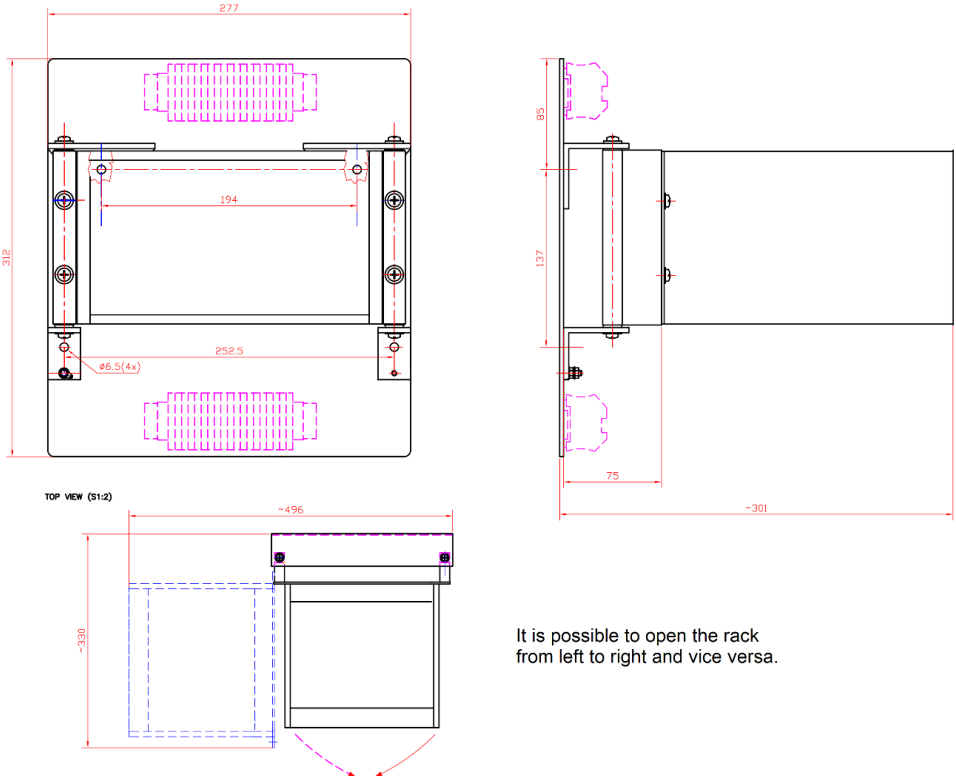


Figure 21-14 Dimensions for wall mounting of 42 HP devices (upper and lower terminals)

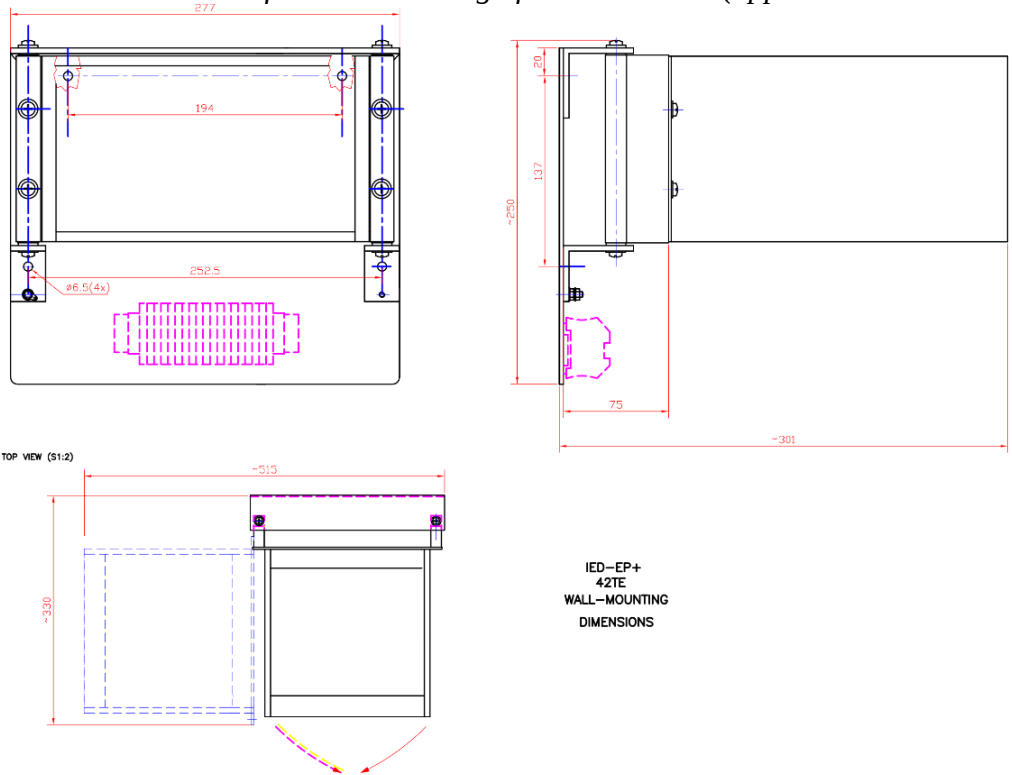


Figure 21-15 Dimensions for wall mounting of 42 HP devices (lower terminal only)

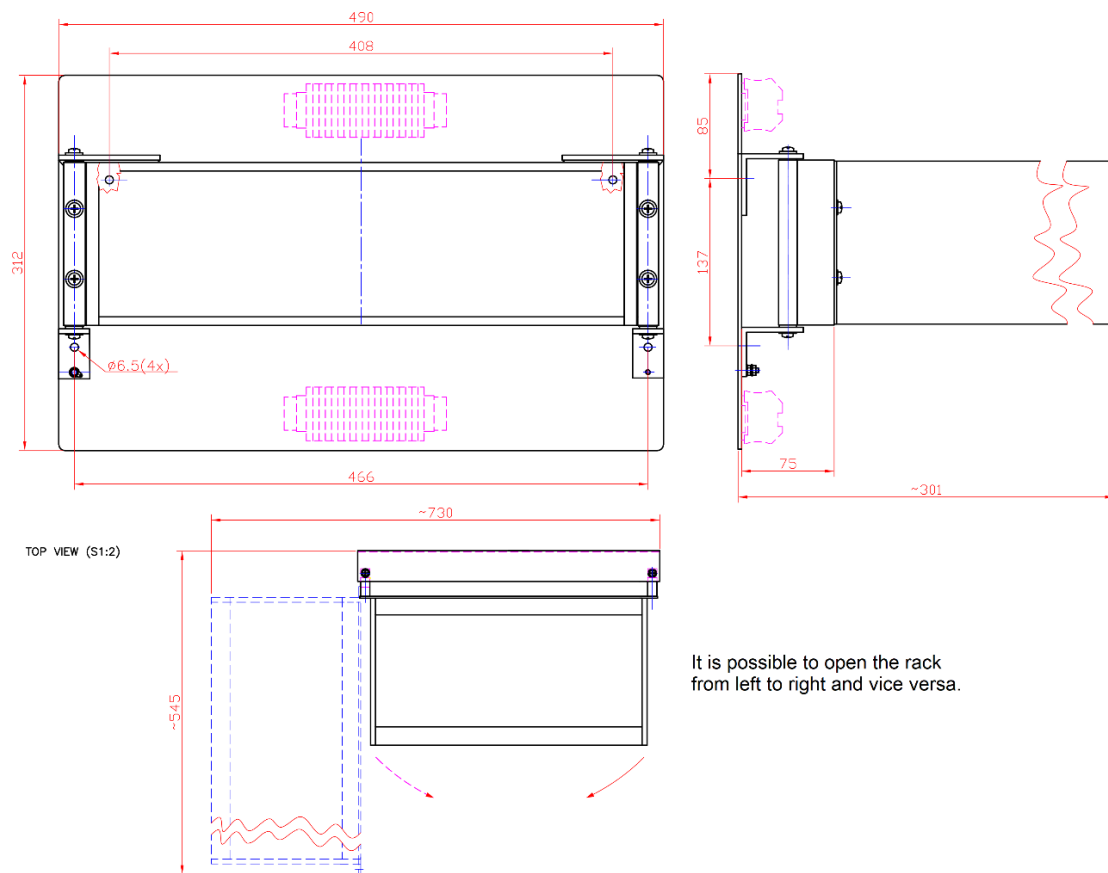


Figure 21-16 Dimensions for wall mounting of 84 HP devices (upper and lower terminals)

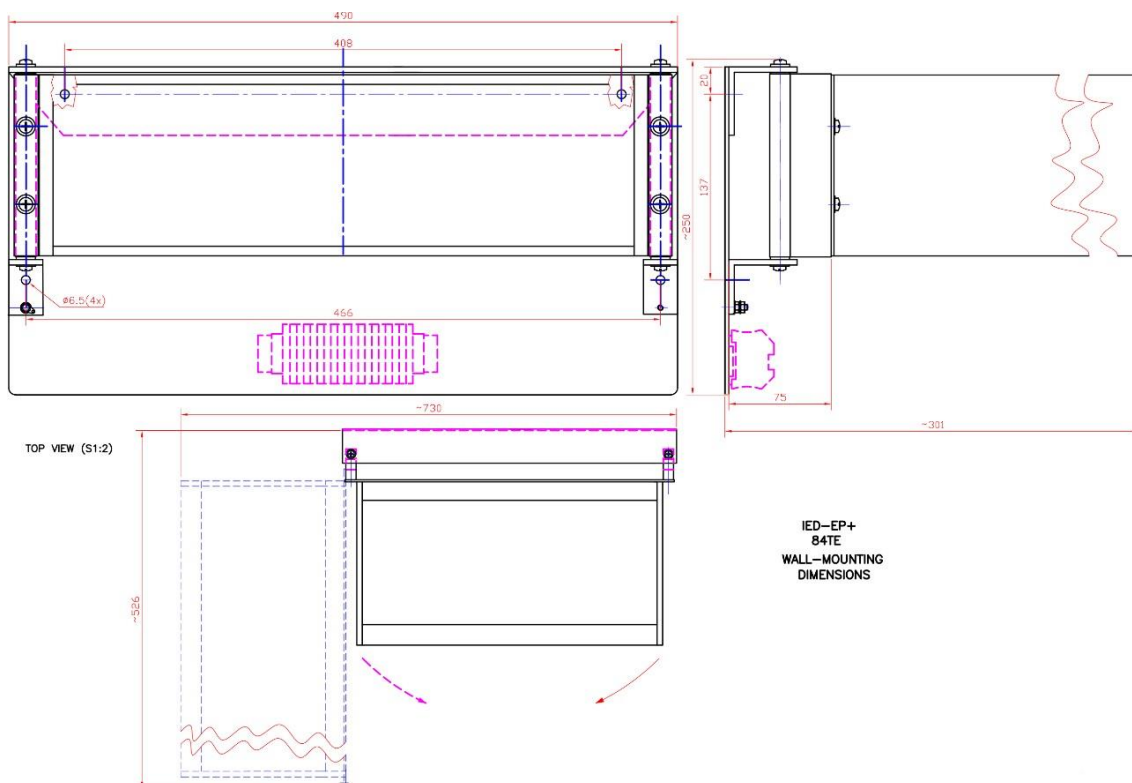


Figure 21-17 Dimensions for wall mounting of 84 HP devices (lower terminals only)

1.4.21.5. Din rail mounting of 24 HP panel instrument case

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

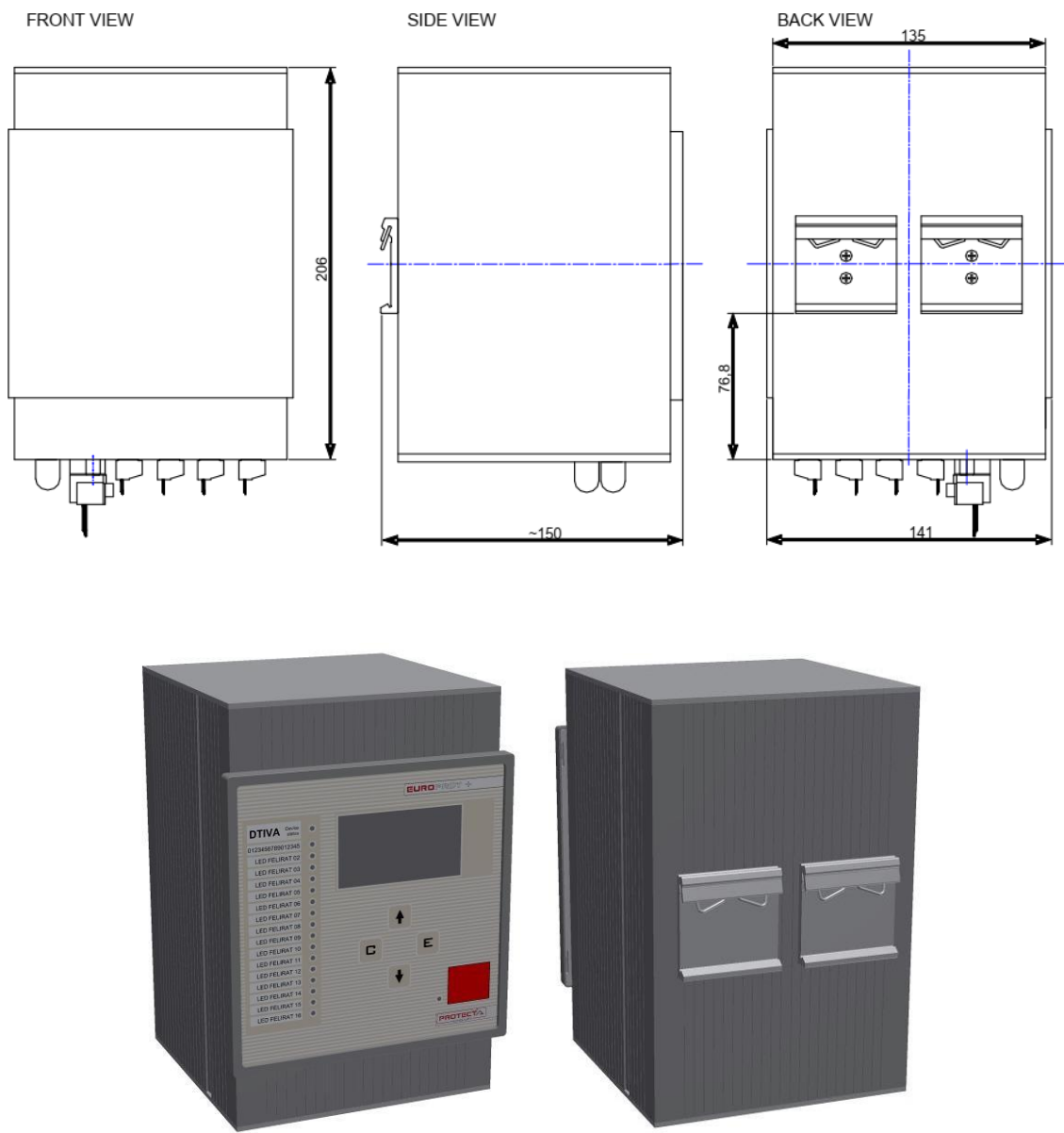


Figure 21-18 Dimensions for din rail mounting of 24 HP panel instrument case

1.4.21.6. IP54 rated mounting kit

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

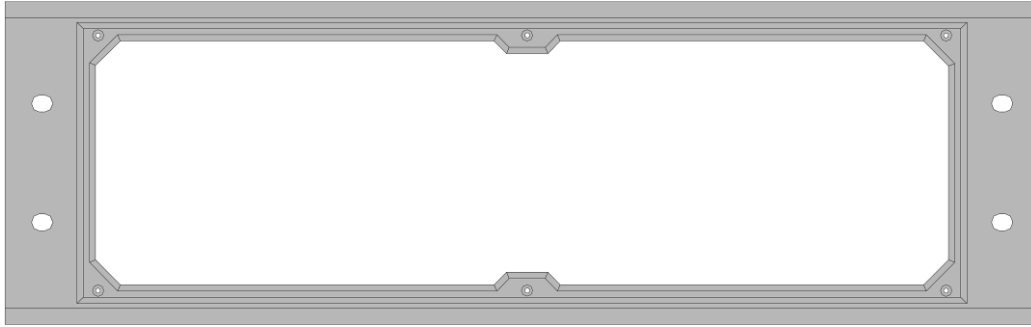


Figure 21-19 84 HP IP frame front view



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!

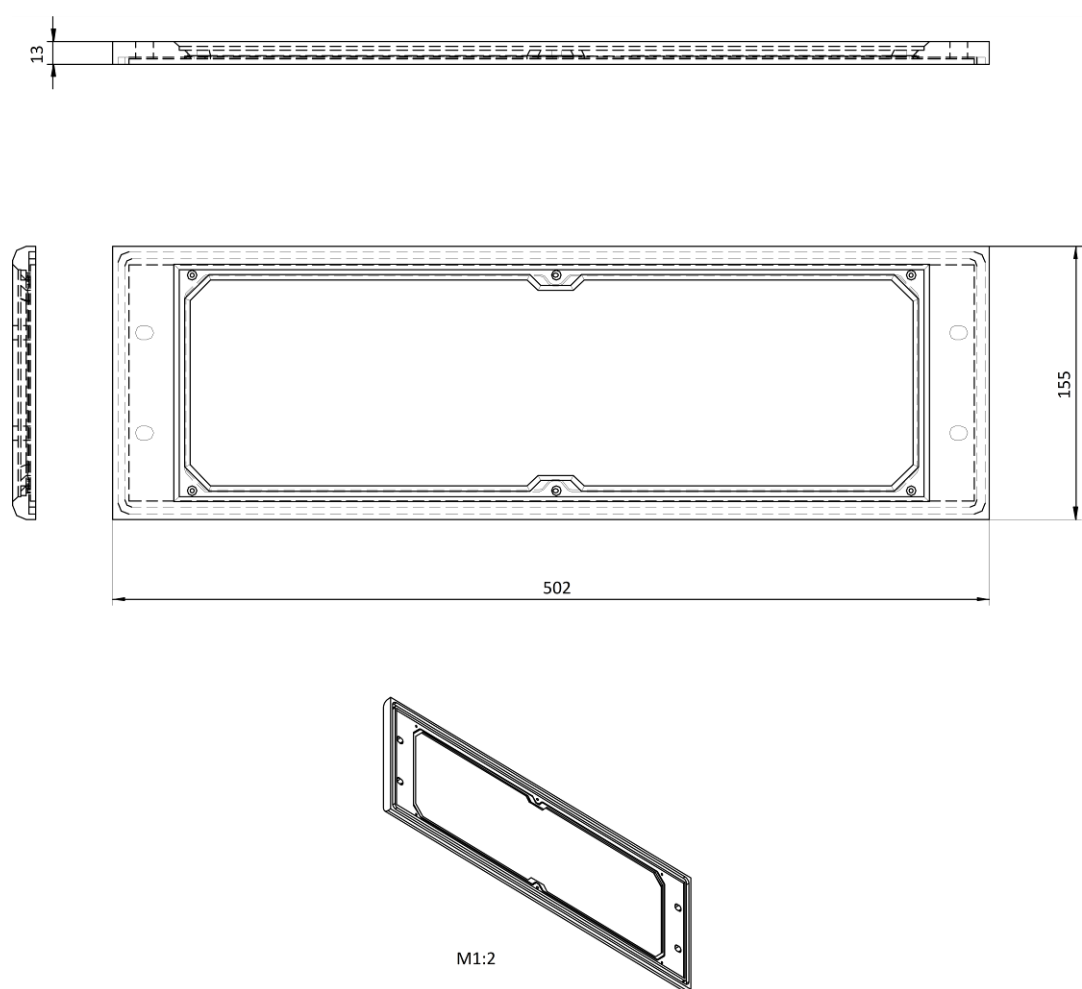


Figure 21-21: 84 HP IP frame dimensions

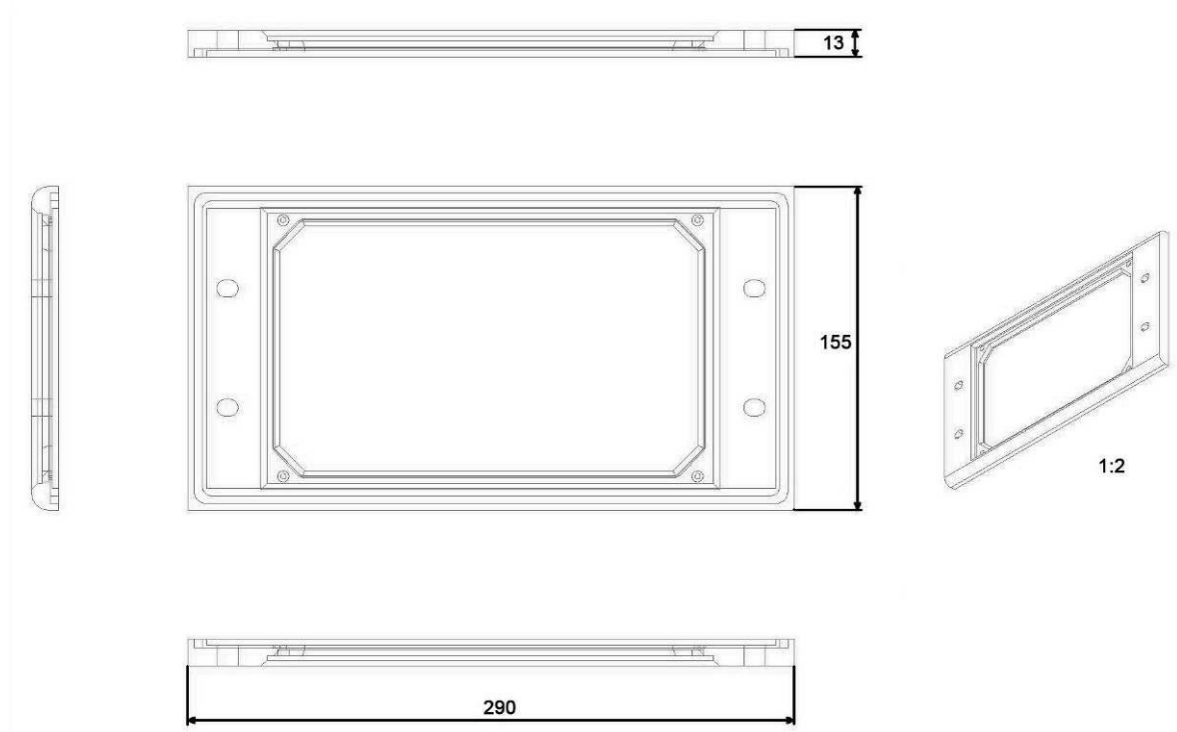


Figure 21-22 42 HP IP frame dimensions

1.4.21.7. Fold-down mounting

1.4.21.7.1. Fold-down mounting without terminals

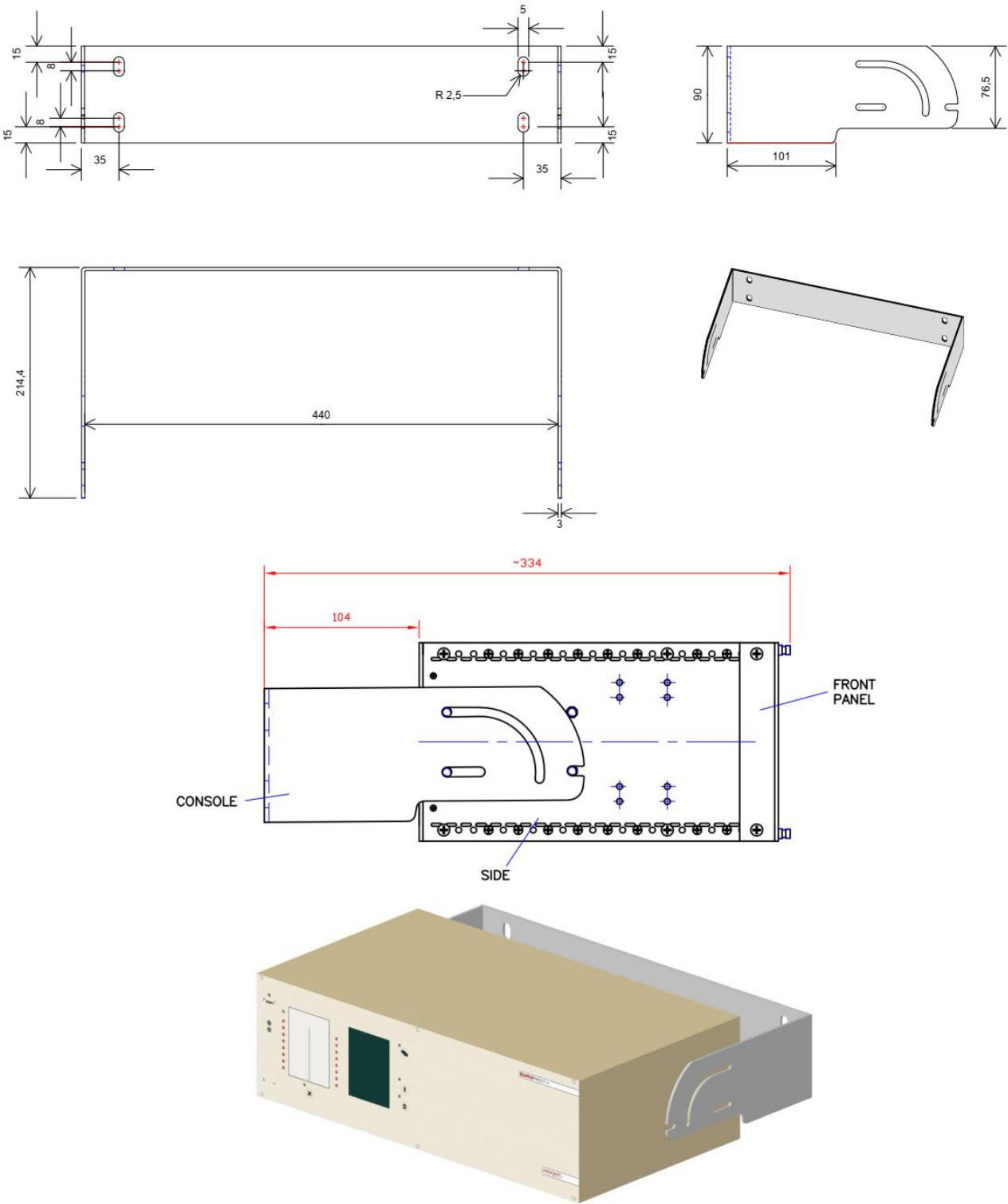


Figure 21-23 84 HP fold-down mounting

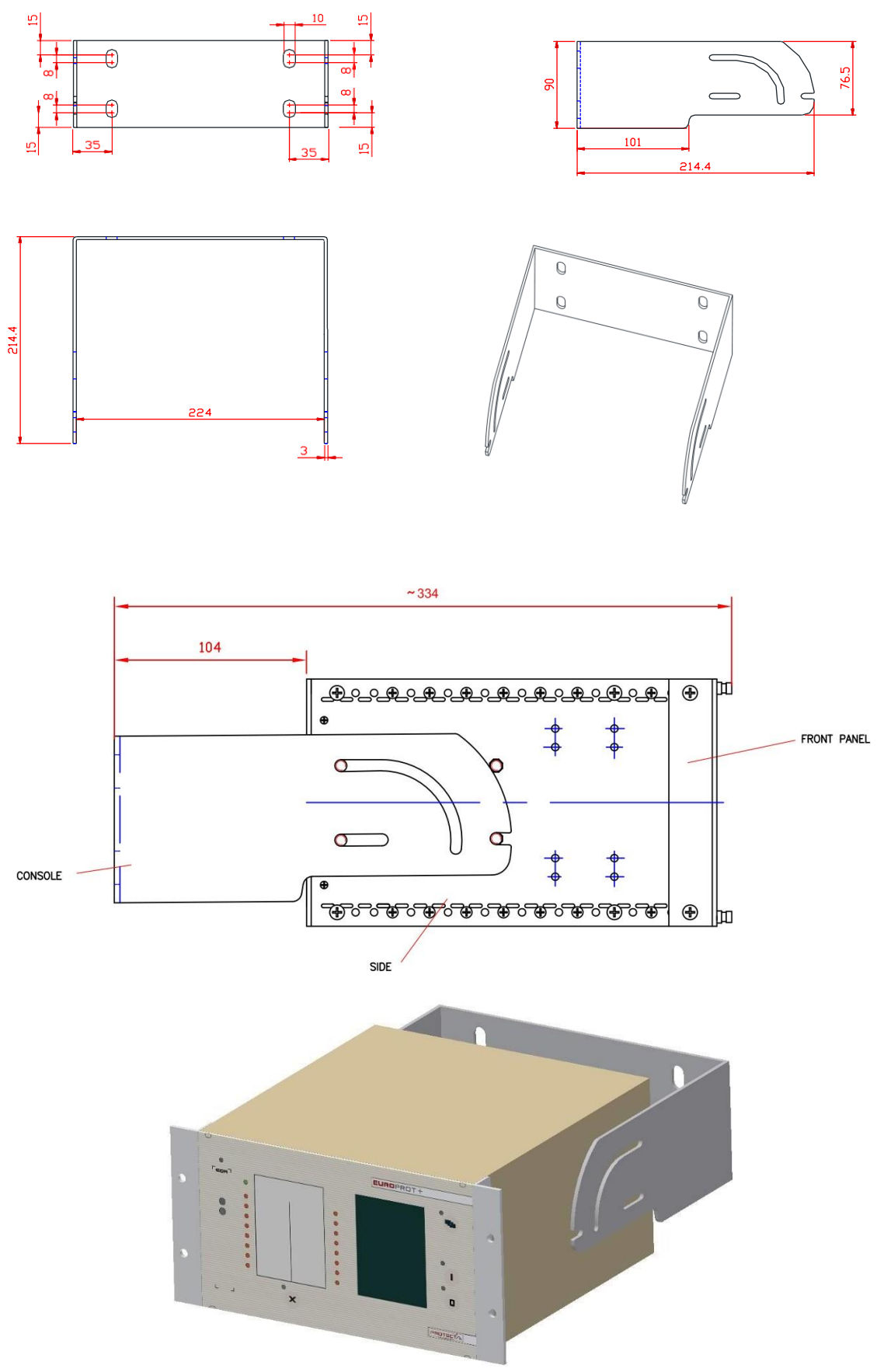


Figure 21-24 42 HP fold-down mounting

1.4.21.7.2. **Fold-down mounting with terminals**

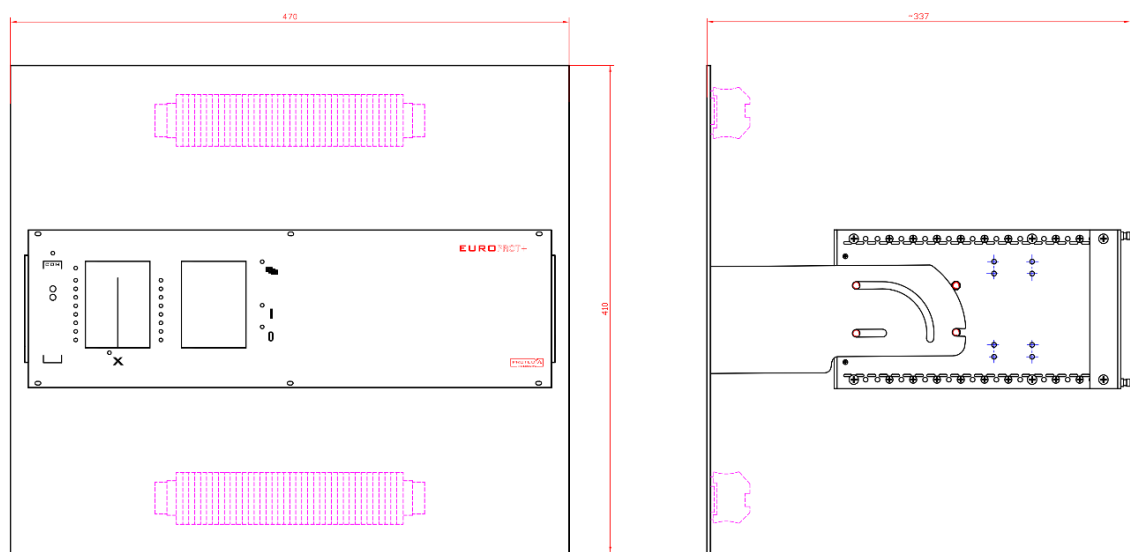


Figure 21-25 Fold-down mounting with terminals for 84HP devices

*Fastening points are customized.

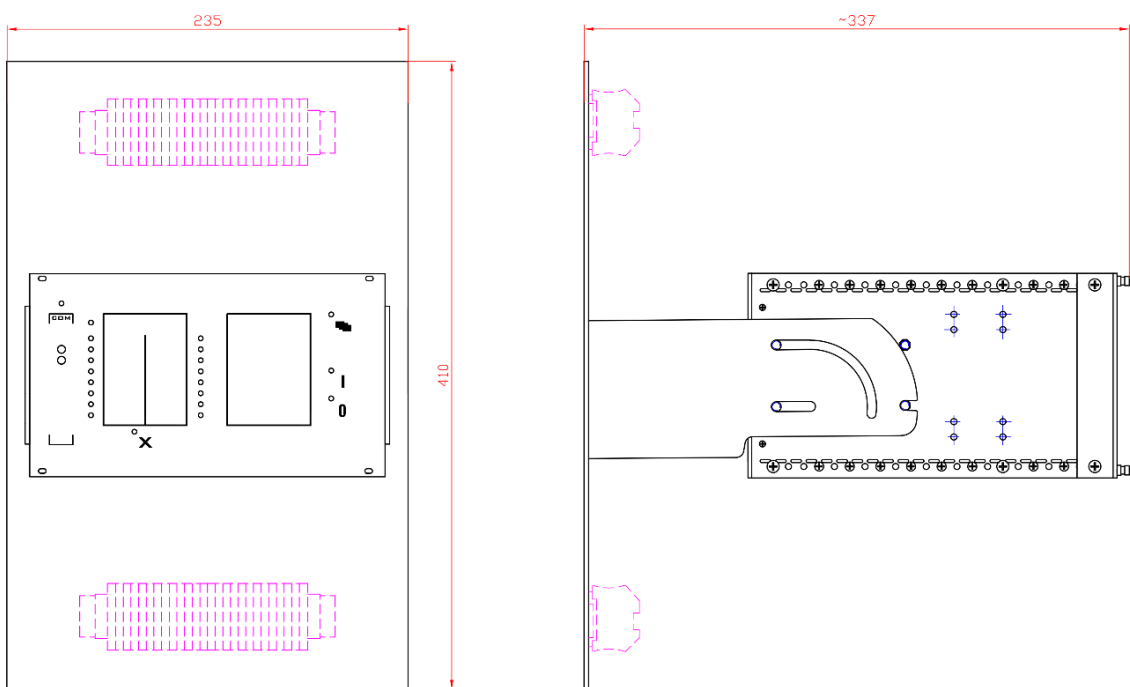
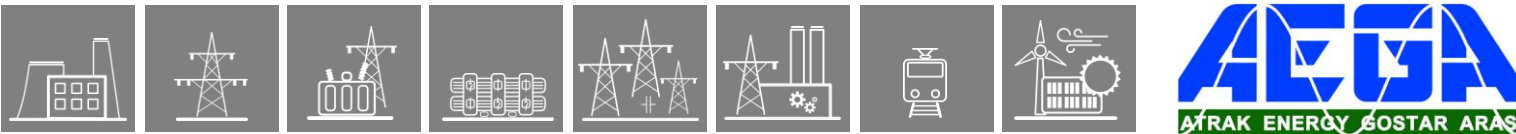


Figure 21-26 Fold-down mounting with terminals for 42HP devices



1.4.21.8. 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)

1.4.21.9. Remote HMI devices

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

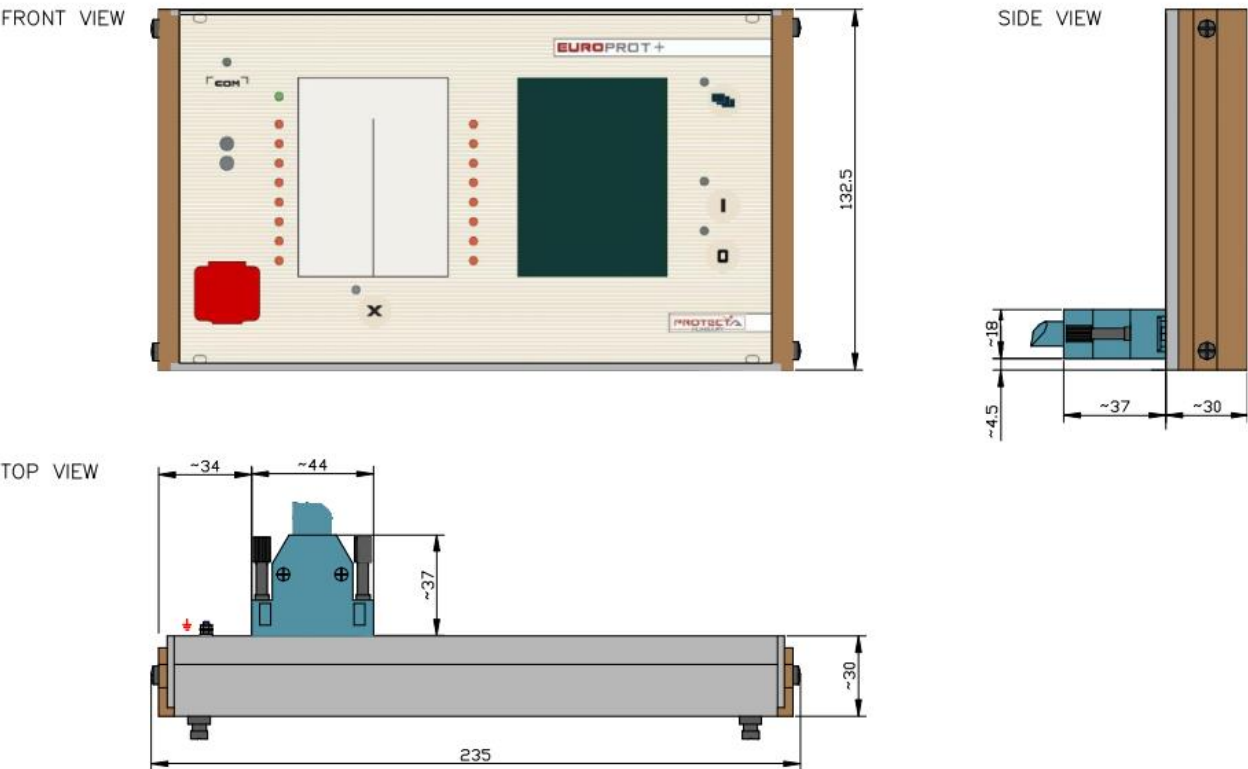


Figure 21-27 Dimensions for 42 HP wide remote HMI

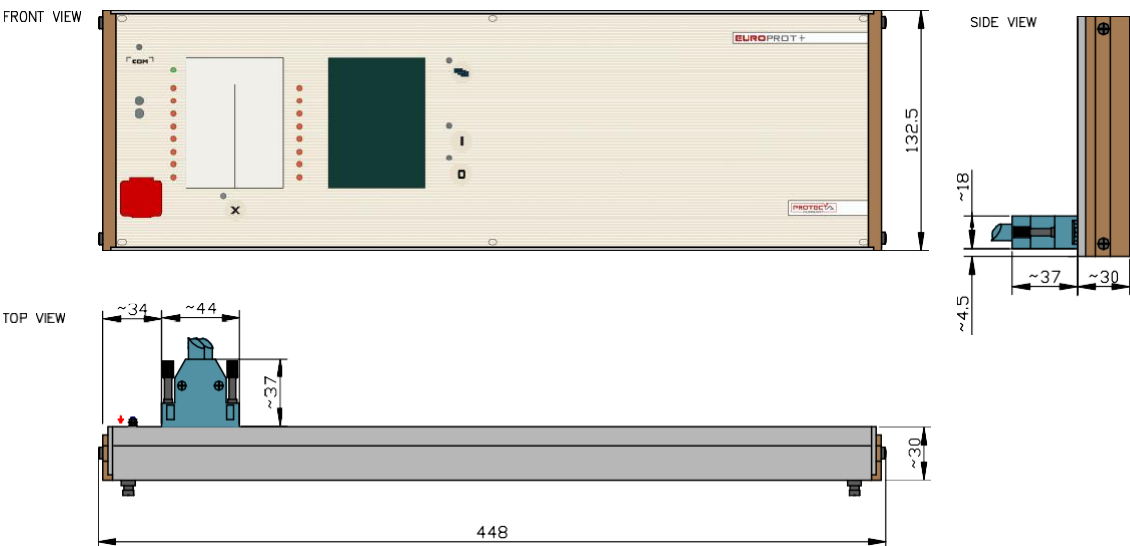
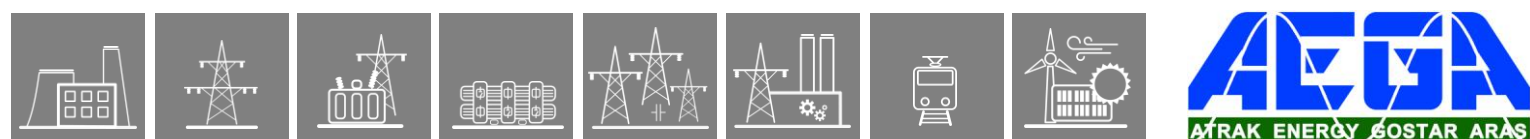


Figure 21-28 Dimensions for 84 HP wide remote HMI



1.4.22. 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:

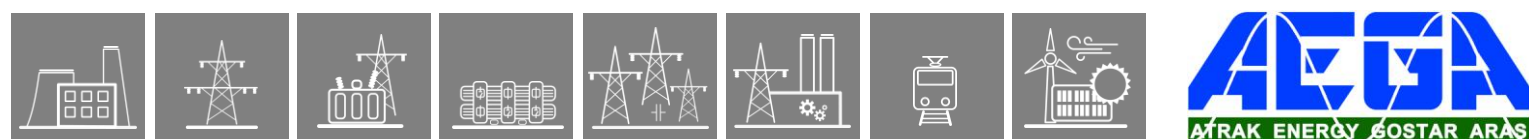
These modules can be ordered in case of special applications which are indicated for each module in its description in the previous chapters.

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
PS3F+/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
F terminal type	Obsolete terminal type. Not recommended for new designs.	2024-05-27
CT+/5101	Obsolete module. Not recommended for new designs.	2024-05-30
CT+/5152	Obsolete module. Not recommended for new designs.	2024-05-30
R8+/01	Obsolete module. Not recommended for new designs.	2024-05-30
R16+/0000	Obsolete module. Not recommended for new designs.	2024-05-30
R16+/8000	Obsolete module. Not recommended for new designs.	2024-05-30
R16+/8080	Obsolete module. Not recommended for new designs.	2024-05-30
CT+/5102	Obsolete module. Not recommended for new designs.	2024-06-03

1.4.22.1. 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.

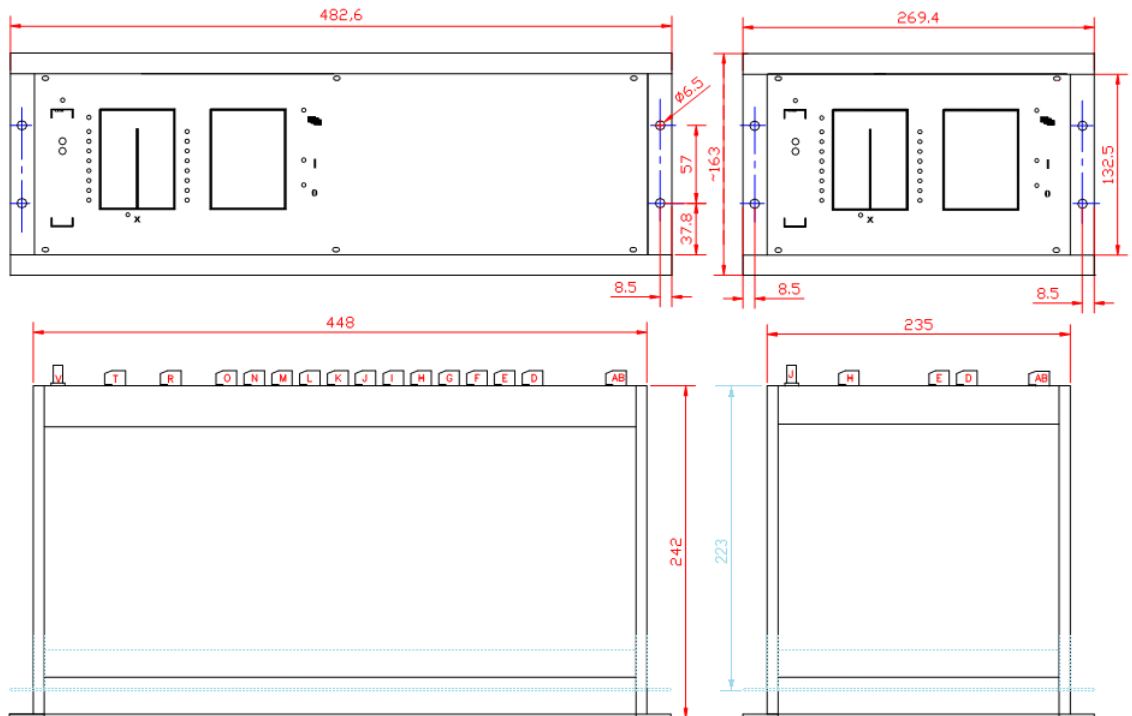


Figure 22-1 Dimensions for flush mounting of the previous 84HP and 42HP single rack, including the new (shorter) rack dimensions as well.

1.4.23. Remote I/O (RIO) server description

1.4.23.1. 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

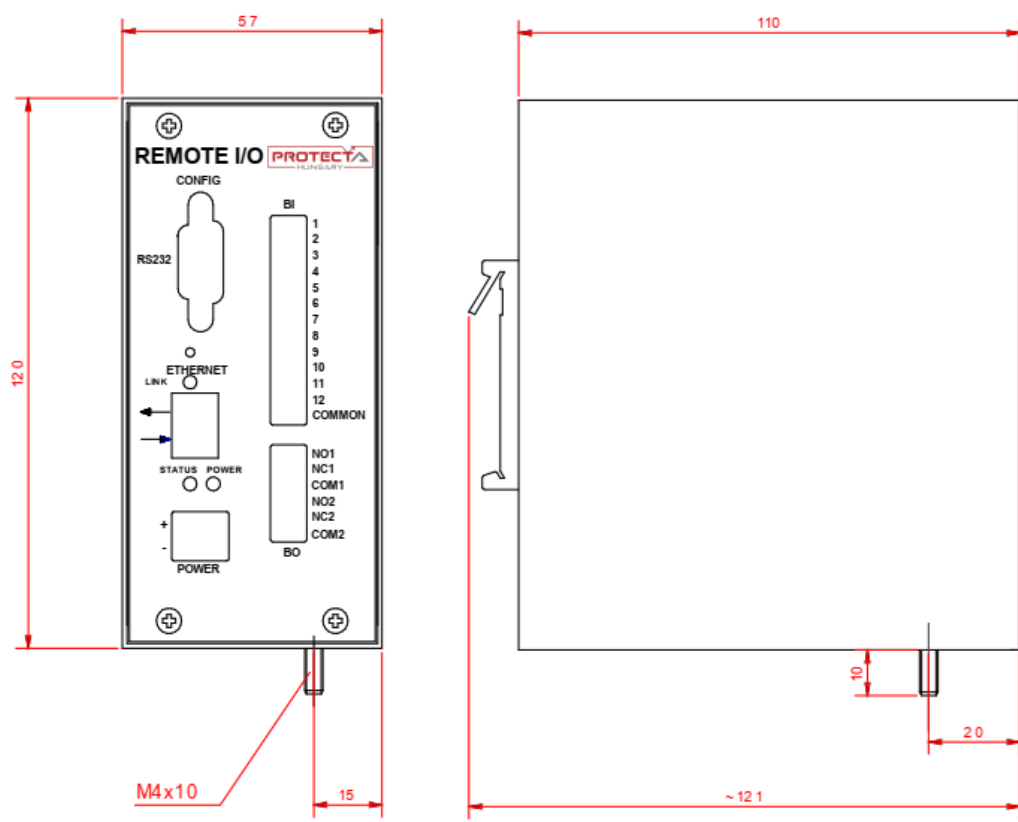
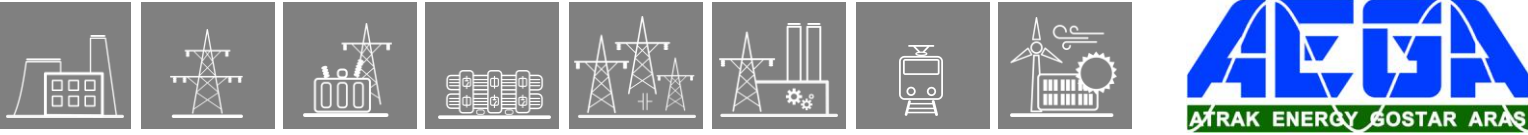


Figure 1-3 Remote I/O dimensions

1.4.23.2. Application

1.4.23.2.1. Connectors, LEDs

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

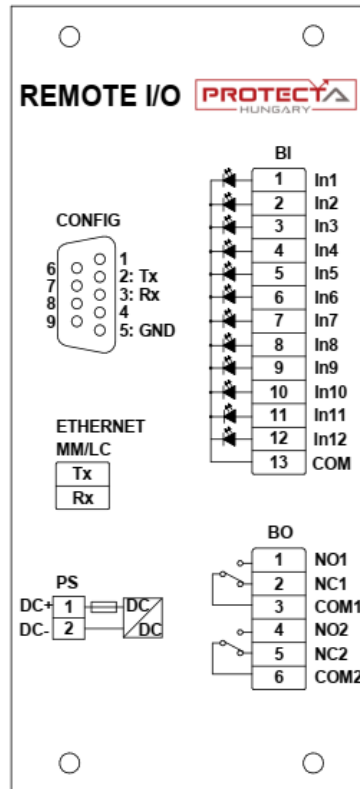


Figure 2-1 Connectors of the device

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

1.4.23.2.2. **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.

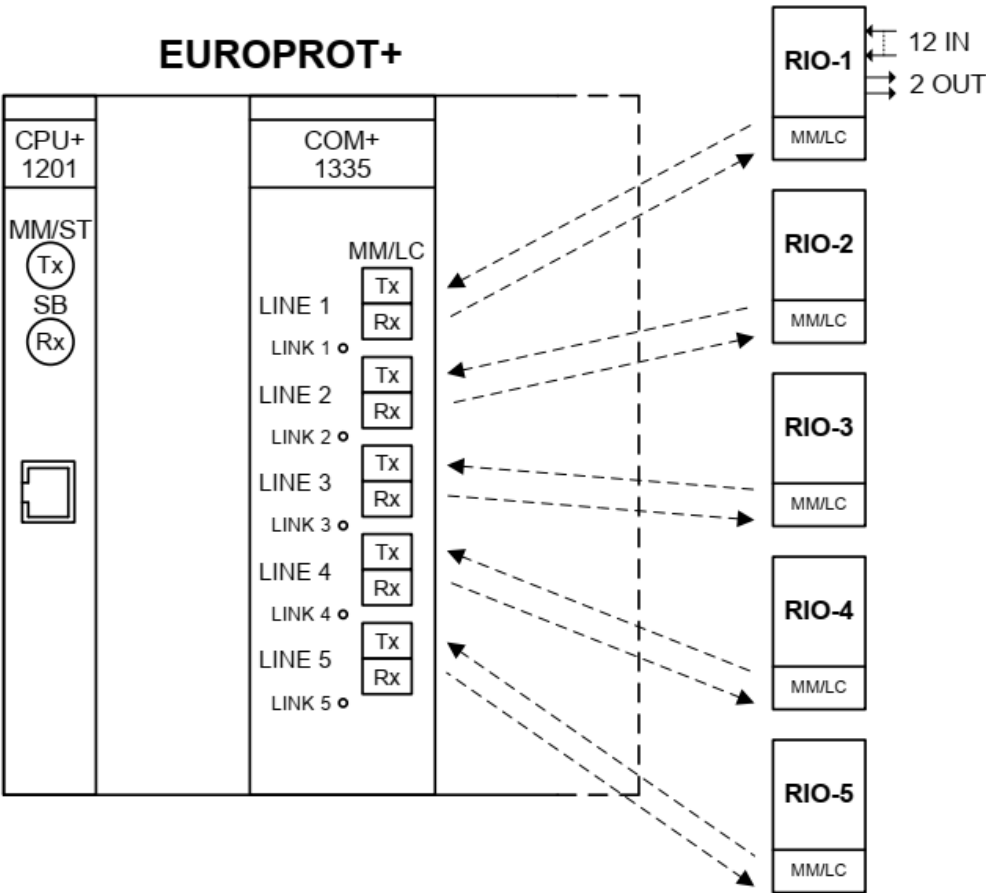


Figure 2-2 Wiring of the Remote I/O-s

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.

1.4.23.3. 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

1.4.23.3.1. SCPU/PS sub-module

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

1.4.23.3.1.1. 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

1.4.23.3.1.2. 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**

1.4.23.3.2. SO12/R2 sub-module

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

1.4.23.3.2.1. 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.

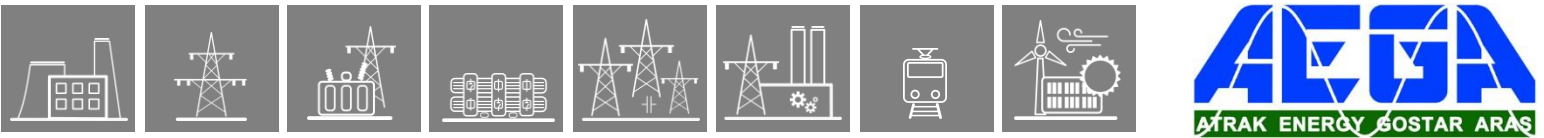
1.4.23.3.2.2. Binary outputs

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



1.4.23.4. General data

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

1.4.23.4.1. Standard conformance

- Electrostatic discharge immunity (ESD), IEC-EN 60255-26:2013, Level 4
 - Test voltages: 15 kV air discharge, 8 kV contact discharge
- Radiated, radio-frequency, electromagnetic field immunity, IEC-EN 60255-26:2013 Level 3
 - Test field strength: 10 V/m
- Electrical fast transient/burst immunity (EFT/B), IEC-EN 60255-26:2013, Level 4
 - Test voltage: 4 kV
- Surge immunity test, IEC-EN 60255-26:2013
 - Test voltages: 2 kV line-to-earth, 1 kV line-to-line
- Immunity to conducted disturbances, induced by radio-frequency fields, IEC-EN 60255-26:2013, Level 3
 - Test voltage: 10 V
- Damped oscillatory wave immunity test, IEC-EN 60255-26:2013
 - Test frequency: 1 MHz
 - Test voltage: 2.5 kV in common mode, 1 kV in differential mode
- Voltage dips, short interruptions and voltage variations immunity, IEC-EN 60255-26:2013
 - Voltage dips: 40 % (200 ms), 70 % (500 ms), 80 % (5000 ms)
- Ripple on d.c. input power port immunity, IEC-EN 60255-26:2013
 - Level 4, 15 % of rated d.c. value
- Power frequency magnetic field immunity test, IEC-EN 60255-26:2013, Level 5
 - Test field strength: 100 A/m continuous, 1000 A/m for 3 s
- Power frequency immunity test on the binary inputs, IEC-EN 60255-26:2013, Class A
 - Test voltages: 300 V in common mode, 150 V in differential mode
- Insulation tests, IEC-EN 60255-27:2013
 - Impulse voltage test
 - Test levels: 5 kV (1 kV for transducer and temperature measuring inputs)
 - Dielectric test
 - Test levels: 2 kV AC 50 Hz (0.705 kV DC for transducer inputs)
 - Insulation resistance
 - Insulation resistance > 15 GΩ
- Radiated emission, IEC-EN 60255-26:2013
 Limits:

• 30 MHz to 230 MHz:	50 dB(μV/m) quasi peak, 3 m
• 230 MHz to 1 000 MHz:	57 dB(μV/m) quasi peak, 3 m
• 1 GHz to 3 GHz:	76 dB(μV/m) peak, 3 m
• 3 GHz to 6 GHz:	80 dB(μV/m) peak, 3 m
- Conducted emission, IEC-EN 60255-26:2013
 Limits:

• 0,15 MHz to 0,50 MHz:	79 dB(μV) quasi peak, 66 dB(μV) average
• 0,5 MHz - 30 MHz:	73 dB(μV) quasi peak, 60 dB(μV) average
- Vibration, shock, bump and seismic tests on measuring relays and protection equipment
 - Vibration tests (sinusoidal), Class I, IEC 60255-21-1:1988
 - Shock and bump tests, Class I, IEC 60255-21-2:1988
 - Seismic tests, Class I, IEC 60255-21-3:1993

1.4.23.5. Mechanical data

1.4.23.5.1. General mechanical data

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

1.4.23.5.2. 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.

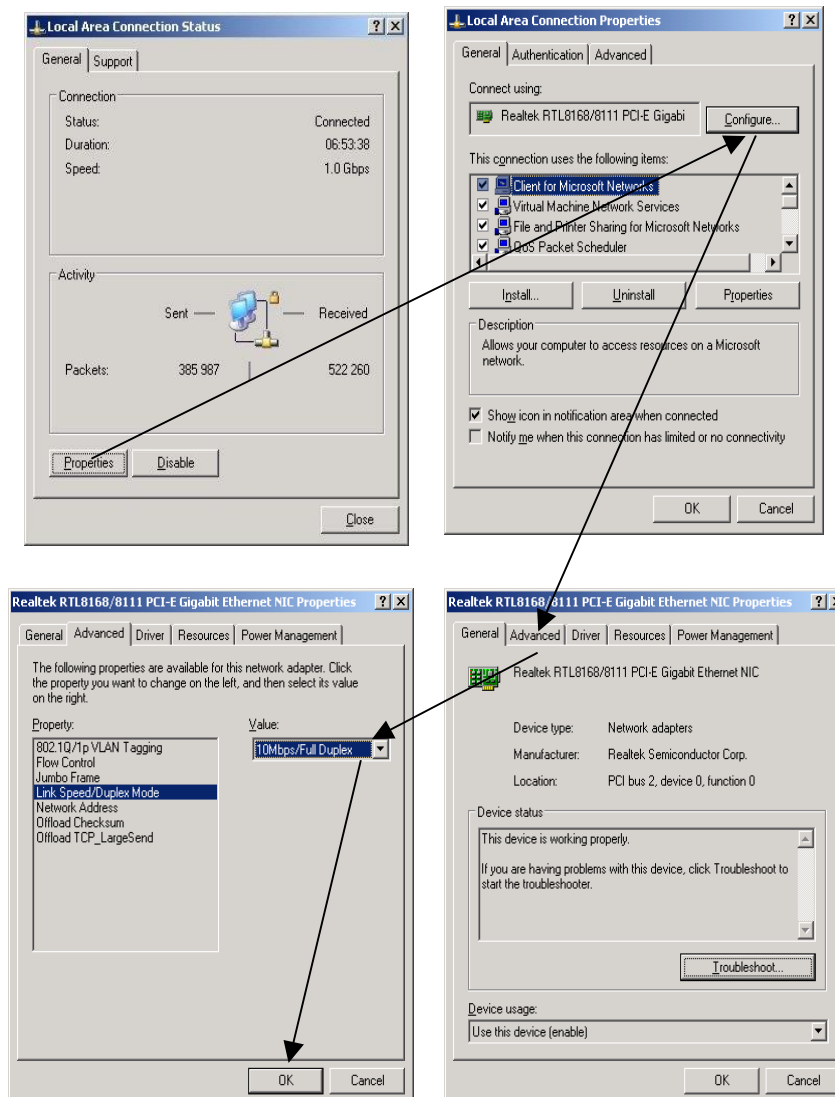
1.4.24. Technical notes on EOB interoperability

1.4.24.1. Description

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

1.4.24.2. EOB Troubleshooting

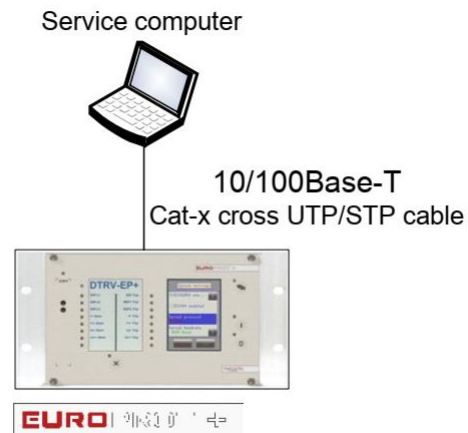
- force NIC speed and mode to 10Base-T Full-duplex (setting method may depend on Your PC hardware configuration) on Your PC. Local Area Network settings can be found at:
 - WindowsXP: Control Panel/Network Connections/Local Area Connection
 - Windows 7: Control Panel\All Control Panel Items\Network and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



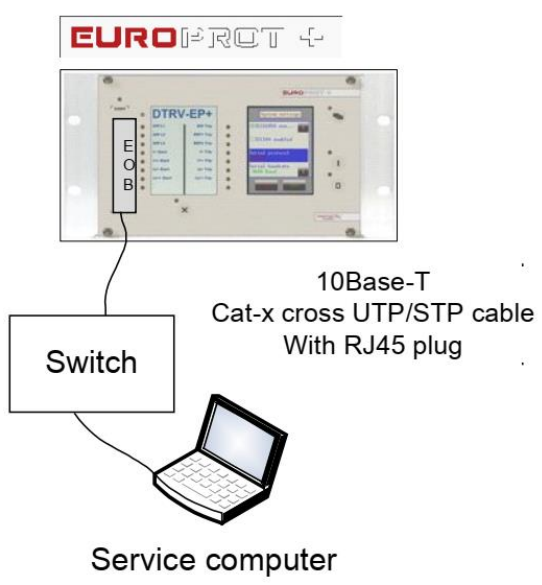
1.4.24.3. Workaround

- 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.



1.4.24.4. Further details

For getting started guide and IP configuration download: <http://www.protecta.hu/epp-prelim/QuickStart/Quick Start Guide V1.0.pdf>

1.4.25. EP+ Installation manual

USED SYMBOLS

Symbols on devices:



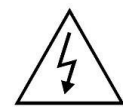
Test voltage: 2 kV



Protective conductor terminal



Do not dispose of this device



Caution, risk of electric shock



Caution, hot surface



Caution, refer to the documentation



Do not dispose of this device

1.4.25.1. 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.

1.4.25.2. Equipment handling

1.4.25.2.1. Unpacking

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

1.4.25.2.2. 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.

1.4.25.2.3. 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.

1.4.25.3. Mounting

1.4.25.3.1. Tools for mounting

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

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

1.4.25.3.2. 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).

1.4.25.3.3. Mounting location

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

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

1.4.25.3.4. 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.

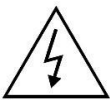
1.4.25.3.5. Safety aspects

1.4.25.3.5.1. Earth connections

1.4.25.3.5.1.1. Protective earth

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

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



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

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



1.4.25.3.5.1.2. 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.

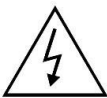
1.4.25.3.5.1.3. Cable screen connection

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



1.4.25.3.5.1.4. CT and VT circuits

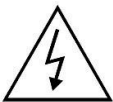


The CT and VT circuits to be connected to the device shall be connected to the station earth system.

1.4.25.3.5.1.5. 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.

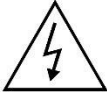
1.4.25.3.5.2. Optical ports



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.

1.4.25.3.5.3. 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.

1.4.25.4. Wiring

1.4.25.4.1. 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.

C

1.4.25.4.2. **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.

1.4.25.5. **Deinstallation and Repair**

1.4.25.5.1. **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.

1.4.25.5.2. **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.

1.4.25.5.3. **Disposal**



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

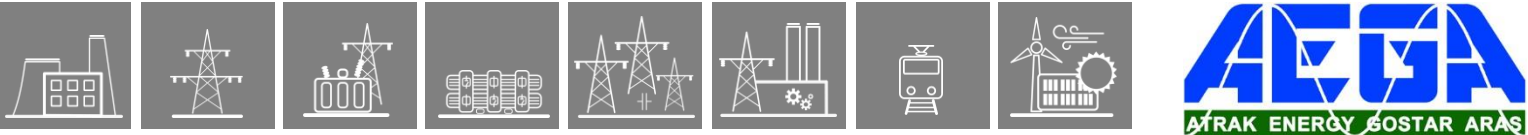
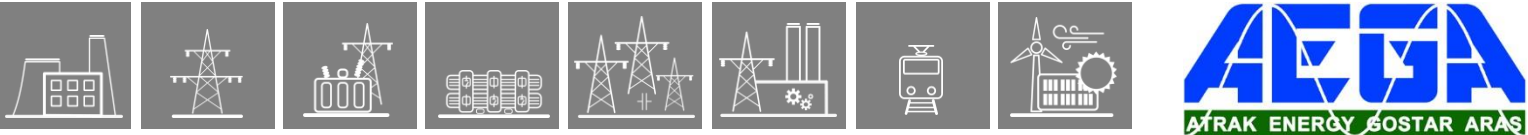


Table 5-3 Disposal of the components and parts

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



2. Function and I/O listing

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

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

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

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

Table 2-1 Basic functionality and I/O

3. Software configuration

3.1. Protection functions

The E1-TR configuration measures three phase currents and the zero sequence current component from both sides of a two winding, three-phase transformer.

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

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

Protection functions	IEC	ANSI	E1-TR
Three-phase instantaneous overcurrent protection	$I >>>$	50	X
Three-phase time overcurrent protection	$I >, I >>$	51	X
Residual instantaneous overcurrent protection	$I_0 >>>$	50N	X
Residual time overcurrent protection	$I_0 >, I_0 >>$	51N	X
Negative sequence overcurrent protection	$I_2 >$	46	X
Thermal protection	$T >$	49	X
Transformer differential	$3I_d T >$	87T	2w
Restricted earth fault	REF	87N	X
Current unbalance protection		60	X
Breaker failure protection	CBFP	50BF	X

Table 1 The protection functions of the E1-TR configuration

The configured functions are drawn symbolically in the Figure below.

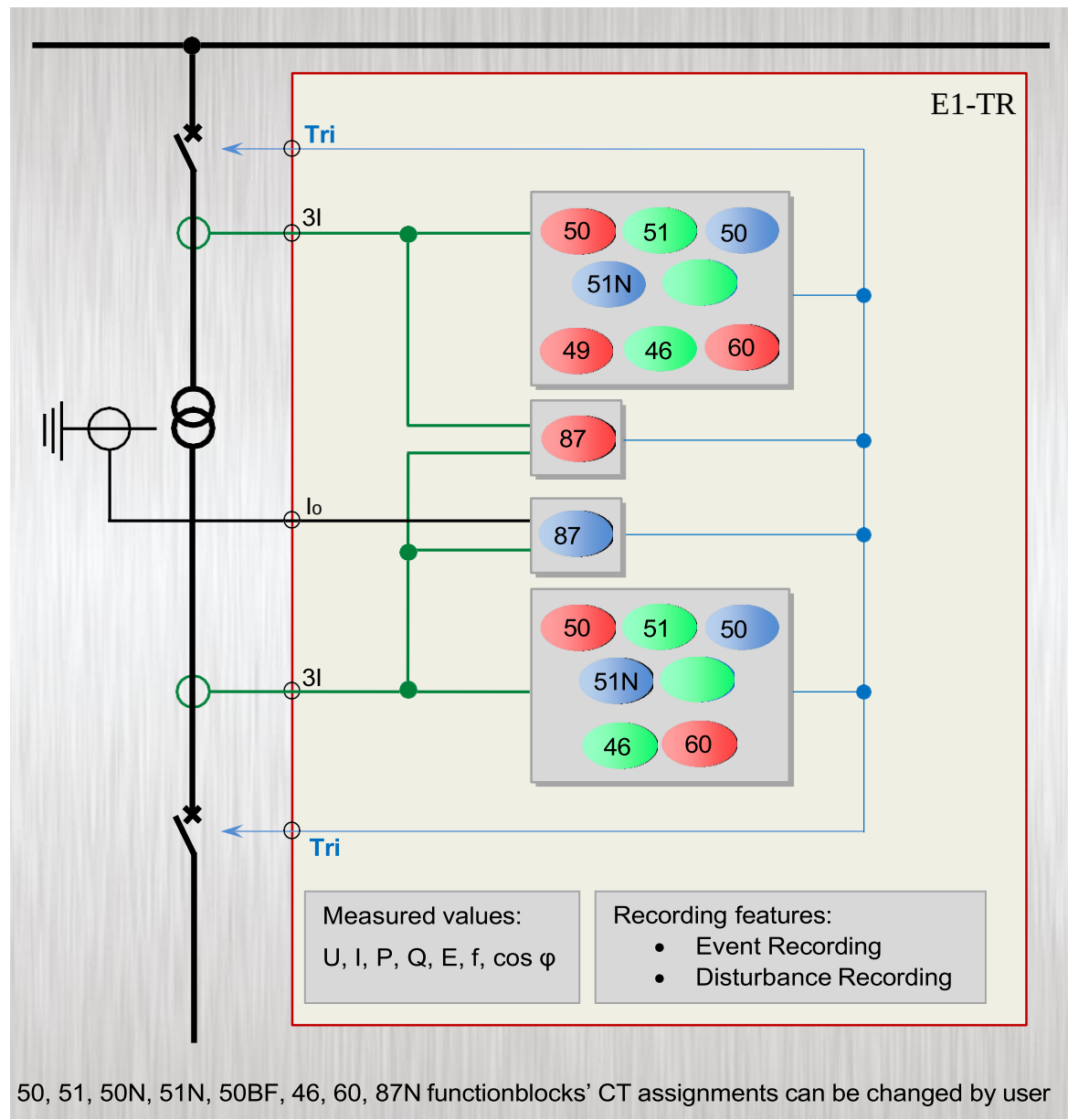


Figure 1 Implemented protection functions

3.1.1. 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.

3.1.1.1. Operating characteristics

3.1.1.1.1. Definite time characteristic

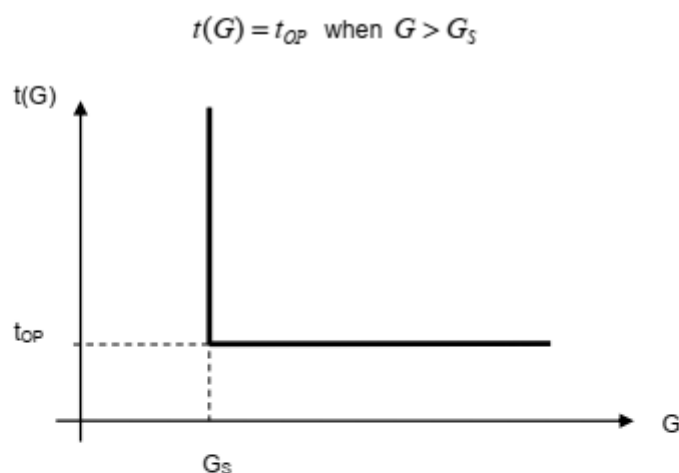


Figure 1-1 Overcurrent definite time characteristic

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

3.1.1.1.2. 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 constant characterizing the selected curve (no dimension),
 G measured value of the characteristic quantity, Fourier base harmonic of the negative sequence current (INFour),
 G_s preset value of the characteristic quantity (TOC46_StCurr_IPar_, Start current),
 TMS preset time multiplier (no dimension).

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

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

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

$$G_D = 20 * G_s$$

Above this value the theoretical operating time is definite:

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

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

Resetting characteristics:

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

where

$t_r(G)$ (seconds)

k_r

α

G

G_s

TMS

theoretical reset time with constant value of G ,

constants characterizing the selected curve (in seconds),

constant characterizing the selected curve (no dimension),

measured value of the characteristic quantity, Fourier base harmonic of the phase current,

preset starting value of the characteristic quantity (TOC51_StCurr_IPar_, Start current),

preset time multiplier (no dimension).

	IEC ref		k_r	α
1	A	IEC Inv	Resetting after fix time delay, according to preset parameter TOC46_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 TOC46_MinDel_TPar_ (Min. Time Delay).

3.1.1.2. Structure of the negative sequence overcurrent protection algorithm

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

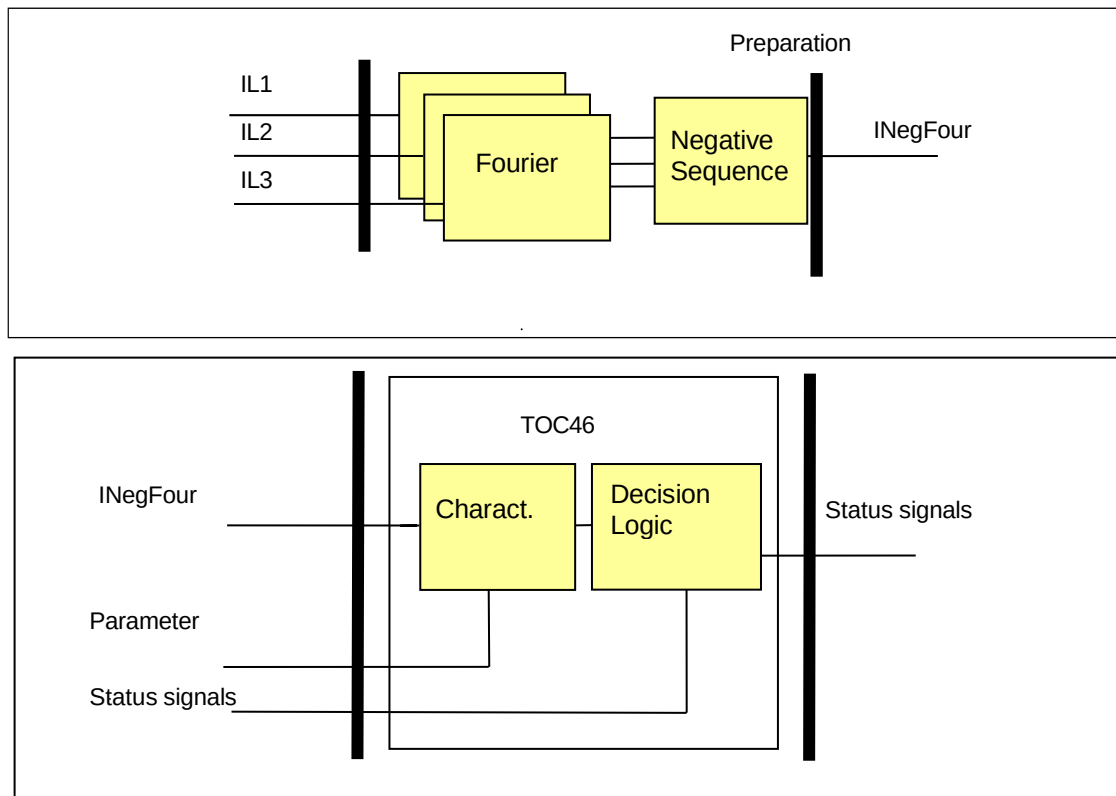


Figure 1-1 Structure of the negative sequence overcurrent protection algorithm

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

The **inputs** are

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

The **output** is

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

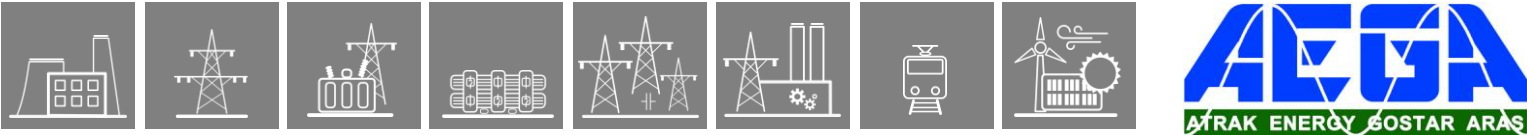
For the TOC46 function:

The **inputs** are

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

The **outputs** are

- the binary output status signals.



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

Fourier calculations

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

Negative sequence

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

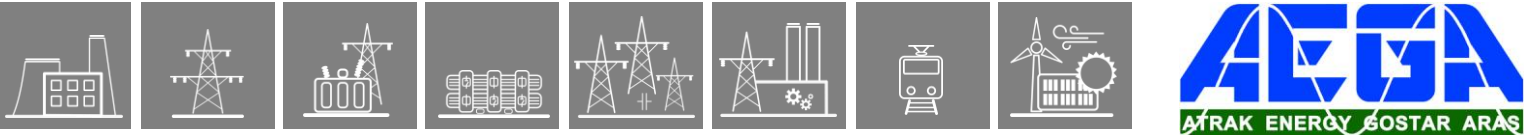
Characteristics

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

Decision logic

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

The following description explains the details of the individual components.



3.1.1.3. The Fourier calculation (Fourier)

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

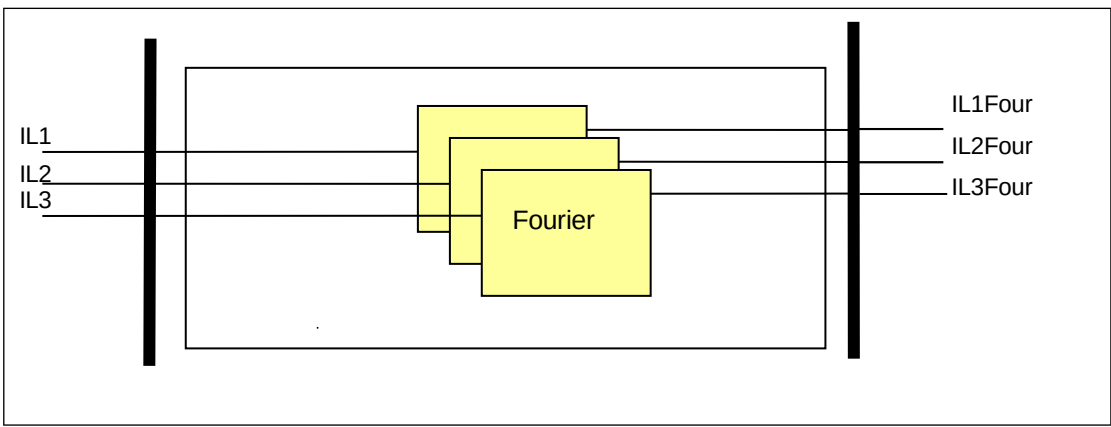
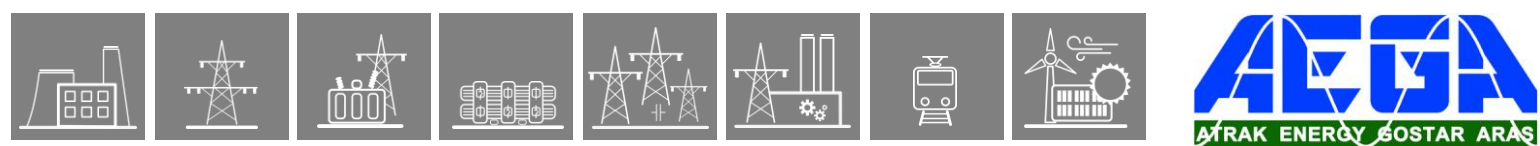


Figure 1-2 Schema of the Fourier calculation

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

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



3.1.1.4. The negative phase sequence calculation (Negative sequence)

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

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

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

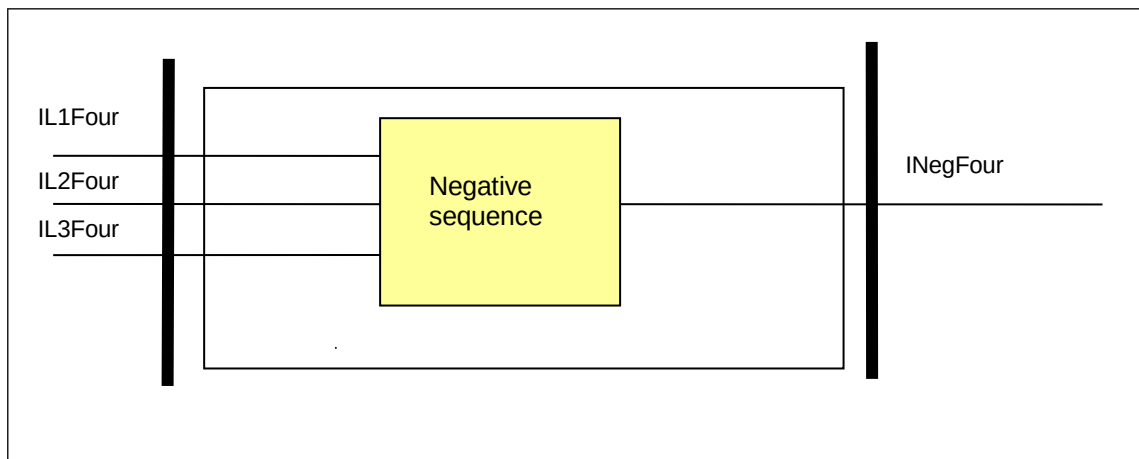
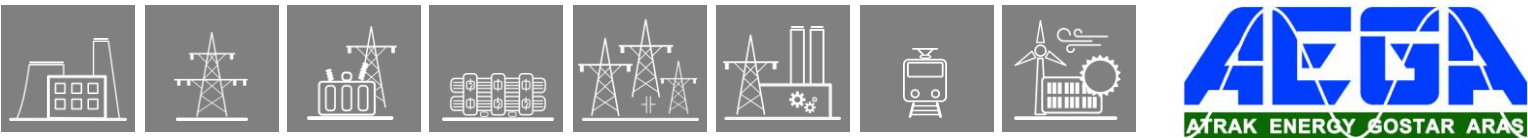


Figure 1-3 Schema of the negative sequence component calculation



3.1.1.5. 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.

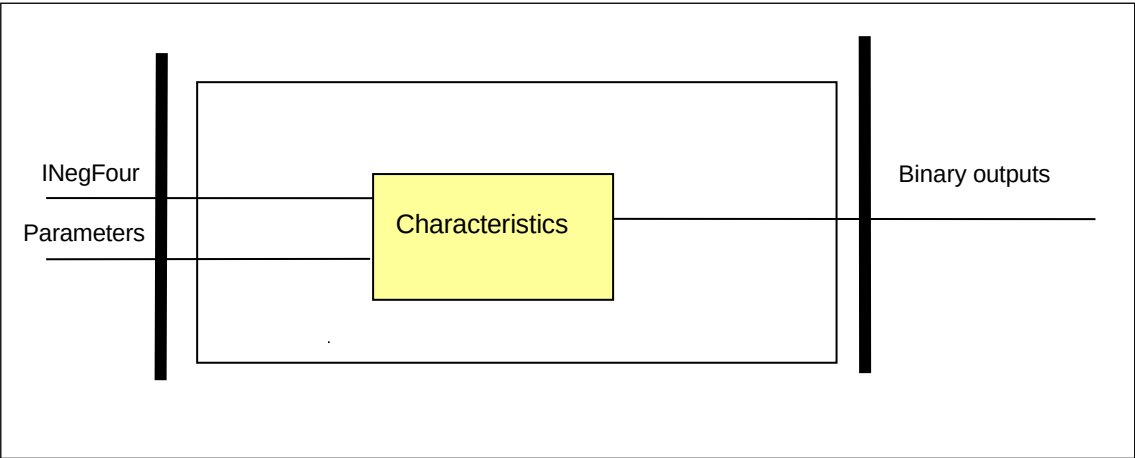


Figure 1-4 Schema of the characteristic calculation

Enumerated parameter

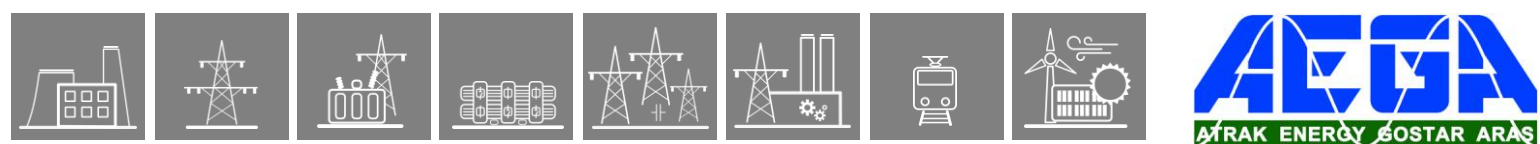
Parameter name	Title	Selection range	Default
Parameter for type selection			
TOC46_Oper_EPar_	Operation	Off, DefinitTime, IEC Inv, IEC VeryInv, IEC ExtInv, IEC LongInv, ANSI Inv, ANSI ModInv, ANSI VeryInv, ANSI ExtInv, ANSI LongInv, ANSI LongVeryInv, ANSI LongExtInv	Off

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 Table 1-7.

Binary output signals	Signal title	Explanation
TOC46_St_Grl_	Start Neg	Starting of the function
TOC46_Tr_Grl_	Trip Neg	Trip command of the function

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

3.1.1.6. The decision logic (Decision logic)

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

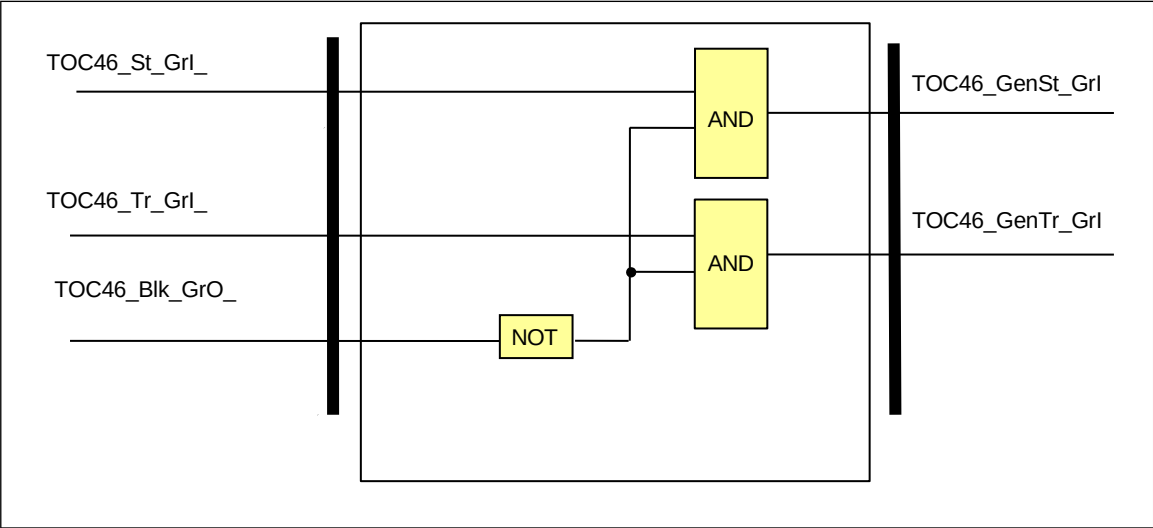


Figure 1-5 The logic scheme of the negative sequence overcurrent protection function

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

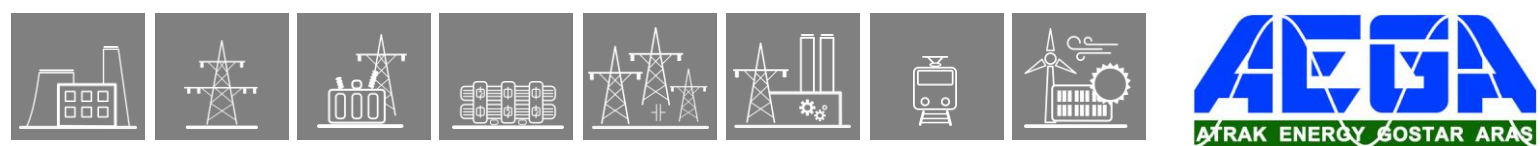
Binary output signals	Signal title	Explanation
TOC46_GenSt_GrI_	General Start	General starting of the function
TOC46_GenTr_GrI_	General Trip	General trip command of the function

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

3.1.1.7. Technical summary

3.1.1.7.1. Technical data

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



Reset time *		<2 % or ± 35 ms, whichever is greater
Dependent time charact. Definite time charact.	approx. 60 ms	
Transient overreach		< 2 %
Pickup time at 2* 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

3.1.1.7.2. The parameters

The parameters are summarized in Chapter 3.1.1.5.

3.1.1.7.3. 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

3.1.1.7.4. 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

3.1.1.7.5. 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.

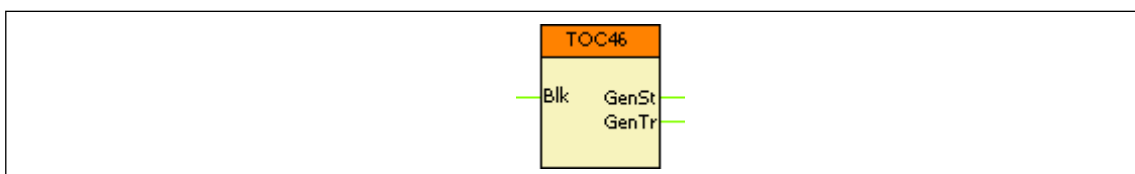
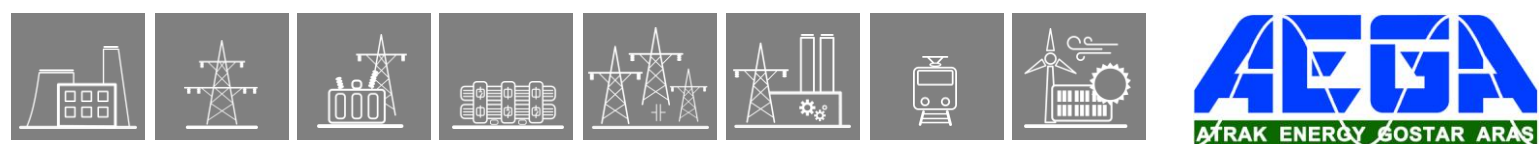


Figure 1-6 The function block of the negative sequence overcurrent protection function



3.1.2. Line thermal protection function

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

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

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

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

TTR49L_Alm_IPar_ (Alarm temperature) TTR49L_Trip_IPar_ (Trip temperature)

TTR49L_Unl_IPar_ (Unlock temperature)

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

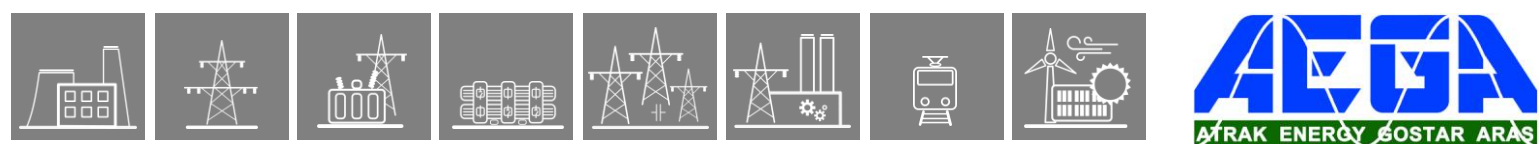
TTR49L_Inom_IPar_	(Rated load current: continuous current applied for the measurement)
TTR49L_Max_IPar_	(Rated temperature: the steady state temperature at rated load current)
TTR49L_Ref_IPar_	(Base Temperature: the temperature of the environment during the measurement of the rated values)
TTR49L_pT_IPar_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

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

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

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

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



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

3.1.2.1. Theory of the thermal replica calculations

3.1.2.1.1. The thermal differential equation

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

The source of the formulas below is that document. The

thermal differential equation to be solved is:

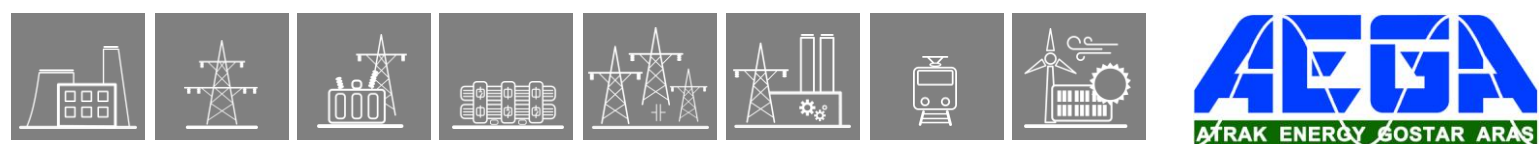
$$\frac{d\Theta}{dt} = \frac{1}{T} \left(\frac{I^2(t)R}{hA} - \Theta \right) \quad (1)$$

The definition of the heat time constant is:

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

In this differential equation:

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



3.1.2.1.2. 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.)

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

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

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

where

Temp_ambient is the ambient temperature.

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

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

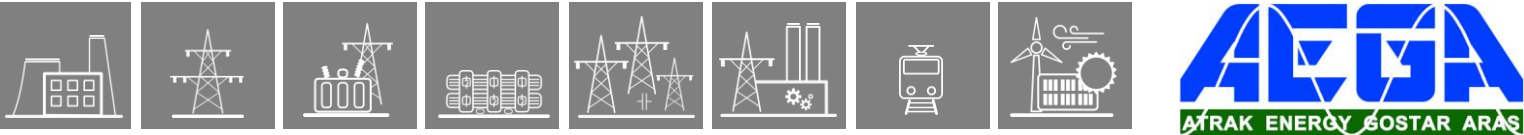
where:

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

Θ_o 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.

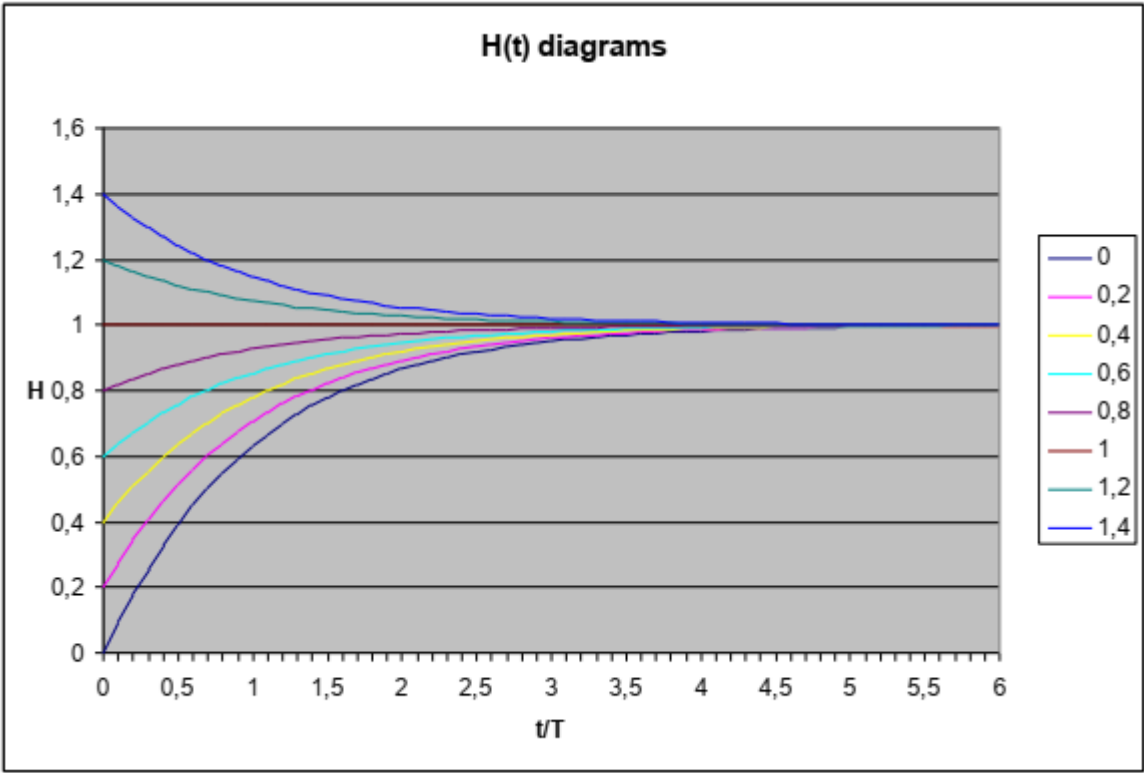


3.1.2.1.3. Formulas for checking the thermal protection functions

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

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

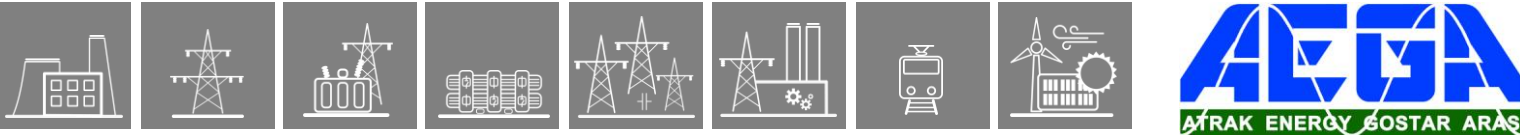


For further tests, the time needed to reach a specific temperature value can be calculated based on equation (3). The derived formula with relative quantities is:

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

where:

- $\Theta_s = \frac{I^2 \Theta_n}{I_n^2}$ is the steady state temperature in case of continuous I current,
- Θ_{set} is the momentary temperature above the ambient temperature; the time to reach this is to be calculated,
- Θ_o is the starting „overtemperature”,
- Θ_n is the reference temperature above the temperature of the environment, which can be measured in steady state, in case of a continuous I_n reference current.



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

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

where:

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

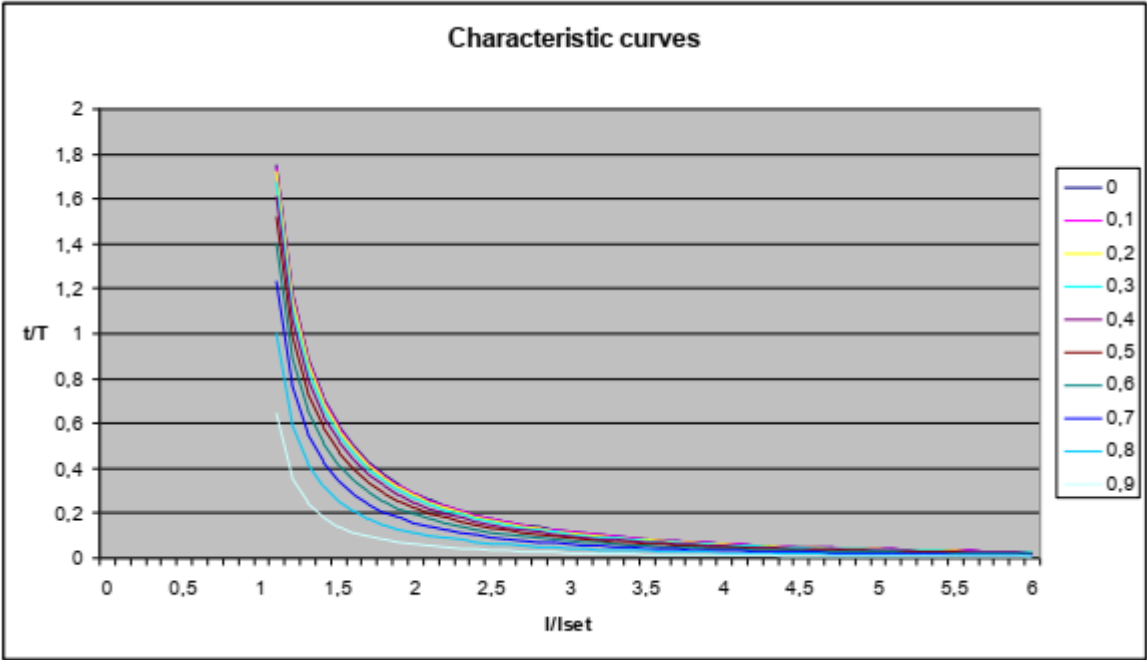
I is the current that is applied to reach the steady state Θ_S “overtemperature”,

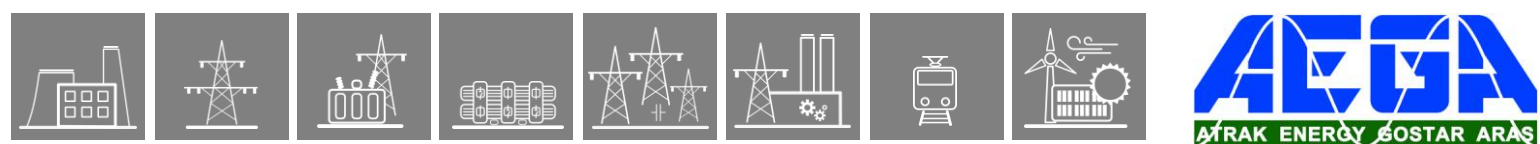
$$(\Theta_S = \frac{I^2 \Theta_n}{I_n^2}).$$

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

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

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





3.1.2.1.4. Numerical solution of the thermal differential equation

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

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

where:

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

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

3.1.2.2. Structure of the line thermal protection

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

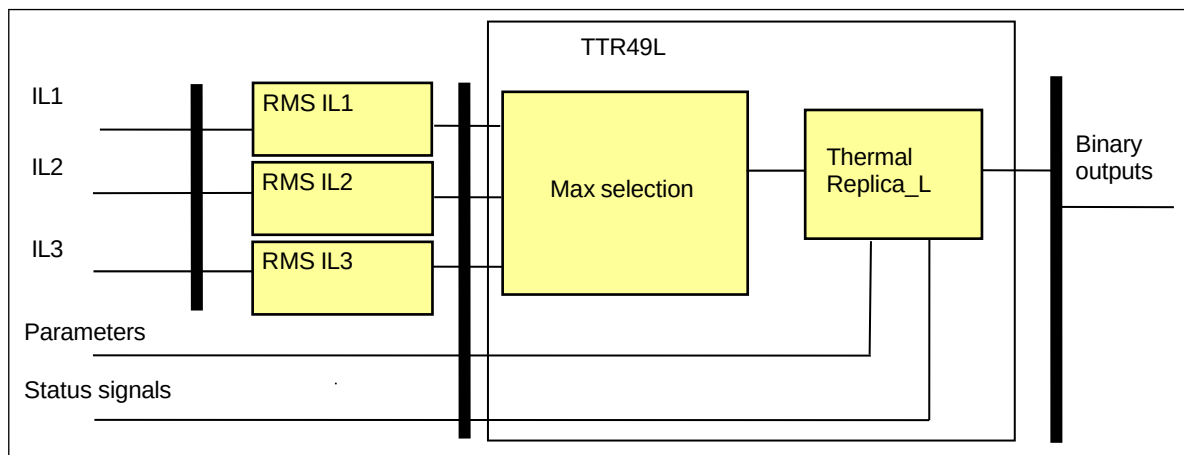


Figure 1-1 Structure of the line thermal protection algorithm

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.

3.1.2.3. 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.

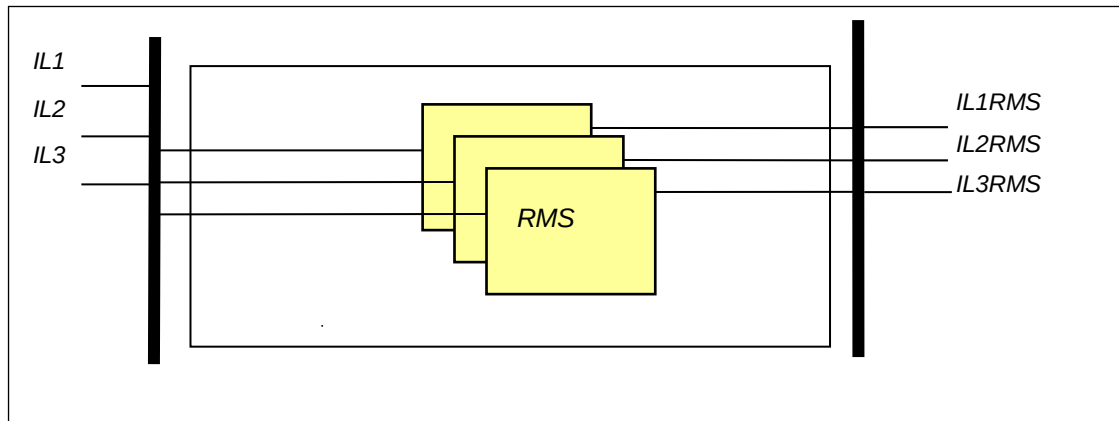


Figure 1-2 Principal scheme of the current RMS calculation

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).

3.1.2.4. The maximum selection (Max selection)

This module selects the maximum of the three RMS values.

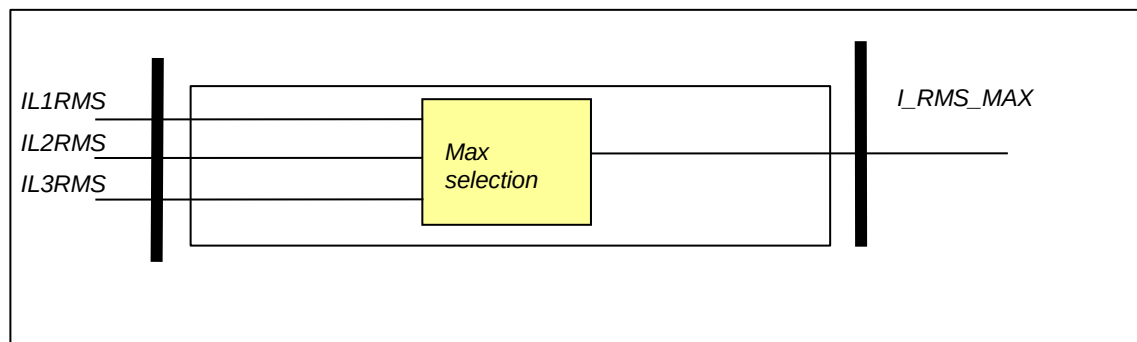
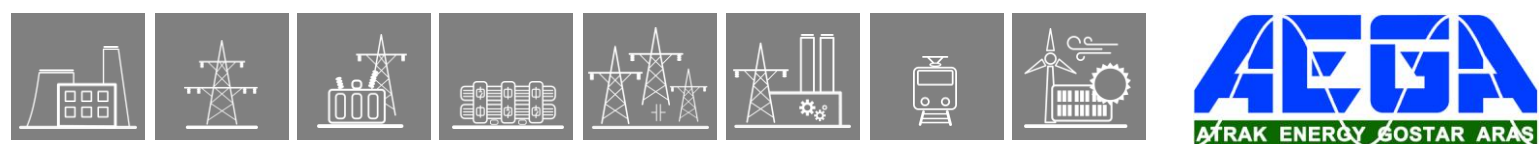


Figure 1-3 Principal scheme of the maximum selection

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

output is the selected maximum of the three RMS values.



3.1.2.5. 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.

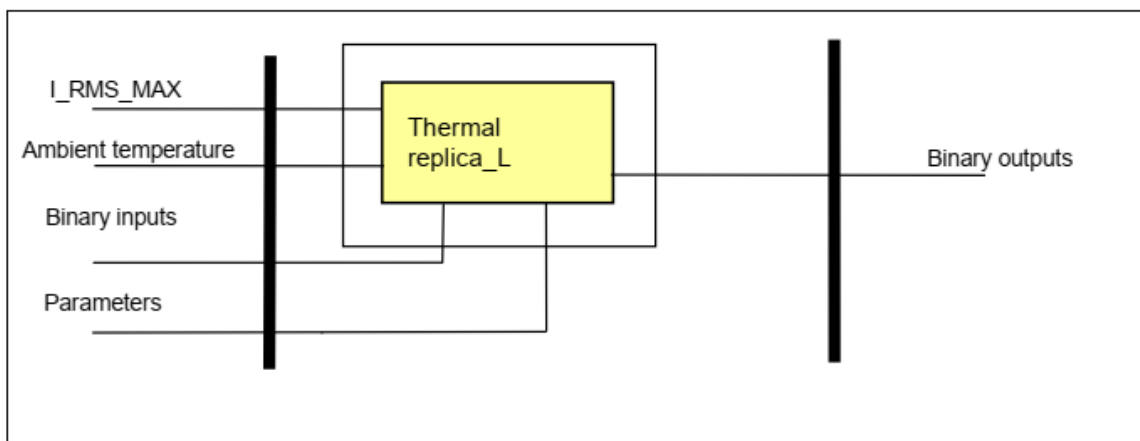
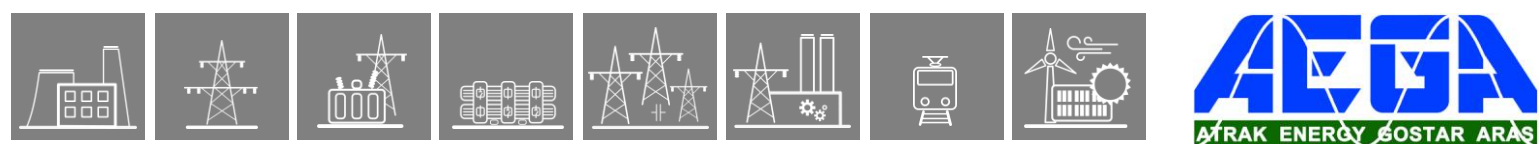


Figure 1-4 Principal scheme of the thermal replica calculation



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

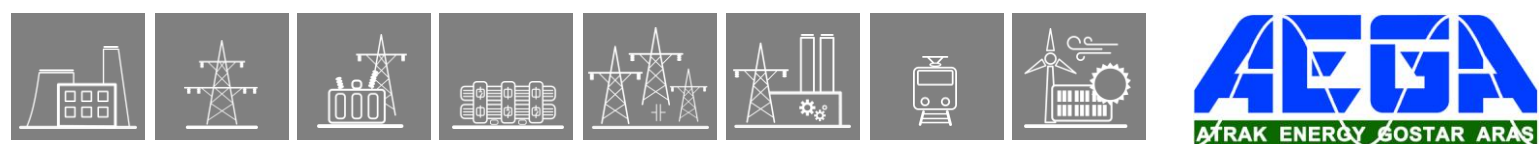
Parameter name	Title	Unit	Min	Max	Step	Default
Alarm Temperature						
TTR49L_Alm_IPar_	Alarm Temperature	deg	60	200	1	80
Trip Temperature						
TTR49L_Trip_IPar_	Trip Temperature	deg	60	200	1	100
Rated Temperature						
TTR49L_Max_IPar_	Rated Temperature	deg	60	200	1	100
Base Temperature						
TTR49L_Ref_IPar_	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.

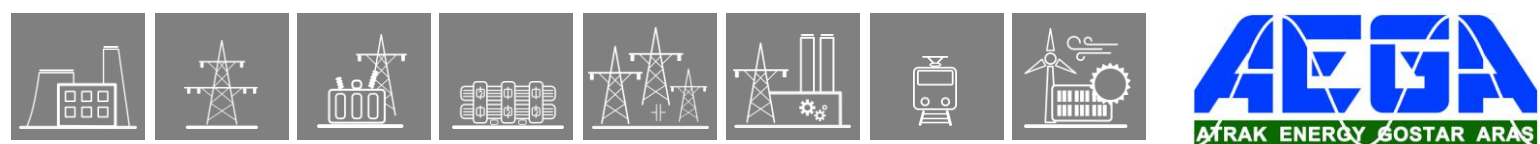
Binary input status signals	Title	Explanation
TTR49L_BlK_GrO_	Block	Output status of a graphic equation defined by the user to disable the line thermal protection function.
TTR49L_Reset_GrO_	Reset	Output status of a graphic equation defined by the user to reset the accumulated heat and set the temperature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



3.1.2.6. Technical summary

3.1.2.6.1. Technical data

Function	Accuracy
Operate time at $I > 1.2 \cdot I_{trip}$	$< 3 \%$ or $< + 20 \text{ ms}$

Table 1-7 Technical data of the line thermal protection function

3.1.2.6.2. The parameters

The parameters are summarized in Chapter 1.5.

3.1.2.6.3. 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

3.1.2.6.4. 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



3.1.2.6.5. 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.

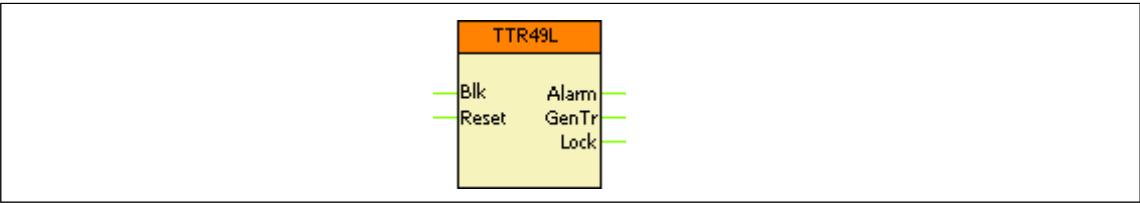


Figure 1-5 The function block of the line thermal protection function

3.1.3. Three-phase instantaneous Overcurrent Protection

3.1.3.1. 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.

3.1.3.1.1. Operating Characteristics

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

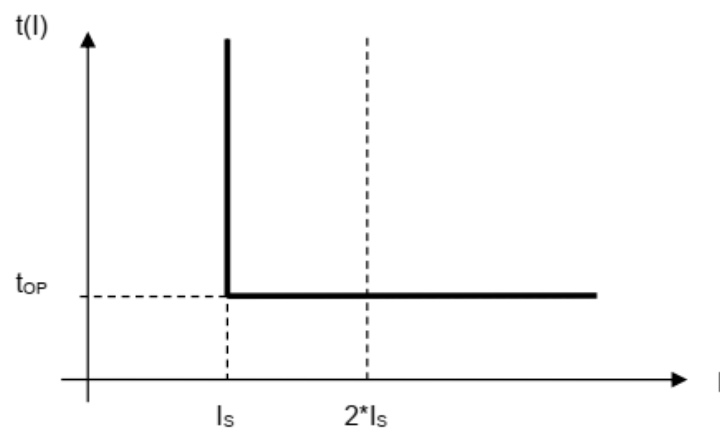


Figure 1-1 Overcurrent independent time characteristic

where:

t_{OP} (sec.)	theoretical operating time if $I > I_{Gs}$ (without additional time delay),
I	measured value of the characteristic quantity, peak values or Fourier base harmonic of the phase currents,
I_s	setting value of the characteristic quantity (<i>Start current</i>)

3.1.3.1.2. Structure of the Protection Algorithm

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

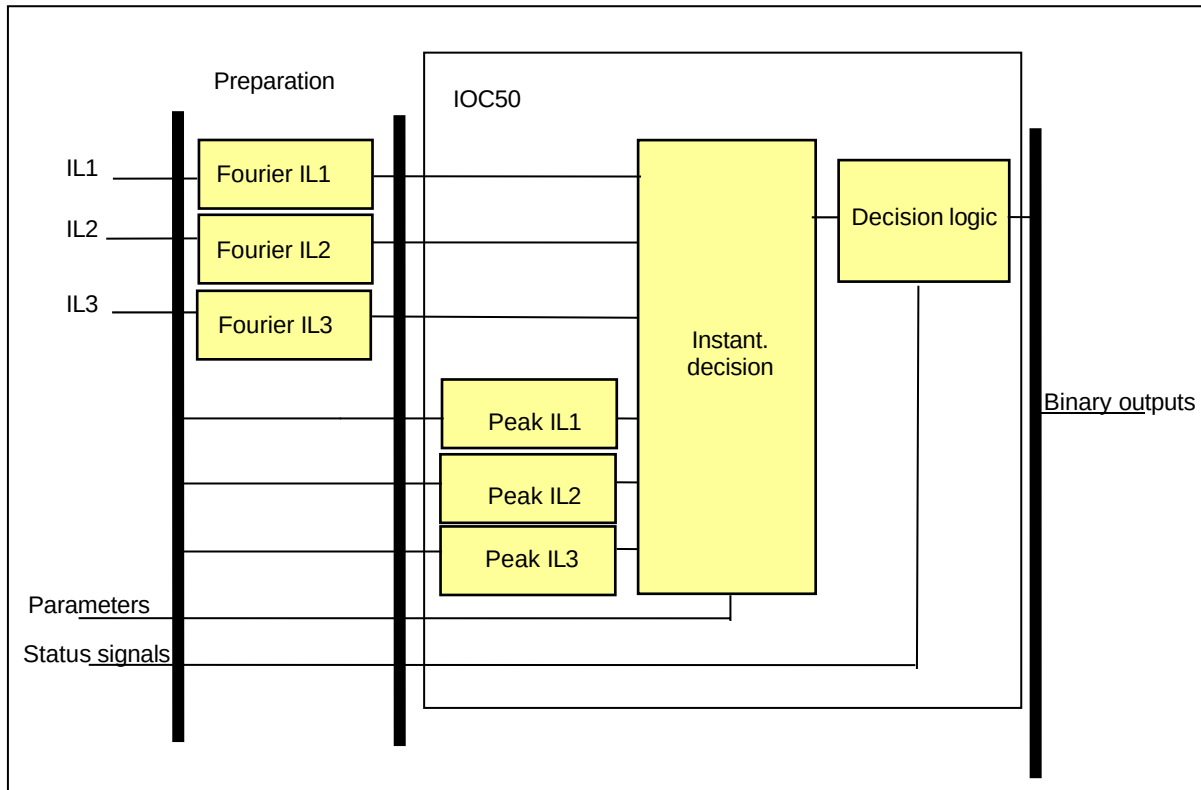


Figure 1-2 Structure of the instantaneous overcurrent protection algorithm

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.

3.1.3.1.3. 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.

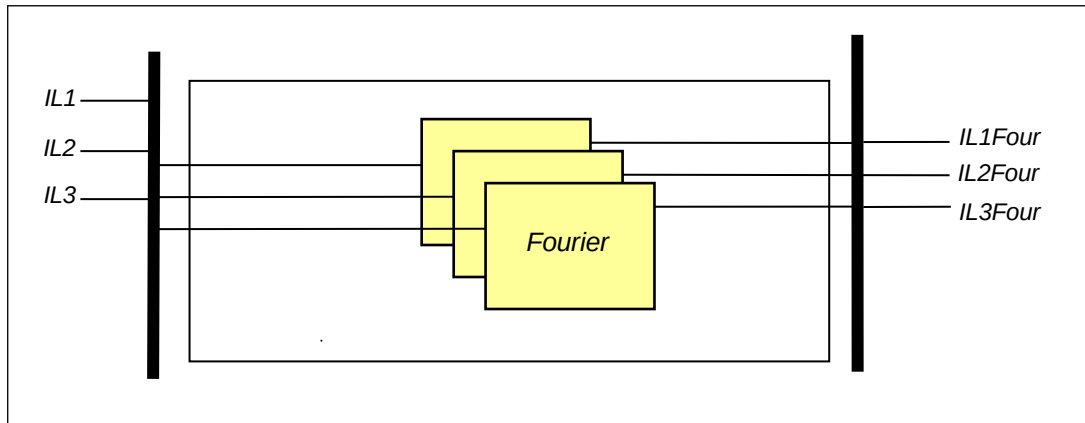


Figure 1-3 Principal scheme of the Fourier calculation

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).

3.1.3.1.4. The Peak Selection (Peak selection)

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

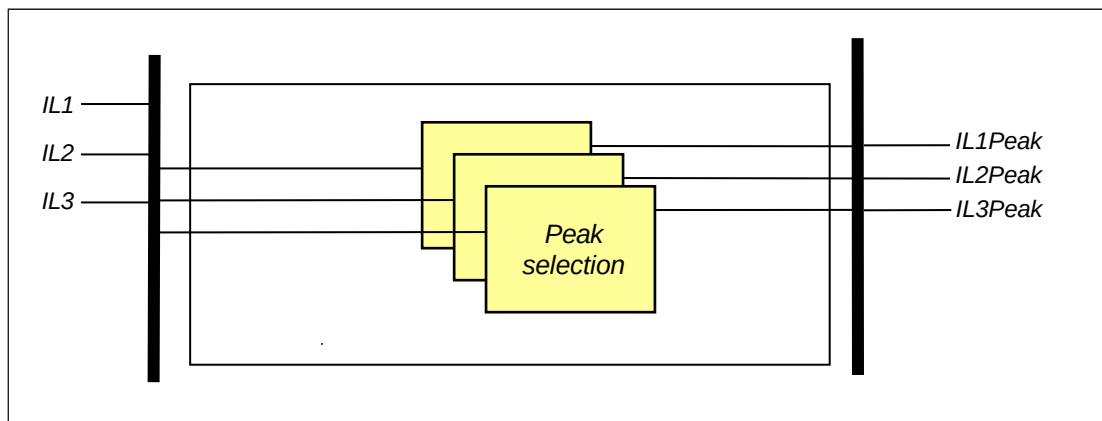


Figure 1-4 Principal scheme of the peak selection

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).

3.1.3.1.5. 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.

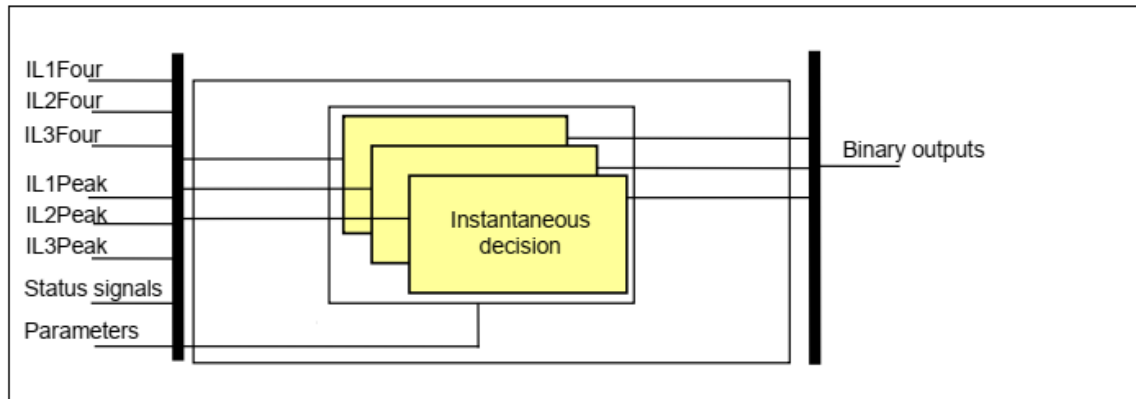


Figure 1-5 Principal scheme of the instantaneous characteristic calculation

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

3.1.3.1.6. The Decision Logic (Decision logic)

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

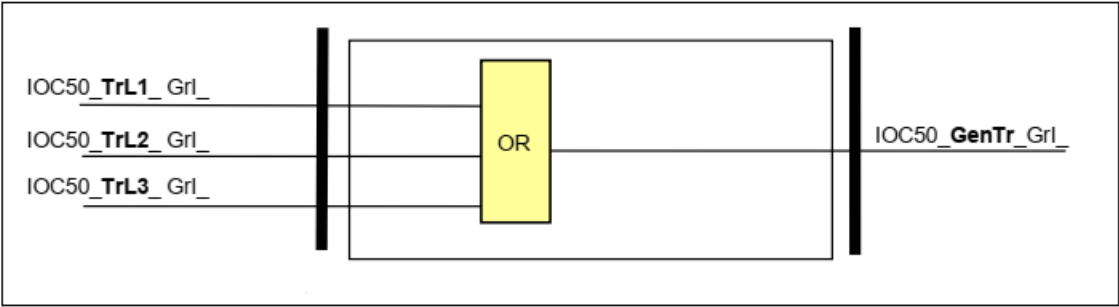


Figure 1-6 The logic scheme of the instantaneous overcurrent protection function

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

BINARY INPUT SIGNAL	SIGNAL TITLE	EXPLANATION
IOC50_TrL1_Grl_	Trip L1	Trip command of the function in phase L1
IOC50_TrL2_Grl_	Trip L2	Trip command of the function in phase L2
IOC50_TrL3_Grl_	Trip L3	Trip command of the function in phase L3

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

BINARY OUTPUT SIGNAL	SIGNAL TITLE	EXPLANATION
IOC50_GenTr_Grl_	General Trip	General trip command of the function

3.1.3.2. 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.

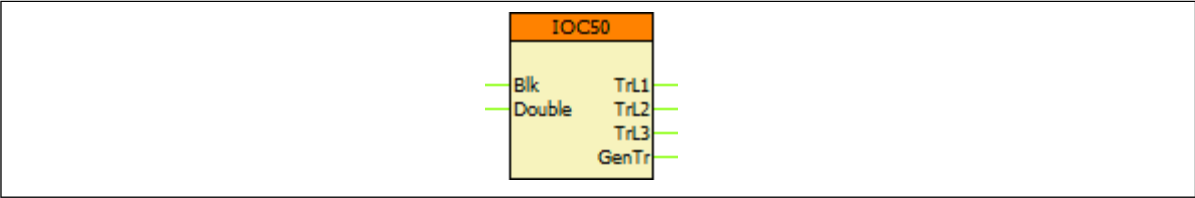


Figure 2-1 The function block of the 3-phase instantaneous overcurrent protection

3.1.3.2.1. Settings

3.1.3.2.1.1. 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}).

3.1.3.2.2. Function I/O

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

3.1.3.2.2.1. Analogue inputs

The analogue inputs are the RMS values of the fundamental Fourier component of the three phase currents.

3.1.3.2.2.2. 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".

3.1.3.2.2.3. 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

3.1.3.2.2.4. 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

3.1.3.2.2.5. 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

3.1.3.2.3. Technical Data

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

FUNCTION	VALUE	ACCURACY
<i>Using peak value calculation</i>		
Operating characteristic	Instantaneous	< 6%
Reset ratio	0.85	
Operate time at 2*Is	< 15 ms	
Reset time*	< 40 ms	
Transient overreach	90%	
<i>Using Fourier fundamental harmonic calculation</i>		
Operating characteristic	Instantaneous	< 2%
Reset ratio	0.85	
Operate time at 2*Is	< 25 ms	
Reset time*	< 60 ms	
Transient overreach	15%	

* Measured with signal contacts

3.1.3.2.4. 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.

3.1.4. Residual Instantaneous Overcurrent Protection

3.1.4.1. Application

The residual instantaneous overcurrent protection function operates according to instantaneous characteristics, using the residual current ($I_N = 3I_0$). The setting value is a parameter, and it can be doubled by a binary input signal defined by the user, applying the graphic programming.

The basic calculation can be based on peak value selection or on the RMS values of the fundamental Fourier component of the residual current, according to the parameter setting. When Fourier calculation is selected then the accuracy of the operation is high, the operation time, however, is above one period of the network frequency. If the operation is based on peak values, then fast sub-cycle operation can be expected, but the transient overreach can be high.

3.1.4.1.1. Operating Characteristics

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

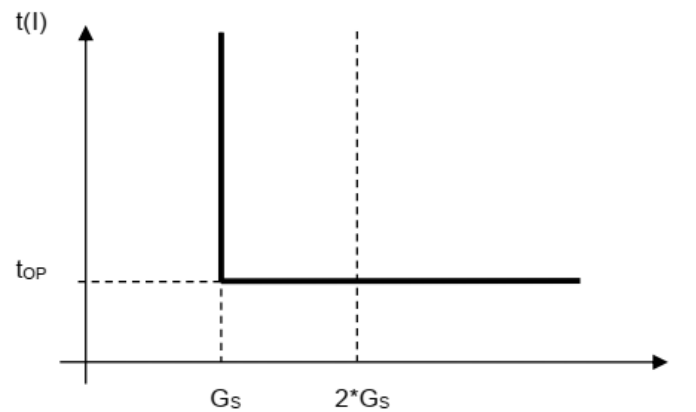


Figure 1-1 Overcurrent independent time characteristic

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 (<i>Start current</i>)

3.1.4.1.2. Structure of the Protection Algorithm

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

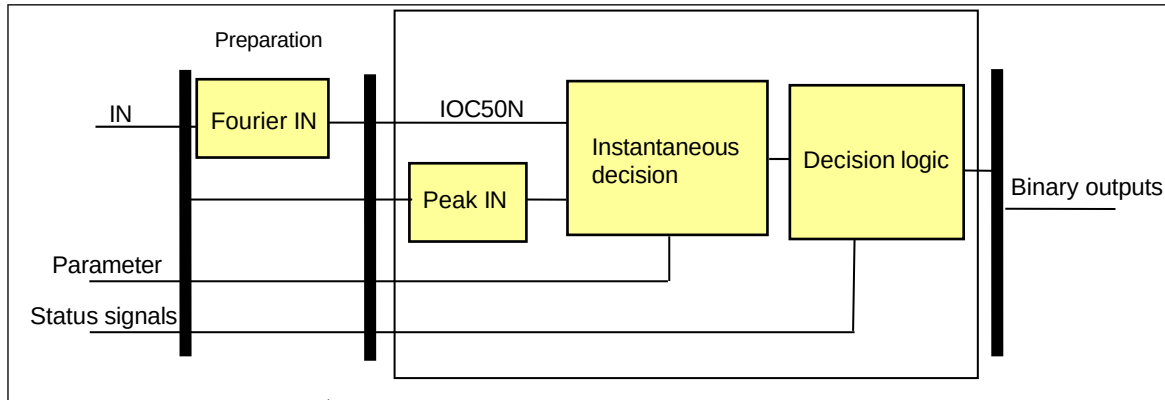


Figure 1-2 Structure of the residual instantaneous overcurrent protection algorithm

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.

3.1.4.1.3. 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.

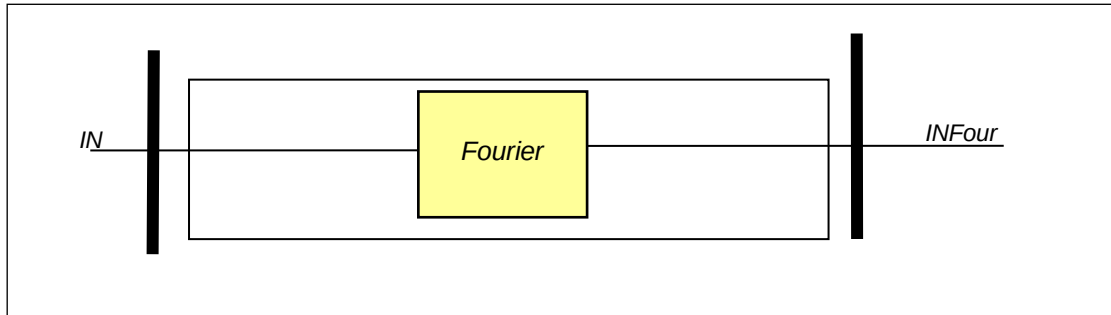


Figure 1-3 Principal scheme of the Fourier calculation

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).

3.1.4.1.4. The Peak Selection (Peak selection)

This module selects the peak values of the residual current.

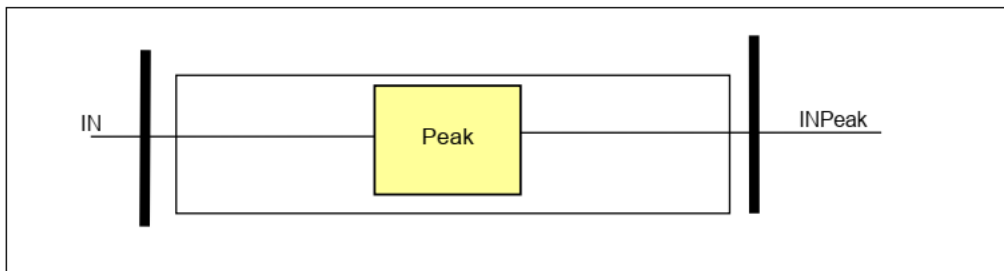


Figure 1-4 Principal scheme of the peak selection

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

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

3.1.4.1.5. 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.

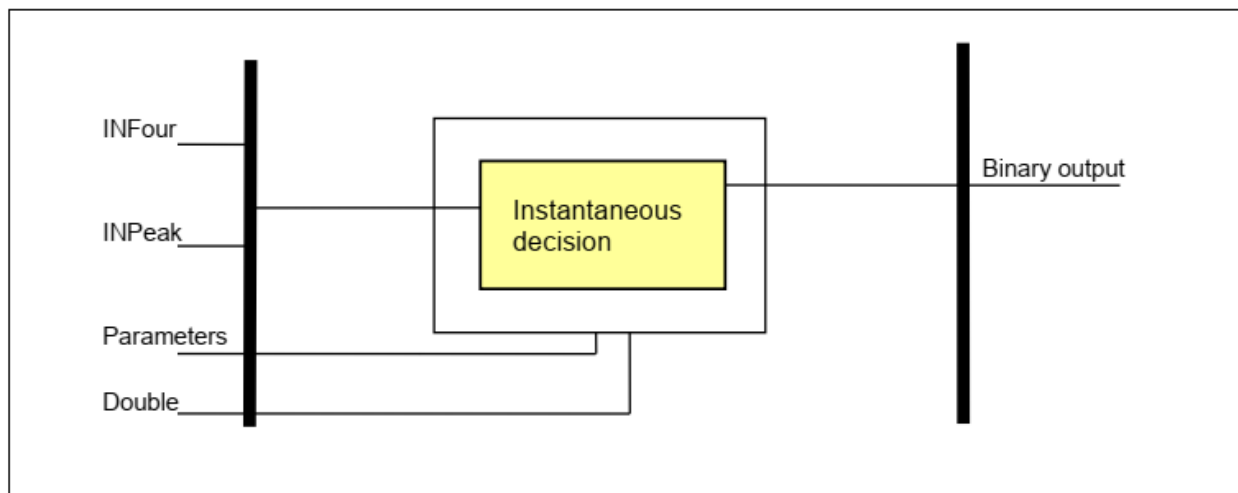


Figure 1-5 Principal scheme of the residual instantaneous characteristic calculation

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

3.1.4.1.6. **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.

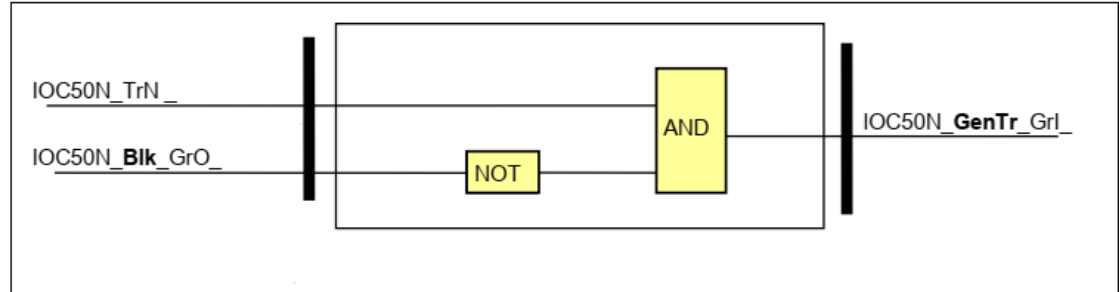


Figure 1-6 The logic scheme of the residual IOC protection function

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

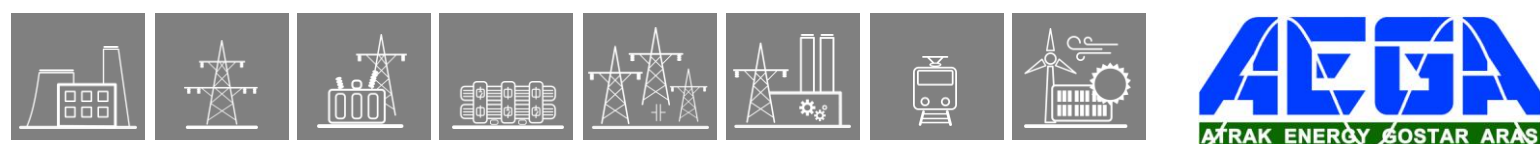
The residual instantaneous overcurrent protection function has a binary input signal, which serves the purpose of disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor.**

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



3.1.4.2.2. 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

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

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 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".

3.1.4.2.2.3. 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 residual IOC function

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

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 residual IOC function

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

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 residual IOC function

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

3.1.4.2.3. Technical Data

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

FUNCTION	VALUE	ACCURACY
<i>Using peak value calculation</i>		
Operating characteristic ($I > 0.1I_n$)	Instantaneous	< 6%
Reset ratio	0.85	
Operate time at $2I_s$	< 15 ms	
Reset time*	< 40 ms	
Transient overreach	85%	
<i>Using Fourier fundamental harmonic calculation</i>		
Operating characteristic ($I > 0.1I_n$)	Instantaneous	< 3%
Reset ratio	0.85	
Operate time at $2I_s$	< 25 ms	
Reset time*	< 60 ms	
Transient overreach	15%	

* Measured with signal contacts

3.1.4.2.4. 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.

3.1.5. Breaker failure protection

3.1.5.1. 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.

3.1.5.1.1. Mode of operation

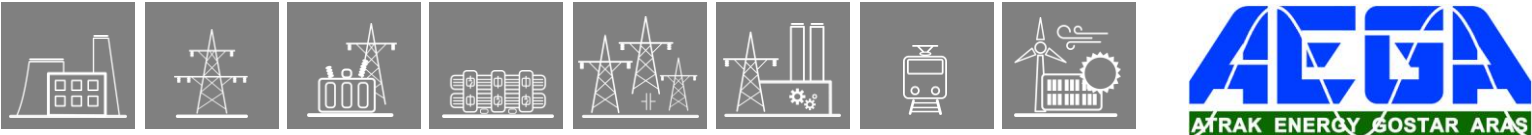
The starting signal of the breaker failure protection function is usually the trip command of any other protection function. The user has the task to define these starting signals using the graphic equation editor as the “General Start” (BRF50_GenSt_GrO_), or if the operation of the individual phases is needed, then the start signals for the phases individually.

The phase start signals are: “Start L1” (BRF50_StL1_GrO_), “Start L2” (BRF50_StL2_GrO_) and “Start L3” (BRF50_StL3_GrO_).

Dedicated timers start at the rising edge of the start signals, one for the backup trip command and one for the repeated trip command, separately for operation in the individual phases. During the running time of the timers the function optionally monitors the currents, the closed state of the circuit breakers or both, according to the user’s choice. The selection is made using the enumerated parameter “Operation”:

- If this parameter setting is “Current”, the current limit values “Start Ph Current” and “Start Res Current” must be set correctly. The binary input indicating the status of the circuit breaker has no meaning.
- If this parameter setting is “Contact”, the current limit values “Start current Ph” and “Start current N” have no meaning. The binary input indicating the status of the circuit breaker must be programmed correctly using the graphic equation editor.
 - By using “BRF50” variant: the input variable to be programmed is: BRF50_CBClosed_GrO_ (CB Closed),
 - By using “BRF50SP” variant: the input variables to be programmed are: BRF50_CBCIL1_GrO_ (CB closed L1), BRF50_CBCIL2_GrO_ (CB closed L2) and BRF50_CBCIL3_GrO_ (CB closed L3).
- If this parameter setting is “Current/Contact”, the current parameters and the status signal must be set correctly. The breaker failure protection function resets only if all conditions for faultless state are fulfilled.

BRF50SP



- The breaker failure protection function can be disabled by setting this parameter to “Off”. If at the end of the running time of the backup timer the currents do not drop below the pre-defined level, and/or the monitored circuit breaker is still in closed position, then a backup trip command is generated. The time delay is defined using the parameter “Backup Time Delay”.

The pulse duration of the trip command is not shorter than the time defined by setting the parameter “Pulse Duration”.

If repeated trip command is to be generated for the circuit breakers that are expected to open, then the enumerated parameter “Retrip” must be set to “On”. In this case, at the end of the retrip timer(s) the delay of which is set by the timer parameter “Retrip Time Delay”, a repeated trip command is also generated in the phase(s) where the backup timer(s) run off.

BRF50SP

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

3.1.5.1.2. 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_ CBCIL1 _GrO_	CB closed L1	Signal indicating the closed state of the circuit breaker in phase L1
BRF50SP_ CBCIL2 _GrO_	CB closed L2	Signal indicating the closed state of the circuit breaker in phase L2
BRF50SP_ CBCIL3 _GrO_	CB closed L3	Signal indicating the closed state of the circuit breaker in phase L3
BRF50_ GenSt _GrO_	General Start	General starting signal
BRF50SP_ StL1 _GrO_	Start L1	Starting signal in phase L1
BRF50SP_ StL2 _GrO_	Start L2	Starting signal in phase L2
BRF50SP_ StL3 _GrO_	Start L3	Starting signal in phase L3
BRF50_ IoSt _GrO_	Start Io	Starting signal for the residual current
Internal signal:	IL1>	Current in phase L1 is above the preset parameter value
Internal signal:	IL2>	Current in phase L2 is above the preset parameter value
Internal signal:	IL3>	Current in phase L3 is above the preset parameter value
Internal signal:	Io>	Current 3Io is above the preset parameter value
Enumerated parameter	Current/Contact	The monitored condition is current, contact or both

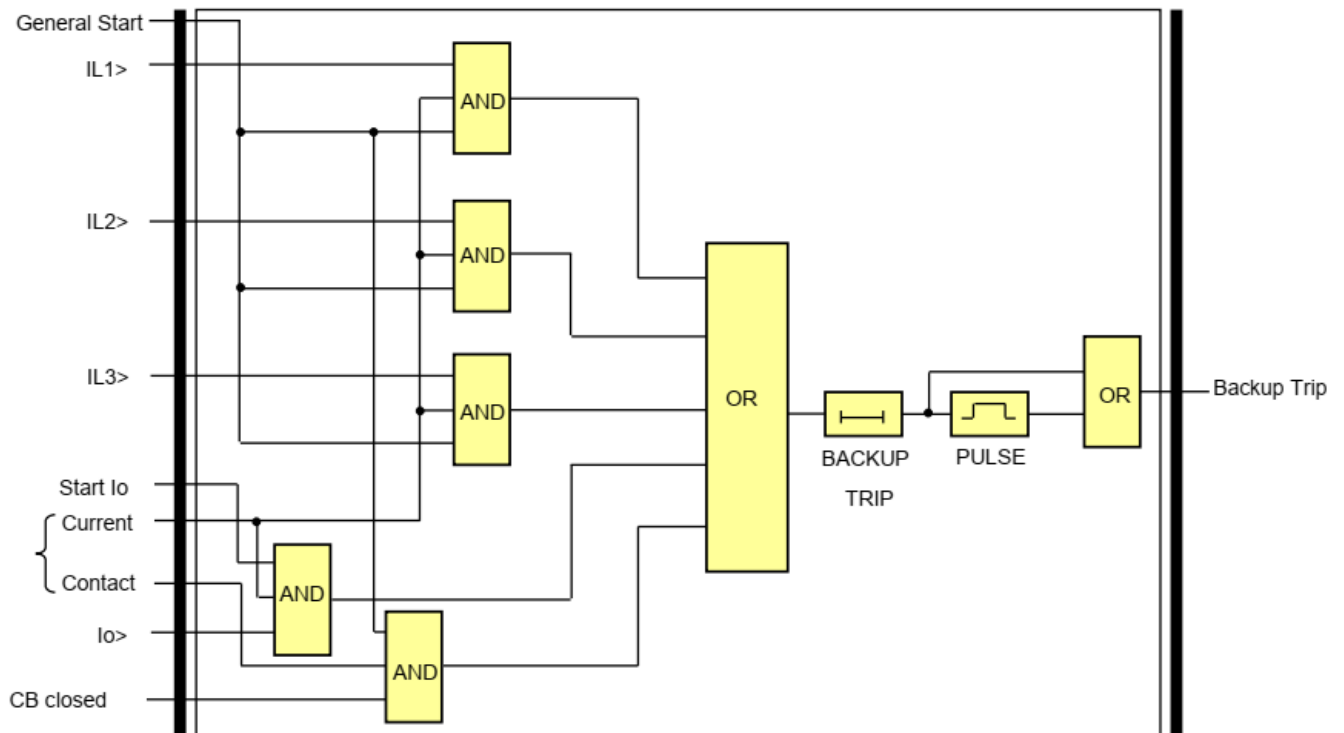


Figure 1-1 The logic scheme of the decision logic of “BRF50” variant

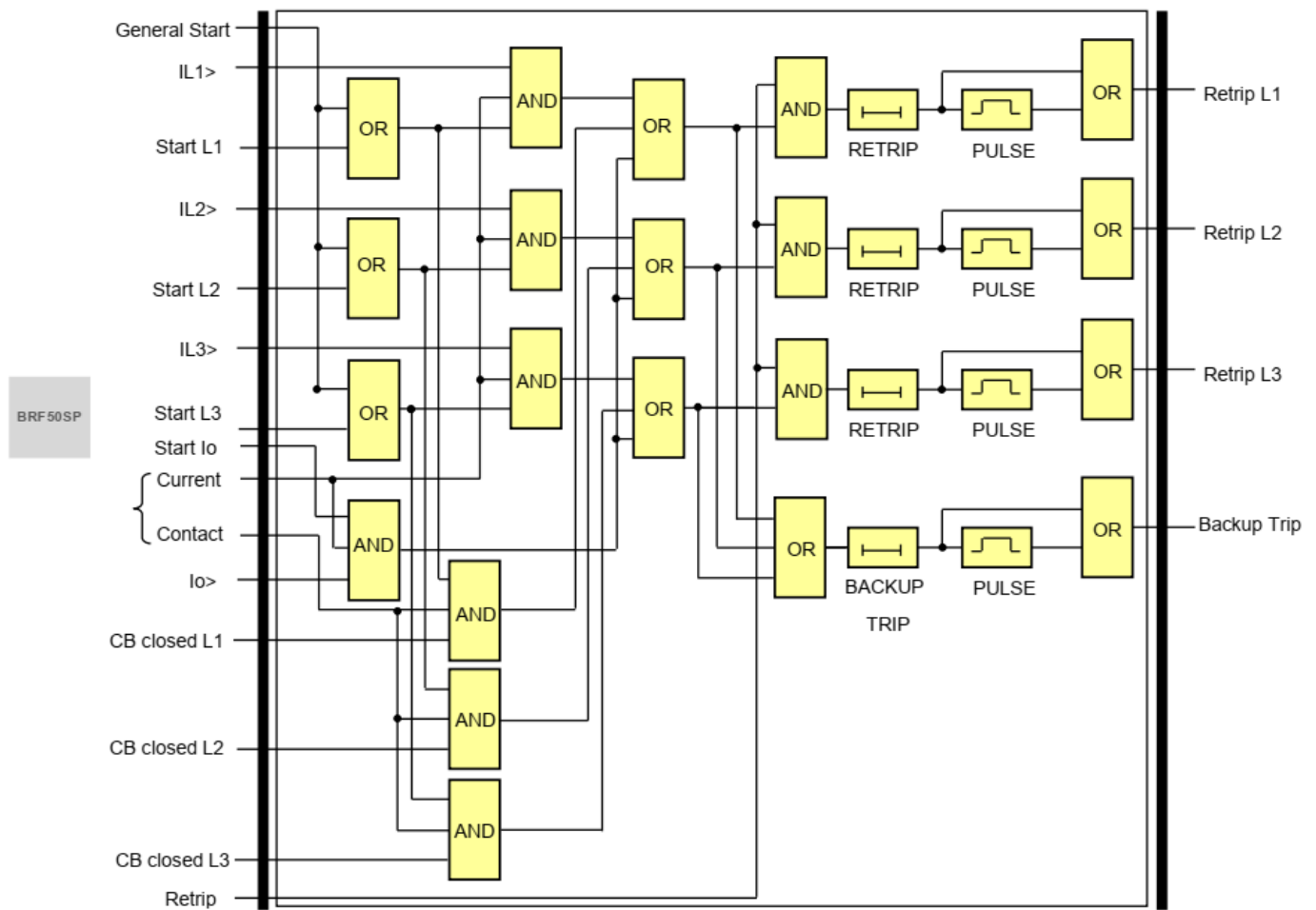
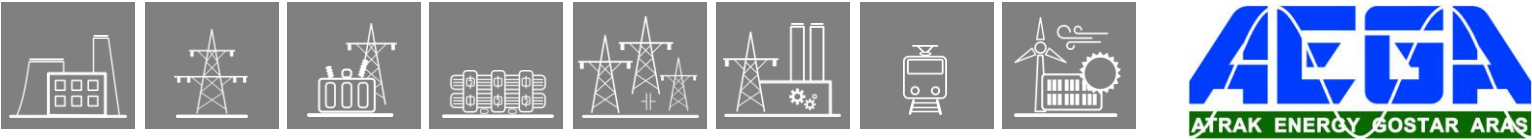


Figure 1-2 The logic scheme of the decision logic of “BRF50SP” variant

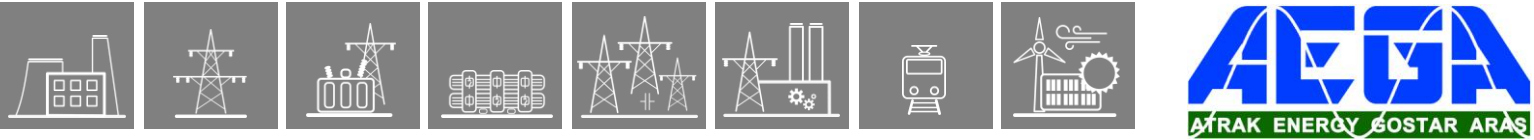


The **binary output status signals** of the breaker failure protection function is detailed in Table 1-2.

Table 1-2 The binary output status signal of the decision logic

BRF50SP

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



3.1.5.2. 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.

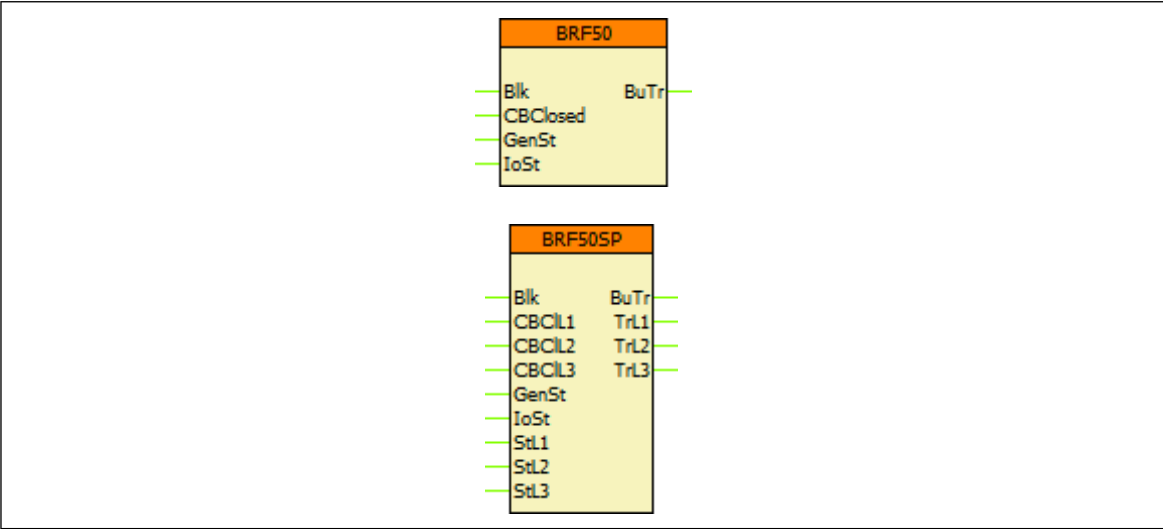


Figure 2-1 Graphic appearance of the variants of the breaker failure protection function block

3.1.5.2.1. Settings

3.1.5.2.1.1. 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 Parameters of the breaker failure protection function

	TITLE	DIM	RANGE	STEP	DEFAULT	EXPLANATION
BRF50SP	Operation	-	Off, Current, Contact, Current/Contact	-	Off	Enabling the function
	Retrip	-	Off, On	-	Off	Enabling the retrip function
	Start Ph Current	%	20 – 200	1	30	Phase current setting
BRF50SP	Start Res Current	%	10 – 200	1	20	Residual current setting
	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

3.1.5.2.2. Function I/O

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

3.1.5.2.2.1. Analogue inputs

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

3.1.5.2.2.2. 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_ CBCIL1 _GrO_	CB closed L1	Signal indicating the closed state of the circuit breaker in phase L1
BRF50SP_ CBCIL2 _GrO_	CB closed L2	Signal indicating the closed state of the circuit breaker in phase L2
BRF50SP_ CBCIL3 _GrO_	CB closed L3	Signal indicating the closed state of the circuit breaker in phase L3
BRF50_ GenSt _GrO_	General Start	General starting signal
BRF50SP_ StL1 _GrO_	Start L1	Starting signal in phase L1
BRF50SP_ StL2 _GrO_	Start L2	Starting signal in phase L2
BRF50SP_ StL3 _GrO_	Start L3	Starting signal in phase L3
BRF50_ IoSt _GrO_	Start Io	Starting signal for the residual current

3.1.5.2.2.3. 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
BRF50_ TrL2 _GrI_	Retrip L2	Repeated trip command in phase L2
BRF50_ TrL3 _GrI_	Retrip L3	Repeated trip command in phase L3

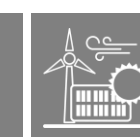
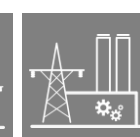
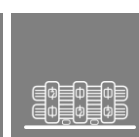
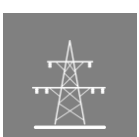
3.1.5.2.2.4. Online data

Visible values on the *online data* page.



Table 2-4 Online displayed data of the breaker failure protection function

SIGNAL TITLE		DIMENSION	EXPLANATION
BRF50SP	Backup Trip	-	Trip command generated for the backup circuit breakers
	Retrip L1	-	Repeated trip command in phase L1
	Retrip L2	-	Repeated trip command in phase L2
	Retrip L3	-	Repeated trip command in phase L3



3.1.5.2.2.5. 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

3.1.5.2.3. 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	

3.1.5.2.4. 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.

3.1.6. Three-phase time overcurrent protection

3.1.6.1. 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.

3.1.6.1.1. Operating characteristics

3.1.6.1.1.1. Independent time characteristic

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

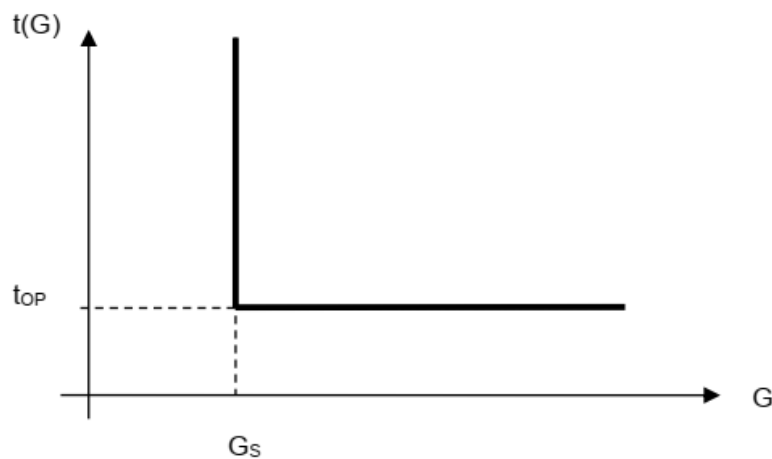


Figure 1-1 Overcurrent independent time characteristic

where

t_{OP} (seconds)	theoretical operating time if $G > G_s$, fix, according to the preset parameter,
G	measured value of the characteristic quantity, Fourier base harmonic of the phase currents,
G_s	preset value of the characteristic quantity ("Start current" parameter).

3.1.6.1.1.2. 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

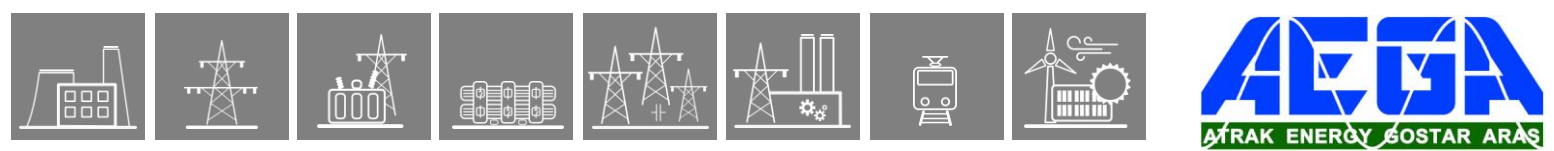
	IEC REF	TITLE	kr	c	α
1	A	IEC Inv	0,14	0	0,02
2	B	IEC VeryInv	13,5	0	1
3	C	IEC ExtInv	80	0	2
4		IEC LongInv	120	0	1
5		ANSI Inv	0,0086	0,0185	0,02
6	D	ANSI ModInv	0,0515	0,1140	0,02
7	E	ANSI VeryInv	19,61	0,491	2
8	F	ANSI ExtInv	28,2	0,1217	2
9		ANSI LongInv	0,086	0,185	0,02
10		ANSI LongVeryInv	28,55	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 $G_T = 1,1 \cdot G_s$. 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	k_r	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

3.1.6.1.2. Structure of the overcurrent protection algorithm

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

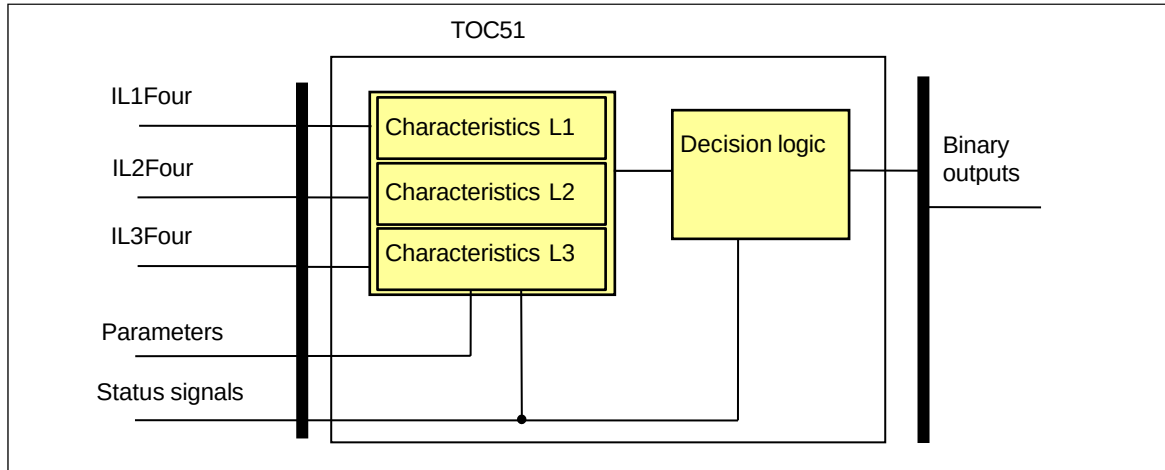


Figure 1-2 Structure of the overcurrent protection algorithm

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.

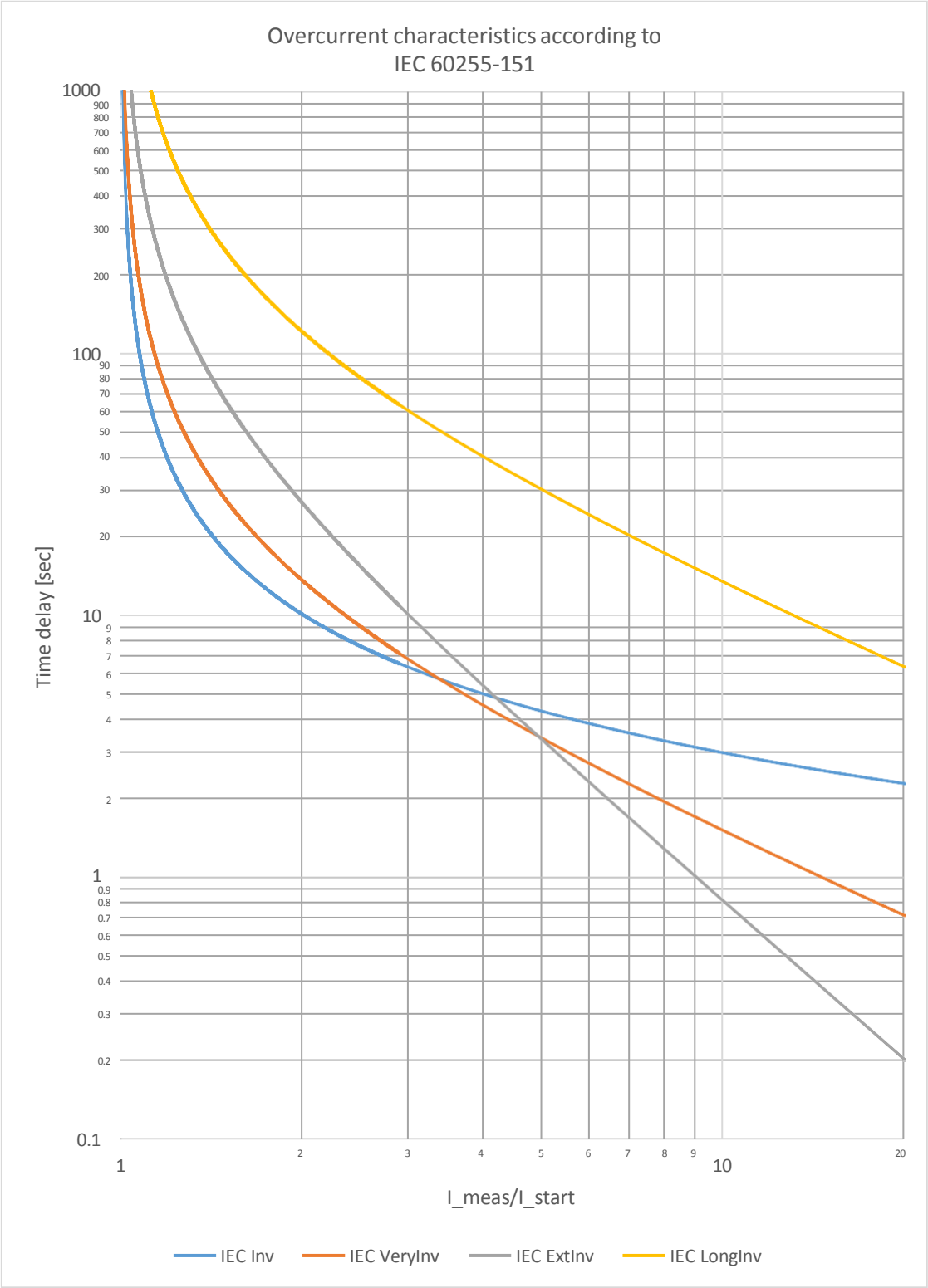


Figure 1-4 Overcurrent characteristics according to IEC 60255-151

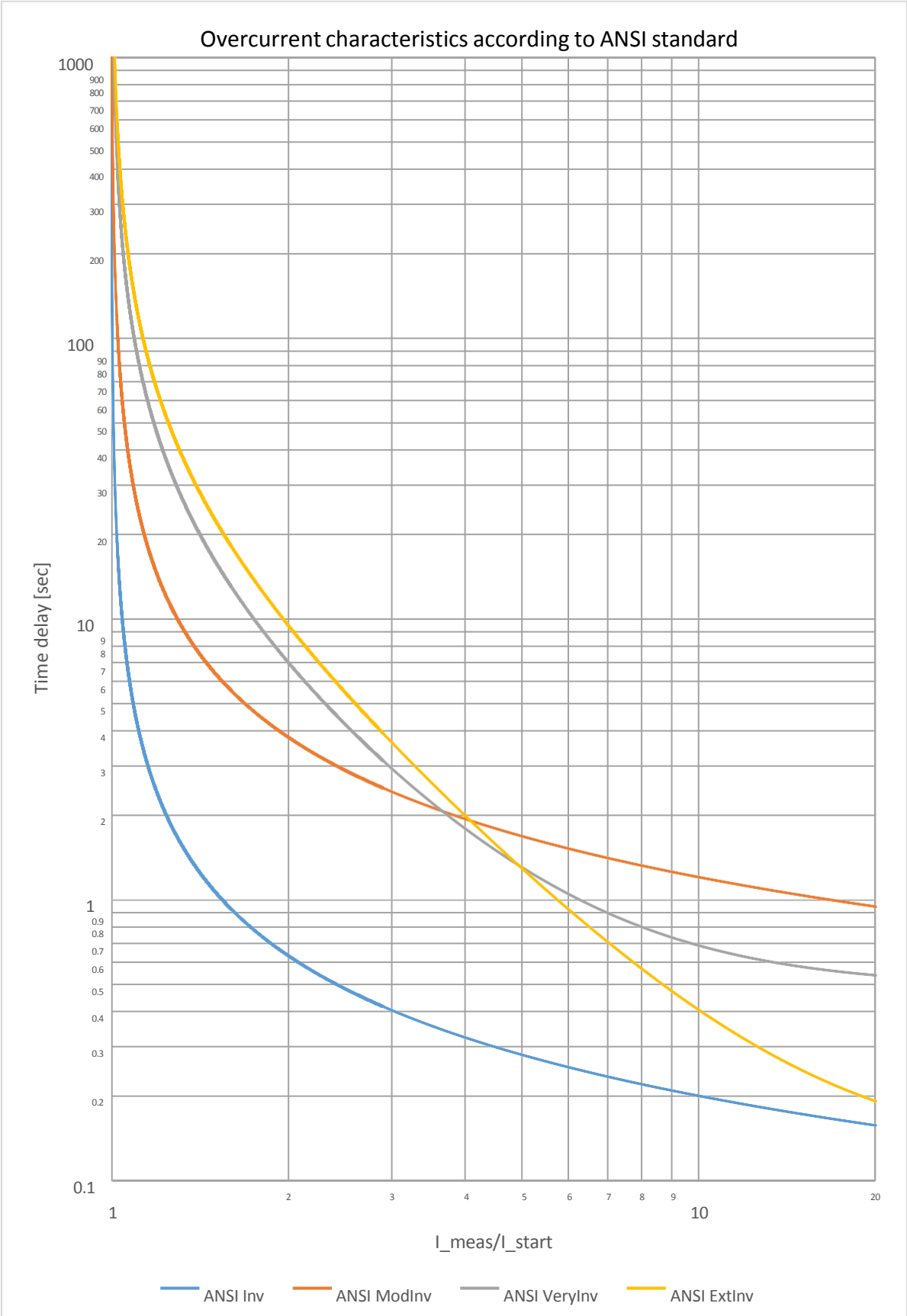


Figure 1-5 Overcurrent characteristics according to ANSI standard

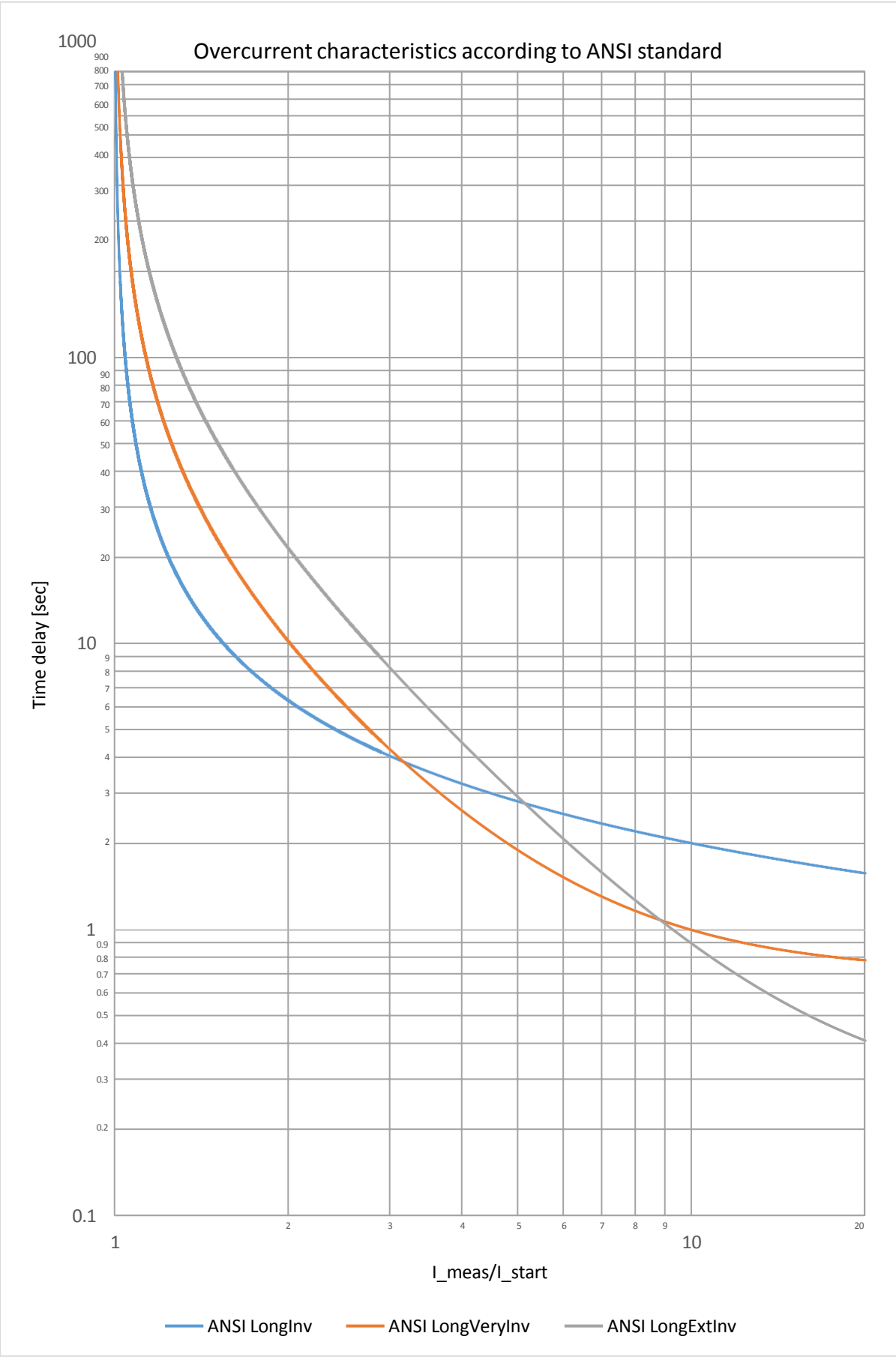


Figure 1-6 Overcurrent characteristics according to ANSI standard

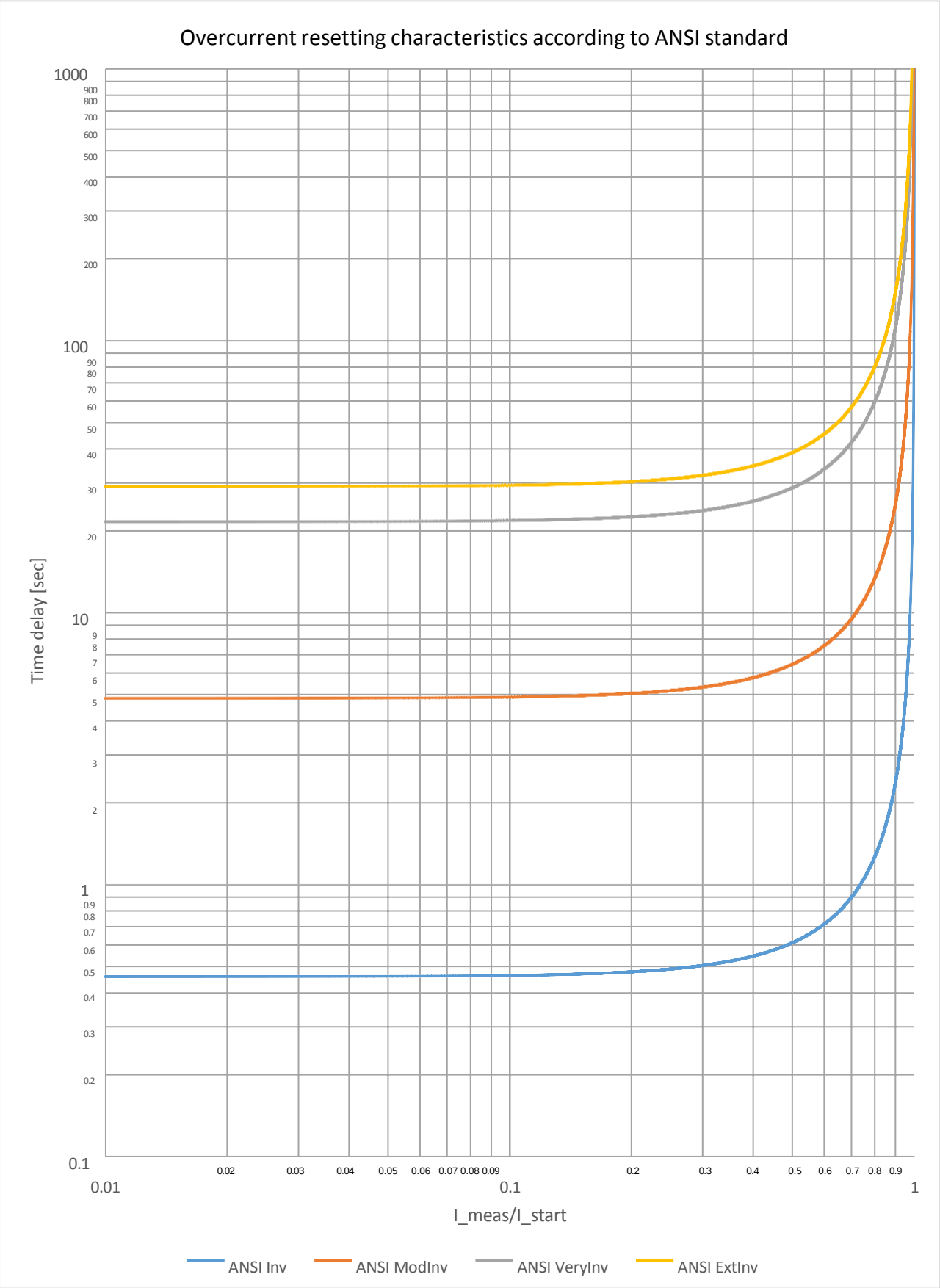


Figure 1-7 Overcurrent resetting characteristics according to ANSI standard

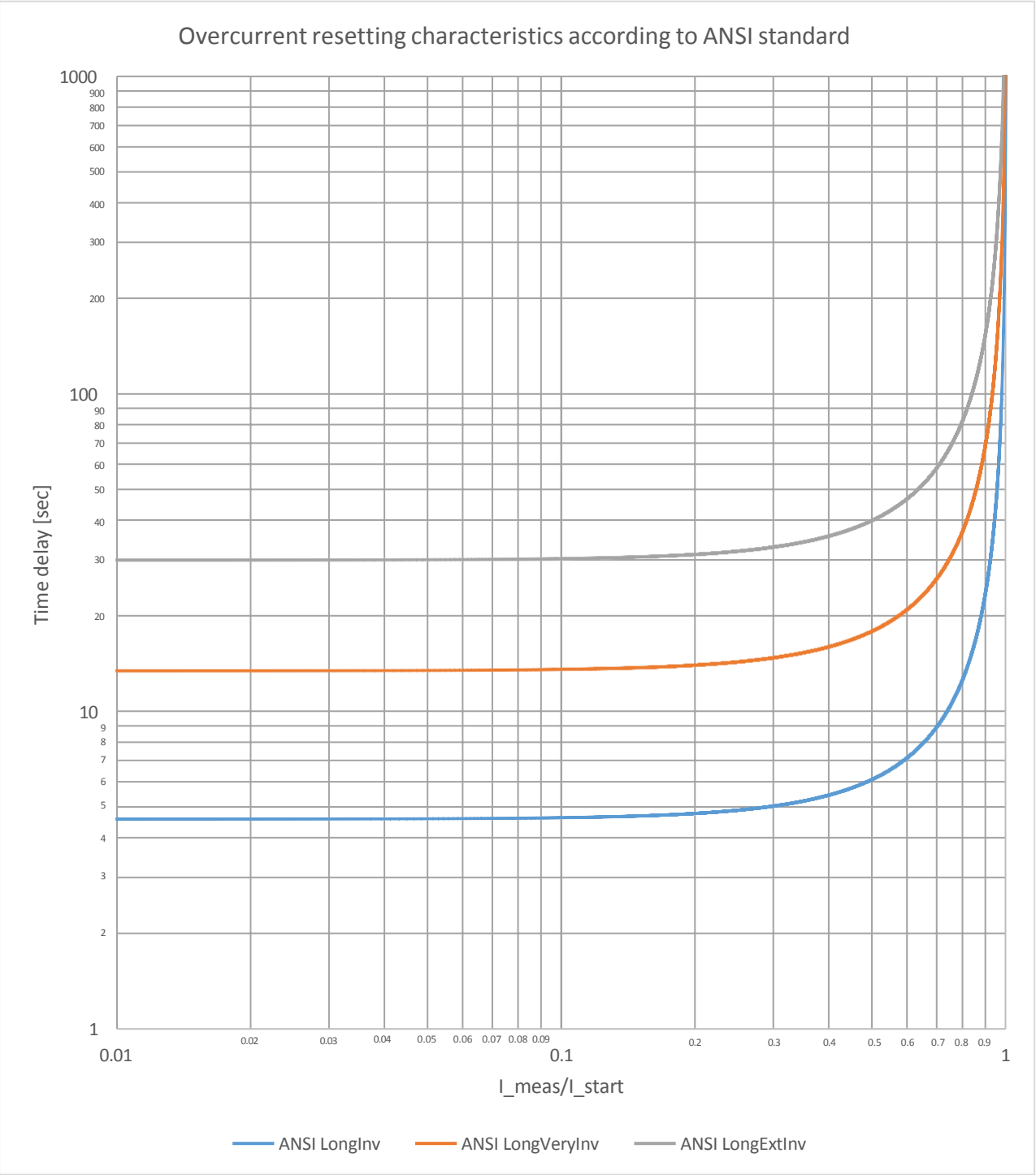


Figure 1-8 Overcurrent resetting characteristics according to ANSI standard

3.1.6.1.4. 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.

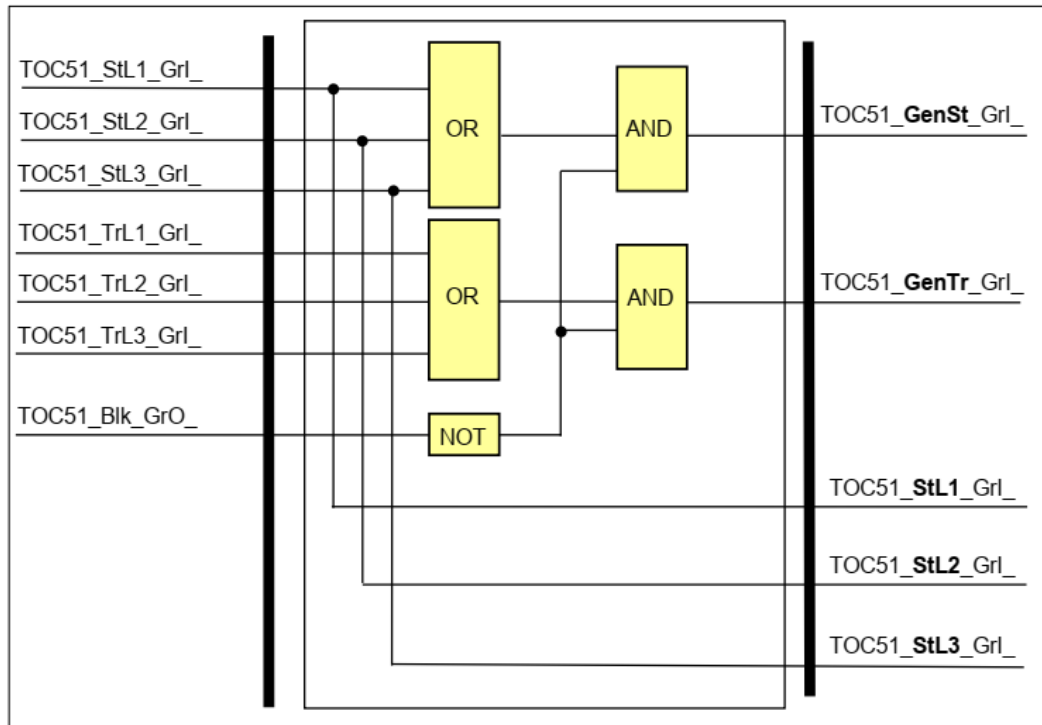
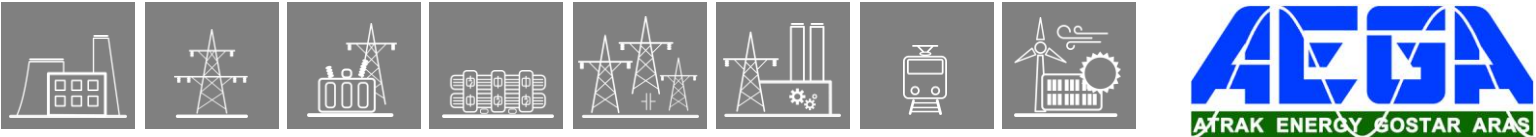


Figure 1-9 The logic scheme of the overcurrent protection function

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_Grl_	Start L1	Starting of the function in phase L1
TOC51_StL2_Grl_	Start L2	Starting of the function in phase L2
TOC51_StL3_Grl_	Start L3	Starting of the function in phase L3
TOC51_GenSt_Grl_	Gen. Start	General starting of the function
TOC51_GenTr_Grl_	Gen. Trip	General trip command of the function

3.1.6.2. 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.

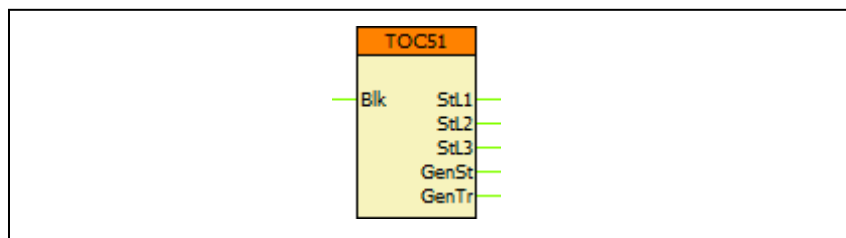


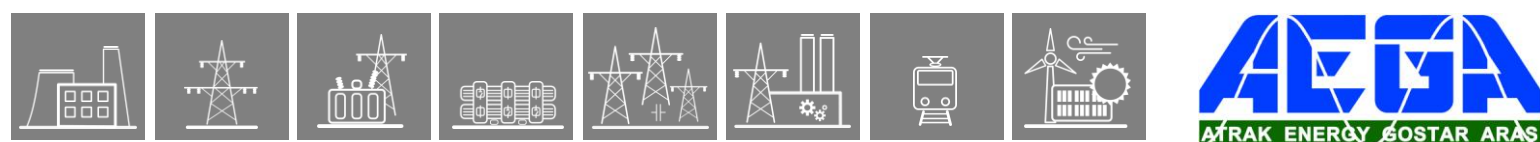
Figure 2-1 The function block of the overcurrent protection function

3.1.6.2.1. Settings

3.1.6.2.1.1. 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



3.1.6.2.2. Function I/O

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

3.1.6.2.2.1. Analogue inputs

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

3.1.6.2.2.2. 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

3.1.6.2.2.3. 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.

3.1.6.2.2.4. 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

3.1.6.2.2.5. 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

3.1.6.2.3. Technical data

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

FUNCTION	VALUE	ACCURACY
Operating accuracy	$20 \leq GS \leq 1000$	< 2 %
Operate time accuracy		$\pm 5\%$ or ± 15 ms, whichever is greater
Reset ratio	0,95	
Reset time * Dependent time char. Definite time char.	Approx. 60 ms	< 5% or ± 35 ms, whichever is greater
Transient overreach		< 2 %
Pickup time *	< 40 ms	
Overshot time Dependent time char. Definite time char.	30 ms 50 ms	
Influence of time varying value of the input current (IEC 60255-151)		< 4 %

* Measured with signal relay contact

3.1.6.2.3.1. 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.



3.1.7. 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 (3I₀) or the calculated zero sequence current component. The characteristics are harmonized with IEC 60255-151, Edition 1.0, 2009-08.

3.1.7.1. Operating characteristics

3.1.7.1.1. Independent time characteristic

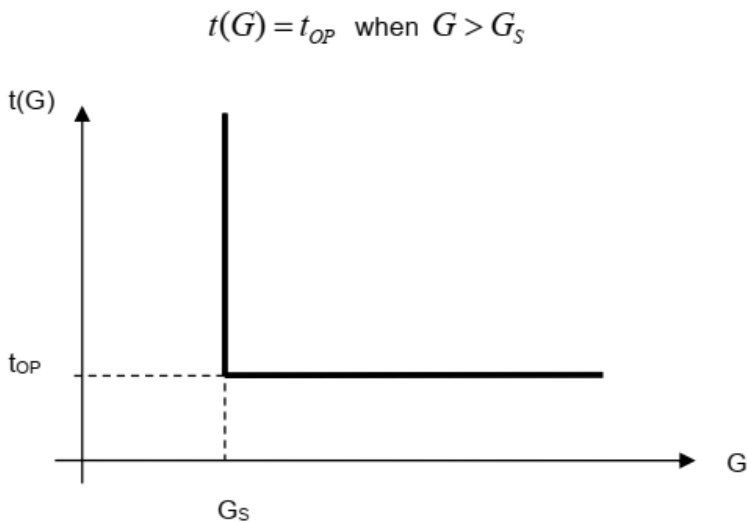


Figure 1-1 Overcurrent independent time characteristic

where	
t_{OP} (seconds)	theoretical operating time if $G > G_s$, fix, according to the preset parameter,
G	measured value of the characteristic quantity, Fourier base harmonic of the residual current,
G_s	preset value of the characteristic quantity (TOC51N_StCurr_IPar_, Start current).

3.1.7.1.2. 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)

k_r, c

α

G

G_s

TMS

theoretical operate time with constant value of G ,
 constants characterizing the selected curve (in seconds),
 constant characterizing the selected curve (no dimension),
 measured value of the characteristic quantity, Fourier base harmonic
 of the residual current (INFour),
 preset value of the characteristic quantity (TOC51N_StCurr_IPar_
 Start current),
 preset time multiplier (no dimension).

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

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

Resetting characteristics:

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

where

$t_r(G)$ (seconds)

k_r

α

G

G_s

TMS

theoretical reset time with constant value of G ,
constants characterizing the selected curve (in seconds),
constant characterizing the selected curve (no dimension),
measured value of the characteristic quantity, Fourier base harmonic
of the residual current,
preset value of the characteristic quantity (TOC51N_StCurr_IPar_
Start current),
preset time multiplier (no dimension).

	IEC ref		k_r	α
1	A	IEC Inv	Resetting after fix time delay, according to preset parameter TOC51N_Reset_TPar_ "Reset delay"	
2	B	IEC VeryInv		
3	C	IEC ExtInv		
4		IEC LongInv		
5		ANSI Inv	0,46	2
6	D	ANSI ModInv	4,85	2
7	E	ANSI VeryInv	21,6	2
8	F	ANSI ExtInv	29,1	2
9		ANSI LongInv	4,6	2
10		ANSI LongVeryInv	13,46	2
11		ANSI LongExtInv	30	2

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

The inverse type characteristics are also combined with a minimum time delay, the value of which is set by user parameter TOC51N_MinDel_TPar_ (Min. Time Delay).

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

$$G_D = 20 * G_s$$

Above this value the theoretical operating time is definite:

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

The combined logic requires expiry both the time defined by the inverse characteristic with the definite section AND the expiry of the minimum time defined by the "Min. Time Delay" parameter.

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

3.1.7.2. Structure of the residual overcurrent protection algorithm

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

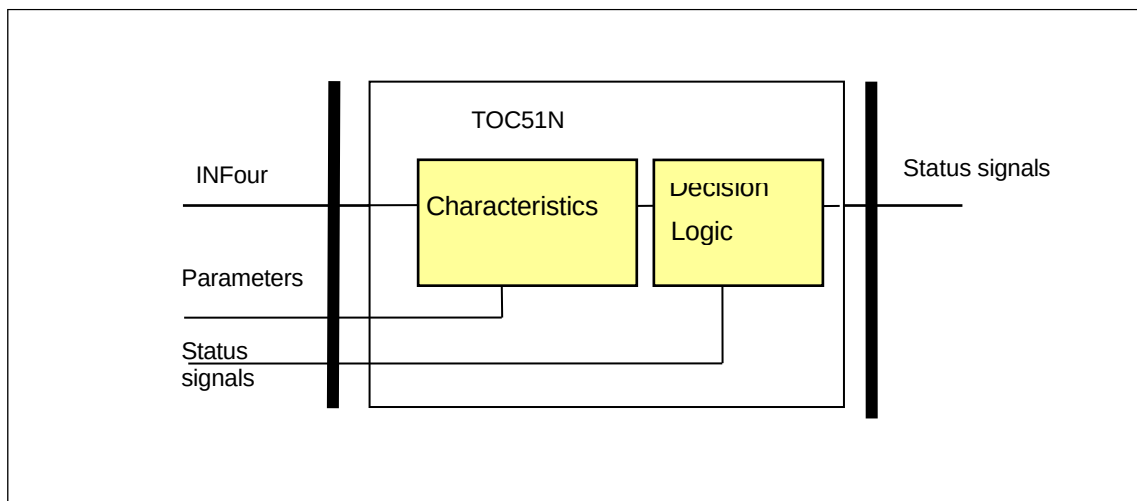


Figure 1-2 Structure of the residual overcurrent protection algorithm

The **inputs** are

the RMS value of the fundamental Fourier component of the residual current ($I_N=3I_o$),
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.



3.1.7.3. 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.

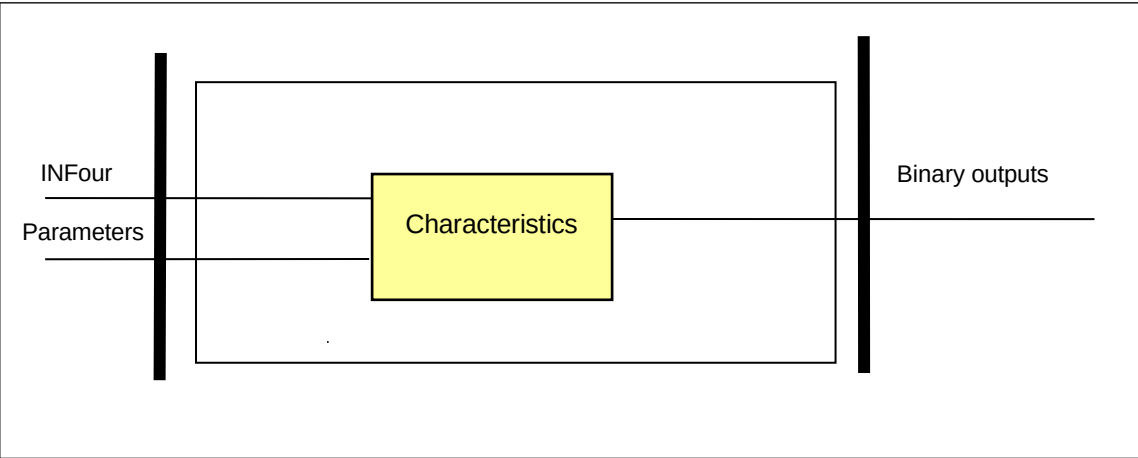


Figure 1-3 Schema of the characteristic calculation

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

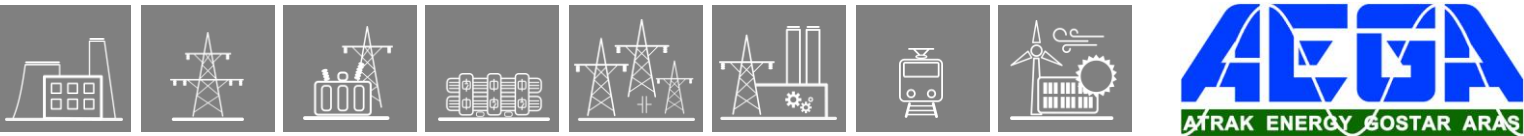
Integer parameters

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

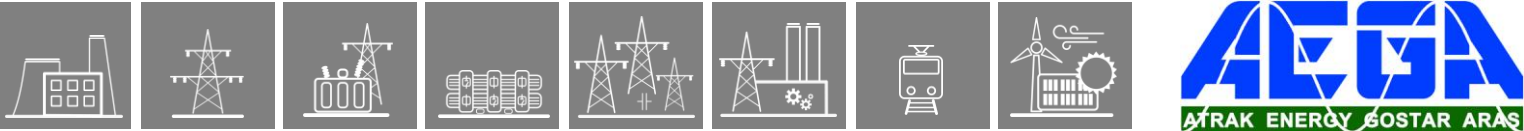
**Valid for definite type characteristics only

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



3.1.7.4. The decision logic (Decision logic)

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

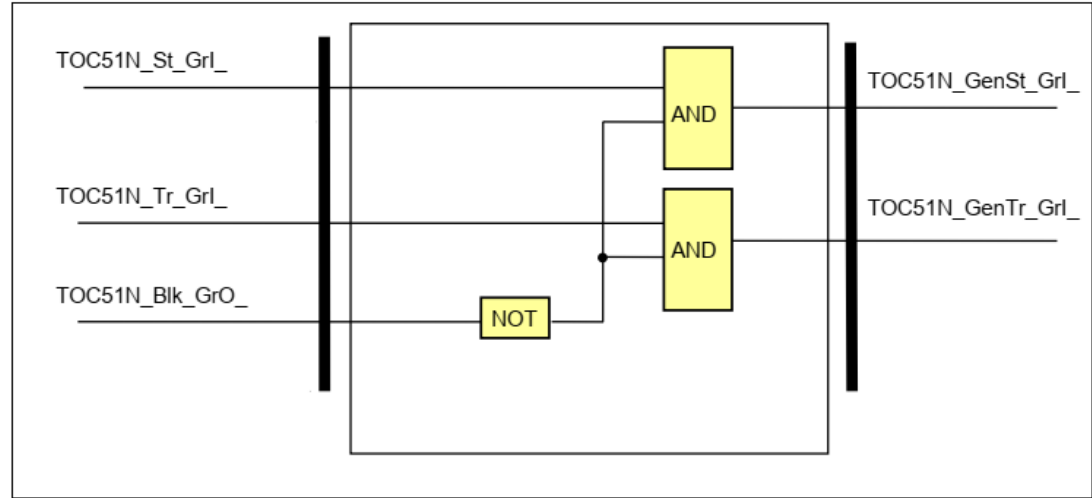


Figure 1-4 The (simplified) logic scheme of the residual overcurrent protection function

Binary input signals	Signal title	Explanation
TOC5N1_St_Grl_	Start	Starting of the function
TOC51N_Tr_Grl_	Trip	Trip command of the function

Table 1-8 The binary input status signals of the residual overcurrent protection function

Binary status signals

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

Binary status signal	Explanation
TOC51N_BlK_GrO_	Output status of a graphic equation defined by the user to disable the residual overcurrent protection function.

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

Binary output signals	Signal title	Explanation
TOC51N_GenSt_Grl_	General Start	General starting of the function
TOC51N_GenTr_Grl_	General Trip	General trip command of the function

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

3.1.7.5. Technical summary

3.1.7.5.1. Technical data

Function	Value	Accuracy
Operating accuracy *	$20 \leq G_s \leq 1000$	< 3 %
Operate time accuracy		$\pm 5\%$ or ± 15 ms, whichever is greater
Reset ratio	0,95	
Reset time * Dependent time char. Definite time char.	Approx 60 ms	< 5% or ± 35 ms, whichever is greater
Transient overreach		2 %
Pickup time	≤ 40 ms	
Overshot time Dependent time char. Definite time char.	30 ms 50 ms	
Influence of time varying value of the input current (IEC 60255-151)		< 4 %

* Measured in version $I_n = 200$ mA

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

3.1.7.5.2. The parameters

The parameters are summarized in Chapter 1.3.

3.1.7.5.3. 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

3.1.7.5.4. The binary output status signals

The **binary output status signals** of the residual overcurrent protection function are listed in Table 1-13.

Binary output signals	Signal title	Explanation
TOC51N_GenSt_Grl_	General Start	General starting of the function
TOC51N_GenTr_Grl_	General Trip	General trip command of the function

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



3.1.7.5.5. The function block

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

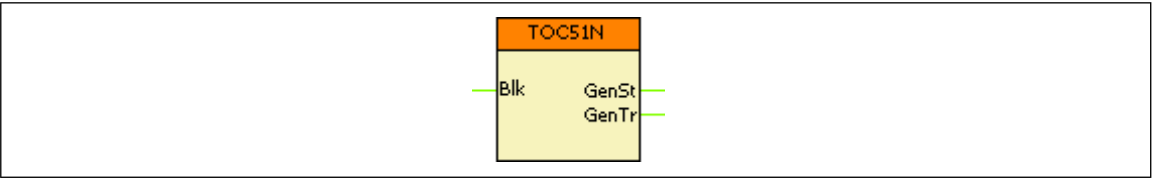


Figure 1-5 The function block of the residual overcurrent protection function

3.1.8. Restricted earth-fault protection function

The restricted earth-fault protection function is basically a low-impedance differential protection function based on zero sequence current components. It can be applied to transformers with grounded neutral. The function compares the measured neutral current at the star point and the calculated zero sequence current component of the phase currents and generates a trip command if the difference of these currents is above the characteristics.

3.1.8.1. Structure of the restricted earth-fault protection algorithm

Fig.1-1 shows the structure of the restricted earth-fault protection (DIF87N) algorithm.

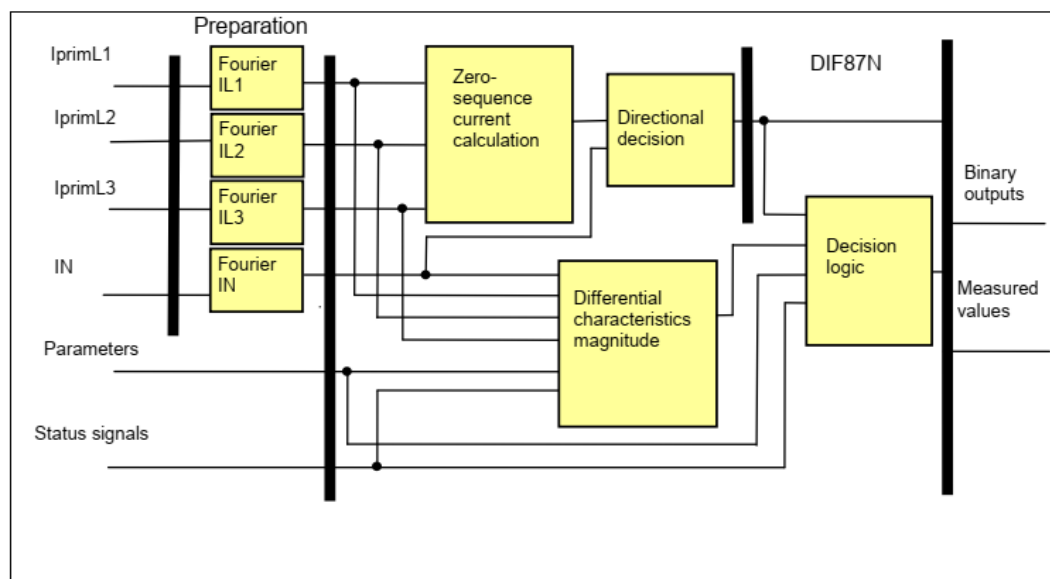


Figure 1-1 Structure of the restricted earth-fault protection algorithm

The **inputs** for the preparation are:

- the sampled values of three primary phase currents,
- the sampled value of the neutral current.

The **outputs** of the preparation are:

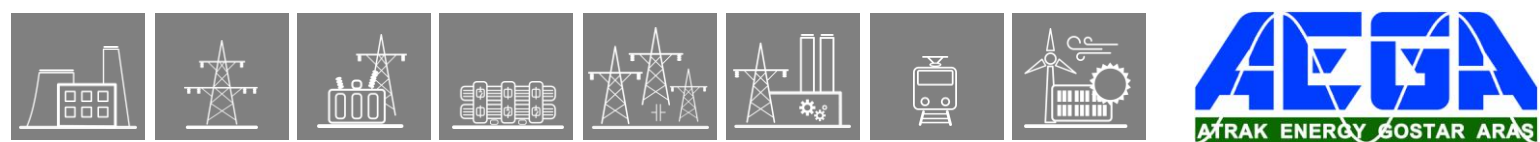
- the RMS values of the fundamental Fourier components of the phase currents and that of the neutral current.

The **inputs** for the DIF87N function are:

- the RMS values of the fundamental Fourier components of the phase currents and that of the neutral current,
- parameters,
- status signal.

The **outputs** of the DIF87N function are:

- the binary output status signal,
- the measured values for displaying.



The **software modules** of the restricted earth-fault protection function:

Fourier calculations

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

Zero sequence current calculation

This module calculates the zero sequence current components based on the Fourier components of the phase currents. These modules belong to the preparatory phase.

Directional decision

This module compares the direction of the neutral current and that of the calculated zero sequence current. In case of small zero sequence components of the high fault currents in the phases, this decision improves the stability of the function.

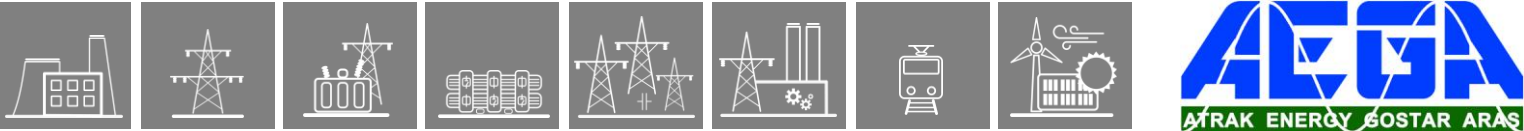
Differential characteristics

This module performs the necessary calculations for the evaluation of the “percentage differential characteristics” and decides if the differential current is above the characteristic curve of the restricted earth-fault protection function. This curve is the function of the restraint current, which is the maximum of the phase currents and the current of the neutral point. The result of this calculation is needed for the decision logic.

Decision logic

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

The following description explains the details of the individual components.



3.1.8.2. The Fourier calculation (Fourier)

These modules calculate the basic Fourier current components of the phase currents and that of the neutral current individually. The magnitudes of these currents are matched to each other using the current transformer rated current values. These modules belong to the preparatory phase.

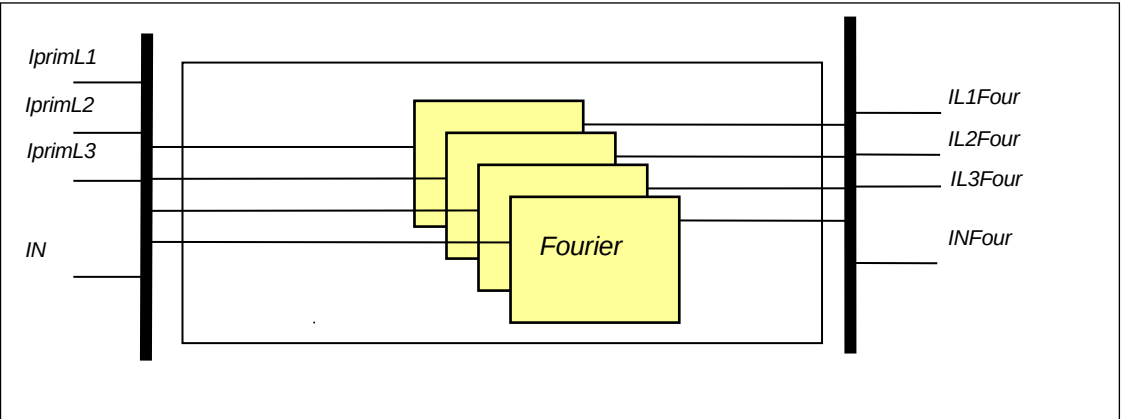


Figure 1-2 Principal scheme of the Fourier calculation

The **inputs** are the sampled values of:

- the three phase currents of the primary side (IprimL1, IprimL2, IprimL3)
- the current measured at the neutral point (IN)

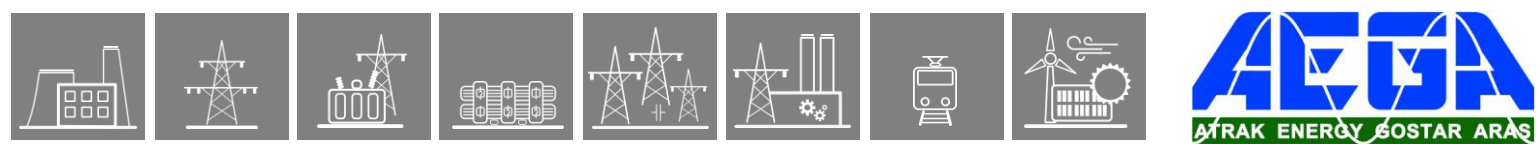
The **outputs** are the basic Fourier components of the analyzed currents (IL1Four, IL2Four, IL3Four, INFour).

The **integer parameters** of the Fourier calculation are listed in (% related to the input rated current)
Table 1-1.

Parameter name	Title	Unit	Min	Max	Step	Default
Parameters for the current magnitude compensation:						
DIF87N_TRPri_IPar__	TR Primary Comp	%	20	500	1	100
DIF87N_TRNeut_IPar__	TR Neutral	%	100	1000	1	500

(% related to the input rated current)

Table 1-1 The integer parameters of the Fourier calculation



3.1.8.3. The zero sequence current calculation (Zero sequence current calculation)

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

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

The **outputs** are the Fourier components of the calculated zero sequence current (3IoFour).

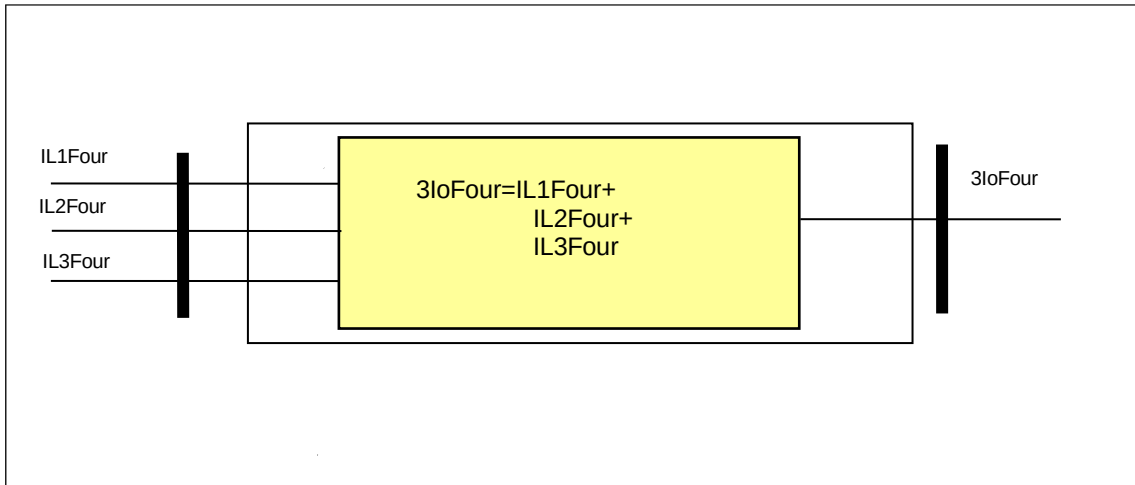


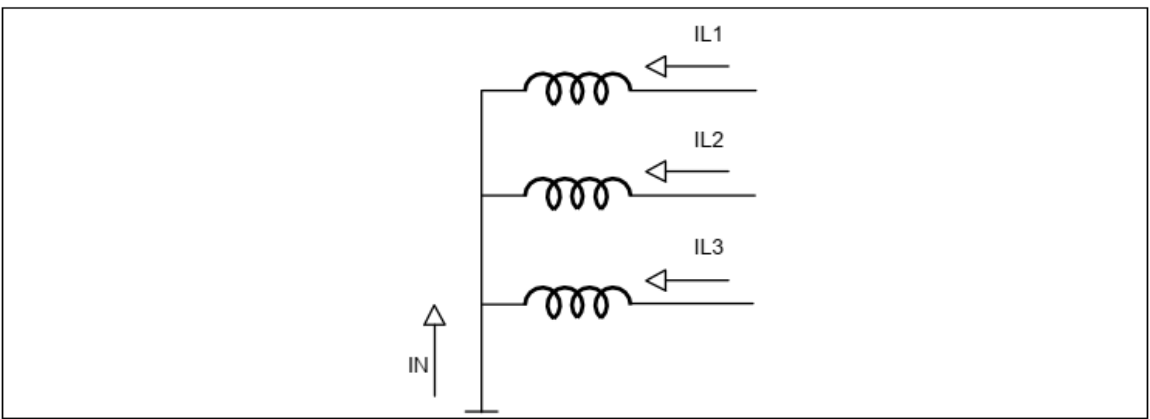
Figure 1-3 Principal scheme of the zero sequence current calculation

3.1.8.4. Directional decision (Directional decision)

This module compares the direction of the neutral current and that of the calculated zero sequence current. In case of small zero sequence component of the high fault currents in the phases, this decision improves the stability of the function.

For the directional decision, the positive directions are drawn in Figure 1-4. In this system, if the angle between the calculated zero sequence current $3I_0$ and the measured neutral current I_N is out of the range of ± 90 degrees, then the restricted earth fault protection can be blocked, the status signal DIF87N_StDir_GrI_ (Dir.element Start) is set to TRUE value.

The blocking of the directional decision is decided in the decision logic of the function, using the binary parameter DIF87N_DirCheck_BPar_.

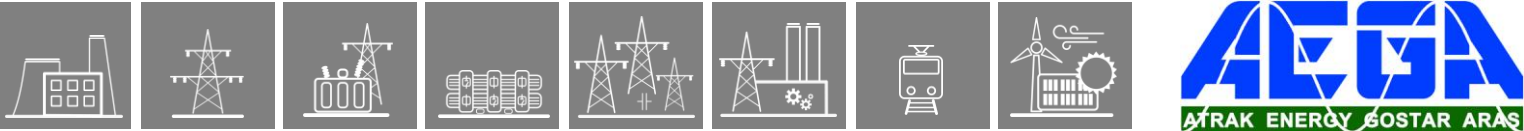


The **inputs** are the Fourier components of the calculated zero sequence current (3IoFour) and that of the neutral current (INFour).

Binary output signals	Signal title	Explanation
DIF87N_StDir_Grl_	Dir.element Start	Directional blocking signal of the zero-sequence directional element

3.1.8.5. The zero sequence differential characteristics (Differential characteristics)

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The differential current is calculated using the following formula:

$$\text{Diff Current} = IL1\text{Four} + IL2\text{Four} + IL3\text{Four} + IN\text{Four}$$

The restraint current is calculated using the following formula:

$$\text{Bias Current} = \text{MAX}(IL1\text{Four}, IL2\text{Four}, IL3\text{Four}, IN\text{Four})$$

Based on these values, the zero sequence differential protection characteristics are shown in *Figure 1-6*.

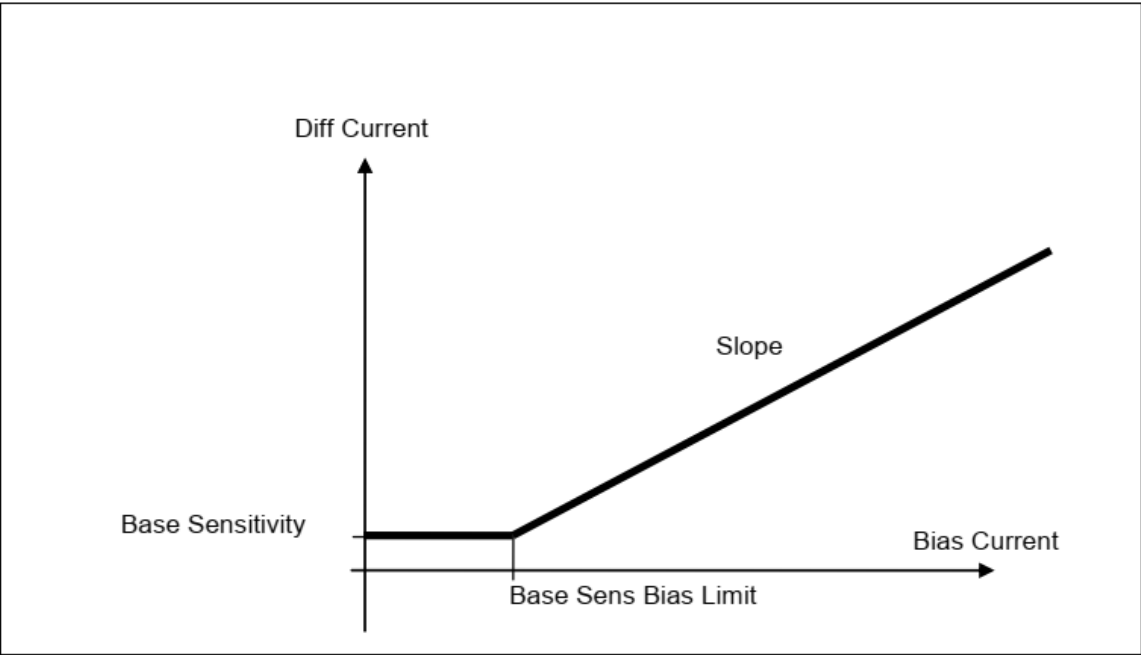


Figure 1-6 The zero sequence differential protection characteristics

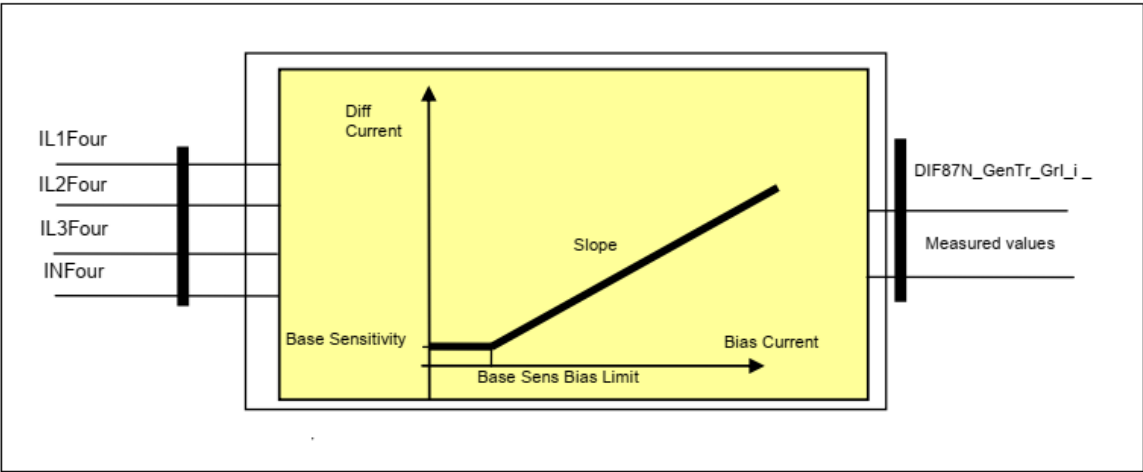
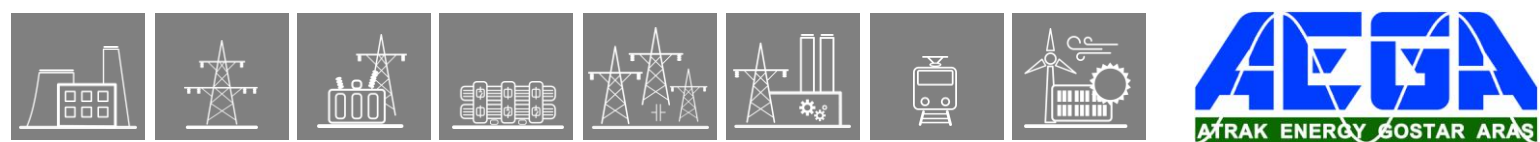


Figure 1-7 Principal scheme of the zero sequence differential protection



The **measured values** of the restricted earth-fault protection function are listed in Table 1-3.

Measured value	Title	Dim.	Explanation
DIF87N_Id_OLM_	Diff Current	In %	The calculated differential current
DIF87N_Bias_OLM_	Bias Current	In %	The calculated restraint current

Table 1-3 The measured analogue values of the zero sequence differential protection characteristics

The **binary output status signal** of the restricted earth-fault protection characteristics is shown in Table 1-4.

Binary output signals	Signal title	Explanation
DIF87N_GenTr_GrI_i	General Trip_i	Internal general trip signal of the differential characteristics

Table 1-4 The binary output status signals of the zero sequence differential protection characteristics

The parameters of the restricted earth-fault protection characteristics are explained in the following tables.

The integer parameters of the restricted earth-fault protection characteristics are listed in Table 1-5.

Parameter name	Title	Unit	Min	Max	Step	Default
Base sensitivity:						
DIF87N_f1_IPar_	Base Sensitivity	%*	10	50	1	30
Slope of the second section of the characteristics:						
DIF87N_f2_IPar_	Slope	%**	50	100	1	70
Break point of the characteristic line:						
DIF87N_f2Brk_IPar_	Base Sens Bias Limit	%*	100	200	1	125

(* % related to the magnitude-compensated current (see Table 1-1)

** % related to the bias current)

Table 1-5 The integer parameters of the zero sequence differential protection characteristics

The binary input signal serves to increase the base sensitivity by 4 times. **The conditions of increasing are defined by the user, applying the graphic equation editor.**

Binary input signal	Explanation
DIF87N_UnSens_GrO_	Output status of a graphic equation defined by the user to increase the base sensitivity by 4 times

Table 1-6 The binary input signal of the zero sequence differential protection characteristics



3.1.8.6. The decision logic (Decision logic)

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

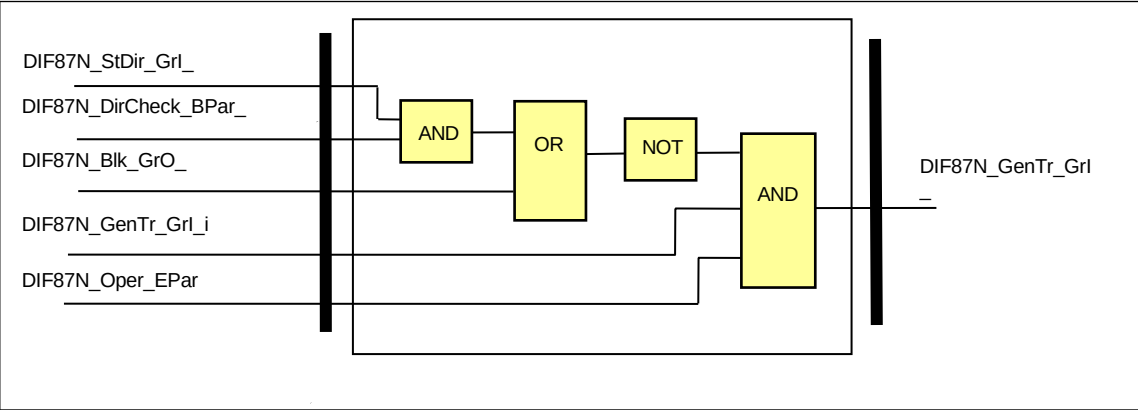


Figure 1-8 The logic scheme of the restricted earth-fault protection function

Binary input signals	Signal title	Explanation
DIF87N_GenTr_GrI_i	General Trip_i	Internal general trip signal of the differential characteristics
DIF87N_StDir_GrI_	Dir.element Start	Directional blocking signal restricted earth-fault protection function

Table 1-7 The binary input status signals of the zero sequence differential protection characteristics

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

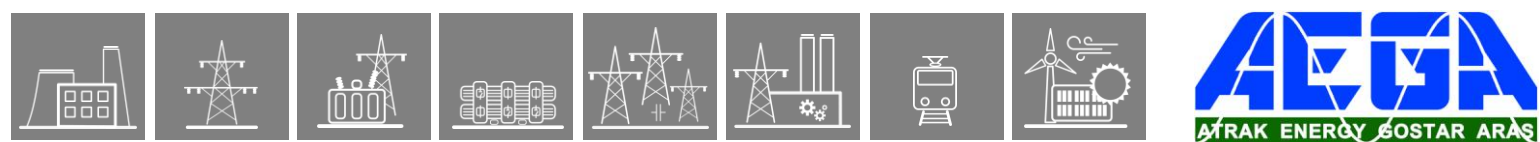
Binary input signal	Explanation
DIF87N_BlK_GrO	Output status of a graphic equation defined by the user to disable the restricted earth-fault protection function.

Table 1-8 The binary input signal of the restricted earth-fault protection function

The binary output signals of the restricted earth-fault protection function are listed in Table 1-9.

Binary output signals	Signal title	Explanation
DIF87N_GenTr_GrI_	General Trip	General trip signal of the zero sequence differential protection characteristics
DIF87N_StDir_GrI_	Dir.element Start	Directional blocking signal of the restricted earth-fault protection function

Table 1-9 The binary output status signals of the zero sequence differential protection characteristics



The enumerated parameter of the restricted earth-fault protection function is shown in Table 1-10:

Parameter name	Title	Selection range	Default
Parameter to enable the zero sequence differential protection function:			
DIF87N_Oper_EPar_	Operation	Off, On	On

Table 1-10 The enumerated parameters of the restricted earth-fault protection function

The Boolean parameter of the restricted earth-fault protection function is shown in Table 1-11:

Parameter name	Title	Default	Explanation
DIF87N_DirCheck_BPar_	Directional check	True	Enabling the directional checking of the measured and calculated zero sequence currents

Table 1-11 The Boolean parameters of the restricted earth-fault protection function

The restricted earth-fault protection function generates a trip signal if the differential current as the function of the bias current is above the differential characteristic lines and the function is not blocked and the operation of the function is enabled by parameter setting.

Blocking can be caused by the directional decision if it is enabled by parameter setting and the angle of the currents is in the blocking area or the user has composed a blocking graphic equation, and the conditions result a TRUE value for the blocking.

3.1.8.7. Technical summary

3.1.8.7.1. Technical data

Function	Value	Accuracy
Operating characteristic	1 breakpoint	
Reset ratio	0,95	
Characteristic accuracy		<2%
Operate time	< 35 ms	
Reset time	< 25 ms	

Table 1-12 Technical data of the restricted earth fault protection

3.1.8.7.2. The measured values

The **measured values** of the restricted earth-fault protection function are listed in Table 1-13.

Measured value	Title	Dim.	Explanation
DIF87N_Id_OLM_	Diff Current	In %	The calculated differential current
DIF87N_Bias_OLM_	Bias Current	In %	The calculated restraint current

Table 1-13 The measured analogue values of the restricted earth-fault protection function

The parameters of the restricted earth-fault protection function are explained in the following tables.

3.1.8.7.3. The parameters

The **enumerated parameter** of the restricted earth-fault protection function is shown in Table 1-14:

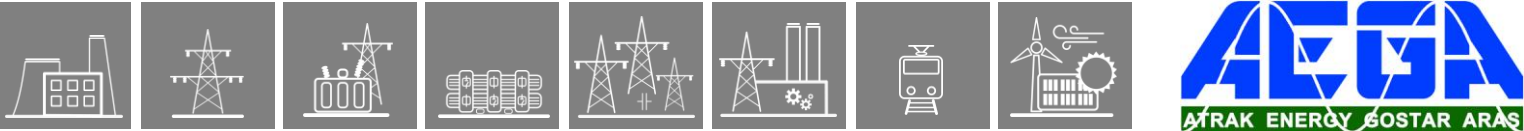
Parameter name	Title	Selection range	Default
Parameter to enable the zero sequence differential protection function:			
DIF87N_Oper_EPar_	Operation	Off, On	On

Table 1-14 The enumerated parameters of the restricted earth-fault protection function

The **Boolean parameter** of the restricted earth-fault protection function is shown in Table 1-15:

Parameter name	Title	Default	Explanation
DIF87N_DirCheck_BPar_	Directional check	True	Enabling the directional checking of the measured and calculated zero sequence currents

Table 1-15 The Boolean parameters of the restricted earth-fault protection function



The integer parameters of the restricted earth-fault protection function are listed in Table 1-16.

Parameter name	Title	Unit	Min	Max	Step	Default
Parameters for the current magnitude compensation:						
DIF87N_TRPri_IPar_	TR Primary Comp	%	20	500	1	100
DIF87N_TRNeut_IPar_	TR Neutral	%	100	1000	1	500
Base sensitivity:						
DIF87N_f1_IPar_	Base Sensitivity	%	10	50	1	30
Slope of the second section of the characteristics:						
DIF87N_f2_IPar_	Slope	%	50	100	1	70
Break point of the characteristic line:						
DIF87N_f2Brk_IPar_	Base Sens Bias Limit	%	100	200	1	125

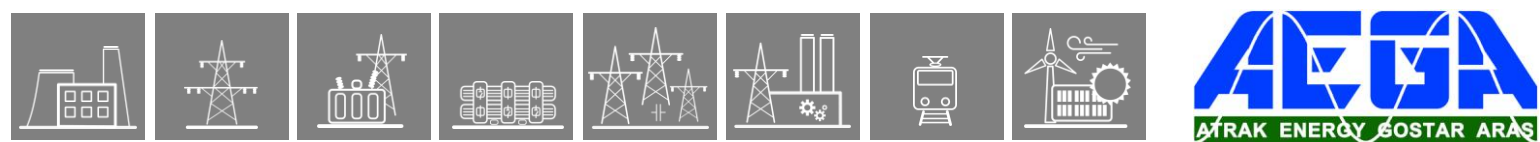
Table 1-16 The integer parameters of the restricted earth-fault protection function

Floating-point parameters

The restricted earth-fault protection function has no floating-point parameters.

Timer parameters

The restricted earth-fault protection function has no timers.



3.1.8.7.4. The binary input status signals

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

The other binary input signal serves to increase the base sensitivity by 4 times. **The conditions of increasing the base sensitivity are defined by the user, applying the graphic equation editor.**

Binary input signal	Explanation
DIF87N_BlK_GrO	Output status of a graphic equation defined by the user to disable the restricted earth-fault protection function.
DIF87N_UnSens_GrO_	Output status of a graphic equation defined by the user to increase the base sensitivity by 4 times

Table 1-17 The binary input signal of the restricted earth-fault protection function

3.1.8.7.5. Binary output status signals

The **binary output status signals** of the restricted earth-fault protection function are listed in Table 1-18.

Binary output signals	Signal title	Explanation
DIF87N_GenTr_GrI_	General Trip	General trip signal of the restricted earth-fault protection function

Table 1-18 The binary output status signals of the restricted earth-fault protection function

3.1.8.7.6. The function block

The function block of the restricted earth fault protection function is shown in Figure 1-9. This block shows all binary input and output status signals that are applicable in the graphic equation editor.

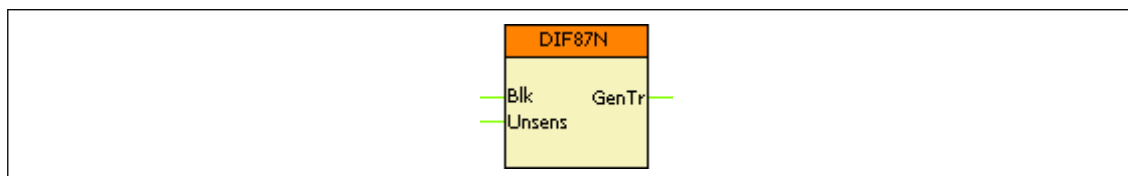
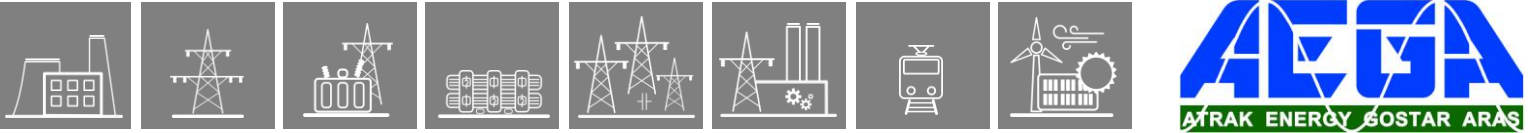


Figure 1-9 The function block of the restricted earth-fault protection function



3.1.8.8. Example for the calculation of settings of the zero sequence differential protection function

As an example, the transformer data:
 $S_n = 25 \text{ MVA}$
 $U_1/U_2 = 120/22 \text{ kV/kV}$
 $Y(d)y_6$

Current transformers:
 $CT_1 \quad 600/1 \text{ A/A}$
 $CT_2 \quad 800/1 \text{ A/A}$
 $CT_N \quad 250/1 \text{ A/A}$

The selected base current is the primary rated current of the transformer: 120 A. If a lower current value is selected, the zero sequence differential protection becomes more sensitive.

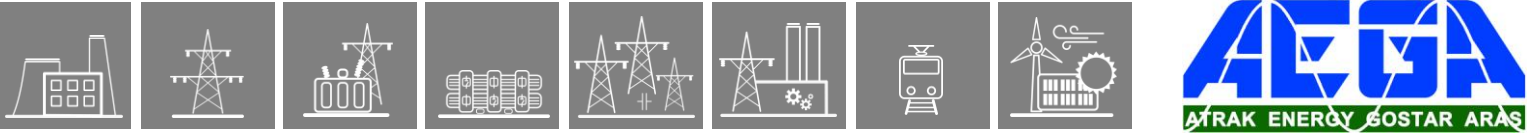
REF on the secondary side:

$I_{1np} = 120 \text{ A}$
 $I_{2np} = 656 \text{ A}$ On the secondary side of the CT $I_{2n} = 0.82 \text{ A}$
 $I_{Np} = 656 \text{ A}$ On the secondary side of the CT $I_N = 2.6 \text{ A}$

The setting parameters:

Parameter name	Title	Setting value
DIF87N_TRPri_IPar_	TR Primary Comp	82%
DIF87N_TRNeut_IPar_	TR Neutral	260%

The base sensitivity refers to the selected “base current” expressed in %, the slope is the ratio of the differential current and the bias current expressed in %.



3.1.8.9. Example for the application

For the application example consider an autotransformer equipped with tertiary, according to Figure 1-1. The coils for the primary and secondary sides are auto-connected with solidly grounded neutral. The tertiary coils are delta connected, and applied also for power transmission.

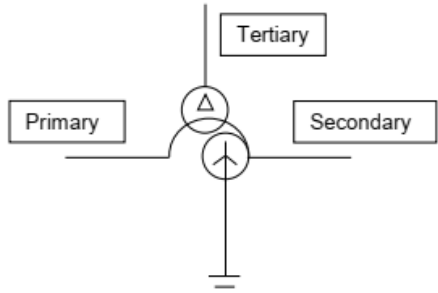


Figure 1-1 Autotransformer application

Example transformer data for the application:

Rated voltages: 220 kV / 132 kV / 11 kV
Rated power: 100 MVA / 100 MVA / 30 MVA
Calculated rated currents: 262 A / 437 A / 1575 A (5249 A)

NOTE: for the tertiary coil two currents are calculated, one is based on the coil rated power; this is 1575 A and one for the highest reference power (5249 A). This higher value is needed for balancing the differential protection function.

Current transformers installed for the application are shown in Figure 1-2. The P1 points are arranged towards the transformer, except the CT in the grounding. For this CT the P2 point is toward the transformer.

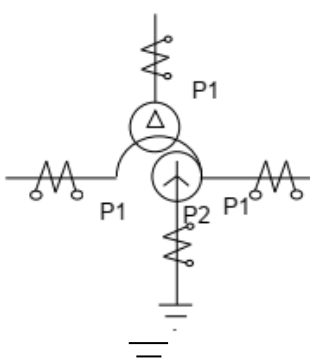


Figure 1-2 Current transformers, assigned to the differential protection and restricted earth-fault protection functions

Current transformer data:

Primary side 300 A / 1 A
Secondary side 500 A / 1 A
Tertiary side 2000 A / 1 A
Grounding 300 A / 1 A

Suppose that the transformer is to be protected by differential protection and restricted earth-fault protection.

The phase differential protection involves the primary, secondary and tertiary windings, for this function the current measured by the CT in the grounding is not applied. The zero sequence current is eliminated numerically using matrix transformation within the differential protection function. See *Figure 1-3*.

The restricted earth-fault protection is applied for the galvanic connected windings. This means the auto-connected coils for the primary and secondary sides. The tertiary side is excluded from the protected zone. See *Figure 1-3*.

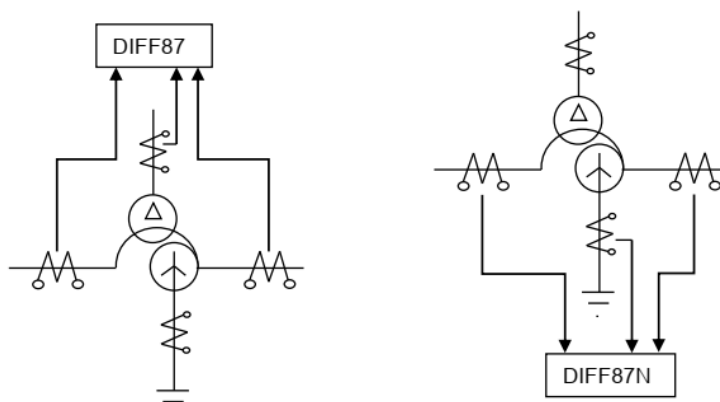


Figure 1-3 Differential protection and restricted restricted earth-fault protection application

The restricted earth-fault protection considers the coils as a node, bordered by current transformers: the three CT-s of the high voltage primary side, three CT-s of the secondary side and the CT in the grounding. Here the Kirchhoff's node-law is to be satisfied: the sum of these seven currents must result zero. In other cases, due to internal fault, a TRIP command is to be generated for the circuit breakers.

If in theory the summation is performed in three steps: first the sum of three primary side currents is calculated, resulting the residual component at the primary side, then the sum of the three secondary currents is calculated, resulting the residual component at the secondary side, finally these calculated residual currents and the residual current measured in the grounding CT is added. As it can be seen, the restricted earth-fault protection is basically a zero sequence differential protection for the galvanic connected coils, as a node.

For the realization of the differential protection and jointly the restricted earth-fault protection function, a Protecta made EuroProt+ device configuration is applied. This device realizes – among other protection, supervision and monitoring functions – also these functions.

The required connection diagram is shown in

Figure 1-4. The device contains three current input modules in positions “R”, “S” and “T”. Each current input module contains four CT inputs. The module in “T” is reserved for the primary three phase currents, and the fourth channel is the input for the CT in the grounding.

The module in “S” is reserved for the secondary three phase currents, and the fourth channel is not applied. Similarly, the module in “R” is reserved for the tertiary three phase currents, and the fourth channel is not applied.

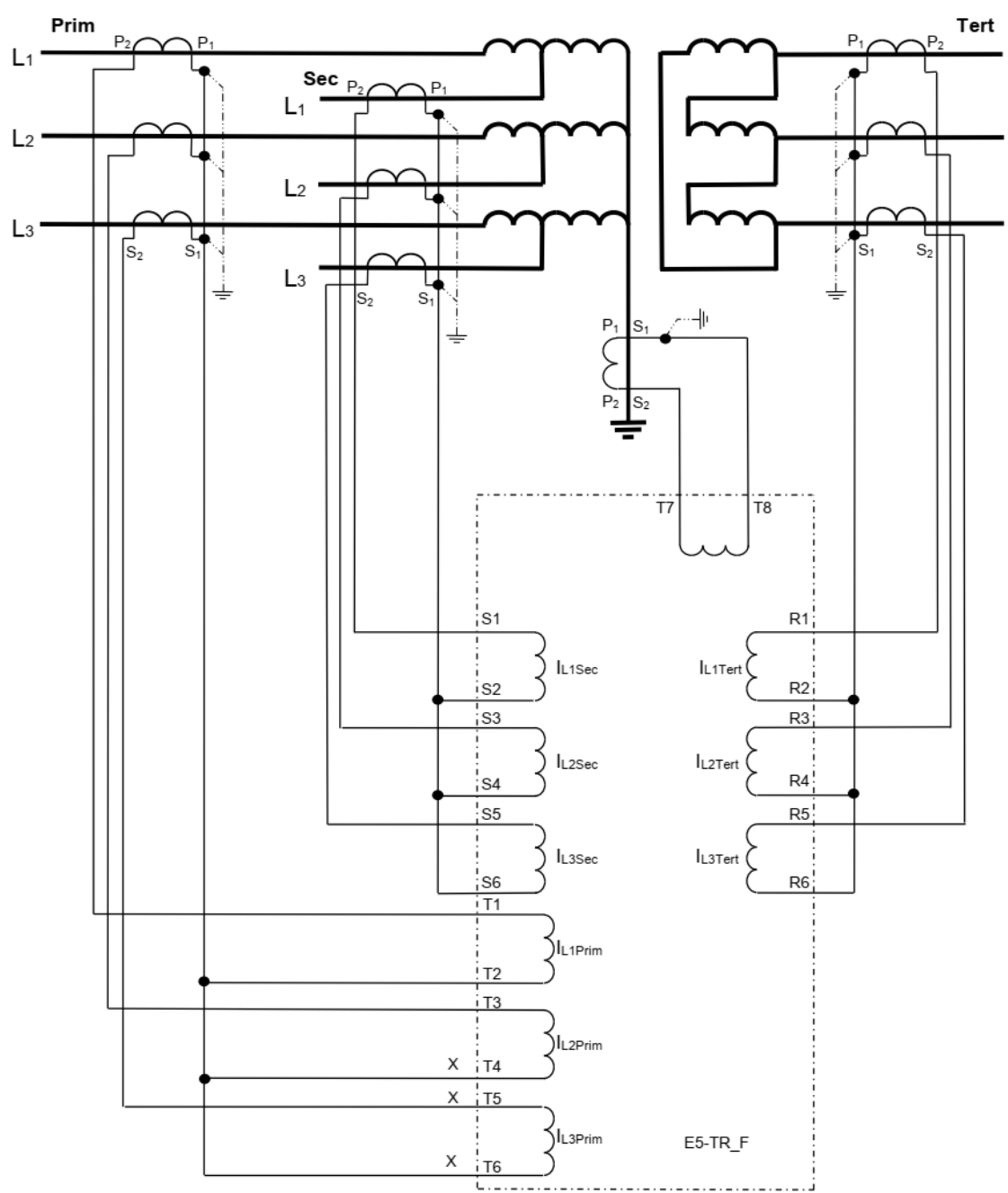
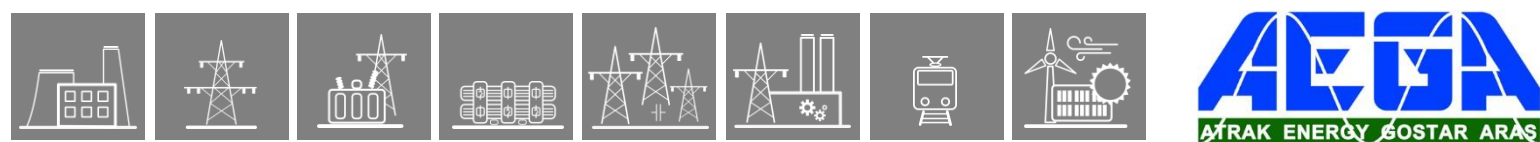


Figure 1-4 EuroProt+ connection diagram for differential protection and restricted earth-fault protection application

NOTE: In this diagram, as default, all CT P1 points are towards the protected object. Due to the reverse connection of the CT in the grounding, applied in the example, this direction is reverted by parameter setting.



In all three sides of the transformer, connect the CT in Y, with the neutral point at the transformer side, according to

Figure 1-4. The vector group compensation, required in Primary/Tertiary and in Secondary/Tertiary relationship is performed numerically within the differential protection function, together with magnitude compensation. Similarly the required zero sequence elimination is solved numerically. No interposing current transformers are required.

3.1.8.9.1. Setting the CT input function blocks

In the EuroProt+ devices the CT inputs are assigned to CT function blocks. They need parameter setting and also displaying functions are assigned to them. *Figure 2-1* shows the parameter screen, when there is Internet connection with the device. For details about this communication see the Protecta document “**Remote user interface description**” available in Protecta WEB site www.protecta.hu.

NOTE: the parameters can be set also using the local LCD touch-screen of the device, if no internet connection is available. For details about this communication see the Protecta document “**LCD touchscreen interface description**” available in Protecta WEB site www.protecta.hu.

The parameters of the current input function are explained in the following tables.

Enumerated parameters

Parameter name	Title	Selection range	Default
Rated secondary current of the first three input channels. 1A or 5A is selected by parameter setting, no hardware modification is needed.			
CT4_Ch13Nom_EPar_	Rated Secondary I1-3	1A,5A	1A
Rated secondary current of the fourth input channel. 1A or 5A (0.2A, 1A) is selected by parameter setting, no hardware modification is needed.			
CT4_Ch4Nom_EPar_	Rated Secondary I4	1A,5A (0.2A, 1A)	1A
Definition of the positive direction of the first three currents, given by location of the secondary star connection point			
CT4_Ch13Dir_EPar_	Starpoint I1-3	Line,Bus	Line
Definition of the positive direction of the fourth current, given as normal or inverted			
CT4_Ch4Dir_EPar_	Direction I4	Normal,Inverted	Normal

Table 2-1 The enumerated parameters of the current input function

Floating point parameters

Parameter name	Title	Dim.	Min	Max	Default
Rated primary current of channel1-3					
CT4_Pr113_FPar_	Rated Primary I1-3	A	100	4000	1000
Rated primary current of channel4					
CT4_Pr14_FPar_	Rated Primary I4	A	100	4000	1000

Table 2-2 The floating point parameters of the current input function

NOTE: The rated primary current of the channels is not needed for the current input function block itself. These values are passed on to the subsequent function blocks.

[-] CT4 module Prim.

	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	Inverted	Inverted	
Rated Primary I1-3	300	300	A
Rated Primary I4	300	300	A

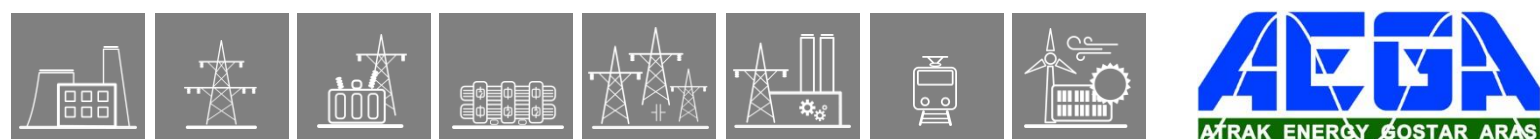
[-] CT4 module Sec.

	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	500	500	A
Rated Primary I4	300	300	A

[-] CT4 module Tert.

	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	2000	2000	A
Rated Primary I4	300	300	A

Figure 2-1 EuroProt+ parameter screen for the CT input modules



Using the information given in this example above, the following setting values are assigned:

Primary side and grounding CT:

Rated Secondary I1-3	1A	Selected, according to the CT applied at the primary side.
Rated Secondary I4	1A	Selected, according to the CT applied in the grounding.
Starpoint I1-3	Line	"Line" in this case means "Toward protected object = Transformer"
Direction I4	Inverted	In this application all P1 points of the CT-s are on the transformer side, except the CT in the grounding, which has P2 point at the transformer side. This is the reason why the positive direction is "Inverted" to fulfill the Kirchhoff's node law.
Rated Primary I1-3	300	Setting, according to the CT applied at the primary side. This parameter is used for scaling the displayed values only
Rated Primary I4	300	Setting, according to the CT applied in the grounding. This parameter is used for scaling the displayed values only

Secondary side:

Rated Secondary I1-3	1A	Selected, according to the CT applied at the secondary side.
Rated Secondary I4		Not applied, the value is not considered.
Starpoint I1-3	Line	"Line" in this case means "Toward protected object = Transformer"
Direction I4		Not applied, the value is not considered.
Rated Primary I1-3	500	Setting, according to the CT applied at the secondary side. This parameter is used for scaling the displayed values only
Rated Primary I4		Not applied, the value is not considered.

Tertiary side:

Rated Secondary I1-3	1A	Selected, according to the CT applied at the tertiary side.
Rated Secondary I4		Not applied, the value is not considered.
Starpoint I1-3	Line	"Line" in this case means "Toward protected object = Transformer"
Direction I4		Not applied, the value is not considered.
Rated Primary I1-3	2000	Setting, according to the CT applied at the tertiary side. This parameter is used for scaling the displayed values only
Rated Primary I4		Not applied, the value is not considered.

Table 2-3 Summary of the CT parameter setting

3.1.8.10. Setting the differential protection function

The parameters of the differential protection function are explained in the following tables.

Enumerated parameters for the differential protection function:

Parameter name	Title	Selection range	Default
Parameter to enable the differential protection function:			
DIF87_Op_EPar_	Operation	Off, On	On
Parameter to select connection group of the transformer coils in primary-secondary relation:			
DIF87_VGrSec_EPar_	Pri-Sec VGroup*	Dy1,Dy5,Dy7,Dy11,Dd0,Dd6,Dz0,Dz2,Dz4,Dz6,Dz8,Dz10,Yy0,Yy6,Yd1,Yd5,Yd7,Yd11,Yz1,Yz5,Yz7,Yz11	Dd0
Parameter to select connection group of the transformer coils in primary-tertiary relation:			
DIF87_VGrTer_EPar_	Pri-Ter VGroup*	Dy1,Dy5,Dy7,Dy11,Dd0,Dd6,Dz0,Dz2,Dz4,Dz6,Dz8,Dz10,Yy0,Yy6,Yd1,Yd5,Yd7,Yd11,Yz1,Yz5,Yz7,Yz11	Dd0

Table 3-1 The enumerated parameters of the differential protection function

* If the connection of the primary winding in primary-secondary and primary tertiary relation is selected in contradiction then the protection function is automatically disabled, and the function generates a warning signal.

Boolean parameter for the differential protection function:

Parameter name	Title	Default	Explanation
DIF87_0Seq_BPar_	Zero Seq Elimination	True	

Table 3-2 The Boolean parameter of the differential protection function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Parameters for the current magnitude compensation:						
DIF87_TRPr_IPar_	TR Primary Comp	%	20	500	1	100
DIF87_TRSec_IPar_	TR Secondary Comp	%	20	500	1	100
DIF87_TRTer_IPar_	TR Tertiary Comp	%	20	200	1	100
Parameter of the second harmonic restraint:						
DIF87_2HRat_IPar_	2nd Harm Ratio	%	5	50	1	15
Parameter of the fifth harmonic restraint:						
DIF87_5HRat_IPar_	5th Harm Ratio	%	5	50	1	25
Parameters of the percentage characteristic curve:						
Base sensitivity:						
DIF87_f1_IPar_	Base Sensitivity	%	10	50	1	20
Slope of the second section of the characteristics:						
DIF87_f2_IPar_	1st Slope	%	10	50	1	20
Bias limit of the first slope:						
DIF87_f3_IPar_	1st Slope Bias Limit	%	200	2000	1	200
Unrestrained differential protection current level:						
DIF87_HCurr_IPar_	UnRst Diff Current	%	800	2500	1	800

Table 3-3 The integer parameters of the differential protection function

[-] Differential 3w

	Device value (Default_set_1)	New value	
Operation	On	On	v
Pri-Sec VGroup	Yy0	Yy0	v
Pri-Ter VGroup	Yd11	Yd11	v
ZeroSeq Elimination	☐	☐	
TR Primary Comp	87	87	%
TR Secondary Comp	87	87	%
TR Tertial Comp	262	262	%
2nd Harm Ratio	15	15	%
5th Harm Ratio	25	25	%
Base Sensitivity	50	50	%
1st Slope	50	50	%
1st Slope Bias Limit	400	400	%
UnRst Diff Current	800	800	%

Figure 3-1 EuroProt+ parameter screen for the differential protection function

These parameters need basic considerations some of them need also calculation. This is explained in the table below:

Operation	On	Set this parameter to “On” for enabling the function. NOTE: In tests, when other protection functions are tested. Switch this parameter to “Off” to prevent false test results
Pri-Sec VGroup	Yy0	This setting is selected according to the protected object. For autotransformers select always Yy0. NOTE: see explanation in paragraph 3.1.
Pri-Ter VGroup	Yd11	This setting is selected according to the protected object. (Example) NOTE: see explanation in paragraph 3.1
Zero Seq Elimination	False	Not checked. This parameter is needed only if there is isolated (Not grounded) side of the transformer and there is and additional neutral grounding transformer within the protected zone. As this additional neutral grounding transformer is not supposed to be present, the checkbox can remain unchecked. This is described in paragraph
TR Primary Comp	87	This value needs calculation. This is described in paragraph 3.2
TR Secondary Comp	87	This value needs calculation. This is described in paragraph 3.2
TR Tertiary Comp	262	This value needs calculation. This is described in paragraph 3.2
2nd Harm Ratio	15	This value needs some considerations. These are described in paragraph 3.3
5nd Harm Ratio	25	This value needs some considerations. These are described in paragraph 3.3
Base Sensitivity	50	Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 3.4
1st Slope	50	Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 3.4
1st Slope Bias Limit	400	Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 3.4
UnRst Diff Current	800	Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 3.4

Table 3-4 Summary of the differential protection parameter setting

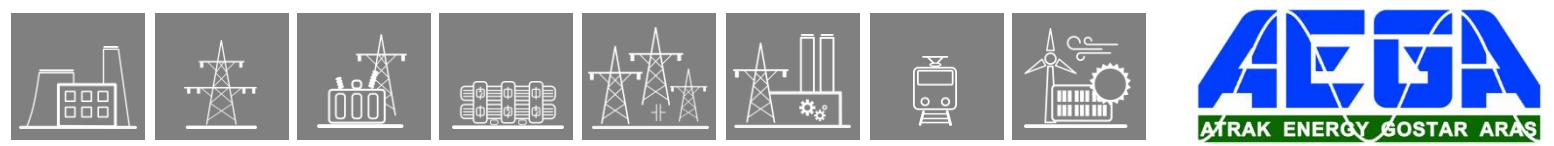
3.1.8.10.1. Vector shift compensation

The Protecta EuroProt+ configurations perform numerical vector shift compensation. The secondary wires of the current transformers are connected in Y, and the three phase currents secondary values are input directly into the current inputs of the device. No interposing CT-s are required.

The principle of the vector shift compensation is the numerical realization of the old principle: on Y side of the transformer apply delta connected secondary, on delta side of the transformer apply Y connected secondary. The advantage of this method is that the zero sequence current elimination is “automatic”.

The numerical solution is matrix multiplication: on Y side a phase shifting matrix is applied, e.g. for Yd11 transformation it is:

$$\begin{bmatrix} I_{1Rshift} \\ I_{1Sshift} \\ I_{1Tshift} \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} I_{1r} \\ I_{1s} \\ I_{1t} \end{bmatrix}$$



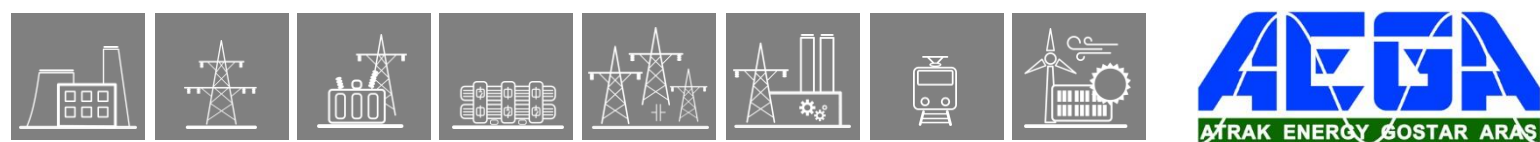
On delta side of the transformer phase shift is not applied, the realization is the unit matrix.

$$\begin{bmatrix} I2R_{shift} \\ I2S_{shift} \\ I2T_{shift} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I2r \\ I2s \\ I2t \end{bmatrix}$$

This means that the reference vector is the “r = L1” phase current of the delta side. The Y side currents are transformed to this reference for comparison.

The details are described in the document “Differential protection function block description”, available in Protecta WEB site www.protecta.hu.

The related parameter setting is easy: consider the clock notation of the transformer. In the example above it is YNyn0d11. The software requires setting for the primary-secondary relationship: it is YNyn0, and the setting for the primary tertiary relationship: it is Ynd11. Then the vector shift compensation is performed automatically.



3.1.8.10.2. Calculation of the amplitude compensation for the differential protection function

The basic principle is that in case of power transfer at rated current the currents to be compared should be the same, 100%. This means that in case of any external faults there will be no current difference, the differential function is balanced and stable.

For a two winding transformer, usually the rated current of the transformer is considered to be the base current, considered to be 100%. The ratio of the secondary and primary rated currents is the turn's ratio of the transformer.

For the setting calculation, calculate the ratio of the transformer rated current and the CT rated primary current. These values expressed in % are the parameter values to be set for parameters „TR Primary Comp” and “TR Secondary Comp”.

For a three winding transformer in the example the rated power of the winding is not the same (100MVA, 100 MVA and 30 MVA), consequently the ratio of rated currents for the windings do not match the turn's ratio of the coils. In this case the usual procedure is to consider the rated current of the primary side, and transform this current both for the secondary and to the tertiary side. These calculated currents should be related to the rated currents of the CT-s. These values expressed in % are the parameter values to be set for parameters „TR Primary Comp”, “TR Secondary Comp” and “TR Tertiary Comp”.

In the example:

The rated primary current is 262 A, see the transformer data above. This is the reference current.

This current is transformed to the secondary is 437 A.

This current is transformed to the tertiary is 5249 A. (Here the rated current would be 1575 A, this value is not considered!) The calculation of the setting values is as follows

$$\text{„TR Primary Comp”} = 100 \cdot 262 \text{ A} / 300 \text{ A} = 87\%$$

$$\text{„TR Secondary Comp”} = 100 \cdot 437 \text{ A} / 500 \text{ A} = 87\%$$

$$\text{„TR Tertiary Comp”} = 100 \cdot 5249 \text{ A} / 2000 \text{ A} = 262\%$$

Using this setting, the reference current on the secondary side is displayed by the differential protection function as 100%.

3.1.8.10.3. Considerations, related to the harmonic restraint

When a transformer is energized then due to the asymmetric saturation of the iron core a high “inrush current” can flow from one side into the transformer. This is a pure differential current. To prevent unwanted operation of the differential protection the special waveform of the inrush current is identified. The principle is the detection of the second harmonic content, which is present in the inrush current, but its value can be neglected in any fault current. For the differential current, the second harmonic component in the evaluation is related to the value of the base harmonic. This is the parameter „2nd Harm Ratio”. If this ratio gets higher due to inrush current, the trip command is blocked.

When a transformer is overexcited then the iron core is saturated symmetrically, resulting high current peaks, distorting both the positive and the negative sinusoidal current shape. In this current shape the fifth harmonic is characteristic. To prevent mal-operation, this component of the differential current is analyzed and compared to the base harmonic. If the ratio is high, then the differential current is caused by the over-excitation, the trip command is blocked. If however the fifth harmonic content is low, then the high differential current, which is a fault current, results trip command. The ratio is the parameter „5th Harm Ratio”.

If no results of detailed harmonic analysis are available, apply the factory setting, which can be corrected later. The proposed setting values are:

„2nd Harm Ratio” = 15 %

and

„5th Harm Ratio” = 25 %

3.1.8.10.4. Considerations, related to the differential characteristic for the differential protection function

The differential characteristic is shown in *Figure 3-2*. If the calculated (I_{bias} , I_{diff}) operating point is above the characteristic, then the differential protection operates.

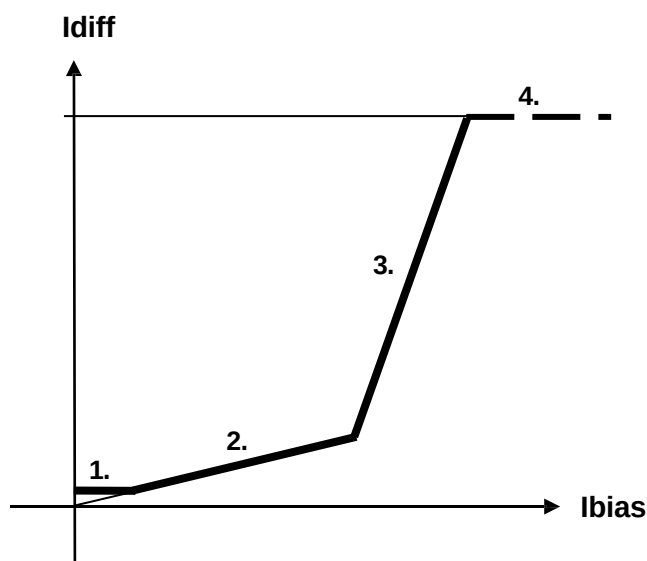
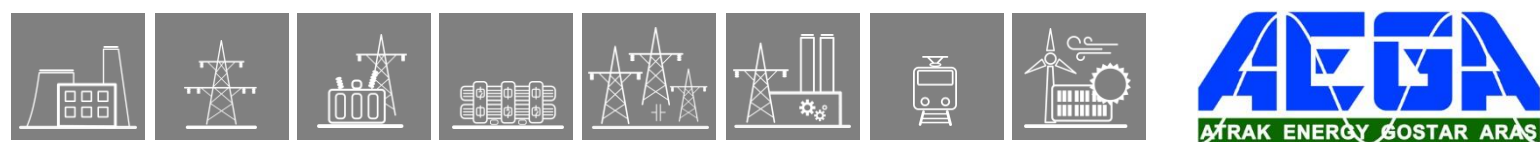


Figure 3-2 The differential characteristic

This characteristic has four sections; each of them is a straight line. The parameters define the position of these lines on the I_{diff} - I_{bias} plane.

The first parameter is “Base Sensitivity”, it defines the minimum differential current for the operation. Its role is to prevent mal-operation in case of current noises and measuring errors for small currents. In this example the selected setting value is the less sensitive selection:



„Base Sensitivity” = 50 %,

This value can be tested easily: inject three phase symmetrical currents from one side only and increase its value. The operation is expected if this current gets above 50% of the reference current. (In this example it is $0.5 \cdot 0.87A$. NOTE: for asymmetrical fault current this value changes due to the matrix transformation.)

The second section of the characteristic is a line through the origin of the I_{diff} - I_{bias} plane. The slope of this line serves to compensate the not correct matching of the CT-s, e.g. due to the different tap-changer positions and the CT errors. Due to these causes the error current increases if the current flowing through the transformer increases. The parameter is “1st Slope”. The mathematical expression of the second section of the characteristic is:

$$I_{diff} = \frac{1stSlope}{100} * I_{bias}$$

The steps for getting the parameter value are as follows:

- Calculate the error in percent, due to not correct matching (To be calculated for all three voltage levels):

$$x\% = \left(1 - \left| \frac{I_{I \cdot required_matching}}{I_{I \cdot matching}} \right| \right) * 100$$

- The unbalance of the differential protection at top or bottom position of the tap changer in percent, related to the value of 0 position ($r_{max}\%$):

$$x\% = |r_{max} \%|$$

Select the biggest value of the calculated $x\%$ values above. The setting value is advised to be above this value.

Example: suppose the voltage control range to be $+18\%/-12\%$, and the reference position for current balancing is the 0 position, then the parameter value with 1,5x safety is:

$$„1st Slope” = 1,5 \cdot 18 = 27 \rightarrow 30 \%$$

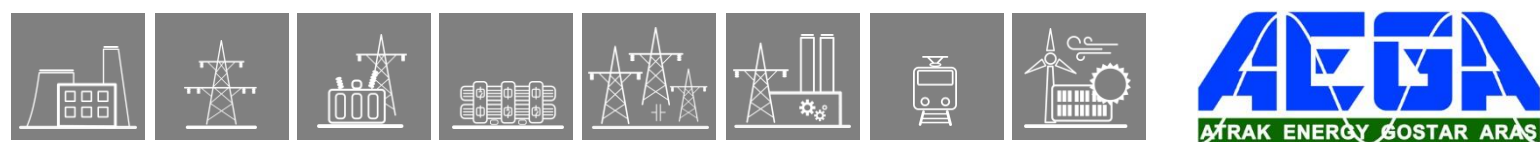
Another choice for calculation is the selection the mid-position of the tap-changer. This is in this example as follows: The full position range is $18 + 12 = 30\%$, The half value is 15% , accordingly the mid-position is $+3\%$. With his the voltage ratio of the transformer to be considered is to be increased by $118/115$, and the balancing of the current is to be determined for this voltage. In this case only $\pm 15\%$ tap position range can be considered, and the value of this parameter is decreased to:

$$„1st Slope” = 1,5 \cdot 15 = 22,5 \rightarrow 25 \%$$

The slope of the third section of the characteristic is higher. This is to compensate the increased CT error, due to the CT saturation at higher currents. This higher slope is a factory setting: 200%. The parameter “1st Slope Bias Limit” defines the intersection point of section 2 and 3.

This parameter value is influenced by the highest fault current in the protected object and the applied current transformer saturation point related to the rated value. If the current transformer is less over-dimensioned then select the parameter value for “1st Slope Bias Limit” low. The usual consideration is: for relatively high currents select 200 %, for low fault currents select 1000 %.

The fourth section of the characteristic is the unrestrained section. The related parameter is “UnRst Diff Current”. This parameter serves unrestrained fast operation if the high magnitude of the fault current indicates internal fault. The calculation determines the maximal external fault current, and the setting value should be above this current.



3.1.8.10.5. Considerations for zero sequence elimination

In solidly grounded high voltage networks, in case of external earth faults, the Y-delta transformers revert zero sequence current, which is present on the Y side only. No zero sequence current can flow on the delta side. When comparing the currents in the differential protection, this could cause unwanted operation.

The differential protection function in the Protecta EuroProt+ devices eliminates the Y side zero sequence current by matrix transformation (simulating the old type delta connected CT secondary behavior). This elimination is automatic, no additional solution is needed.

In several cases, however, there is additional neutral grounding transformer on the delta side of the transformer within the protected zone. Between the neutral point of this additional transformer an arc suppression Petersen coil, or a grounding resistor is connected. The Petersen coil minimizes the earth-fault current to some Amperes, the resistor limits the earth-fault current to 100 A (in some cases to 200 A).

If the neutral grounding transformer is not in the protected zone, it is outside the current transformers, then set:

„ZeroSeq Elimination” = „False” (Not checked)

In some cases, however, the neutral grounding transformer is closely connected to the main transformer's delta side terminals, it is in the protected zone. The advantage of this arrangement is that the energizing the transformer immediately solves the neutral grounding problems.

In case of external earth-fault the zero sequence current of the neutral grounding transformer is detected by the delta side current transformers. The zero sequence elimination is needed. In this case set

„ZeroSeq Elimination” = „True” (Checked)

3.1.8.11. Setting the restricted earth-fault protection function

The restricted earth-fault protection function is basically a zero sequence (residual) differential protection (DIF87N), applied for the galvanic interconnected coils.

The parameters of the restricted earth-fault protection function are explained in the following tables.

Enumerated parameter for the restricted earth-fault protection function:

Parameter name	Title	Selection range	Default
Parameter to enable the differential protection function:			
DIF87N_Op_EPar_	Operation	Off, On	On

Table 4-1 The enumerated parameter of the restricted earth-fault protection function

Boolean parameter for the differential protection function:

Parameter name	Title	Default	Explanation
DIF87N_DirCheck_BPar_	Directional check	True	

Table 4-2 The Boolean parameter of the restricted earth-fault protection function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Parameters for the current magnitude compensation:						
DIF87N_TRPri_IPar_	TR Primary Comp	%	4	500	1	100
DIF87N_TRSec_IPar_	TR Secondary Comp	%	4	500	1	100
DIF87N_TRNeut_IPar_	TR Neutral Comp	%	4	1000	1	500
Parameters of the percentage characteristic curve:						
Base sensitivity:						
DIF87N_f1_IPar_	Base Sensitivity	%	10	50	1	20
Slope of the second section of the characteristics:						
DIF87N_f2_IPar_	Slope	%	50	100	1	70
Bias limit of the first slope:						
DIF87N_f2Brk_IPar_	Base Sensitivity Bias Limit	%	100	200	1	125

Table 4-3 The integer parameters of the restricted earth-fault protection function

[-] Restricted EF

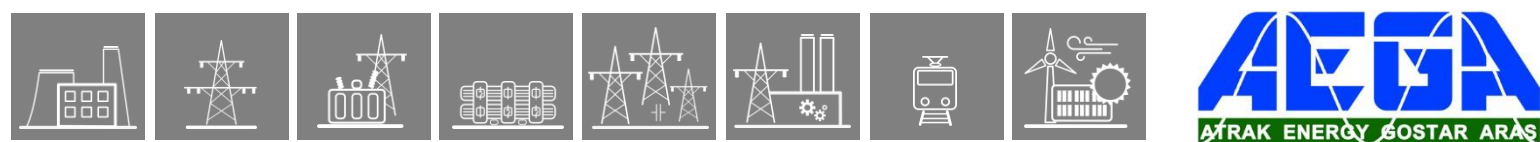
	Device value (Default_set_1)	New value	
Operation	On	On ▼	
Directional check	☐	☐	
TR Primary Comp	15	15 %	
TR Secondary Comp	9	9 %	
TR Neutral Comp	15	15 %	
Base Sensitivity	50	50 %	
Slope	50	50 %	
Base Sens Bias Limit	125	125 %	

Figure 4-1 EuroProt+ parameter screen for the restricted earth-fault protection function

These parameters need basic considerations some of them need also calculation. This is explained in the table below:

Operation	On	Set this parameter to “On” for enabling the function. NOTE: In tests, when other protection functions are tested, switch this parameter to “Off” to prevent false test results
Directional check	False	Not checked. This parameter is needed to increase the security of the function in case of low level external faults. This is described in paragraph 4.3
TR Primary Comp	15	This value needs calculation. This is described in paragraph 4.1
TR Secondary Comp	9	This value needs calculation. This is described in paragraph 4.1
TR Neutral Comp	15	This value needs calculation. This is described in paragraph 4.1
Base Sensitivity	50	Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 4.2
1st Slope	50	Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 4.2
1st Slope Bias Limit	125	Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 4.2

Table 4-4 Summary of the CT parameter setting



3.1.8.11.1. Calculation of the amplitude compensation for the restricted earth-fault protection function

The basic principle is that in case of any external faults there will be no current difference, the zero sequence differential function is balanced and stable.

The setting of the restricted earth-fault protection function is independent of the setting of the differential protection function.

Here the same current is freely selected as the base current for the whole, galvanic connected coil system. The choice of the current is free. For more sensitive protection select a relatively low value. In the example the following value is selected:

$$I_{Base} = 44 \text{ A}$$

This is a primary value, which is transformed by the current transformers to the secondary side. For the setting, it is related to the rated primary currents of the current transformers:

$$\begin{aligned} \text{„TR Primary Comp“} &= 100 \cdot 44 \text{ A} / 300 \text{ A} = 15\% \\ \text{„TR Secondary Comp“} &= 100 \cdot 44 \text{ A} / 500 \text{ A} = 9\% \\ \text{„TR Neutral Comp“} &= 100 \cdot 44 \text{ A} / 300 \text{ A} = 15\% \end{aligned}$$

In the restricted earth-fault protection these values are used for amplitude matching the secondary currents

3.1.8.11.2. Considerations, related to the differential characteristic for the restricted earth-fault protection function

The differential characteristic is shown in *Figure 4-2*. If the calculated (I_{bias}, I_{diff}) operating point is above the characteristic, then the differential protection operates.

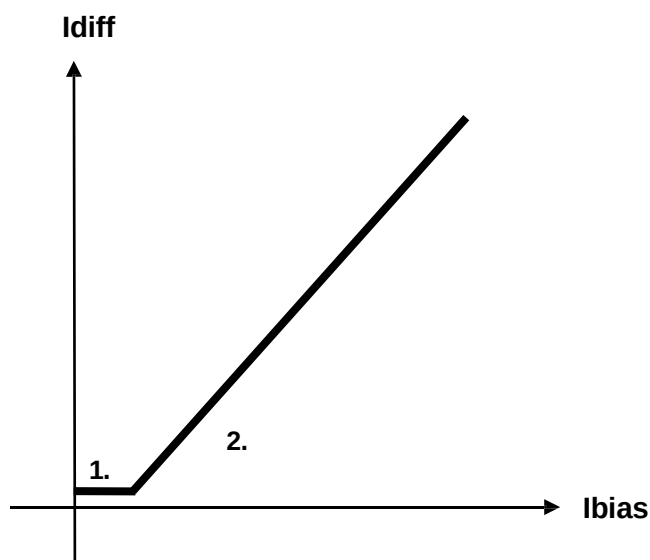
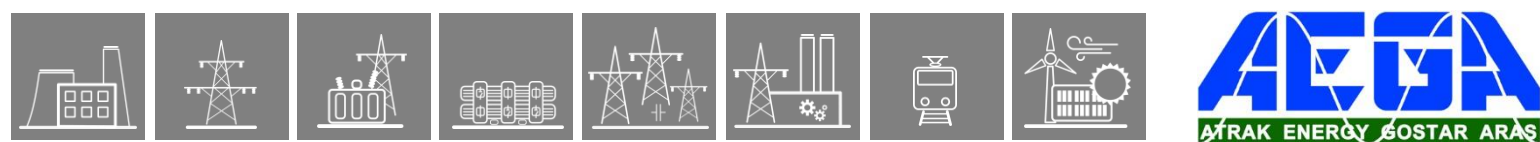


Figure 4-2 The differential characteristic for the restricted earth-fault protection function

This characteristic has two sections; each of them is a straight line. The parameters define the position of these lines on the I_{diff} - I_{bias} plane.



The parameters are expressed in percent, the basis is the “IBase” selected current. The first parameter is “Base Sensitivity”, it defines the minimum differential current for the operation. Its role is to prevent mal-operation in case of current noises and measuring errors for small currents. In this example the selected setting value is the less sensitive selection:

$$\text{„Base Sensitivity”} = 50 \%,$$

NOTE: The percent value is related to the “IBase” selected current. In the example the restricted earth-fault protection summarizes the secondary currents of seven current transformers. It is advised to avoid too sensitive setting, due to the accumulated errors of several CT-s. Similarly select not too low current for “IBase” base current for the reference and for the calculation.

This value can be tested easily: inject a single residual current e.g. into the grounding CT input and increase its value. The operation is expected if this current gets above 50% of the reference current. (In this example it is $0.5 \cdot 44\text{A} / 300\text{A} \cdot 1\text{A} = 73.3 \text{ mA}$.)

The slope of the second section of the characteristic intends to compensate the not correct matching of the CT-s, e.g. due to the CT errors. Consider that the error current increases if the zero sequence current flowing through the transformer increases. In the example the selected setting value is:

$$\text{„1st Slope”} = 50 \%,$$

NOTE: The percent value is related to the IBias current.

The third parameter defines the intersection point of the two characteristic lines. Do not select this point too high, because near to the intersection point it leaves too much area, where error currents can intersect the characteristic.

In the example the selected setting value is:

$$\text{„1st Slope Bias Limit”} = 125 \, \%.$$

NOTE: The percent value is related to the “IBase” selected current.

3.1.8.11.3. Considerations, related to the directional check

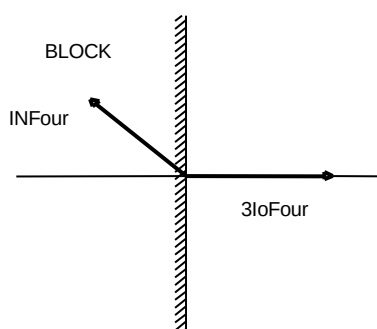


Figure 4-3 Principle of the directional check

In the directional check the vector position of the residual current measured in the grounding (INFour) and that of the vectorial sum of all other currents (3IoFour) is compared.

Figure 4-3 shows a vector position which blocks the operation of the restricted earth fault protection, if the Boolean parameter “Directional check” is True (Checked). If the checkbox is not checked then the directionality is not considered. This parameter is needed to increase the security of the function in case of low level external faults

3.1.8.12. Testing instructions

3.1.8.12.1. Testing the differential protection

When testing a function, it is advised to disable all other functions to avoid trip commands generated by the other functions.

The applied test set supports the tests with 2*3 currents. With this test set the differential protection can be tested in three steps: Primary/Secondary, Primary/Tertiary and Secondary/Tertiary relationship. In all cases the currents of the not tested side is supposed to be zero.

This paragraph shows the tests in Primary/Secondary relationship.

The basic parameters are documented by the test set, as it is shown in

Test Object - Differential Parameters

Protected Object:

Protected Object: Transformer
Vector Group: YY0D11

Winding/Leg Name:	Primary	Secondary	Tertiary
Voltage:	220,00 kV	132,00 kV	11,00 kV
Power:	100,00 MVA	100,00 MVA	30,00 MVA
Starpoint Grounding:	Yes	Yes	No
Delta-connected CT:	No	No	No

CT:

Winding/Leg Name:	Primary	Secondary	Tertiary
CT Current Prim:	300,00 A	500,00 A	2000,00 A
CT Current Sec:	1,00 A	1,00 A	1,00 A
CT Grounding:	tow. Prot. Obj.	tow. Prot. Obj.	tow. Prot. Obj.
Gnd CT Prim Current:	200,00 A	800,00 A	800,00 A
Gnd CT Sec Current:	1,00 A	1,00 A	1,00 A
Gnd CT Grounding:	n/a	n/a	n/a

Figure 5-1 Basic test parameters

The setting values of the function correspond to the values described above.

Please consider that the differential protection function is the cooperation of three “measuring elements”. Each measuring element gets the magnitude- and phase-compensated currents. NOTE that in case of asymmetric fault the input current values are modified due to the matrix phase-shift compensation as compared to the injected fault currents, if the fault is supposed to be on the Y side of the transformer.

In the characteristic tests please consider that the I_{diff} differential current in the differential protection function is the vectorial sum of all nine phase-compensated and magnitude compensated currents in three groups, related to the three “measuring elements”. The I_{bias} current is the sum of the absolute values of three currents in the measuring elements divided by 2.

The simplest test is a three phase injection test for testing the accuracy of the differential characteristic.



Test Results for Fault Location L1-L2-L3 at Reference Side Primary							
Ibias	Idiff Nominal	Idiff Actual	Dev (rel)	Dev (abs)	Check Test	State	Result
0,50 In	0,500 In	0,497 In	-0,62 %	-0,0031 In		Tested	Passed
1,00 In	0,500 In	0,505 In	1,00 %	0,0050 In		Tested	Passed
1,50 In	0,750 In	0,747 In	-0,38 %	-0,0028 In		Tested	Passed
2,00 In	1,000 In	0,997 In	-0,34 %	-0,0034 In		Tested	Passed
2,50 In	1,250 In	1,246 In	-0,32 %	-0,0040 In		Tested	Passed
3,00 In	1,500 In	1,495 In	-0,31 %	-0,0046 In		Tested	Passed
4,00 In	2,000 In	1,991 In	-0,43 %	-0,0087 In		Tested	Passed
5,00 In	4,000 In	3,948 In	-1,31 %	-0,0523 In		Tested	Passed
6,00 In	6,000 In	5,954 In	-0,77 %	-0,0463 In		Tested	Passed
7,00 In	8,000 In	7,966 In	-0,43 %	-0,0342 In		Tested	Passed
8,00 In	8,000 In	7,972 In	-0,35 %	-0,0281 In		Tested	Passed
9,00 In	8,000 In	7,972 In	-0,35 %	-0,0281 In		Tested	Passed
10,00 In	8,000 In	7,966 In	-0,43 %	-0,0344 In		Tested	Passed

Operating Characteristic Diagram

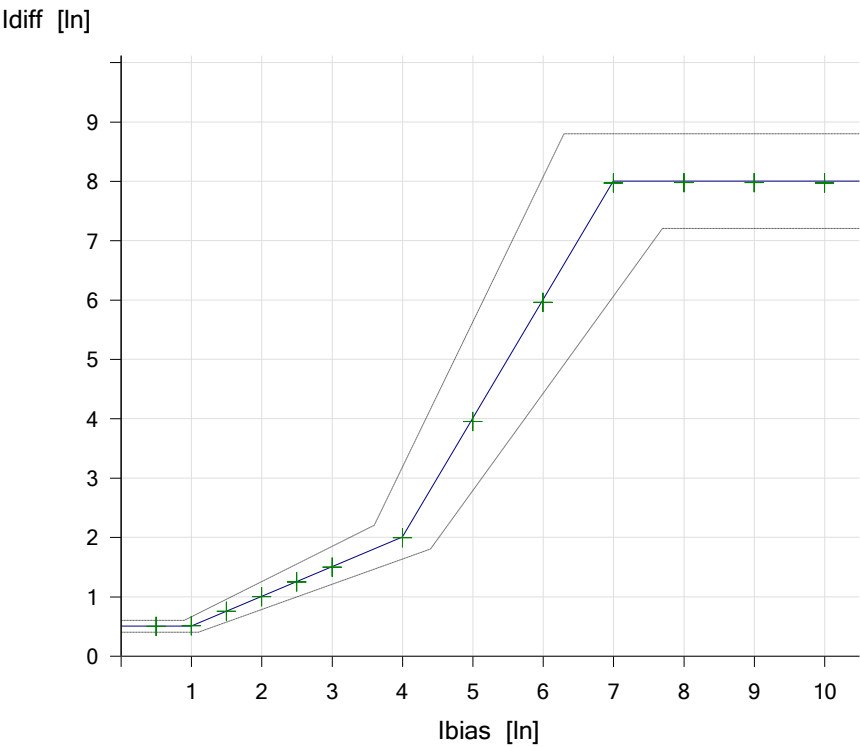


Figure 5-2 Result of three phase fault test, the fault is at the secondary side, supplied from the primary side

NOTE that the measured points match the original characteristic.

For asymmetric fault tests the expected characteristic is modified to cover the current modification of the vector shift compensation.

Test Results for Fault Location L2-L3 at Reference Side Primary

Ibias	Idiff Nominal	Idiff Actual	Dev (rel)	Dev (abs)	Check Test	State	Result
0,50 In	0,433 In	0,430 In	-0,72 %	-0,0031 In		Tested	Passed
1,00 In	0,495 In	0,498 In	0,54 %	0,0027 In		Tested	Passed
1,50 In	0,745 In	0,742 In	-0,40 %	-0,0030 In		Tested	Passed
2,00 In	0,995 In	0,991 In	-0,37 %	-0,0036 In		Tested	Passed
2,50 In	1,245 In	1,241 In	-0,34 %	-0,0043 In		Tested	Passed
3,00 In	1,495 In	1,490 In	-0,33 %	-0,0049 In		Tested	Passed
4,00 In	1,995 In	1,992 In	-0,16 %	-0,0031 In		Tested	Passed
5,00 In	2,495 In	2,491 In	-0,15 %	-0,0037 In		Tested	Passed
6,00 In	2,995 In	2,991 In	-0,15 %	-0,0044 In		Tested	Passed
7,00 In	3,600 In	3,586 In	-0,41 %	-0,0146 In		Tested	Passed
8,00 In	5,606 In	5,626 In	0,35 %	0,0197 In		Tested	Passed
9,00 In	6,930 In	6,903 In	-0,39 %	-0,0274 In		Tested	Passed
10,00 In	6,930 In	6,900 In	-0,43 %	-0,0298 In		Tested	Passed

Operating Characteristic Diagram

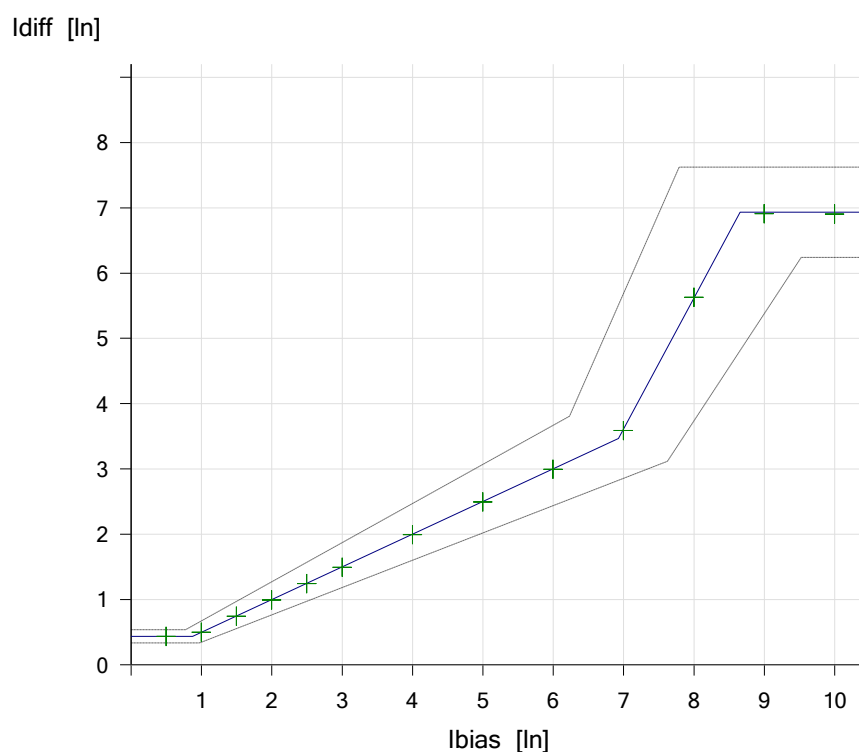


Figure 5-3 Result of double phase fault test, the fault is at the secondary side, supplied from the primary side

NOTE The matrix vector shift compensation decreases the compared current by $\sqrt{3}$. Consequently the detected knee points of the characteristic are shifted to increased current values. (The setting values of the differential protection function are the same as those applied in three-phase fault test.)

Similarly, in case of single phase faults, the expected characteristic is modified. (The setting values of the differential protection function are the same as those applied in three-phase fault test.) This is shown in Figure 5-4.

Operating Characteristic Diagram

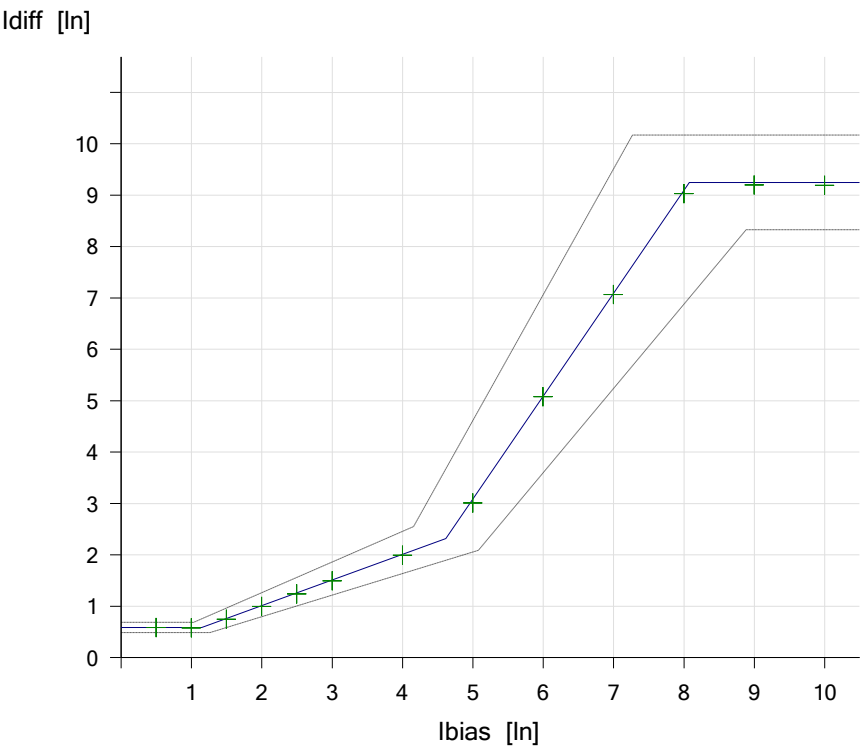
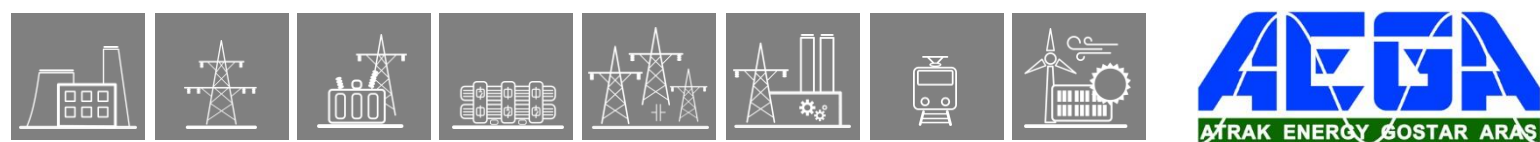


Figure 5-4 Result of single phase fault test, the fault is at the secondary side, supplied from the primary side



3.1.8.12.2. Testing the restricted earth-fault protection

When testing a function, it is advised to disable all other functions to avoid trip commands generated by the other functions.

The applied test set supports the tests with 2*3 currents. With this test set the restricted earth-fault protection can be tested in two steps: Primary/Neutral, and Secondary/Neutral relationship. In all cases the currents of the not tested sides (Secondary or Primary respectively) is supposed to be zero. Note that the Tertiary side is not involved in the restricted earth-fault protection.

In the characteristic tests please consider that the I_{diff} differential current in the restricted earth-fault protection function is the vectorial sum of six phase currents plus the neutral current. The I_{bias} current is the maximum of these seven currents.

3.1.8.12.2.1. Characteristic accuracy tests

This paragraph shows the tests in Primary/Neutral relationship. Three-phase current are injected in the Primary side and the sum of the other three current set is injected in the Neutral.

Test Results for Fault Location L1-E at Reference Side Primary

I_{bias}	I_{diff} Nominal	I_{diff} Actual	Dev (rel)	Dev (abs)	Check Test	State	Result
0,50 In	0,500 In	0,503 In	0,63 %	0,0031 In		Tested	Passed
1,00 In	0,500 In	0,447 In	-10,62 %	-0,0531 In		Tested	Passed
1,50 In	0,625 In	0,612 In	-2,17 %	-0,0136 In		Tested	Passed
2,00 In	0,875 In	0,838 In	-4,29 %	-0,0375 In		Tested	Passed
4,00 In	1,876 In	1,880 In	0,20 %	0,0037 In		Tested	Passed
6,00 In	2,877 In	2,791 In	-2,97 %	-0,0855 In		Tested	Passed
8,00 In	3,877 In	3,798 In	-2,05 %	-0,0796 In		Tested	Passed
10,00 In	4,878 In	4,838 In	-0,82 %	-0,0401 In		Tested	Passed
12,00 In	5,878 In	5,848 In	-0,52 %	-0,0304 In		Tested	Passed
14,00 In	6,879 In	6,811 In	-0,99 %	-0,0681 In		Tested	Passed
16,00 In	7,880 In	7,802 In	-0,98 %	-0,0775 In		Tested	Passed
18,00 In	8,880 In	8,748 In	-1,49 %	-0,1320 In		Tested	Passed
20,00 In	9,881 In	9,885 In	0,04 %	0,0043 In		Tested	Passed

Operating Characteristic Diagram

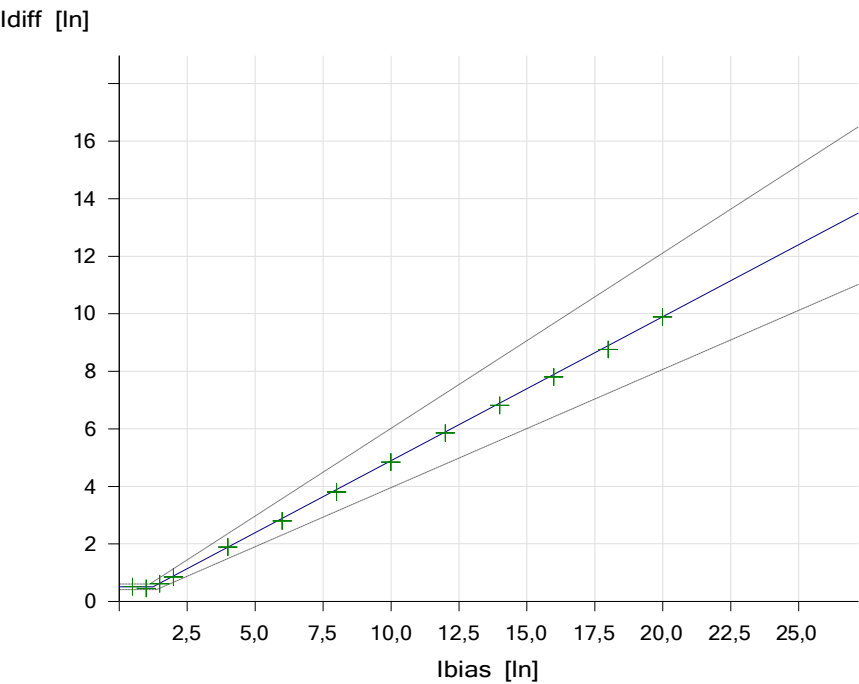


Figure 5-5 Result of characteristic accuracy test of the restricted earth-fault protection

3.1.8.13. Single shot fault simulation

In this test an external earth-fault is supposed at the secondary side with 1500A primary current. The primary current distribution is shown in Figure 5-6.

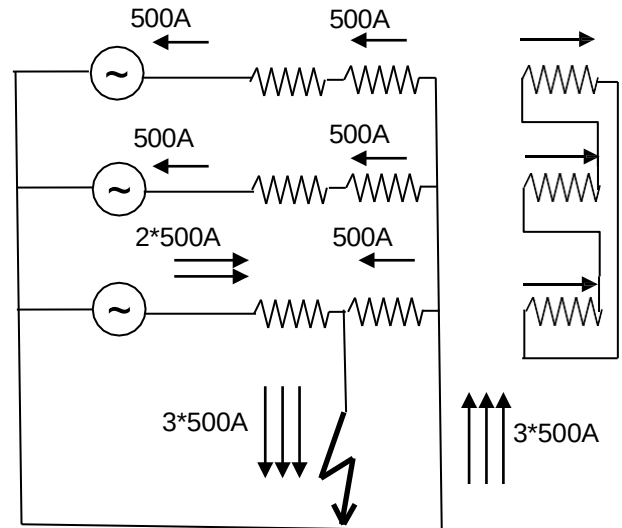


Figure 5-6 Primary current distribution

The currents are transformed to the device side by the current transformers:

$$I_{\text{primary L1}} = 2 \times 500 \text{ A} \times 1/300 = 3.33 \text{ A}$$

$$I_{\text{primary L2}} = I_{\text{primary L3}} = 500 \text{ A} \times 1/300 = 1.66 \text{ A}$$

$$I_{\text{secondary L1}} = 3 \times 500 \text{ A} \times 1/500 = 3 \text{ A}$$

$$I_{\text{neutral}} = 3 \times 500 \text{ A} \times 1/300 = 3.33 \text{ A}$$

These currents are drawn in Figure 5-7. Note that the Kirchhoff's node law is satisfied with primary currents only. The secondary currents are transformed with CT with different ratios. (This deviation is compensated by the current matching parameters of the restricted earth- fault protection function.)

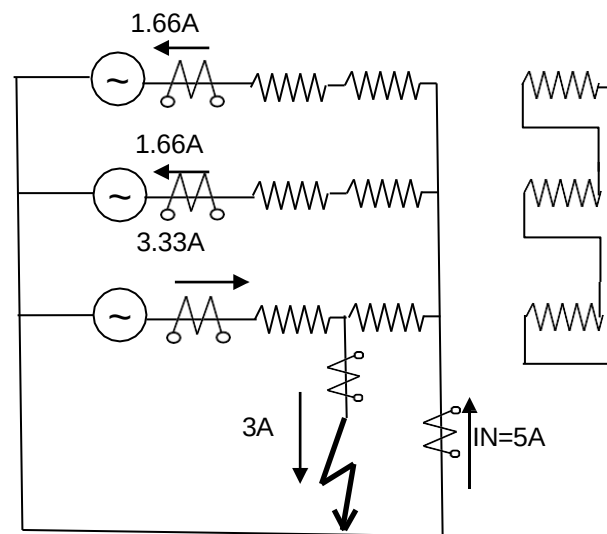


Figure 5-7 Secondary current distribution

NOTE. The current in the neutral point is measured with a CT of reverse polarity. This is not indicated in the figure.

Figure 5-8 below shows the measured (secondary) currents of the CT modules. The first module shows the three currents of the primary side and the current in the grounding CT. The second module measures the single fault current of the secondary side. (The currents of the tertiary side are all zero.)



Figure 5-8 Measured currents of the CT modules

Figure 5-9 shows the displayed values by the restricted earth-fault protection function. The differential current value is small (not zero due to the not accurate current injection). The high bias (restraint) current prevents operation, i.e. the “General Trip” box is not checked in the figure. The behavior is correct.

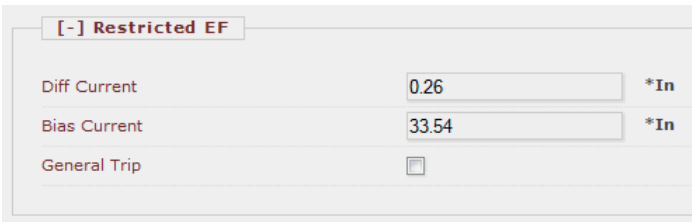


Figure 5-9 On-line display of the restricted earth-fault function with correct CT connection

If for example the grounding CT is reversed connected, then the function generates the trip command, due to the false high differential current (i.e. the “General Trip” box is checked in the figure). The behavior is correct.

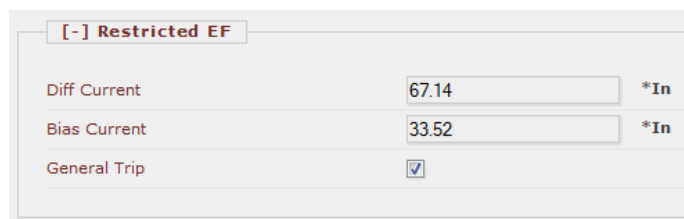


Figure 5-10 On-line display of the restricted earth-fault function with reverse CT connection in the grounding

3.1.8.13.1.1. Checking the directional blocking

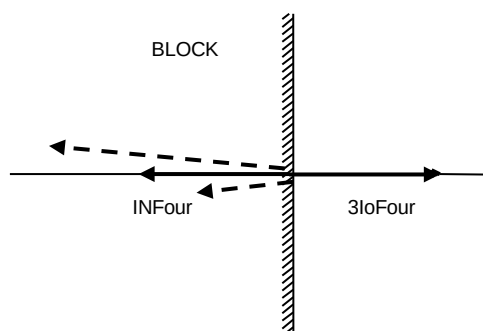


Figure 5-11 Checking the directional blocking

For checking the directional blocking, consider

Figure 5-11. For external fault the restricted earth-fault is balanced, the function does not generate the trip command. In this state the “3IoFour” vector, which is the sum of the currents of all phase current transformers has the same magnitude as “INFour” (solid vector on the figure), but the direction is opposite.

Now suppose that due to any measuring errors this balance is not fulfilled for external fault, and suppose that “INFour” is different in magnitude and/or phase angle. This is illustrated with dotted vectors. It is obvious that the difference of the solid “INFour” vector and the dotted version is the “Idiff” differential current, detected by the restricted earth-fault protection function. If this “Idiff” error current is large enough, the function generates the trip command.

For the test consider a balanced state, as shown in Figure 5-7. Here the “INFour” current corresponds to $I_N=5A$. Increase /decrease the magnitude and/or phase angle of this vector to generate sufficient “Idiff” current for the operation of the restricted earth-fault protection function, if the Boolean parameter “Directional check” is FALSE (not checked).

NOTE: Remember that the “Ibias” is the maximum of any applied phase currents or the IN neutral current. Considering this, for the trip command, the (IBias,Idiff) point must be above the characteristic.

Now change the parameter “Directional check” to TRUE (checked). In this state no trip command is generated if the phase angle between “3IoFour” and “INFour” is out of the range -90° to $+90^\circ$, this is the left side of Figure 5-11. (An internal fault supposes that the phase angle between these vectors is in the range -90° to $+90^\circ$, this is the right side of Figure 5-11.)

3.1.9. Inrush current detection function

3.1.9.1. 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.

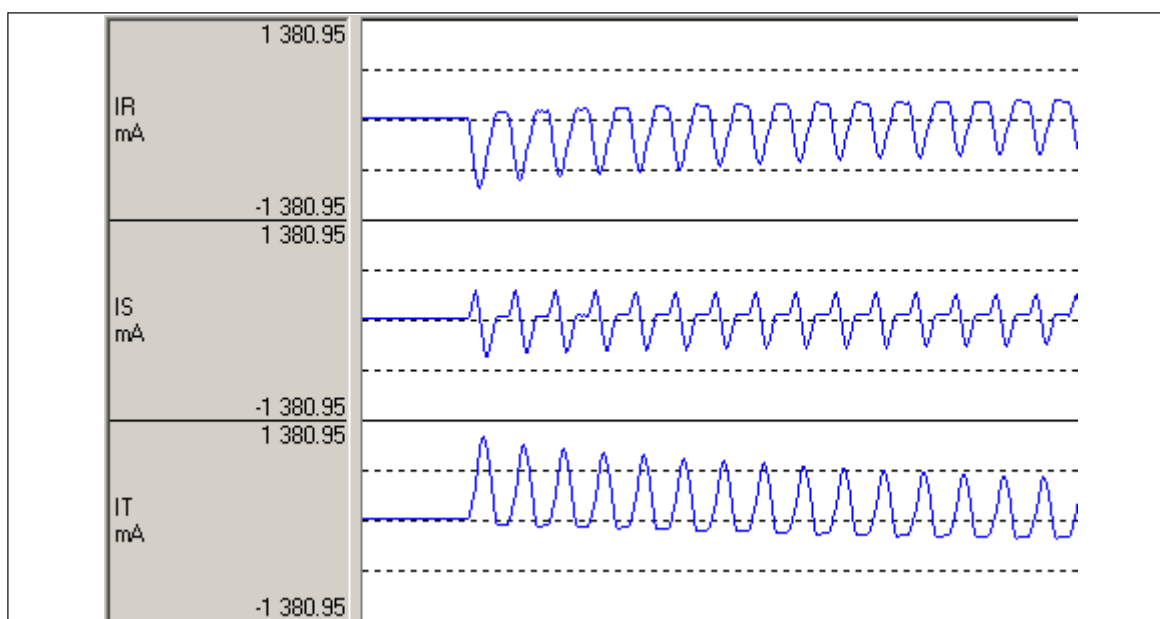
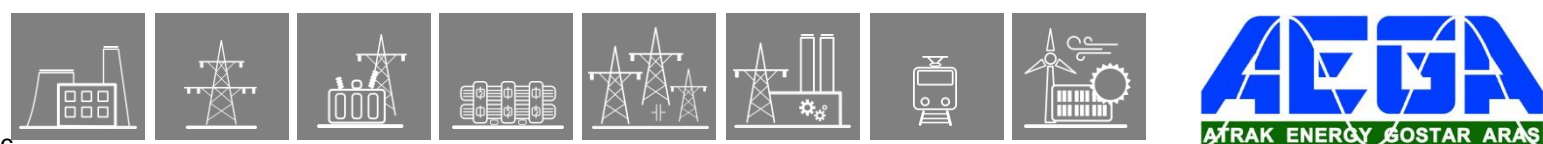


Figure 1-1 Example: A typical inrush current

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.



3.1.9.1.1. Mode of operation

The operating principle of the inrush current detection function is based on the special shape of the inrush current.

As Figure 1-1 shows, the typical inrush current in one or two phases is distorted and asymmetrical to the time axis: for example, in IT of the Figure above the positive peaks are high while no peaks can be detected in the negative domain.

The theory of the Fourier analysis states that even harmonic components (2nd, 4th etc.) are dominant in waves distorted as described above. The component with the highest value is the second one.

Typical overload and fault currents do not contain high even harmonic components.

The inrush current detection function processes the Fourier basic harmonic component and the second harmonic component of the three phase currents. If the ratio of the second harmonic and the base Fourier harmonic is above the setting value of the parameter 2nd Harm Ratio, an inrush detection signal is generated.

The signal is output only if the base harmonic component is above the level defined by the setting of the parameter IPh Base Sens. This prevents unwanted operation in the event that low currents contain relatively high error signals.

The function operates independently using all three phase currents individually, and additionally, a general inrush detection signal is generated if any of the phases detects inrush current.

The function can be disabled by the binary input INR2_**Blk**_GrO_. This signal is the result of logic equations graphically edited by the user.

The **inputs** of the inrush current detection function are

- the basic and second Fourier components of three phase currents,
- binary input,
- parameters.

The **output** signals of the inrush current detection function are

- inrush detection in phases L1, L2 or L3 individually,
- a general inrush detection signal.

3.1.9.2. 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.

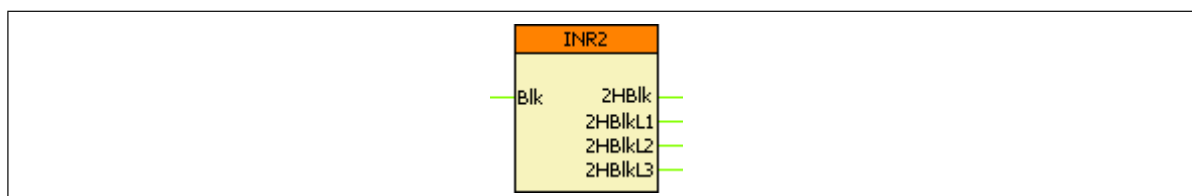


Figure 2-1 The function block of the inrush current detection function

3.1.9.2.1. 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 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

3.1.9.2.2. Function I/O

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

3.1.9.2.2.1. Analogue inputs

The basic and second Fourier components of three phase currents.

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 signal of the inrush current detection function

BINARY INPUT SIGNAL	EXPLANATION
INR2_ Blk _GrO_	Blocking input of the function

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 inrush current detection function

BINARY OUTPUT SIGNAL	SIGNAL TITLE	EXPLANATION
INR2_ 2HBIk _GrI_	Inrush	Inrush current detected in one of the three phases
INR2_ 2HBIkL1 _GrI_	Inrush L1	Inrush current detected in phase L1
INR2_ 2HBIkL2 _GrI_	Inrush L2	Inrush current detected in phase L2
INR2_ 2HBIkL3 _GrI_	Inrush L3	Inrush current detected in phase L3

3.1.9.2.2.4. Online data

Visible values on the *online data* page.

Table 2-4 Online displayed data of the inrush current detection function

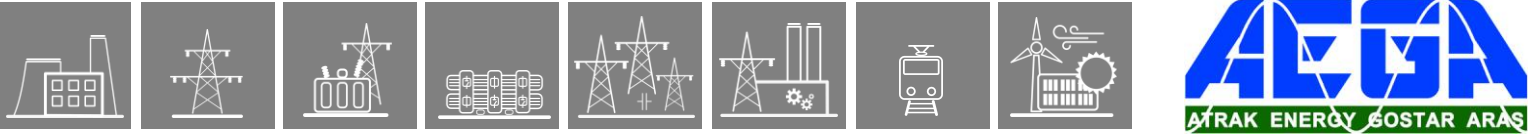
SIGNAL TITLE	DIMENSION	EXPLANATION
Inrush L1	-	Inrush current detected in phase L1
Inrush L2	-	Inrush current detected in phase L2
Inrush L3	-	Inrush current detected in phase L3
Inrush	-	Inrush current detected in one of the three phases

3.1.9.2.2.5. 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 inrush current detection function

EVENT	VALUE	EXPLANATION
2 nd Harm. Restraint	off, on	Inrush current detected in one of the three phases



3.1.9.2.3. **Technical data**

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

FUNCTION	VALUE	ACCURACY
Current accuracy	20 – 2000% of I_n	$\pm 1\%$ of I_n

3.1.9.2.4. **Notes for testing**

The differential protection function block (DIF87) has its own, built-in 2nd harmonic restraint feature which works independently from the function described here. For further information, see the Differential Protection Function description.

Keep in mind that there is a minimum requirement for the fundamental component of the current (% is the % of the CT nominal), and the function operates according to the 2nd harmonic content related to the fundamental component.

3.1.10. Differential protection function

3.1.10.1. Operation principle

The differential protection function provides main protection for transformers, generators or large motors, but it can be applied for overhead lines and cables of solidly grounded networks or for protection of any combination of the mentioned protected objects.

The version DIF87T3 can be applied to protect three-winding transformers. The simpler version DIF87T2 does not process analogue inputs from the tertiary side. This document is the description of the three-winding transformer version, but it hints necessary changes in application with two sides only.

3.1.10.1.1. Structure of the differential protection algorithm

The figure below shows the structure of the differential protection (DIF87T3) algorithm.

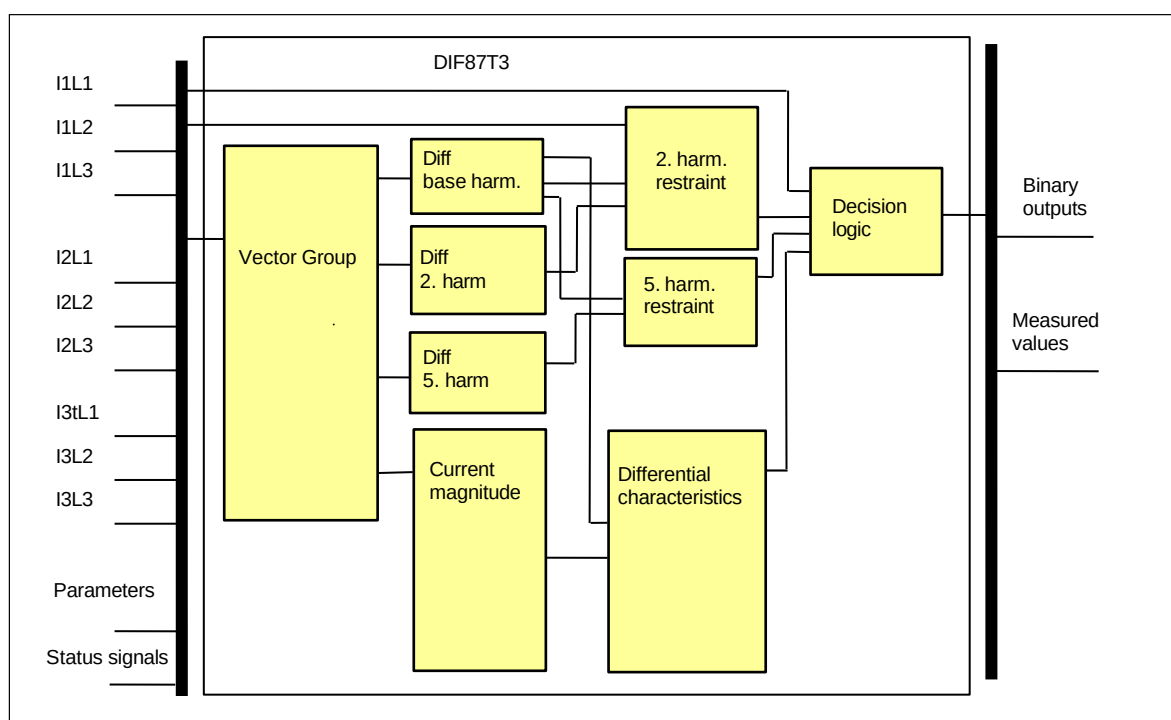


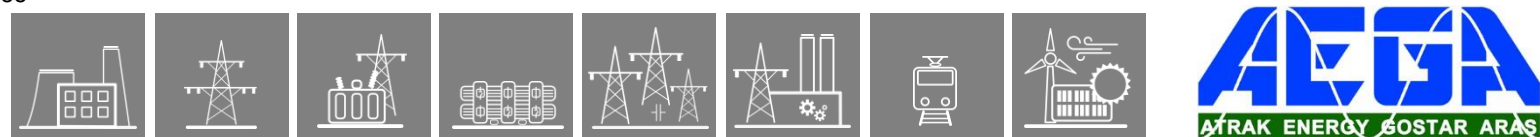
Figure 1-1 Structure of the differential protection algorithm

The **inputs** are

- the sampled values of three primary phase currents,
- the sampled values of three secondary phase currents,
- the sampled values of three tertiary phase currents (in DIF87T3 version only),
- parameters
- status signal.

The **outputs** are

- the binary output status signals,
- the measured values for displaying.



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

Vector group

This module compensates the phase shift and turn's ratio of the transformer. The results of this calculation are the "sampled values" of the phase-shifted phase currents for all three (two) sides of the transformer and those of the three differential currents.

Diff base harm.

This module calculates the basic Fourier components of the three differential currents. These results are needed for the high-speed differential current decision and for the second and fifth harmonic restraint calculation.

Diff 2. harm.

This module calculates the second harmonic Fourier components of the three differential currents. These results are needed for the second harmonic restraint decision.

Diff 5. harm.

This module calculates the fifth harmonic Fourier components of the three differential currents. These results are needed for the fifth harmonic restraint decision.

2. harm. restraint

The differential current can be high in case of transformer energizing, due to the current distortion caused by the transformer iron core asymmetric saturation. In this case the second harmonic content of the differential current is applied in this module to disable the operation of the differential protection function.

The differential current can be high in case of external faults, due to the current distortion caused by saturated CT on the faulty side. Additional usage of the second harmonic restraint in these cases can help to disable the operation of the differential protection function.

The result of this calculation is needed for the decision logic.

5. harm. restraint

The differential current can be high in case of over-excitation of the transformer, due to the current distortion caused by the transformer iron core symmetric saturation. In this case the fifth harmonic content of the differential current is applied in this module to disable the operation of the differential protection function. The result of this calculation is needed for the decision logic.

Current magnitude

This module calculates the magnitude of the phase-shifted phase currents and that of the differential currents. The result of this calculation is needed for the differential characteristic evaluation.

Differential characteristics

This module performs the necessary calculations for the evaluation of the "percentage differential characteristics". The result of this calculation is needed for the decision logic.

Decision logic

The decision logic module decides if the differential current of the individual phases is above the characteristic curve of the differential protection function. This curve is the function of the restraint current, which is calculated based on the magnitude of the phase-shifted phase currents. This module calculates the second and fifth harmonic ratio of the differential current, relative to the basic harmonic content. The result can restrain the operation of the differential protection function. The high-speed overcurrent protection function based on the differential currents is performed in this module too.

The following description explains the details of the individual components.

3.1.10.1.2. Turn's ratio matching and vector shift compensation (Vector group)

The three-phase power transformers transform the primary current to the secondary side according to the turn's ratio and the vector group of the transformers. The Y (star) D (delta) or Z (zig-zag) connection of the three phase coils on the primary and on the secondary side causes vector shift of the currents. The conventional electromechanical or static electronic devices of the differential protection compensate the vector shift with appropriate connection of the current transformer coils. The numerical differential protection function applies matrix transformation to the directly measured currents of one side of the transformer to match them with the currents of the other side(s).

In the transformer differential protection of Protecta the software module „Vector_group” calculates the matrix transformation and the turn's ratio matching. Here the target of the matrix transformation is the delta (D) side.

3.1.10.1.2.1. Turn's ratio matching

In the transformer, the magnitude of the current is transformed according to the turn's ratio (and the vector group) of the transformers. In practical terms this transformation is expressed as the voltage ratio(s). For the calculation, the rated voltages of the transformation is to be declared: “Un Primary”, “Un Secondary” and in case of transformer with three voltage levels also “Un Tertiary”.

The differential protection function needs also a reference current. The specific points of the differential characteristic are expressed as percent of this reference current. This value is calculated internally, based on the rated power of the transformer. It is usual that for transformers with three voltage levels – where the rated power for all three sides can be different – the value for the primary side is to be set as a parameter. NOTE: when selecting other values, the scaling of the differential characteristic also changes.

The summary of the parameters needed for turn's ratio matching are summarized in Table 1-1.

Floating point parameters

Table 1-1 The floating-point parameters for the turn's ratio compensation

PARAMETER NAME	TITLE	DIM.	MIN	MAX	DEFAULT
Rated power (primary side) of the transformer					
DIF87_Sn_FPar_	Sn	MVA	1.00	1000.00	125.00
Rated voltages Un1, Un2 (and Un3 if tertiary side also available)					
DIF87_UTRPri_FPar_	Un Primary	kV	1.00	1000.00	132.00
DIF87_UTRSec_FPar_	Un Secondary	kV	1.00	1000.00	22.00
DIF87_UTRTer_FPar_	Un Tertiary	kV	1.00	1000.00	11.50

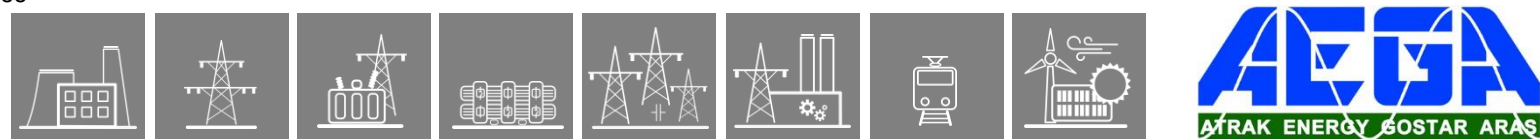
Based on these parameters, the reference current for the high voltage primary side of the transformer is calculated with the well-known formula:

$$I_{reference_1} = \frac{S_n}{\sqrt{3} Un1}$$

Where:

$I_{reference_1}$ is the reference current for the high voltage primary side of the transformer,
 S_n is the rated power of the primary side of the transformer,
 $Un1$ is the rated voltage of the primary side of the transformer.

This reference current can be transformed to the secondary or to the tertiary sides of the transformer for the reference values of other sides. For the relay, these reference values are transmitted by the current transformers, according to the CT turn's ratios. This information is set in the CT modules of the device as parameter values.



3.1.10.1.2.2. Principle of transformation to the D side

The conventional electromechanical or static electronic devices of the differential protection compensate the vector shift with appropriate connection of the current transformer coils. The principle is that the Y connected current transformers on the delta side of the transformer do not shift the currents flowing out of the transformer. The delta connected current transformers on the Y side of the transformer however result a phase shift. This means that the Y side currents are shifted according to the vector group of the transformer to match the delta side currents.

Additionally, the delta connection of the currents transformers eliminates the zero sequence current component flowing on the grounded Y side of the transformer. As on the delta side no zero-sequence current can be detected, this compensation is unavoidable for the correct operation of the differential protection.

If a phase-to-ground fault occurs at the Y side of the transformer, then zero sequence current flows on the grounded Y side, but on the delta side no out-flowing zero sequence current can be detected. Without elimination of the zero-sequence current component the differential protection generates a trip command in case of external ground fault. If the connection group of the current transformers on the Y side is delta however, then no zero sequence current flows out of the group. So the problem of zero sequence current elimination in case of external ground fault is automatically solved.

The special problem of zero sequence current on the delta side, with the provided solution, is discussed in paragraph 1.1.5.

3.1.10.1.2.3. Mathematical modeling of the current transformer's vector group connection

The numerical differential protection function applies numerical matrix transformation for modeling the delta connection of the current transformers. In the practice it means cyclical subtraction of the phase currents.

In the vector shift compensation, the sampled $L1$, $L2$, $L3$ currents of the primary side ($I1L1$, $I1L2$, $I1L3$) and those of the secondary and tertiary side ($I2L1$, $I2L2$, $I2L3$) and ($I3L1$, $I3L2$, $I3L3$) are transformed to ($I1L1shift$, $I1L2shift$, $I1L3shift$) ($I2L1shift$, $I2L2shift$, $I2L3shift$) and ($I3L1shift$, $I3L2shift$, $I3L3shift$) values of the sides respectively, using matrix transformation. The method of transformation is defined by the Pri-Sec VGroup and Pri-Ter VGroup parameters, identifying the transformer vector group connection.

3.1.10.1.2.4. The matrix equations

In the Vector group compensation software module, the transformation matrices of Table 1-2 are applied. The Matrix ID can start with character

- U for Unit matrix;
- P for Phase shifting matrix;
- Z for Zero sequence eliminating matrix.

The number in the Matrix ID indicates the phase shift in clock notation. (e.g. P11 matrix is a phase shifting matrix to 11 o'clock from 0 o'clock, i.e. 30 degrees anti-clockwise.)

Table 1-2 Vector shift compensation matrices

Matrix ID	Matrix
U0	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$
U6	$\begin{bmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{bmatrix}$
P11	$\frac{1}{\sqrt{3}} * \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix}$
P5	$\frac{1}{\sqrt{3}} * \begin{bmatrix} -1 & 1 & 0 \\ 0 & -1 & 1 \\ 1 & 0 & -1 \end{bmatrix}$
P1	$\frac{1}{\sqrt{3}} * \begin{bmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix}$
P7	$\frac{1}{\sqrt{3}} * \begin{bmatrix} -1 & 0 & 1 \\ 1 & -1 & 0 \\ 0 & 1 & -1 \end{bmatrix}$
Z0	$\frac{1}{3} * \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix}$
Z6	$\frac{1}{3} * \begin{bmatrix} -2 & 1 & 1 \\ 1 & -2 & 1 \\ 1 & 1 & -2 \end{bmatrix}$
Z4	$\frac{1}{3} * \begin{bmatrix} -1 & 2 & -1 \\ -1 & -1 & 2 \\ 2 & -1 & -1 \end{bmatrix}$
Z10	$\frac{1}{3} * \begin{bmatrix} 1 & -2 & 1 \\ 1 & 1 & -2 \\ -2 & 1 & -1 \end{bmatrix}$
Z8	$\frac{1}{3} * \begin{bmatrix} -1 & -1 & 2 \\ 2 & -1 & -1 \\ -1 & 2 & -1 \end{bmatrix}$
Z2	$\frac{1}{3} * \begin{bmatrix} 1 & 1 & -2 \\ -2 & 1 & 1 \\ 1 & -2 & 1 \end{bmatrix}$
U4	$\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix}$
U10	$\begin{bmatrix} 0 & -1 & 0 \\ 0 & 0 & -1 \\ -1 & 0 & 0 \end{bmatrix}$

Application of the matrix transformation for two winding transformers

The primary winding of a power transformer can be “Y” or “D” (Delta) connected.

If the primary is “Y” connected then the secondary can be configured to “y”, “d” or “z”. The possible combinations are shown in Table 1-.

Table 1-3 Vector shift compensation matrices for two winding transformers of primary “Y” connection

Primary	Y
Secondary	Transformation
y0	P1 P1
y6	P1 P7
d1	P1 U0 P1 Z0
d5	P11 U6 P11 Z6
d7	P1 U6 P1 Z6
d11	P11 U0 P11 Z0
z1	P1 Z0
z5	P11 Z6
z7	P1 Z6
z11	P11 Z0

As an example: In the differential protection of a YNd11 type transformer, the primary phase currents are transformed to match the secondary currents using the P11 matrix. The secondary currents are transformed using the U0 unit matrix (resulting no modification in the secondary currents). However, if there is a neutral grounding transformer in the protected zone on the secondary side of the transformer then the zero sequence current needs elimination. For this purpose, the Z0 matrix is applied. The choice depends on parameter setting “Zero Seq Elimination”, according to the application.

In the YNd11 transformer of the example, the primary “Y” side currents are transformed with matrix multiplication:

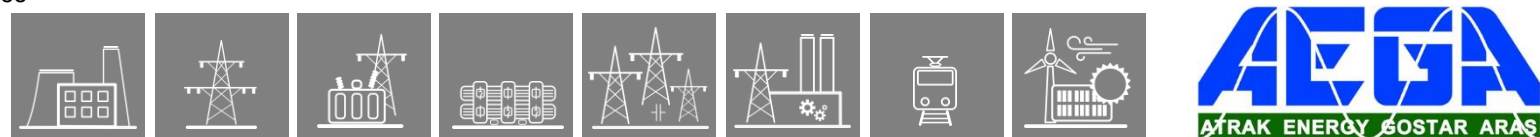
$$\begin{bmatrix} I_{1L1Shift} \\ I_{1L2Shift} \\ I_{1L3Shift} \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix} * \begin{bmatrix} I_{1L1} \\ I_{1L2} \\ I_{1L3} \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} I_{1L1} - I_{1L2} \\ I_{1L2} - I_{1L3} \\ I_{1L3} - I_{1L1} \end{bmatrix}$$

NOTE: This transformation means also that the phase currents are transformed to the values of a “measuring element”. Accordingly, on the Y side of the transformer these values do not mean “phase currents” in the original sense.

In the YNd11 transformer of the example, the secondary “d” side currents are transformed with matrix multiplication *supposing no neutral grounding transformer in the protected zone:

$$\begin{bmatrix} I_{2L1Shift} \\ I_{2L2Shift} \\ I_{2L3Shift} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} I_{2L1} \\ I_{2L2} \\ I_{2L3} \end{bmatrix} = \begin{bmatrix} I_{2L1} \\ I_{2L2} \\ I_{2L3} \end{bmatrix}$$

NOTE: This means that the delta side currents are unchanged, and the Y side currents are phase shifted to match the secondary currents. At the same time, the zero sequence current components are automatically eliminated from the transformed currents.



If the primary is “D” connected then the secondary can be configured to “y”, “d” or “z”. The possible combinations are shown in Table 1-4.

Table 1-4 Vector shift compensation matrices for transformers of primary “D” connection

Primary	D
Secondary	Transformation
y1	U0 P11
y5	U0 P7
y7	U0 P5
y11	U0 P1
d0	U0 U0
d6	U0 U6
z0	U0 Z0
z2	U0 Z10

Application of the matrix transformation for three winding transformers

The primary winding of a power transformer can be “Y” or “D” (Delta) connected.

If the primary is “Y” connected then the secondary and/or the tertiary can be configured to “y”, “d” or “z”. The possible combinations are shown in Table 1-5.

Table 1-5 Vector shift compensation matrices for tree winding transformers of primary “Y” connection

Secondary	y0	y6	d1	d5	d7	d11
y0	P1 P1 P1	P1 P1 P7	P1 P1 U0	P11 P11 U6	P1 P1 U6	P11 P11 U0
y6	P1 P7 P1	P1 P7 P7	P1 P7 U0	P11 P5 U6	P1 P7 U6	P11 P5 U0
d1	P1 U0 P1	P1 U0 P7	P1 U0 U0	P11 U10 U6	P1 U0 U6	P11 U10 U0
d5	P11 U6 P11	P11 U6 P5	P11 U6 U10	P11 U6 U6	P11 U6 U4	P11 U6 U0
d7	P1 U6 P1	P1 U 6 P7	P1 U6 U0	P11 U4 U6	P1 U6 U6	P11 U4 U0
d11	P11 U0 P11	P11 U0 P5	P11 U0 U10	P11 U0 U6	P11 U0 U4	P11 U0 U0
z1	P1 Z0 P1	P1 Z0 P7	P1 Z0 U0	P11 Z1 0U6	P1 Z0 U6	P11 Z10 U0
z5	P11 Z6 P11	P11 Z6 P5	P11 Z6 U10	P11 Z6 U6	P11 Z6 U4	P11 Z6 U0
z7	P1 Z6 P1	P1 Z6 P7	P1 Z6 U0	P11 Z4 U6	P1 Z6 U6	P11 Z4 U0
z11	P11 Z0 P11	P11 Z0 P5	P11 Z0 U10	P11 Z0 U6	P11 Z0 U4	P11 Z0 U0

Secondary	z1	z5	z7	z11
y0	P1 P1 Z0	P11 P11 Z6	P1 P1 Z6	P11 P11 Z0
y6	P1 P7 Z0	P11 P5 Z6	P1 P7 Z6	P11 P5 Z0
d1	P1 U0 Z0	P11 U10 Z6	P1 U0Z 6	P11 U10 Z0
d5	P11 U6 Z10	P11 U6 Z6	P11 U6 Z4	P11 U6 Z0
d7	P1 U6 Z0	P11 U4 Z6	P1U6 Z6	P11 U4 Z0
d11	P11 U0 Z10	P11 U0 Z6	P11 U0 Z4	P11 U0 Z0
z1	P1 Z0 Z0	P11 Z10 Z6	P1 Z 0Z6	P11 Z10 Z0
z5	P11 Z6 Z10	P11 Z6 Z6	P11 Z6 Z4	P11 Z6 Z0
z7	P1 Z6 Z0	P11 Z4 Z6	P1 Z6 Z6	P11 Z4 Z0
z11	P11 Z0 Z10	P11 Z0 Z6	P11Z0 Z4	P11 Z0 Z0

NOTE: If the secondary and/or tertiary is “d” and there is a neutral grounding transformer in the protected zone then Z matrix should be applied instead of U (controlled by the parameter “Zero Seq Elimination”), using the same clock rotation.

If the primary is “D” connected then the secondary and/or the tertiary can be configured to “y”, “d” or “z”. The possible combinations are shown in Table 1-3.

Table 1-6 Vector shift compensation matrices for tree winding transformers of primary “D” connection

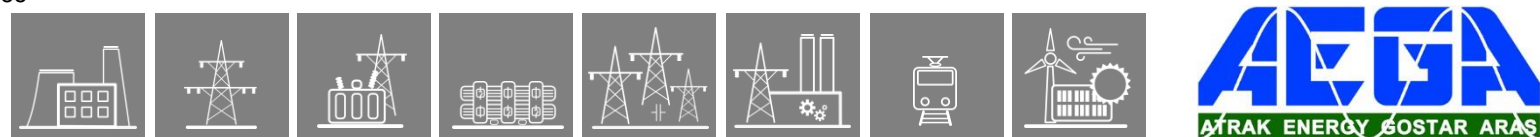
Primary D						
Secondary	Tertiary					
	y1	y5	y7	y11	d0	d6
y1	U0 P11 P11	U0 P11 P7	U0 P11 P5	U0 P11 P1	U0 P11 U0	U0 P11 U6
y5	U0 P7 P11	U0 P7 P7	U0 P7 P5	U0 P7 P1	U0 P7 U0	U0 P7 U6
y7	U0 P5 P11	U0 P5 P7	U0 P5 P5	U0 P5 P1	U0 P5 U0	U0 P5 U6
y11	U0 P1 P11	U0 P1 P7	U0 P1 P5	U0 P1 P1	U0 P1 U0	U0 P1 U6
d0	U0 U0 P11	U0 U0 P7	U0 U0 P5	U0 U0 P1	U0 U0 U0	U0 U0 U6
d6	U0 U6 P11	U0 U6 P7	U0 U6 P5	U0 U6 P1	U0 U6 U0	U0 U6 U6
z0	U0 Z0 P11	U0 Z0 P7	U0 Z0 P5	U0 Z0 P1	U0 Z0 U0	U0 Z0 U6
z2	U0 Z10 P11	U0 Z10 P7	U0 Z10 P5	U0 Z10 P1	U0 Z10 U0	U0 Z10 U6
z4	U0 Z8 P11	U0 Z8 P7	U0 Z8 P5	U0 Z8 P1	U0 Z8 U0	U0 Z8 U6
z6	U0 Z6 P11	U0 Z6 P7	U0 Z6 P5	U0 Z6 P1	U0 Z6 U0	U0 Z6 U6
z8	U0 Z4 P11	U0 Z4 P7	U0 Z4 P5	U0 Z4 P1	U0 Z4 U0	U0 Z4 U6
z10	U0 Z2 P11	U0 Z2 P7	U0 Z2 P5	U0 Z2 P1	U0 Z2 U0	U0 Z2 U6

Primary D						
Secondary	Tertiary					
	z0	z2	z4	z6	z8	z10
y1	U0 P11 Z0	U0 P11 Z10	U0 P11 Z8	U0 P11 Z6	U0 P11 Z4	U0 P11 Z2
y5	U0 P7 Z0	U0 P7 Z10	U0 P7 Z8	U0 P7 Z6	U0 P7 Z4	U0 P7 Z2
y7	U0 P5 Z0	U0 P5 Z10	U0 P5 Z8	U0 P5 Z6	U0 P5 Z4	U0 P5 Z2
y11	U0 P1 Z0	U0 P1 Z10	U0 P1 Z8	U0 P1 Z6	U0 P1 Z4	U0 P1 Z2
d0	U0 U0 Z0	U0 U0 Z10	U0 U0 Z8	U0 U0 Z6	U0 U0 Z4	U0 U0 Z2
d6	U0 U6 Z0	U0 U6 Z10	U0 U6 Z8	U0 U6 Z6	U0 U6 Z4	U0 U6 Z2
z0	U0 Z0 Z0	U0 Z0 Z10	U0 Z0 Z8	U0 Z0 Z6	U0 Z0 Z4	U0 Z0 Z2
z2	U0 Z10 Z0	U0 Z10 Z10	U0 Z10 Z8	U0 Z10 Z6	U0 Z10 Z4	U0 Z10 Z2
z4	U0 Z8 Z0	U0 Z8 Z10	U0 Z8 Z8	U0 Z8 Z6	U0 Z8 Z4	U0 Z8 Z2
z6	U0 Z6 Z0	U0 Z6 Z10	U0 Z6 Z8	U0 Z6 Z6	U0 Z6 Z4	U0 Z6 Z2
z8	U0 Z4 Z0	U0 Z4 Z10	U0 Z4 Z8	U0 Z4 Z6	U0 Z4 Z4	U0 Z4 Z2
z10	U0 Z2 Z0	U0 Z2 Z10	U0 Z2 Z8	U0 Z2 Z6	U0 Z2 Z4	U0 Z2 Z2

The differential currents are calculated using the ($I_{...shift}$) values and the rated currents $I_{reference_1}$, $I_{reference_2}$ (and $I_{reference_3}$ if this is applicable). These currents are calculated internally, using the rated power and rated voltages, as given by parameters. (The positive direction of the currents is flowing IN on both sides.)

$$\begin{aligned}
 \begin{bmatrix} IdL1 \\ IdL2 \\ IdL3 \end{bmatrix} &= \begin{bmatrix} I1L1shift' \\ I1L2shift' \\ I1L3shift' \end{bmatrix} + \begin{bmatrix} I2L1shift' \\ I2L2shift' \\ I2L3shift' \end{bmatrix} = \\
 &= \frac{1}{I_{reference_1}} \begin{bmatrix} I1L1shift \\ I1L2shift \\ I1L3shift \end{bmatrix} + \frac{1}{I_{reference_2}} \begin{bmatrix} I2L1shift \\ I2L2shift \\ I2L3shift \end{bmatrix}
 \end{aligned}$$

This means that the differential currents (and also the phase shifted currents marked with character ‘ are “per unit currents”, and the reference values are the calculated reference currents. The current measuring software modules process these momentary values of the differential currents, and calculate values, which are proportional to the RMS values.



3.1.10.1.2.5. Operation with the zero-sequence current in case of phase-to-ground fault on the delta side

On the secondary side of a high voltage/medium voltage transformer which is connected in delta on the medium voltage side, an additional neutral grounding transformer is applied. Between the neutral point of this grounding transformer and the ground, either a grounding resistor is connected to limit the single phase to ground fault currents below 100 A (in some cases 200 A), or here a Petersen coil is applied which limits the single phase fault currents to a small value of some Amps.

In these cases, there are two locations for the currents transformers on the delta side to supply the differential protection. In one case the neutral grounding transformer is located inside the protected zone of the differential protection (*in Figure 3-7 and Figure 3-8 of the Appendix* it is the location "Z"), in the other case the neutral grounding transformer is outside the protected zone (*in Figure 3-7 and Figure 3-8 of the Appendix* this is the application of the current transformers on location „Y”).

If the neutral grounding transformer is in the protected zone, then the current distribution depends on the location of the supplying generator, as it is shown *in Figure 3-7 and Figure 3-8 of the Appendix*. In these cases, for correct operation of the differential protection (if the operating characteristic lines are set to be sensitive) the subtraction of the zero sequence current is needed. This additional transformation „replaces” the measuring location to the point („Y”), where no zero sequence current can flow, so these transformed currents do not include the zero sequence current of the neutral grounding transformer.

3.1.10.1.2.6. The principal scheme of the vector group compensation

Figure 1-2 shows the principal scheme of the vector shift compensation.

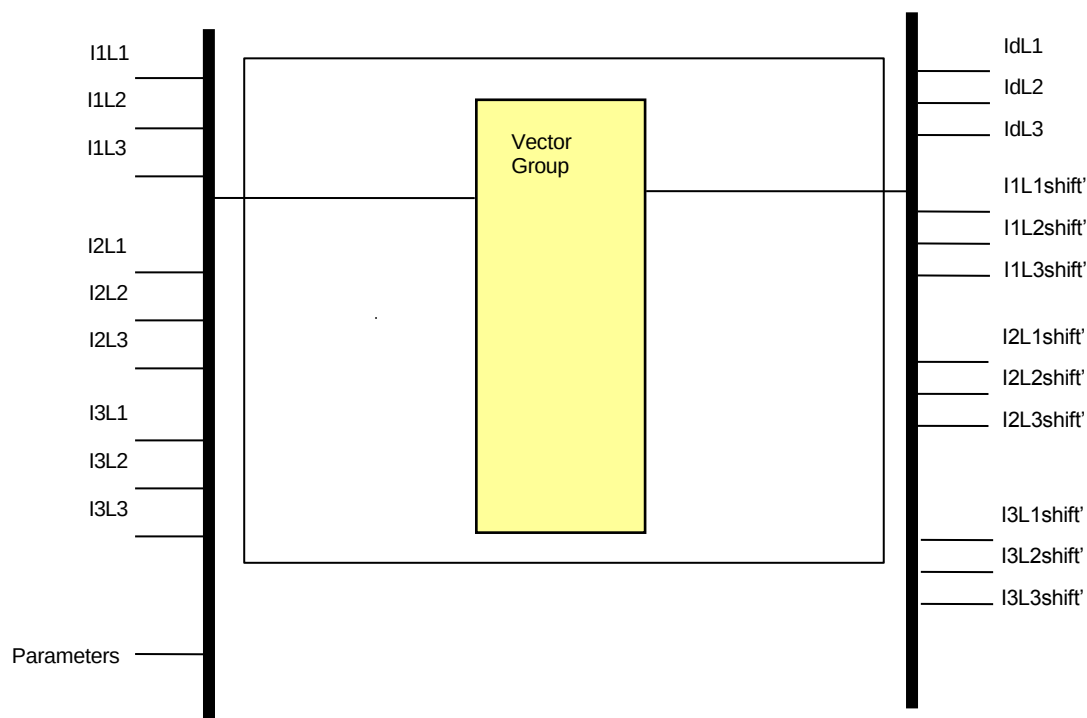


Figure 1-2 Principal scheme of the vector shift compensation.

The **inputs** are the sampled values of:

- The three phase currents of the primary side (I1L1, I1L2, I1L3)
- The three phase currents of the secondary side (I2L1, I2L2, I2L3)
- The three phase currents of the tertiary side (I3L1, I3L2, I3L3 in DIF87T3 version only)
- Parameters for vector shift and turn's ratio compensation.

Enumerated parameters for the vector shift compensation:

Table 1-7 Enumerated parameters for the vector shift compensation

Parameter name	Title	Selection range	Default
Parameter to select connection group of the transformer coils in primary-secondary relation:			
DIF87_VGrSec_EPar_	Pri-Sec VGroup*	Dy1,Dy5,Dy7,Dy11,Dd0,Dd6,Dz0,Dz2,Dz4,Dz6,Dz8,Dz10,Yy0,Yy6,Yd1,Yd5,Yd7,Yd11,Yz1,Yz5,Yz7,Yz11	Dd0
Parameter to select connection group of the transformer coils in primary-tertiary relation:			
DIF87_VGrTer_EPar_	Pri-Ter VGroup*	Dy1,Dy5,Dy7,Dy11,Dd0,Dd6,Dz0,Dz2,Dz4,Dz6,Dz8,Dz10,Yy0,Yy6,Yd1,Yd5,Yd7,Yd11,Yz1,Yz5,Yz7,Yz11	Dd0

* If the connection of the primary winding in primary-secondary and primary tertiary relation is selected in contradiction then the protection function is automatically disabled, and the function generates a warning signal.

Boolean parameter for the vector shift compensation:

Table 1-8 The Boolean parameter for the vector shift compensation

Parameter name	Title	Default	Explanation
DIF87_0Seq_BPar_	Zero Seq Elimination	True	See Chapter 1.1.5

The **outputs** are the “sampled values” of the phase-shifted currents:

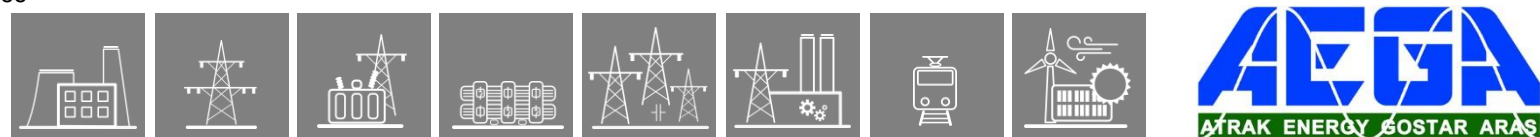
- The differential currents after phase-shift.

$$\begin{bmatrix} IdL1 \\ IdL2 \\ IdL3 \end{bmatrix}$$
- The primary currents after phase-shift.

$$\begin{bmatrix} I1L1shift \\ I1L2shift \\ I1L3shift \end{bmatrix}$$
- The secondary currents after phase-shift.

$$\begin{bmatrix} I2L1shift \\ I2L2shift \\ I2L3shift \end{bmatrix}$$
- The tertiary currents after phase-shift (in DIF87T3 version only).

$$\begin{bmatrix} I3L1shift \\ I3L2shift \\ I3L3shift \end{bmatrix}$$



3.1.10.1.3. Harmonic analysis of the differential currents (Diff basic harm.), (Diff 2. harm.), (Diff 5. harm.)

3.1.10.1.3.1. The principle of calculation

The differential current can be high in case of transformer energizing, due to the current distortion caused by the transformer iron core asymmetric saturation. In this case the second harmonic content of the differential current is applied to disable the operation of the differential protection function.

The differential current can also be high in case of external faults, due to the current distortion caused by saturated CT on the faulty side. Additional usage of the second harmonic restraint in these cases disables the operation of the differential protection function.

The differential current can be high in case of over-excitation of the transformer, due to the current distortion caused by the transformer iron core symmetric saturation. In this case the fifth harmonic content of the differential current is applied to disable the operation of the differential protection function.

The harmonic analysis block of modules consists of three individual software modules.

Diff base harm.

This module calculates the basic Fourier components of the three differential currents. These results are needed for the high-speed differential current decision and for the second and fifth harmonic restraint calculation.

Diff 2. harm.

This module calculates the second harmonic Fourier components of the three differential currents. These results are needed for the second harmonic restraint decision.

Diff 5. harm.

This module calculates the fifth harmonic Fourier components of the three differential currents. These results are needed for the fifth harmonic restraint decision.

3.1.10.1.3.2. The principal scheme of the harmonic analysis

Figure 1-3 shows the structure of the harmonic analysis.

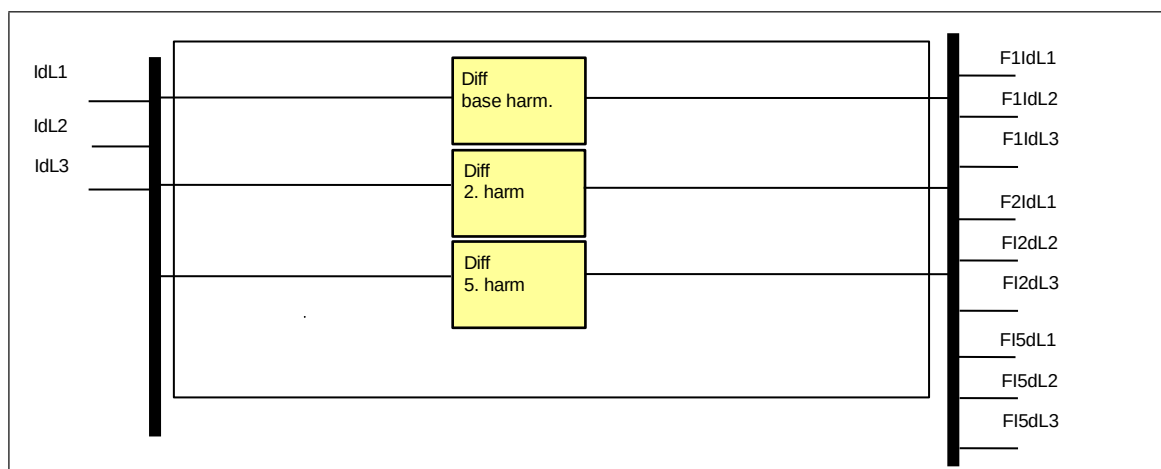


Figure 1-3 Principal scheme of the harmonic analysis.

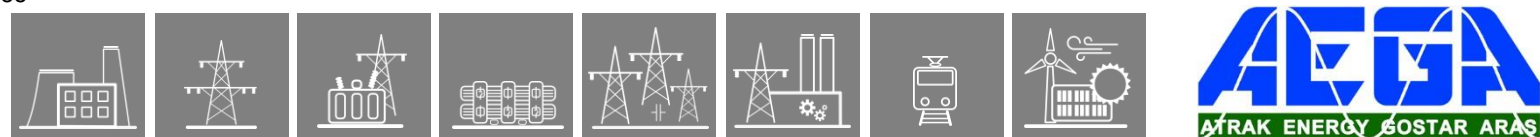
The **inputs** are the “sampled values” of the differential currents, based on the phase-shifted currents:

- The differential currents after phase-shift.
- $$\begin{bmatrix} IdL1 \\ IdL2 \\ IdL3 \end{bmatrix}$$

The **outputs** are the basic, the second and the fifth harmonic Fourier components of the differential currents (also as p.u. of the reference current):

- The basic harmonic Fourier components of the differential currents $\begin{bmatrix} F1IdL1 \\ F1IdL2 \\ F1IdL3 \end{bmatrix}$
- The second harmonic Fourier components of the differential currents $\begin{bmatrix} F2IdL1 \\ F2IdL2 \\ F2IdL3 \end{bmatrix}$
- The fifth harmonic Fourier components of the differential currents $\begin{bmatrix} F5IdL1 \\ F5IdL2 \\ F5IdL3 \end{bmatrix}$

These values are processed by the software modules **2. harmonic restraint** and **5. harmonic restraint**



3.1.10.1.4. The harmonic restraint decision (2. harmonic restraint) and (5. harmonic restraint)

3.1.10.1.4.1. The principle of the restraint decision

The differential current can be high in case of transformer energizing, due to the current distortion caused by the transformer iron core asymmetric saturation. In this case the second harmonic content of the differential current is applied to disable the operation of the differential protection function.

The differential current can be high in case of external faults, due to the current distortion caused by saturated CT on the faulty side. Additional usage of the second harmonic restraint in these cases can help to disable the operation of the differential protection function.

The differential current can be high in case of over-excitation of the transformer as well, due to the current distortion caused by the transformer iron core symmetric saturation. In this case the fifth harmonic content of the differential current is applied to disable the operation of the differential protection function.

The harmonic analysis block of modules consists of two sub-blocks, one for the second harmonic decision and one for the fifth harmonic decision. Each sub-block includes three individual software modules for the phases.

The software modules evaluate the harmonic content relative to the basic harmonic component of the differential currents, and compare the result with the parameter values, set for the second and fifth harmonic. If the content is high, then the assigned status signal is set to “true” value. If the duration of the active status is at least 25 ms (or 20.83 ms on a 60 Hz system), then resetting of the status signal is delayed by additional 15 ms (12.5 ms on a 60 Hz system).

Depending on the dedicated Boolean parameter setting “Cross Blocking”, there are two modes of operation:

- If the “Cross Blocking” parameter is FALSE (not checked) then the three “measuring elements” operate individually. The internal output signal of the “measuring element” is blocked only if the own differential current contains harmonics (second and/or fifth) above the setting level, indicating inrush current or over-excitation. Other measuring element may generate trip requirement.
- If the “Cross Blocking” parameter is TRUE (checked) then the three blocking any of the “measuring elements” by harmonics (second and/or fifth) above the setting level blocks also the internal output signal of all three “measuring elements”. The function does not generate trip requirement.

The duration of the cross blocking is set by a dedicated parameter “Cross Blocking Limit”. This is the maximum duration of cross-blocking; after timeout, the cross-blocking resets even if there are high values of harmonics in another “measuring element(s)”. Note that the “measuring element(s)” with high values of harmonics will keep on self-blocking.

3.1.10.1.4.2. The principal scheme of the harmonic restraint decision

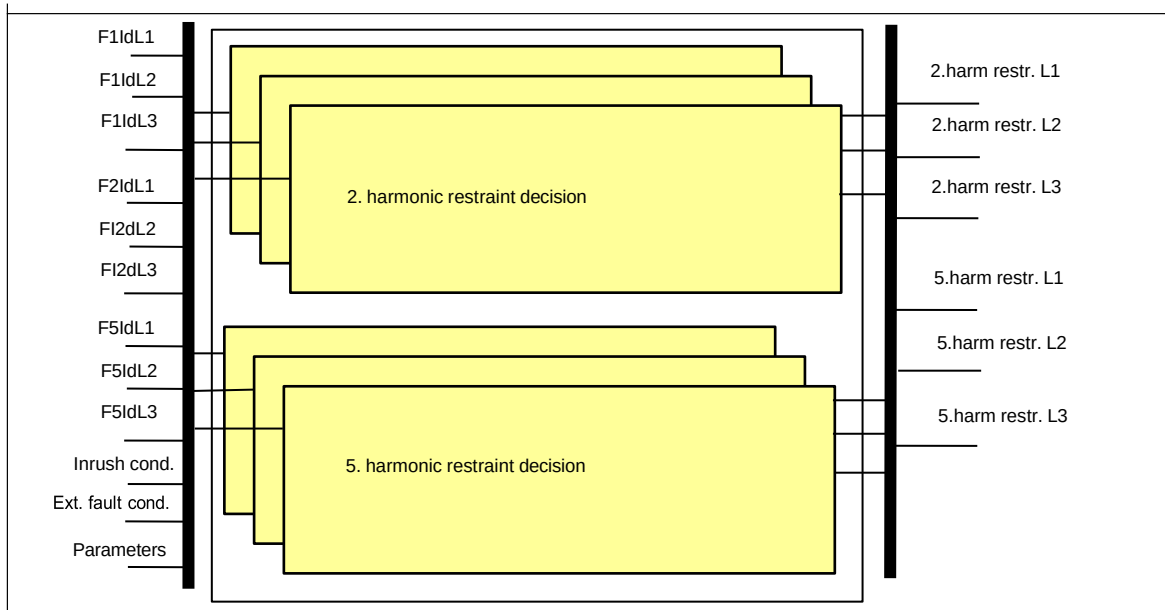


Figure 1-4 Principal scheme of the harmonic restraint decision

The **inputs** are the following:

- The basic harmonic Fourier components of the differential currents

$$\begin{bmatrix} F1dL1 \\ F1dL2 \\ F1dL3 \end{bmatrix}$$

- The second harmonic Fourier components of the differential currents

$$\begin{bmatrix} F2dL1 \\ F2dL2 \\ F2dL3 \end{bmatrix}$$

- The fifth harmonic Fourier components of the differential currents.

$$\begin{bmatrix} F5dL1 \\ F5dL2 \\ F5dL3 \end{bmatrix}$$

- Inrush condition detection for 2nd harmonic decision
- External fault condition detection for 2nd harmonic decision
- Parameter settings for harmonic detection

The outputs of the modules are the status signals for each phase and for second and fifth harmonics separately, indicating the restraint status caused by high harmonic contents.

Binary output status signals of the harmonic restraint decision function are listed in Table 1-9.

Table 1-9 The binary output status signals of the harmonic restraint decision function

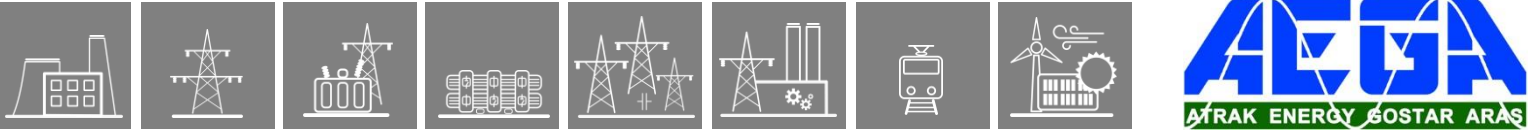
Binary output signals	Signal title	Explanation
Second harmonic restraint signals		
DIF87_2HBikL1_Grl_	2.harm Restr. L1	High second harmonic content detected in the differential current in phase L1
DIF87_2HBikL2_Grl_	2.harm Restr. L2	High second harmonic content detected in the differential current in phase L2
DIF87_2HBikL3_Grl_	2.harm Restr. L3	High second harmonic content detected in the differential current in phase L3
DIF87_InrushL1_Grl_	Inrush. L1	Restraint in phase L1 caused by high second harmonic content in the differential current during inrush or external fault
DIF87_InrushL2_Grl_	Inrush L2	Restraint in phase L2 caused by high second harmonic content in the differential current during inrush or external fault
DIF87_InrushL3_Grl_	Inrush L3	Restraint in phase L3 caused by high second harmonic content in the differential current during inrush or external fault
DIF87_Inrush_Grl_	Inrush.	Restraint caused by high second harmonic content in any of the differential currents during inrush or external fault
Fifth harmonic restraint signals		
DIF87_5HBikL1_Grl_	5.harm Restr. L1	Restraint in phase L1 caused by high fifth harmonic content in the differential current
DIF87_5HBikL2_Grl_	5.harm Restr. L2	Restraint in phase L2 caused by high fifth harmonic content in the differential current
DIF87_5HBikL3_Grl_	5.harm Restr. L3	Restraint in phase L3 caused by high fifth harmonic content in the differential current
DIF87_5HBik_Grl_	5.Harm Restr.	Restraint caused by high fifth harmonic content in any of the differential currents

Integer parameters of the harmonic restraint decision function are listed in Table 1-10.

Table 1-10 The integer parameters of the harmonic restraint decision function

Parameter name	Title	Unit	Min	Max	Step	Default
Parameter of the second harmonic restraint:						
DIF87_2HRat_IPar_	2nd Harm Ratio	%	5	50	1	15
Parameter of the fifth harmonic restraint:						
DIF87_5HRat_IPar_	5th Harm Ratio	%	5	50	1	25

(% related to the 1st harmonic of the differential current)

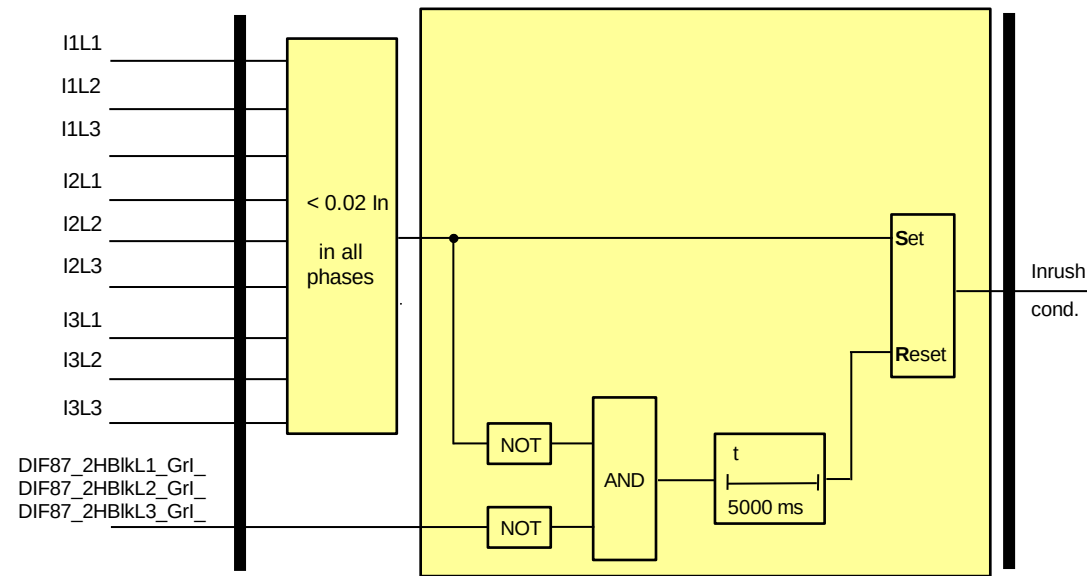


3.1.10.1.4.2.1. Inrush condition for 2nd harmonic block

For blocking the differential protection function during inrush, the second harmonic restraint is evaluated if the transformer is detected to be either off or recently switched on. The **Inrush condition** signal indicates this state.

The inrush condition deactivates after a *5 seconds delay (or 4.167 seconds on a 60 Hz system)* if the following two conditions are fulfilled:

- any of the phase currents exceed 2%,
- there are no 2nd harmonics detected, see Figure 1-7 and the figure below:



**the value is connected to the cycle time of 50 Hz. For 60 Hz applications it becomes lower: 4166.67 ms*

Figure 1-5 Logic scheme of the inrush condition

3.1.10.1.4.2.2. External fault condition for 2nd harmonic block

The second harmonic restraint is also evaluated for disabling the differential protection function during external faults with CT saturation. The **Ext. fault condition** signal indicates this state. This signal activates when the shifted and compensated currents between the two sides have at least an angle difference of **75 degrees**.

For valid angle measurement, it is required that the involved sides' shifted currents' magnitude is larger than **10%** (of the reference current, which is the transformer rated current).

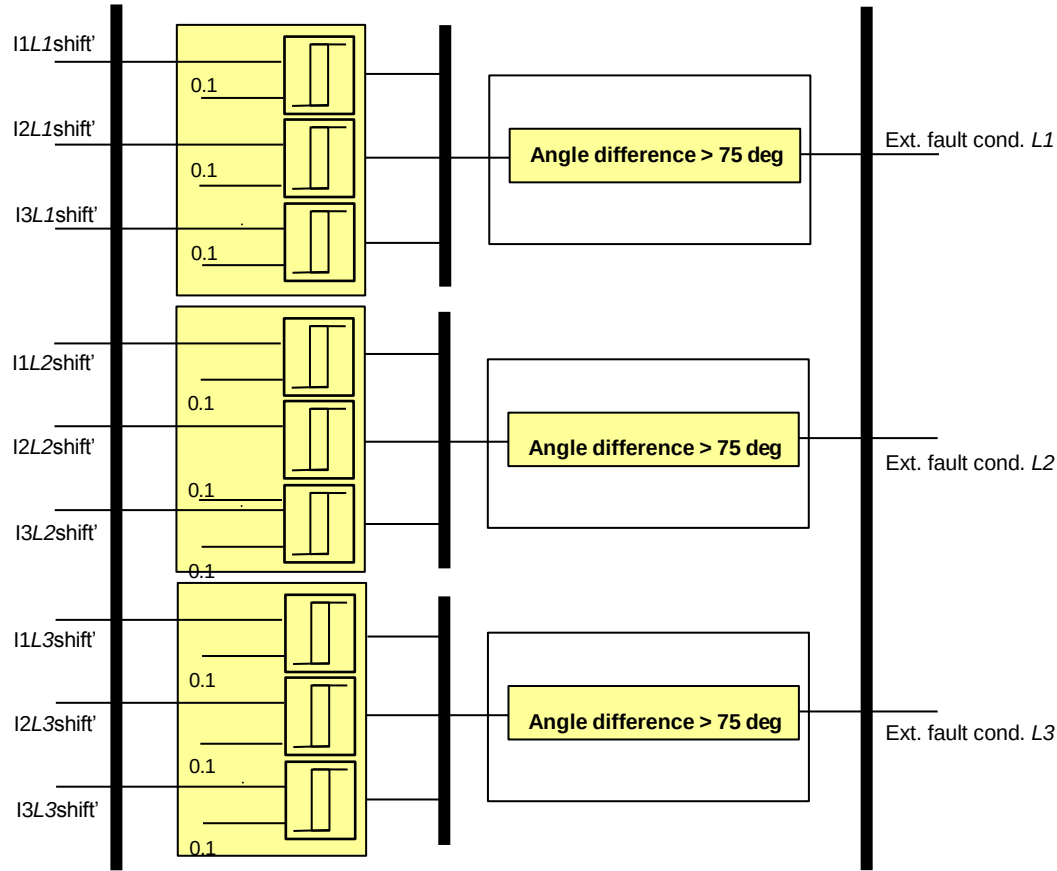
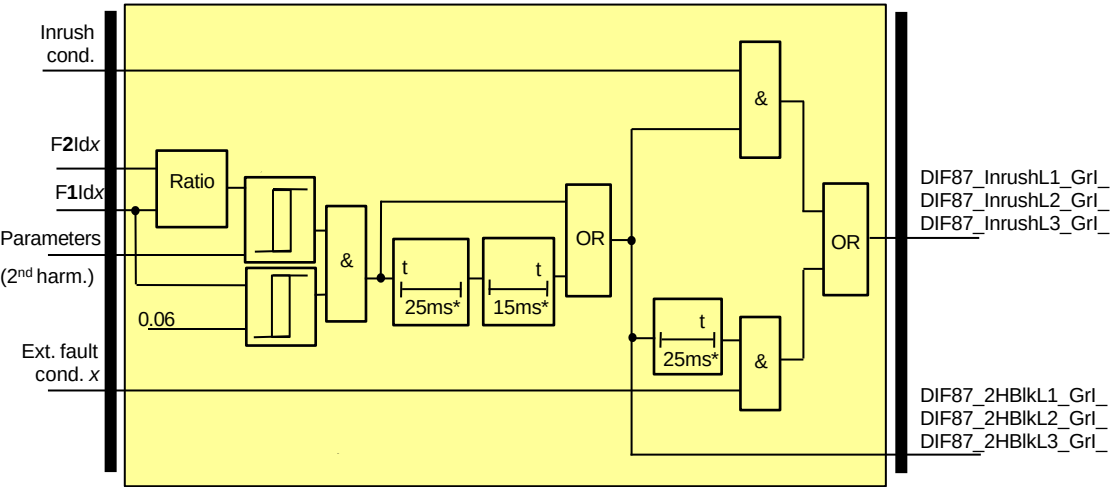


Figure 1-6 Logic scheme of the external fault condition

3.1.10.1.4.3. 2nd harmonic blocking scheme

The 2nd harmonic restraint function follows the logic below:



*the values are connected to the cycle time of 50 Hz. For **60 Hz** applications these become lower: **20.83 ms** and **12.5 ms**

Figure 1-7 Logic scheme of the 2nd harmonic decision based on inrush or external fault

The logic scheme is repeated for the **second** harmonic restraint decision for all three phases ("measuring elements") separately ($x=L1, L2, L3$).

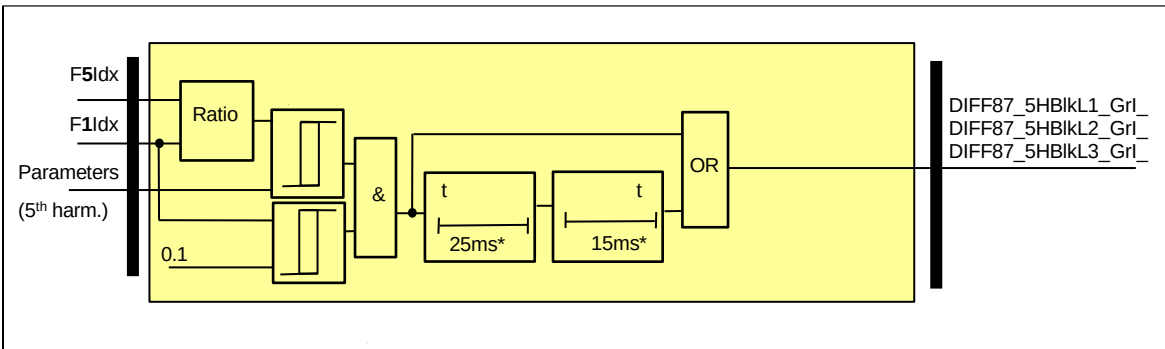
First the ratio of the harmonic and the base harmonic is calculated, and this ratio is compared to the parameter setting (second and fifth separately). In case of high ratio value, the restraint signal is generated immediately, and at the same time a timer is started. If the 25 ms (or 20.83 ms on a 60 Hz system) delay is over, and during the running time the high ratio was continuous, then a drop-off timer is started, which extends the duration of the restraint signal.

The restraint signal is generated if either the inrush condition or the external fault condition is active.

The decisions of the phases are connected in OR gate to result harmonic restraint status signal: DIF87_Inrush_GrI_ (Inrush). Note that the signal includes both cases where the 2nd harmonics are evaluated.

3.1.10.1.4.3.1. 5th harmonic blocking scheme

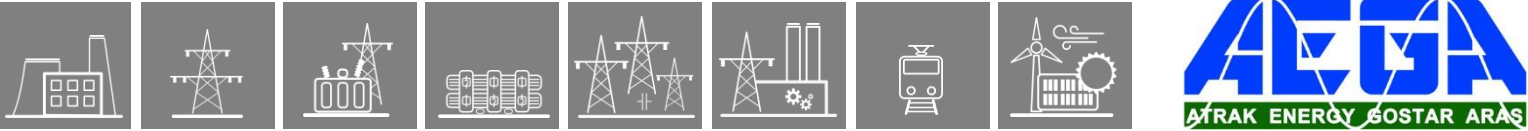
The 5th harmonic restraint function follows the logic below:



*the values are connected to the cycle time of 50 Hz. For **60 Hz** applications these become lower: **20.83 ms** and **12.5 ms**

Figure 1-8 Logic scheme of the 5th harmonic restraint decision

The logic for the fifth harmonic restraint decision is like the second harmonic one with the difference that there are no further conditions other than the minimum differential current.



3.1.10.1.4.3.2. Cross blocking logic

Depending on the dedicated Boolean parameter setting “Cross Blocking”, there are two modes of operation:

- If the “Cross Blocking” parameter is FALSE (not checked) then the three “measuring elements” operate individually. The internal output signal of the “measuring element” is blocked only if the own differential current contains harmonics (second and/or fifth) above the setting level, indicating inrush current or over-excitation. Other measuring element may generate trip requirement.
- If the “Cross Blocking” parameter is TRUE (checked) then the three blocking any of the “measuring elements” by harmonics (second and/or fifth) above the setting level blocks also the internal output signal of all three “measuring elements”. The function does not generate trip requirement.

The duration of the cross blocking is set by a dedicated parameter “Cross Blocking Limit”. This is the maximum duration of cross-blocking; after timeout, the cross-blocking resets even if there are high values of harmonics in another “measuring element(s)”. Note that the “measuring element(s)” with high values of harmonics will keep on self-blocking.

Boolean parameter of the harmonic restraint decision function is shown in Table 1-11:

Table 1-11 The Boolean parameter of the harmonic restraint decision function

Parameter name	Title	Default	Explanation
Harmonic cross blocking			
DIF87_Cross_BPar_	Cross Blocking	True	The True setting enables cross-blocking for the maximum duration defined by the dedicated timer parameter

Timer parameter of the harmonic restraint decision function is shown in Table 1-12.

Table 1-12 The timer parameter of the harmonic restraint decision function

Parameter name	Title	Unit	Min	Max	Step	Default
Duration of the cross-blocking (if it is enabled):						
DIF87_CrossLimit_TPar_	Cross Blocking Limit	ms	100	60000	1	5000



3.1.10.1.5. The current magnitude calculation (Current magnitude)

3.1.10.1.5.1. The principle of the current magnitude calculation

The module, which evaluates the differential characteristics, compares the magnitude of the differential currents and those of the restraint currents. For this calculation the current magnitudes are needed. These magnitudes are calculated in this module.

3.1.10.1.5.2. The principal scheme of the current magnitude calculation

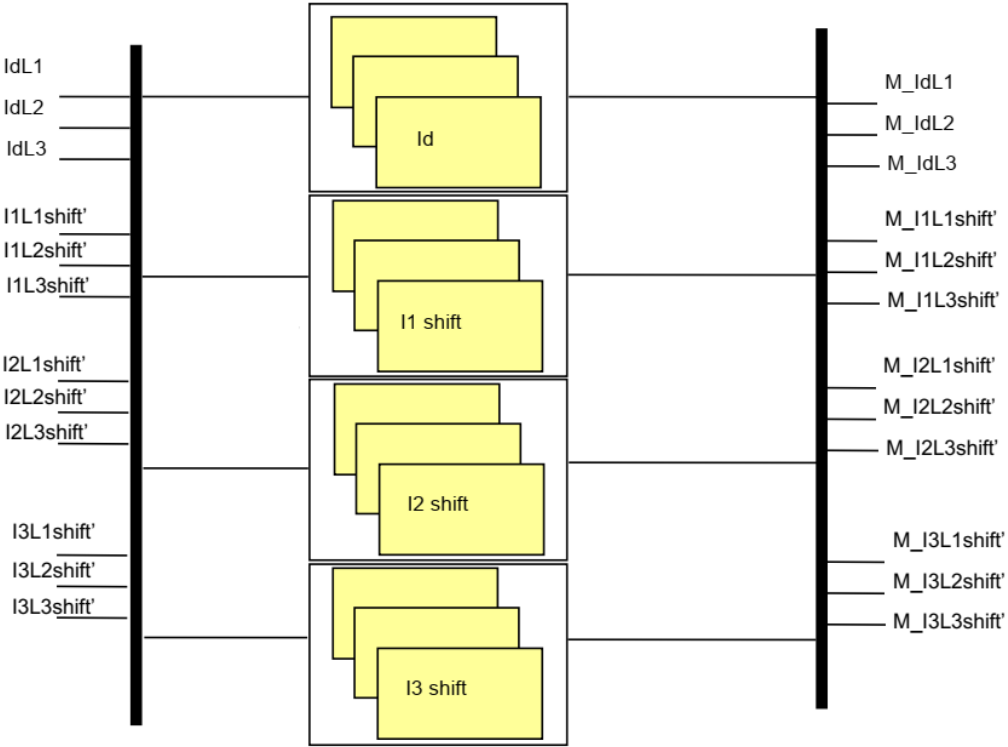


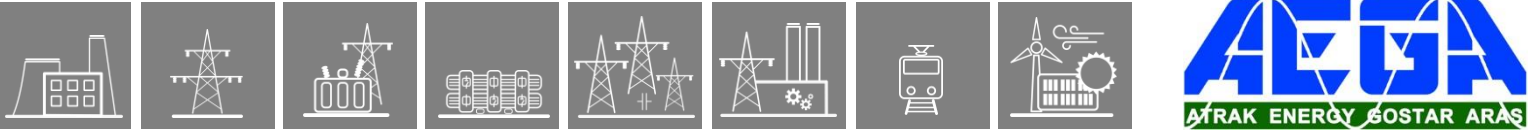
Figure 1-9 Principal scheme of the current magnitude calculation

The **inputs** are the “sampled values” of the phase-shifted currents:

- The differential currents after phase-shift

$$\begin{bmatrix} IdL1 \\ IdL2 \\ IdL3 \end{bmatrix}$$
- The primary currents after phase-shift

$$\begin{bmatrix} I1L1shift' \\ I1L2shift' \\ I1L3shift' \end{bmatrix}$$



- The secondary currents after phase-shift

$$\begin{bmatrix} I2L1shift \\ I2L2shift \\ I2L3shift \end{bmatrix}$$
- The tertiary currents after phase-shift (in DIF87T3 version only)

$$\begin{bmatrix} I3L1shift \\ I3L2shift \\ I3L3shift \end{bmatrix}$$

The **outputs** are the magnitude of the calculated currents

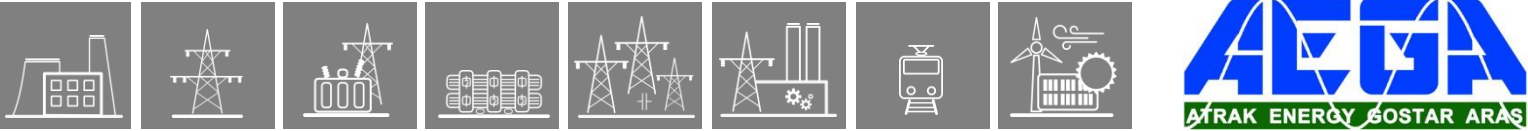
- The magnitudes of the differential currents after phase-shift

$$\begin{bmatrix} M_IdL1 \\ M_IdL2 \\ M_IdL3 \end{bmatrix}$$
- The magnitudes of the primary currents after phase-shift

$$\begin{bmatrix} M_I1L1shift \\ M_I1L2shift \\ M_I1L3shift \end{bmatrix}$$
- The magnitudes of the secondary currents after phase-shift

$$\begin{bmatrix} M_I2L1shift \\ M_I2L2shift \\ M_I2L3shift \end{bmatrix}$$
- The magnitudes of the tertiary currents after phase-shift
(in DIF87T3 version only)

$$\begin{bmatrix} M_I3L1shift \\ M_I3L2shift \\ M_I3L3shift \end{bmatrix}$$



3.1.10.1.6. The evaluation of differential characteristics (Differential characteristics)

3.1.10.1.6.1. The principle of the differential characteristics

This module evaluates the differential characteristics. It compares the magnitude of the differential currents and those of the restraint currents. The restraint (bias) currents are calculated using the following formulas:

$$M_{IbiasL1} = \frac{M_{I1L1shift'} + M_{I2L1shift'} + M_{I3L1shift''}}{2}$$

$$M_{IbiasL2} = \frac{M_{I1L2shift'} + M_{I2L2shift'} + M_{I3L2shift''}}{2}$$

$$M_{IbiasL3} = \frac{M_{I1L3shift'} + M_{I2L3shift'} + M_{I3L3shift''}}{2}$$

Based on these values (denoted generally as “Ibias”) and the values of the differential current magnitudes (denoted generally as “Idiff”) the differential protection characteristics are shown on Figure 1-10.

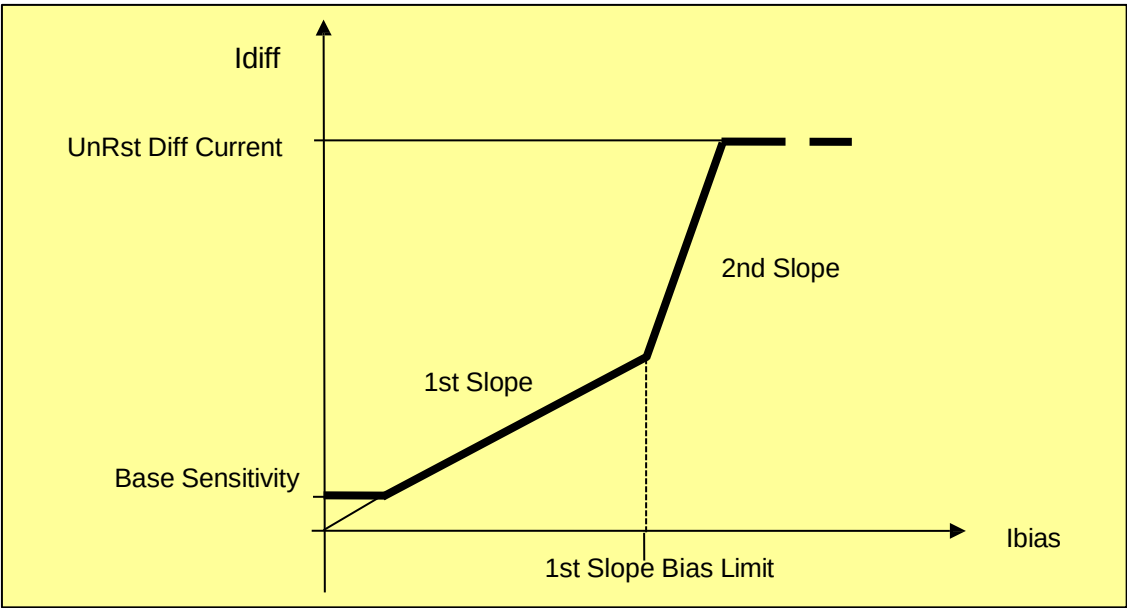


Figure 1-10 The differential protection characteristics

Additionally separate status-signals are set to “true” value if the differential currents in the individual phases are above the limit, set by parameter (see “Unrestrained differential function”).



Table 1-16 The binary output status signals of the unrestrained differential protection characteristics

Binary output signals	Signal title	Explanation
Unrestrained decision		
DIF87_UnRL1St_Grl_i	Start L1 unrestr.	This internal status is true if the differential current in measuring element L1 is above the high current setting
DIF87_UnRL2St_Grl_i	Start L2 unrestr.	This internal status is true if the differential current in measuring element L2 is above the high current setting
DIF87_UnRL3St_Grl_i	Start L3 unrestr.	This internal status is true if the differential current in measuring element L3 is above the high current setting

3.1.10.1.6.3. The principal scheme of the evaluation of differential characteristics

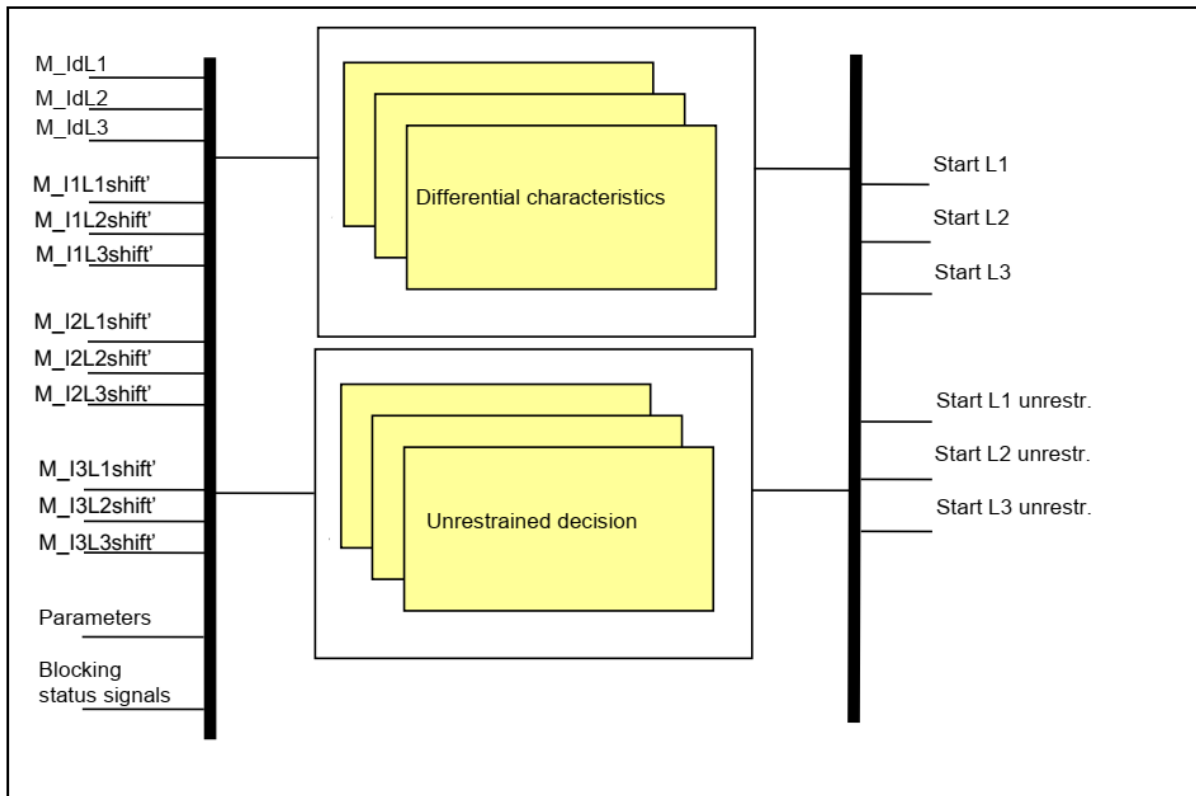
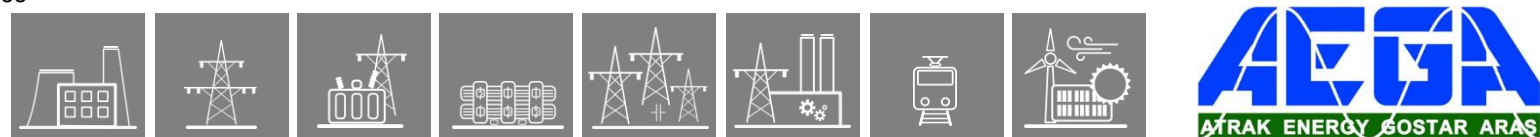


Figure 1-11 The Scheme of evaluation of differential protection characteristics.

The **inputs** are the magnitude of the calculated currents:

- The magnitudes of the differential currents after phase-shift $\begin{bmatrix} M_IdL1 \\ M_IdL2 \\ M_IdL3 \end{bmatrix}$
- The magnitudes of the primary currents after phase-shift $\begin{bmatrix} M_I1L1shift' \\ M_I1L2shift' \\ M_I1L3shift' \end{bmatrix}$



- The magnitudes of the secondary currents after phase-shift $\begin{bmatrix} M_I2L1shift^t \\ M_I2L2shift^t \\ M_I2L3shift^t \end{bmatrix}$
- The magnitudes of the tertiary currents after phase-shift $\begin{bmatrix} M_I3L1shift^t \\ M_I3L2shift^t \\ M_I3L3shift^t \end{bmatrix}$
(in DIF87T3 version only)

Table 1-17 The binary output status signals of the restrained and unrestrained differential protection characteristics

Binary output signals	Signal title	Explanation
Differential characteristics		
DIF87_ L1St _Grl_	Start L1	This status is true if the differential current in measuring element L1 at the restraint current is above the characteristic lines
DIF87_ L2St _Grl_	Start L2	This status is true if the differential current in measuring element L2 at the restraint current is above the characteristic lines
DIF87_ L3St _Grl_	Start L3	This status is true if the differential current in measuring element L3 at the restraint current is above the characteristic lines
Unrestrained decision		
DIF87_ UnRL1St _Grl_	Start L1 unrestr.	This status is true if the differential current in measuring element L1 is above the high current setting
DIF87_ UnRL2St _Grl_	Start L2 unrestr.	This status is true if the differential current in p measuring element L2 is above the high current setting
DIF87_ UnRL3St _Grl_	Start L3 unrestr.	This status is true if the differential current in measuring element L3 is above the high current setting

3.1.10.1.7. The decision logic (Decision logic)

3.1.10.1.7.1. The principle of the decision logic

The decision logic combines the following binary signals:

- Start signals of the differential characteristic module
- Unrestrained start signals of the differential characteristic module
- Harmonic restraint signals of the 2. harmonic restraint decision
- Harmonic restraint signals of the 5. harmonic restraint decision
- Disabling status signal defined by the user, using graphic equation editor DIF87_**Blk**_GrO_

3.1.10.1.7.2. The principal scheme of the decision logic

The inputs are the calculated status signals of the Differential characteristics and Unrestrained differential modules, those of the 2.harmonic restraint and 5.harmonic restraint modules and binary input parameters.

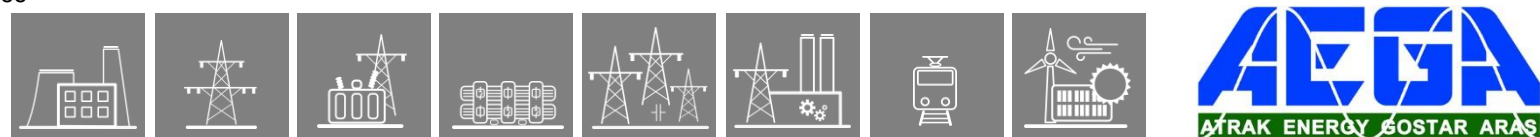


Table 1-18 The binary input status signals of the decision logic

Binary input signals	Signal title	Explanation
Differential characteristics		
DIF87_L1St_GrI_i	Start L1	This internal status is true if the differential current in measuring element L1 at the restraint current is above the characteristic lines
DIF87_L2St_GrI_i	Start L2	This internal status is true if the differential current in measuring element L2 at the restraint current is above the characteristic lines
DIF87_L3St_GrI_i	Start L3	This internal status is true if the differential current in measuring element e L3 at the restraint current is above the characteristic lines
Unrestrained decision		
DIF87_UnRL1St_GrI_i	Start L1 unrestr.	This internal status is true if the differential current in measuring element e L1 is above the high current setting
DIF87_UnRL2St_GrI_i	Start L2 unrestr.	This internal status is true if the differential current in measuring element L2 is above the high current setting
DIF87_UnRL3St_GrI_i	Start L3 unrestr.	This internal status is true if the differential current in measuring element L3 is above the high current setting
Second harmonic restraint signals		
DIF87_InrushL1_GrI_	Inrush L1	Restraint in measuring element L1 caused by high second harmonic content in the differential current while either condition (inrush or external fault) is active
DIF87_InrushL2_GrI_	Inrush L2	Restraint in measuring element L2 caused by high second harmonic content in the differential current while either condition (inrush or external fault) is active
DIF87_InrushL3_GrI_	Inrush L3	Restraint in measuring element L3 caused by high second harmonic content in the differential current while either condition (inrush or external fault) is active
Fifth harmonic restraint signals		
DIF87_5HBiL1_GrI_	5.Harm Restr. L1	Restraint in measuring element L1 caused by high fifth harmonic content in the differential current
DIF87_5HBiL2_GrI_	5.Harm Restr. L2	Restraint in measuring element L2 caused by high fifth harmonic content in the differential current
DIF87_5HBiL3_GrI_	5.Harm Restr. L3	Restraint in measuring element L3 caused by high fifth harmonic content in the differential current

Blocking input signal

The differential protection function has a binary input signal, which serves disabling the function. **The conditions of disabling are defined by the user, applying the graphic equation editor for the signal DIF87_BlK_GrO.**

Table 1-19 The blocking input status signal of the decision logic

Binary input signal	Explanation
DIF87_BlK_GrO_	Output status of a graphic equation to disable the differential protection function. Only the measurements work and are displayed.

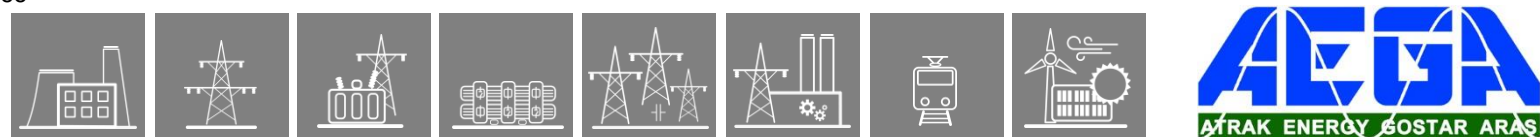


Table 1-20 The binary output status signals of the differential protection characteristics

Binary output signals	Signal title	Explanation
Differential characteristics		
DIF87_ L1St _Grl_	Start L1	This status is true if the differential current in measuring element L1 at the restraint current is above the characteristic lines and the function is not blocked
DIF87_ L2St _Grl_	Start L2	This status is true if the differential current in measuring element L2 at the restraint current is above the characteristic lines and the function is not blocked
DIF87_ L3St _Grl_	Start L3	This status is true if the differential current in measuring element L3 at the restraint current is above the characteristic lines and the function is not blocked
DIF87_ GenSt _Grl_	GenStart	This status is true if the differential current in any measuring element at the restraint current is above the restrained characteristic lines and the function is not blocked
Unrestrained decision		
DIF87_ UnrL1St _Grl_	Start L1 - unrestrained	This status is true if the differential current in measuring element e L1 is above the high current setting and the function is not blocked
DIF87_ UnrL2St _Grl_	Start L2 - unrestrained	This status is true if the differential current in measuring element L2 is above the high current setting and the function is not blocked
DIF87_ UnrL3St _Grl_	Start L3 - unrestrained	This status is true if the differential current in measuring element L3 is above the high current setting and the function is not blocked
DIF87_ UnrGenSt _Grl_	GenStart - unrestrained	This status is true if the differential current in any measuring elements is above the high current setting and the function is not blocked
Harmonic blocking		
DIF87_ Inrush _Grl_	Inrush	Restraint caused by high second harmonic content during inrush or external fault
DIF87_ 5HBik _Grl_	5.Harm Restr.	Restraint caused by high fifth harmonic content in any of the differential currents

The **GenSt** and **UnrGenSt** signals are processed by the trip logic of the device in the so-called Fast Logic (Fast Equations). These can be checked with the EuroCAP software in the .epc configuration file of the device in the Software Configuration → Equations → Fast Logic.

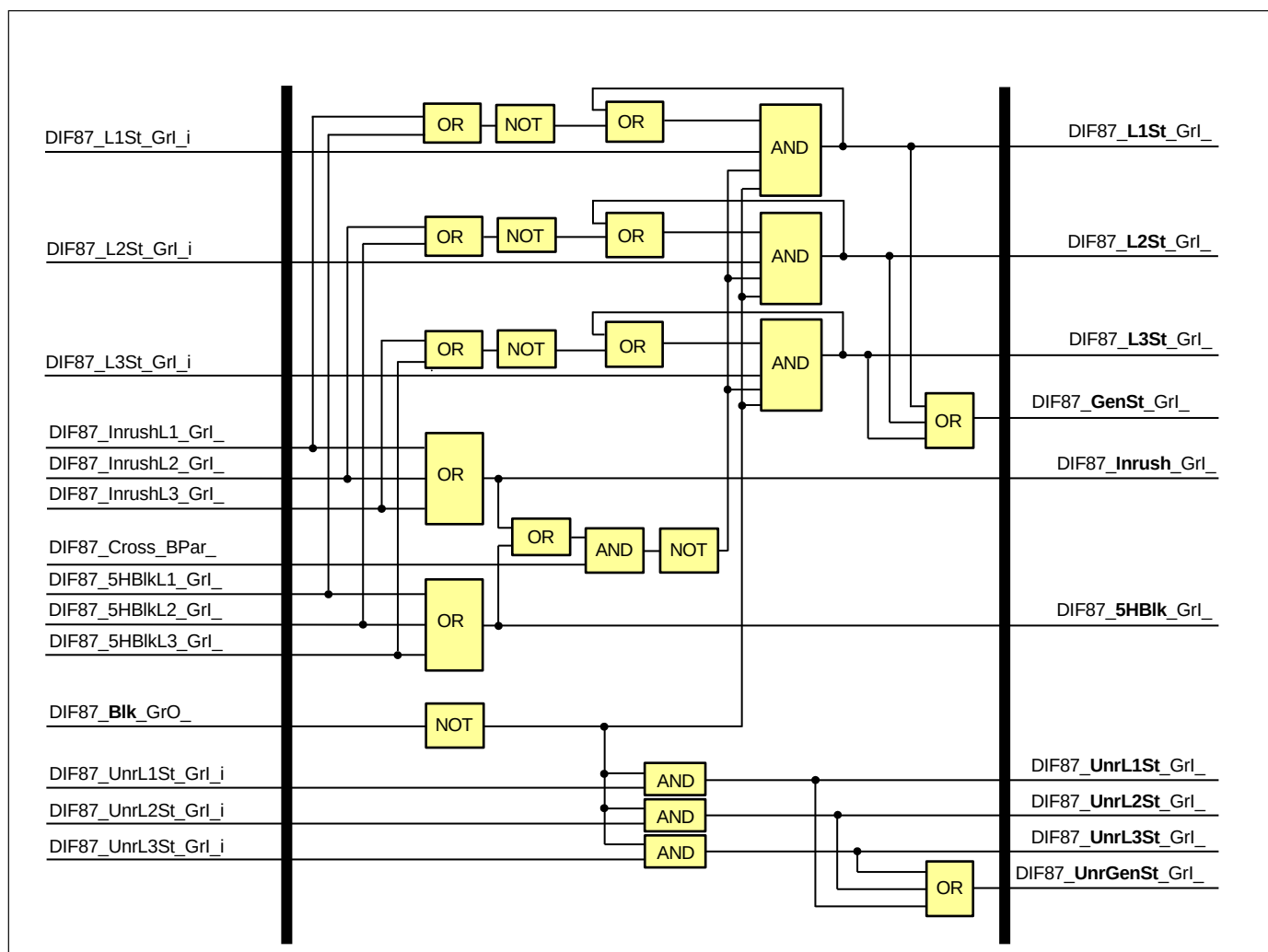


Figure 1-12 The decision logic schema of the differential protection function

3.1.10.1.7.3. Special measures for CT saturation during external faults

Basically, the 2nd slope of the differential characteristic is set to cover the errors caused by saturated CT, however, there are further methods implemented to stabilize the differential protection function even more in case of external faults (while keeping it sensitive for internal ones) with saturated CT. This chapter explains these two special functionalities and their conditions to activate.

- **Adaptive characteristics**

In case of external faults, the differential currents appear a little while after the CT has become saturated. In case of internal faults, these two events happen at the same time. Based on this principle, the differential protection function switches to a less sensitive characteristic if such sign of an external fault is detected.

*The condition: the measured Bias current in any phase is above **1.25In** for at least **3 milliseconds** while the **differential current is less than the set Base Sensitivity**. This condition falls off if the Bias current drops below **0.8In**.*

*The characteristic: 1st slope **50%** and 2nd slope **200%***

- **Usage of the 2nd harmonic restraint**

The second harmonic restraint decision can be enabled if there is at least 75 degrees difference between the measured currents after vector shift compensation (indicating an external fault), see Chapter 1.3.



3.1.10.2. Differential protection function overview

The graphic appearance of the function blocks of the differential protection function for transformers of two or three voltage levels are shown on Figure 2-1. These blocks show all binary input and output status signals, which are applicable in the graphic equation editor.

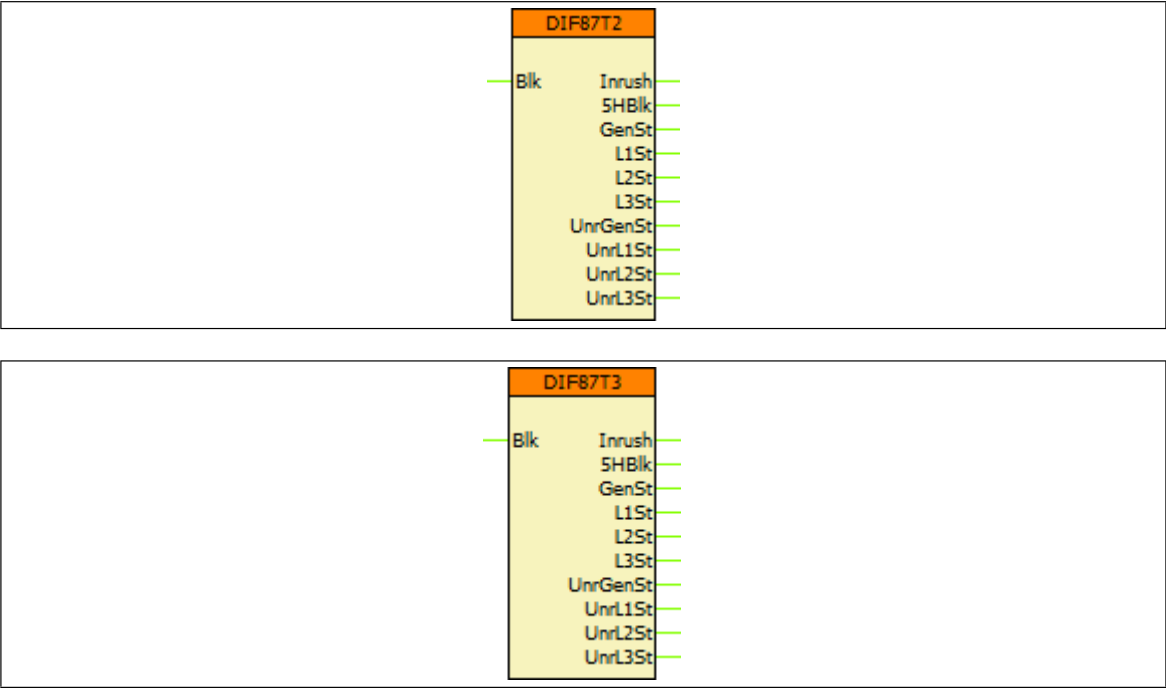
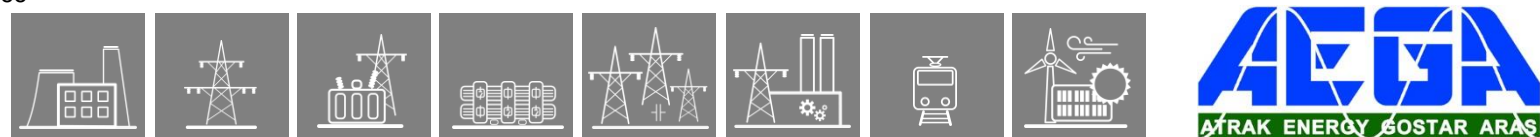


Figure 2-1 Graphic appearance of the function blocks of the differential protection function

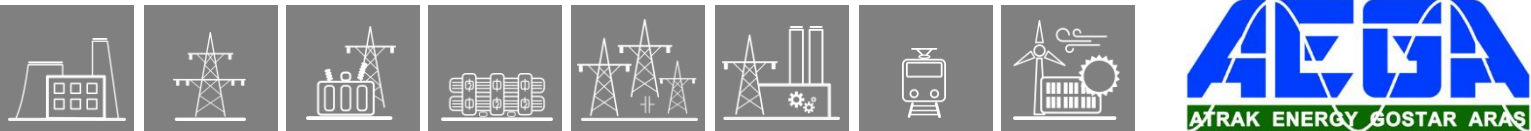


3.1.10.2.1. Settings

3.1.10.2.1.1. Parameters

Table 2-1 Parameters of the differential protection function

TITLE	DIM	RANGE	STEP	DEFAULT	EXPLANATION
Operation	-	Off, On	-	Off	Enabling the differential protection function
<i>Parameters related to the protected transformer</i>					
Pri-Sec VGroup	-	Dy1,Dy5,Dy7,Dy11, Dd0,Dd6,Dz0,Dz2, Dz4,Dz6,Dz8,Dz10, Yy0,Yy6,Yd1,Yd5, Yd7,Yd11,Yz1,Yz5, Yz7,Yz11	-	Dd0	Connection group of the transformer coils in primary-secondary relation
Pri-Ter VGroup*	-	Dy1,Dy5,Dy7,Dy11, Dd0,Dd6,Dz0,Dz2, Dz4,Dz6,Dz8,Dz10, Yy0,Yy6,Yd1,Yd5, Yd7,Yd11,Yz1,Yz5, Yz7,Yz11	-	Dd0	Connection group of the transformer coils in primary-tertiary relation
ZeroSeq Elimination	-	FALSE, TRUE	-	FALSE	Check this when a neutral grounding transformer is applied in the protected zone on the delta side (see Chapter 1.1.5)
Sn	MVA	1.00 – 1000.00	0.01	125.00	Rated apparent power of the transformer
Un Primary	kV	1.00 – 1000.00	0.01	132.00	Rated voltage of the transformer primary side
Un Secondary	kV	1.00 – 1000.00	0.01	22.00	Rated voltage of the transformer secondary side
Un Tertiary	kV	1.00 – 1000.00	0.01	11.50	Rated voltage of the transformer tertiary side
<i>Parameters related to the harmonic restraint</i>					
Cross Blocking	-	FALSE, TRUE	-	FALSE	When selected, the harmonic restraint blocks all phases instead of only the affected ones (see Chapter 1.3.2)
2nd Harm Ratio	% (Idiff)	5 – 50	1	15	Second harmonic restraint ratio related to the <i>basic harmonic of the differential current</i>
5th Harm Ratio	% (Idiff)	5 – 50	1	15	Fifth harmonic restraint ratio related to the <i>basic harmonic of the differential current</i>
Cross Blocking Limit	msec	100 – 60000	1	5000	After expiration the phases that still have high harmonic content will remain blocked, the others are released



TITLE	DIM	RANGE	STEP	DEFAULT	EXPLANATION
<i>Parameters related to the differential characteristic</i>					
Base Sensitivity	% (In)	10 – 50	1	20	Base sensitivity - 1st section of the characteristic curve related to the <i>nominal current of the transformer</i>
1st Slope	% (Ibias)	10 – 50	1	20	1st Slope - 2nd section of the characteristic curve related to the <i>bias current</i>
1st Slope Bias Limit	% (In)	200 – 2000	1	200	Bias current limit of the 1st slope (2nd section) of the characteristic curve related to the <i>nominal current of the transformer</i>
2nd Slope	% (Ibias)	30 – 200	1	200	2nd Slope - 3rd section of the characteristic curve related to the <i>bias current</i>
Unrestrained Diff Current	% (In)	800 – 2500	1	800	Unrestrained differential current - 4th section of the characteristic curve related to the <i>nominal current of the transformer</i>

** If the connection of the primary winding in primary-secondary and primary tertiary relation is selected in contradiction, then the protection function is automatically disabled, and the function (and the device itself) generates a warning signal.*

3.1.10.2.1.2. Characteristics

The function uses a 2-slope characteristic with unrestrained section, see Figure 2-2.

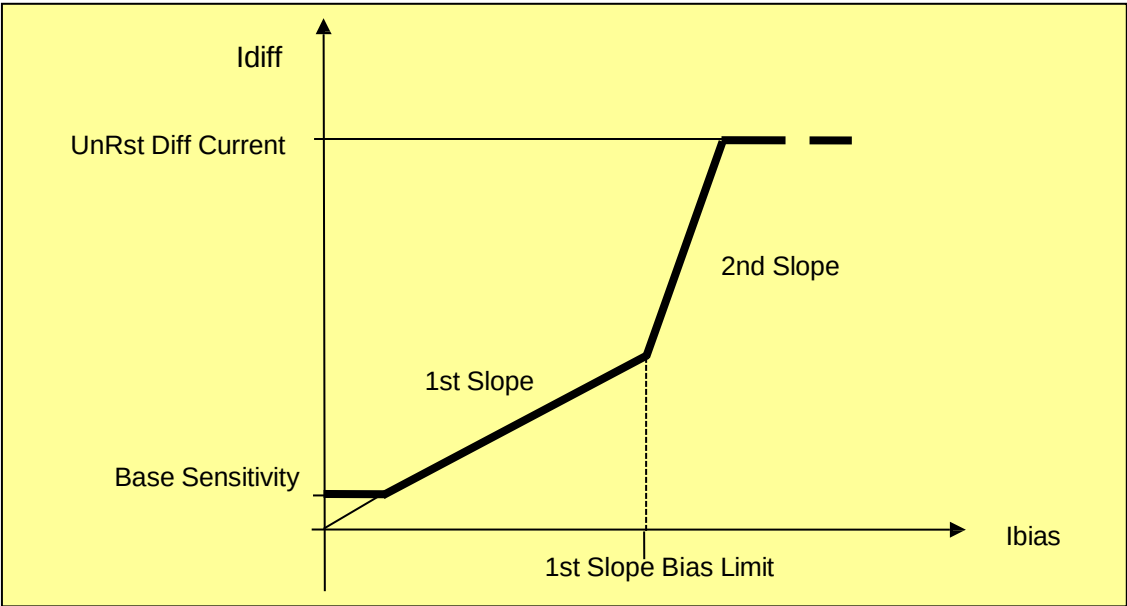
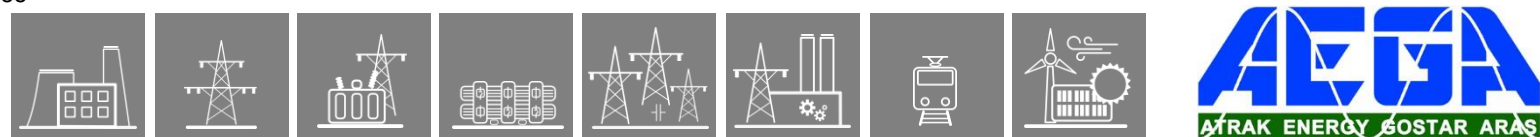


Figure 2-2 The differential protection characteristics



3.1.10.2.2. 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 of each side.

3.1.10.2.2.2. Analogue outputs (measurements)

The measured values of the differential protection function are listed in the table below.

Table 2-2 The measured analogue values of the differential protection function

MEASURED VALUE	DIMENSION	EXPLANATION
Differential current L1	In %	The calculated differential current in measuring element L1 (after vector group compensation)
Differential current L2	In %	The calculated differential current in measuring element L2 (after vector group compensation)
Differential current L3	In %	The calculated differential current in measuring element L3 (after vector group compensation)
Bias current L1	In %	The calculated restraint current in measuring element L1 (after vector group compensation)
Bias current L2	In %	The calculated restraint current in measuring element L2 (after vector group compensation)
Bias current L3	In %	The calculated restraint current in measuring element L3 (after vector group compensation)

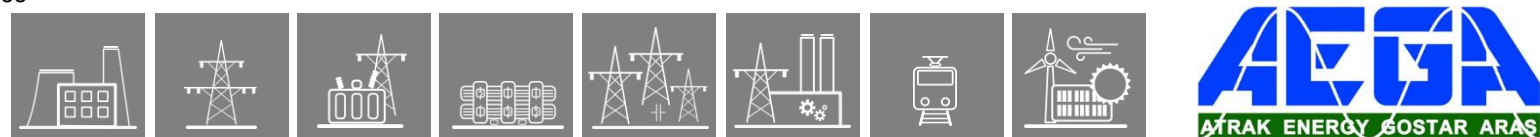
Remark: The evaluated basic harmonic values of the measured input phase currents (without vector group compensation) help the commissioning of the differential protection function. These evaluations however are performed by an independent software measuring module, so this chapter excludes the description of these measurements.

3.1.10.2.2.3. Binary input signals (graphed output statuses)

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

Table 2-3 The binary input signal of the differential protection function

BINARY INPUT SIGNAL	EXPLANATION
DIF87_ Blk _GrO_	Output status of a graphic equation defined by the user to disable the differential protection function. Only the measurements work and are displayed.

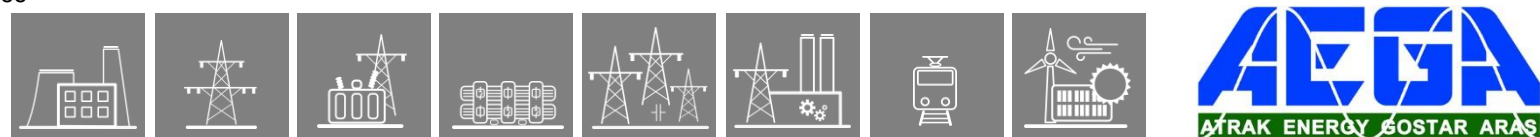


3.1.10.2.2.4. Binary output signals (graphed input statuses)

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

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

BINARY OUTPUT SIGNAL	SIGNAL TITLE	EXPLANATION
Harmonic blocking		
DIF87_ Inrush _GrI_	Inrush	Restraint caused by high second harmonic content in any of the differential currents during inrush or external fault
DIF87_ 5HBlk _GrI_	5.Harm Restraint	Restraint caused by high fifth harmonic content in any of the differential currents
Restrained differential protection function		
DIF87_ GenSt _GrI_	General Start	General start of the restrained differential protection function
DIF87_ L1St _GrI_	Start L1	Start of the restrained differential protection function in measuring element L1 (after vector group compensation)
DIF87_ L2St _GrI_	Start L2	Start of the restrained differential protection function in measuring element L2 (after vector group compensation)
DIF87_ L3St _GrI_	Start L3	Start of the restrained differential protection function in measuring element L3 (after vector group compensation)
Unrestrained differential protection function		
DIF87_ UnRGenSt _GrI_	General Start unrestr	General start of the unrestrained differential protection function
DIF87_ UnRL1St _GrI_	Start L1 unrestr.	Start of the unrestrained differential protection function in measuring element L1 (after vector group compensation)
DIF87_ UnRL2St _GrI_	Start L2 unrestr.	Start of the unrestrained differential protection function in measuring element L2 (after vector group compensation)
DIF87_ UnRL3St _GrI_	Start L3 unrestr.	Start of the unrestrained differential protection function in measuring element L3 (after vector group compensation)

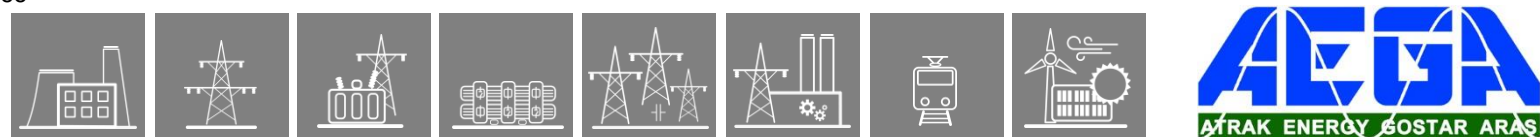


3.1.10.2.2.5. On-line data

Visible values on the on-line data page:

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

SIGNAL TITLE	DIMENSION	EXPLANATION
Differential current L1	In %	The calculated differential current in measuring element L1 (after vector group compensation)
Differential current L2	In %	The calculated differential current in measuring element L2 (after vector group compensation)
Differential current L3	In %	The calculated differential current in measuring element L3 (after vector group compensation)
Bias current L1	In %	The calculated restraint current in measuring element L1 (after vector group compensation)
Bias current L2	In %	The calculated restraint current in measuring element L2 (after vector group compensation)
Bias current L3	In %	The calculated restraint current in measuring element L3 (after vector group compensation)
Inrush L1	-	Restraint caused by high second harmonic content in L1 differential current during inrush or external fault
Inrush L2	-	Restraint caused by high second harmonic content in L2 differential current during inrush or external fault
Inrush L3	-	Restraint caused by high second harmonic content in L3 differential current during inrush or external fault
Inrush	-	Restraint caused by high second harmonic content in any of the differential currents during inrush or external fault
5.Harm Restr. L1	-	Restraint caused by high fifth harmonic content in L1 differential current
5.Harm Restr. L2	-	Restraint caused by high fifth harmonic content in L2 differential current
5.Harm Restr. L3	-	Restraint caused by high fifth harmonic content in L3 differential current
5.Harm Restraint	-	Restraint caused by high fifth harmonic content in any of the differential currents
Start L1	-	Start of the restrained differential protection function in measuring element L1 (after vector group compensation)
Start L2	-	Start of the restrained differential protection function in measuring element L2 (after vector group compensation)
Start L3	-	Start of the restrained differential protection function in measuring element L3 (after vector group compensation)
General Start	-	General start of the restrained differential protection function
Start L1 - unrestrained	-	Start of the unrestrained differential protection function in measuring element L1 (after vector group compensation)
Start L2 - unrestrained	-	Start of the unrestrained differential protection function in measuring element L2 (after vector group compensation)
Start L3 - unrestrained	-	Start of the unrestrained differential protection function in measuring element L3 (after vector group compensation)
General Start - unrestrained	-	General start of the unrestrained differential protection function



3.1.10.2.2.6. Events

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

Table 2-6 Events of the differential protection function

EVENT	VALUE	EXPLANATION
Inrush L1	off, on	Restraint in phase L1 caused by high second harmonic content in the differential current during inrush or external fault
Inrush L2	off, on	Restraint in phase L2 caused by high second harmonic content in the differential current during inrush or external fault
Inrush L3	off, on	Restraint in phase L3 caused by high second harmonic content in the differential current during inrush or external fault
Start L1	off, on	Start of the restrained differential protection function in measuring element L1 (after vector group compensation)
Start L2	off, on	Start of the restrained differential protection function in measuring element L2 (after vector group compensation)
Start L3	off, on	Start of the restrained differential protection function in measuring element L3 (after vector group compensation)
General Start	off, on	General start of the restrained part of the differential protection function
Start L1 – unrestrained	off, on	Start of the unrestrained differential protection function in measuring element L1 (after vector group compensation)
Start L2 – unrestrained	off, on	Start of the unrestrained differential protection function in measuring element L2 (after vector group compensation)
Start L3 – unrestrained	off, on	Start of the unrestrained differential protection function in measuring element L3 (after vector group compensation)
General Start – unrestrained	off, on	General start of the unrestrained part of the differential protection function

3.1.10.2.3. Technical data and notes

Table 2-7 Technical data of the transformer differential protection

FUNCTION	VALUE	ACCURACY
Operating characteristic	2 breakpoints	
Reset ratio	0,9	
Characteristic accuracy*		<3%
Operate time, unrestrained	Typically 20 ms	<10 ms
Reset time, unrestrained	Typically <55 ms	
Operate time, restrained	Typically 30 ms*	<10 ms
Reset time, restrained	Typically <35 ms	

*Bias current is above 0.2 In; see Chapter 2.3.2 for more information

3.1.10.2.3.1. Notes for testing

There is an XRIO setting file available for the function. With that, only the parameters of the CT modules and the differential protection function should be entered along the type of the fault to be generated. By using this file, testing the operation characteristic will not need any further setting.

Normally in the EuroProt+ devices the trip contacts are assigned to the Trip Logic function block, and not to the protection function blocks. Because of this the testing personnel must make sure that the Trip Logic is switched on ('Operation' parameter is set to other than 'Off') before starting the testing, otherwise there will be no physical trip on the relay.

Notes for testing the operation characteristics:

- Direction settings in the CT4 module function are 'Line' and 'Bus'. However, in case of differential protection 'Line' means 'Towards protected object'. So if the two CTs' starpoints are towards protected object, their settings should be 'Line' for both. (with XRIO file this point is obsolete)
- Reference winding is the delta side (see Chapter 1.1.2). Reference current is the nominal current of the transformer (see Chapter 1.1.1). (with XRIO file this point is obsolete)
- When setting up the characteristics in the relay tester, and when checking the results, keep in mind that the currents are transformed to the delta side, which results in different behavior compared to the applications of other manufacturers. (with XRIO file this point is obsolete)
- The adaptive characteristics to external faults might cause different test results, as the characteristics will be different under certain circumstances (see Chapter 1.6.3). To avoid this, the prefault currents should not exceed $1 \cdot I_n$.

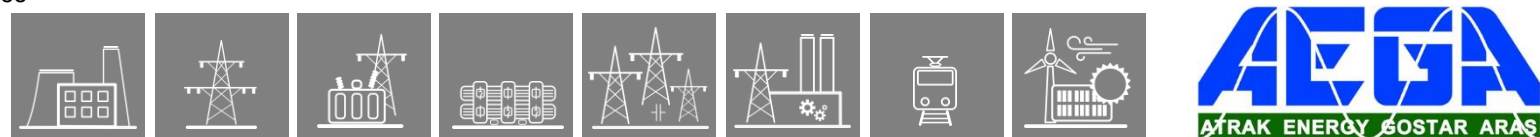
If the prefault currents cannot be adjusted, then setting the *prefault time to zero* also solves the issue.

Notes for testing the harmonic restraint characteristic:

- When testing the **2nd harmonic** restraint, keep in mind that either of the two conditions (inrush or external fault, see Chapter 1.3) must be fulfilled to activate the restraint along with the condition of the differential current to be at least $0.1I_n$.
- The **5th harmonic** restraint can be tested freely the condition of the differential current to be at least $0.1I_n$.

3.1.10.2.3.2. CT sizing requirements

The CT sizing guidelines for internal and external faults (according to the IEC60255-187-1 standard) can be acquired on request from Protecta personnel on application@protecta.hu



3.1.10.2.3.3. Transformer and primary CT rated current ratios

When ordering a device with differential protection, it must be taken into consideration that the function's characteristics are based on the *transformer's rated current*. This means that the rated currents of the primary CTs shall be selected in a way that their secondary currents are reasonably high to be measured accurately on the protection device's CT modules.

The desirable value for the primary CTs' rated current would be close to that of the transformer's rated currents, so that their measurements stay accurate for the differential protection.

For example, let's take a transformer with the following data:

$$S_n = 50 \text{ MVA}$$

$$U_{n1} = 230 \text{ kV}$$

$$U_{n2} = 22 \text{ kV}$$

The reference currents (transformer rated currents) on the primary and secondary sides in this case are:

$$I_{reference1} = \frac{S_n}{\sqrt{3} U_{n1}} \rightarrow I_{reference1} = 125.5 \text{ A}$$

$$I_{reference2} = \frac{S_n}{\sqrt{3} U_{n2}} \rightarrow I_{reference2} = 2624.4 \text{ A}$$

Staying at the example, if a CT with a rated current of 2000A is installed on the *primary (1)* side, and another CT with 3000A on the *secondary (2)* side, the matching ratios between the transformer's and the CT's rated currents would be the following:

$$TR_1 = \frac{I_{TRn1}}{I_{CTn1}} \rightarrow TR_1 = \frac{125.5 \text{ A}}{2000 \text{ A}} = 0.06275 = 6.275\%$$

$$TR_2 = \frac{I_{TRn2}}{I_{CTn2}} \rightarrow TR_2 = \frac{2624.4 \text{ A}}{3000 \text{ A}} = 0.8748 = 87.48\%$$

The issue is on the primary side, where a rated current (100%) flowing on the transformer would represent only **6.275%** on the CT. In other words, if 6.275% current (62.75 mA on 1A rated secondary) is flowing on the primary side and no current on the secondary side, the differential protection function will show 100% differential current on its on-line data. With a base sensitivity setting of 20%, 12.55 mA current (1.255%) could already cause the function to operate.

3.1.10.2.3.3.1. Recommended CT/TR nominal current matching ratios

Because of the issue above, applying the function to different matching ratios might provide different accuracy results (the lower the ratio, the better the accuracy); this also depends on the function block settings, see the table below.

Table 2-8 Characteristic accuracy depending on the CT/TR matching ratio

CHARACTERISTICS' PARAMETERS		MATCHING RATIO (PRIMARY SIDE)*		
BASE SENSITIVITY	1ST SLOPE	7 (14.29%)	12 (8.33%)	16 (6.25%)
10% (minimum)	10% (minimum)	3%	6%	10%
20% (default)	20% (default)	3%	4%	7%
20% (default)	30%	3%	3%	5%

*CT/TR ratio on the secondary side is constant (87.48%, see the example above)

The 3% accuracy shown in Table 2-7 with the base sensitivity of 20% can be expected with a matching ratio of **7 or lower** (or higher than 14.29% if shown in TR/CT ratio instead).

If the 1st slope is at least 20% as well (default setting), the same accuracy can be reached until the ratio of **12**.

3.1.10.3. Appendix

3.1.10.3.1. Current distribution inside the Y/d transformers

For the explanation the following positive directions are applied:

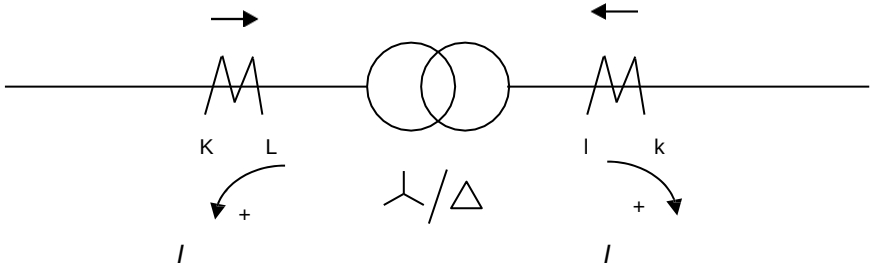


Figure 3-1 Positive directions.

3.1.10.3.1.1. Three-phase fault (or normal load state)

The figure below shows the current distribution inside the transformers in case of three-phase fault or at normal, symmetrical load state:

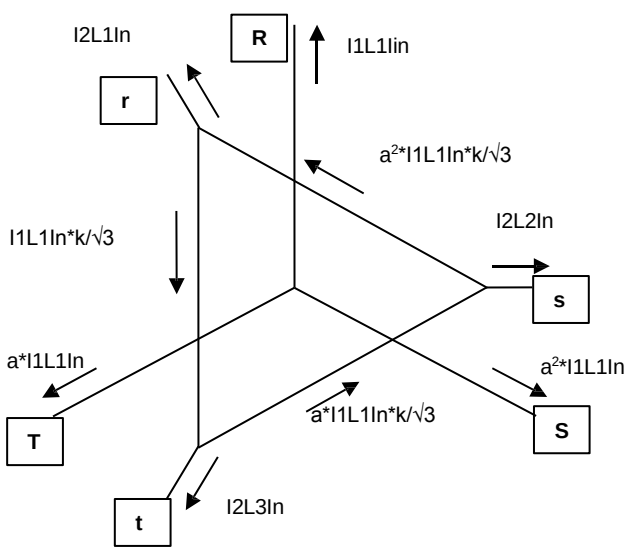


Figure 3-2 Currents in case of normal load (or three-phase fault)

On this figure k is the current ratio. The positive directions are supposed to be directed out of the transformer on both sides, as it is supposed by the differential protection. (If the directions suppose currents flowing through the transformer, then

$$I_{2L1} In = k \cdot I / \sqrt{3} (a^2 - 1)$$

This indicates that the connection group of this transformer is Yd11.



Here the primary currents form a symmetrical system:

$$\begin{bmatrix} I_{L1} \\ I_{L2} \\ I_{L3} \end{bmatrix} = I \begin{bmatrix} 1 \\ a^2 \\ a \end{bmatrix}$$

The secondary currents can be seen on the figure (please consider the division factor $\sqrt{3}$ in the effective turn's ratio):

$$\begin{bmatrix} I_{2L1} \\ I_{2L2} \\ I_{2L3} \end{bmatrix} = k * I \frac{1}{\sqrt{3}} \begin{bmatrix} (a^2 - 1) \\ (a - a^2) \\ (1 - a) \end{bmatrix}$$

3.1.10.3.1.2. Phase-to-phase fault on the Y side

Assume I current on the primary Y side between phases S ($\equiv L2$) and T ($\equiv L3$).

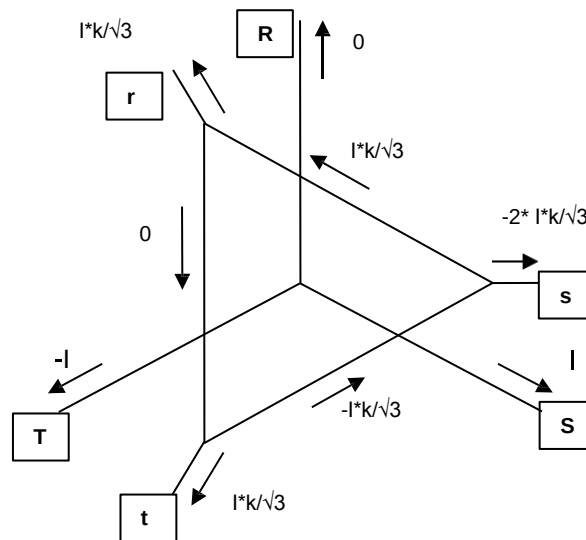


Figure 3-3 Currents inside the transformer at ST fault on the Y side

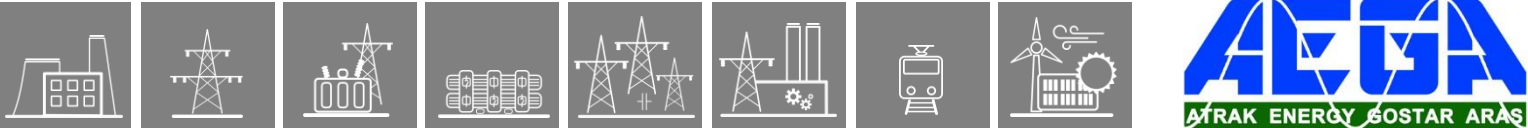
On this figure k is the current ratio.

The Y side currents are:

$$\begin{bmatrix} I_{L1} \\ I_{L2} \\ I_{L3} \end{bmatrix} = I \begin{bmatrix} 0 \\ 1 \\ -1 \end{bmatrix}$$

The delta side currents can be seen on this figure:

$$\begin{bmatrix} I_{2L1} \\ I_{2L2} \\ I_{2L3} \end{bmatrix} = k * \frac{1}{\sqrt{3}} * I \begin{bmatrix} 1 \\ -2 \\ 1 \end{bmatrix}$$



3.1.10.3.1.3. Phase-to-phase fault at the delta side

Assume I current on the secondary delta side between phases “s” ($\equiv L2$) and “t” ($\equiv L3$).

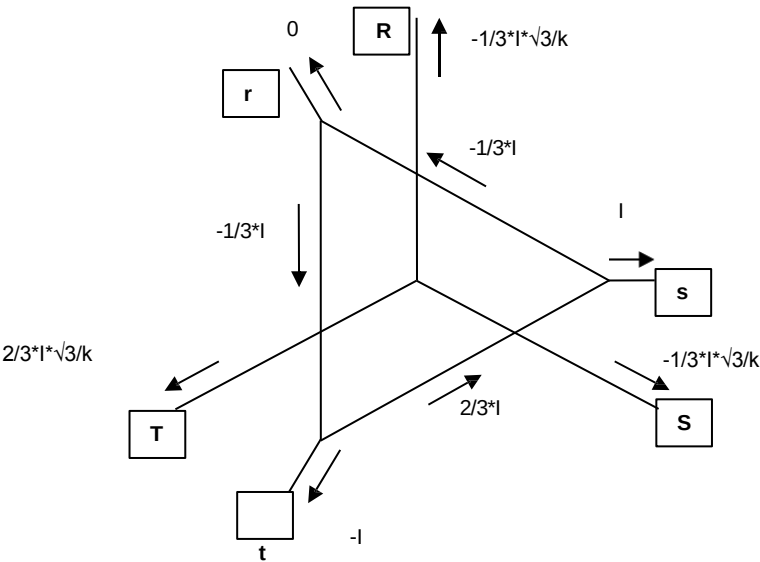


Figure 3-4 Currents inside the transformer at “st” fault on the delta side

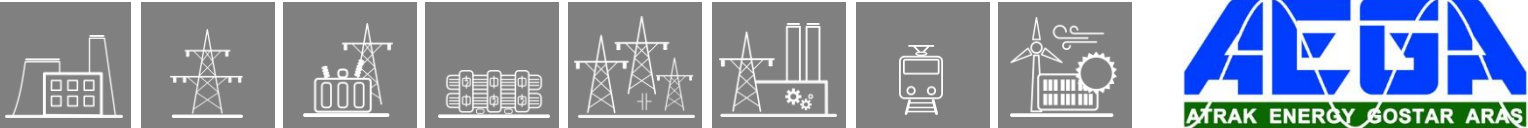
On this figure k is the current ratio.

The secondary currents are:

$$\begin{bmatrix} I_{2L1ln} \\ I_{2L2ln} \\ I_{2L3ln} \end{bmatrix} = I \begin{bmatrix} 0 \\ 1 \\ -1 \end{bmatrix}$$

These are distributed in the delta supposing $2/3 : 1/3$ distribution factor. So the primary Y side currents can be seen on this figure:

$$\begin{bmatrix} I_{1L1ln} \\ I_{1L2ln} \\ I_{1L3ln} \end{bmatrix} = \frac{1}{k} * \frac{\sqrt{3}}{3} * I \begin{bmatrix} -1 \\ -1 \\ 2 \end{bmatrix}$$



3.1.10.3.1.4. Single phase external fault at the Y side

- Assume I fault current in the phase R ($\equiv L1$) in case of solidly grounded neutral. No power supply is supposed at the delta side:

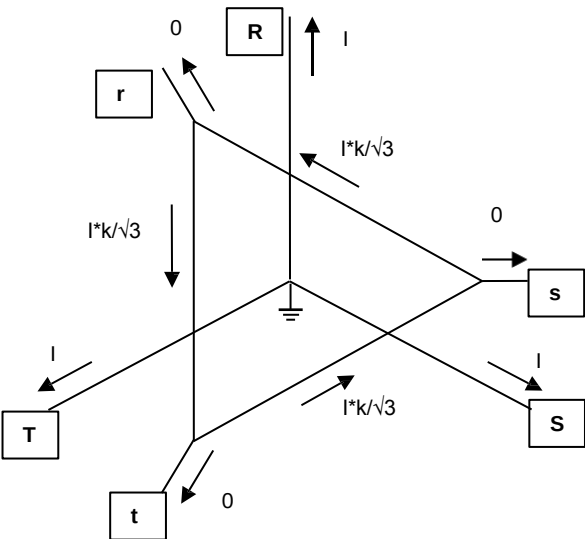


Figure 3-5 Currents inside the transformer at single phase fault at the Y side (Bauch effect)

On this figure k is the current ratio.

The primary Y side currents are:

$$\begin{bmatrix} I_{L1} \\ I_{L2} \\ I_{L3} \end{bmatrix} = I \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$$

On the delta side there are no currents flowing out of the transformer:

$$\begin{bmatrix} I_{2L1} \\ I_{2L2} \\ I_{2L3} \end{bmatrix} = I \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

- Assume I fault current at the Y side in phase R ($\equiv L1$) in case of solidly grounded neutral.
Assume the power supply at the delta side:

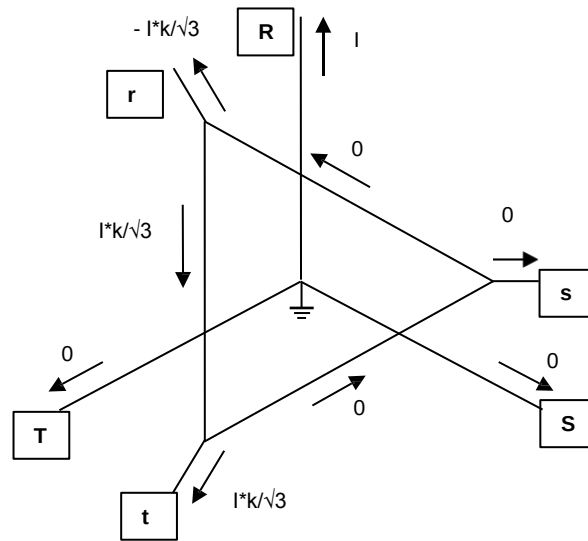


Figure 3-6 Currents inside the transformer at single phase fault at the Y side, supply at the delta side

On this figure k is the current ratio.

The primary Y side currents are:

$$\begin{bmatrix} I_{L1ln} \\ I_{L2ln} \\ I_{L3ln} \end{bmatrix} = I \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

The delta side currents can be seen on this figure:

$$\begin{bmatrix} I_{2L1ln} \\ I_{2L2ln} \\ I_{2L3ln} \end{bmatrix} = k * \frac{1}{\sqrt{3}} * I \begin{bmatrix} -1 \\ 0 \\ 1 \end{bmatrix}$$

3.1.10.3.1.5. Single phase fault at the delta side

The delta side is applied usually at medium voltage levels. If a high/medium voltage transformer with delta secondary is applied then for neutral grounding (Petersen or grounding resistance) a separate neutral grounding transformer is applied. The impedance between the neutral point and the ground suppresses the fault current below 100 A (perhaps 200 A), the Petersen coil allows only some Amperes.

At the delta side there are two locations for the current transformers, supplying the differential protection. In one case the neutral grounding transformer is within the protected zone (see figure below, current transformers at location „Z”). In the other possibility the neutral grounding transformer is excluded from the protected zone (see figure below, current transformers at location „Y”).

3.1.10.3.1.5.1. Power supply at the Y side

As the zero sequence current component of the delta side can influence the behavior of the differential protection (sensitive setting), this chapter analyses the current distribution in case of single phase to ground fault at the delta side.

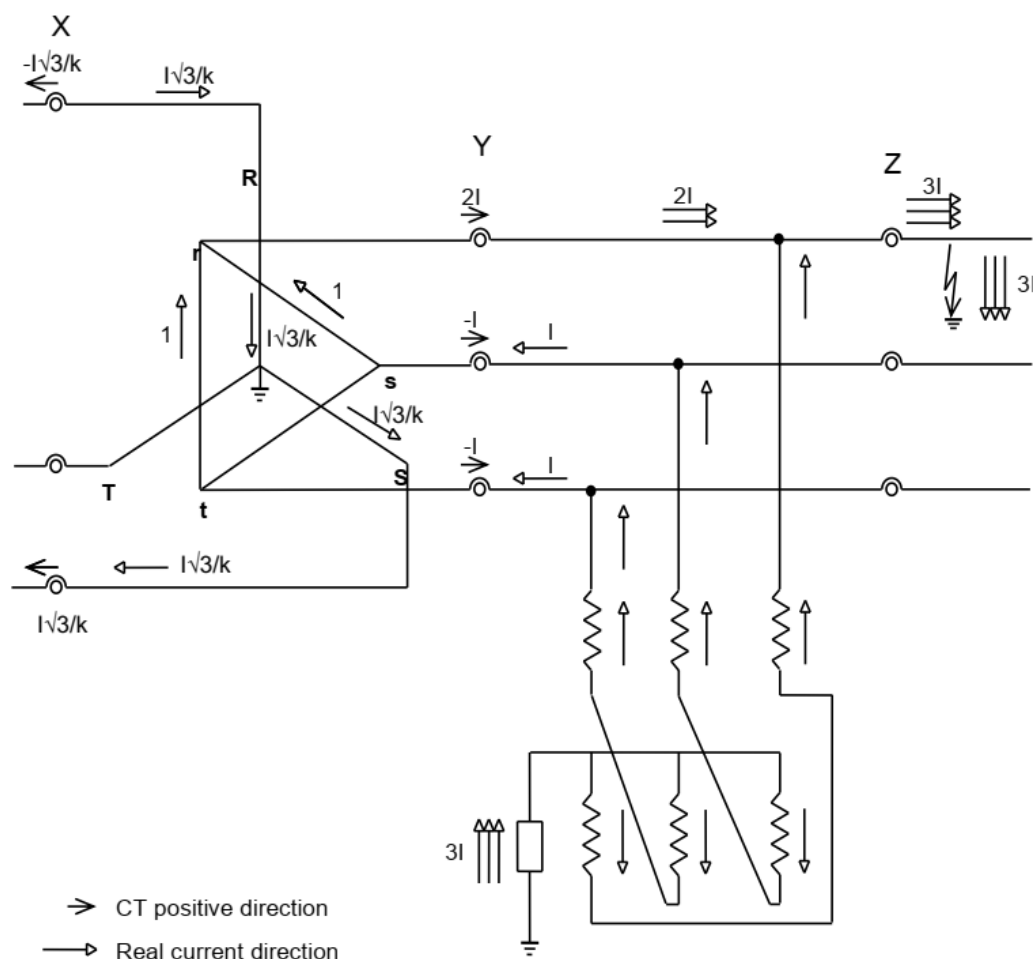


Figure 3-7 Current distribution at external single phase to ground fault, Y side power supply

For the current distribution an external „r” phase fault is assumed, and at the fault location the current is $I_r = 3I_0$. The arrows indicating the real currents can be constructed at this starting point.



Based on the figure above, with positive directions out of the transformer the currents in the CTs are:

On the Y side (location X in Fig. 2-7):

$$\begin{bmatrix} I_{1L1In} \\ I_{1L2In} \\ I_{1L3In} \end{bmatrix} = I\sqrt{3}/k \begin{bmatrix} -1 \\ 1 \\ 0 \end{bmatrix}$$

The delta side currents at the location „Y”:

$$\begin{bmatrix} I_{2L1In} \\ I_{2L2In} \\ I_{2L3In} \end{bmatrix} = I \begin{bmatrix} 2 \\ -1 \\ -1 \end{bmatrix}$$

If the current is measured at location „Z” then the node - which has to fulfill the Kirchhoff's node law – is extended by the neutral grounding transformer, but the current flowing between the neutral point and the ground is not measured and not added to the current summation. This current is the 3I₀ zero sequence component, which can be calculated as the sum of the phase currents. At location „Z” the zero sequence component has no other path to flow, but the neutral grounding transformer.

The delta side currents at the location „Z”:

$$\begin{bmatrix} I_{2L1In} \\ I_{2L2In} \\ I_{2L3In} \end{bmatrix} = I \begin{bmatrix} 3 \\ 0 \\ 0 \end{bmatrix}$$

In this case the zero sequence current is I. If the vector group compensation is for the delta side, then the transformation does not change this current, on the high voltage side however there is no zero sequence component. But anyhow the transformation would filter this component out.

In the practice this zero sequence current component is always below the rated current of the transformer, but in case of sensitive setting of the differential protection, or at mechanical application of a relay test set without any logic control this can result faulty operation of the differential protection in case of external fault.

To avoid this faulty operation there is a binary parameter in the differential protection, the effect of which is to subtract the zero sequence current component from the phase currents, if it is needed:

$$\begin{bmatrix} I_{2L1In} \\ I_{2L2In} \\ I_{2L3In} \end{bmatrix} = \begin{bmatrix} I_{2L1In'} - I_{20} \\ I_{2L2In'} - I_{20} \\ I_{2L3In'} - I_{20} \end{bmatrix} = I \begin{bmatrix} 3 \\ 0 \\ 0 \end{bmatrix} - I \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} = I \begin{bmatrix} 2 \\ -1 \\ -1 \end{bmatrix}$$

It means that based on the currents of the CT-s located at „Z” the current is calculated, which could be measured at location „Y”.

REMARK: This zero sequence current subtraction could be applied without any consequences in case of current transformers at location „Y” too, because in case of external faults, at this location no zero sequence current can be detected. In case of internal fault however this decreases the faulty phase current by 2/3. This could worsen the sensitivity of the differential protection in case high impedance internal faults. The application of the mentioned binary parameter can disable the subtraction of the zero sequence current in case of measurement at location „Y”.

3.1.10.3.1.5.2. Power supply at the delta side

If on a medium voltage network with neutral grounding transformer connects distributed generators, a possible state of operation can be that the transformer is disconnected at the high voltage Y side. On the Y side no current can flow, and if the differential protection measures the currents on the medium voltage side at location „Z” (Fig. 2-8) then in case of sensitive setting of the characteristic lines or at testing, the differential protection can generate a faulty trip command. The current distribution according to Fig. 2-8 is as follows:

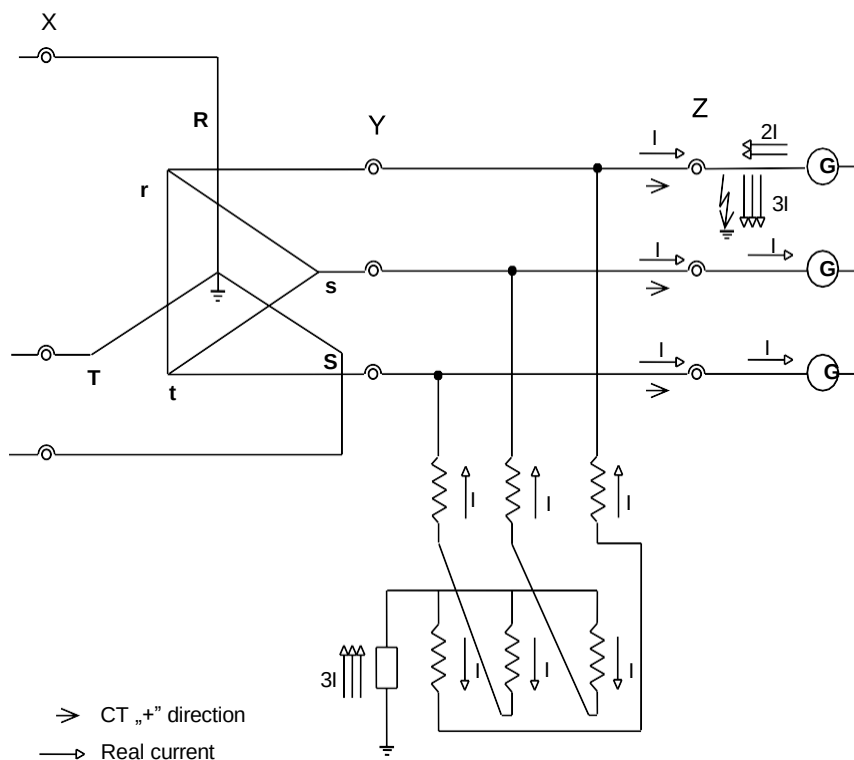


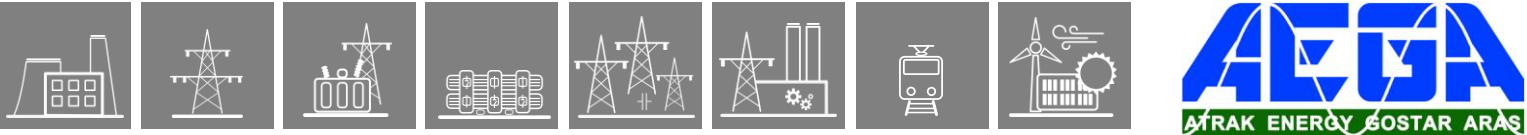
Figure 3-8 Current distribution in case of delta side single phase fault, supply at the delta side

In this case no current is detected at the point „X” (CB open):

$$\begin{bmatrix} I_{L1In} \\ I_{L2In} \\ I_{L3In} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

The measured currents at „Z” can be seen in the figure:

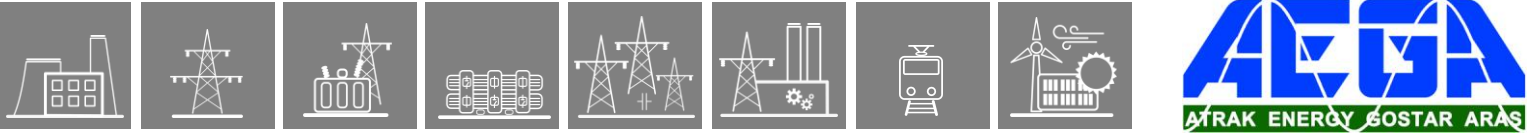
$$\begin{bmatrix} I_{L1In} \\ I_{L2In} \\ I_{L3In} \end{bmatrix} = I \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$$



To avoid mal-operation (trip) at external fault a binary parameter is applied, the effect of which is to subtract the zero sequence current at the delta side:

$$\begin{bmatrix} I_{2L1ln} \\ I_{2L2ln} \\ I_{2L3ln} \end{bmatrix} = \begin{bmatrix} I_{2L1ln'} - I_{20} \\ I_{2L2ln'} - I_{20} \\ I_{2L3ln'} - I_{20} \end{bmatrix} = I \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - I \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

It means that based on the currents of the CT-s located at „Z” the current is calculated, which could be measured at location „Y”.
With this transformation the unwanted trip is avoided.



3.1.10.4. Example for application

For the application example consider a transformer with three voltage levels, according to [Figure 1-1](#). The coils for the primary are connected Y with solidly grounded neutral. The secondary coils are delta connected, and the tertiary coils are also Y connected, but the neutral point is isolated. In this example it is supposed that no neutral grounding transformer is connected within the protected zone.

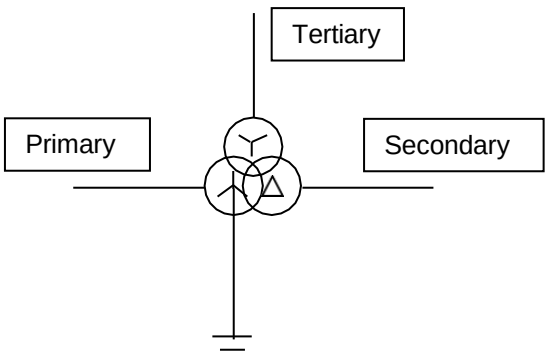


Figure 1-1 Application example

Example transformer data for the application:

Rated voltages:	$U1/U2/U3 = 120/36,75/22 \text{ kV}$
Rated power:	$S_n = 40/30/20 \text{ MVA}$
Connection group:	YNd11y6

Current transformers installed for the application are shown in [Figure 1-2](#). All P1 points are arranged towards the transformer.

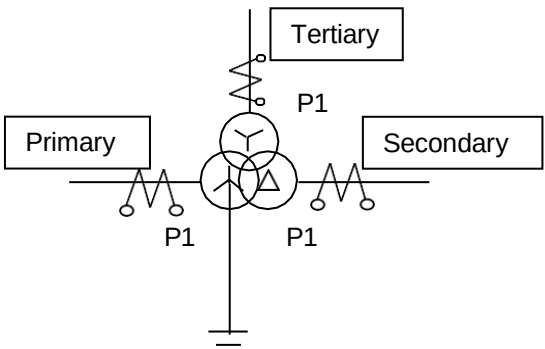
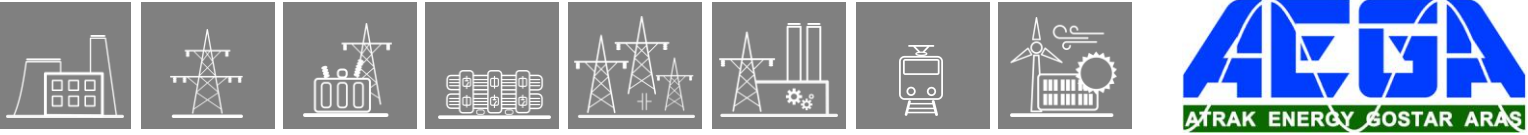


Figure 1-2 Current transformers, assigned to the differential protection function

Current transformer data:

Primary side	1000/1 A
Secondary side	500/1 A
Tertiary side	600/1 A

Suppose that the transformer is to be protected by differential protection.



The phase differential protection involves the primary, secondary and tertiary windings, for this function the current in the grounding is not applied. The zero sequence current is eliminated numerically using matrix transformation within the differential protection function. See Figure 1-3.

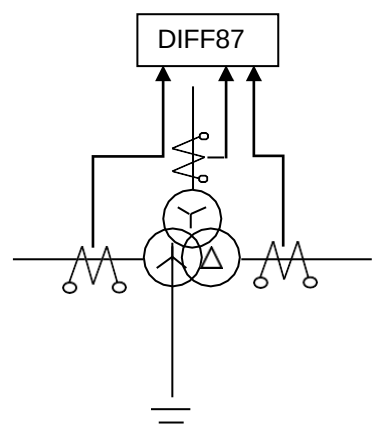


Figure 1-3 Differential protection application

The required connection diagram is shown in Figure 1-4. The device contains three current input modules in positions “R”, “S” and “T”. Each current input module contains four CT inputs. The module in “T” is assigned to the primary three phase currents, and the fourth channel is not applied. The module in “S” is reserved for the secondary three phase currents, and the fourth channel is not applied. Similarly, the module in “R” is reserved for the tertiary three phase currents, and the fourth channel is not applied.

Figure 1-4 Shows that the secondary coils of the current transformers are all connected to Y, and the common point is at the transformer side for all voltage levels of the transformer. No auxiliary current transformers are needed.

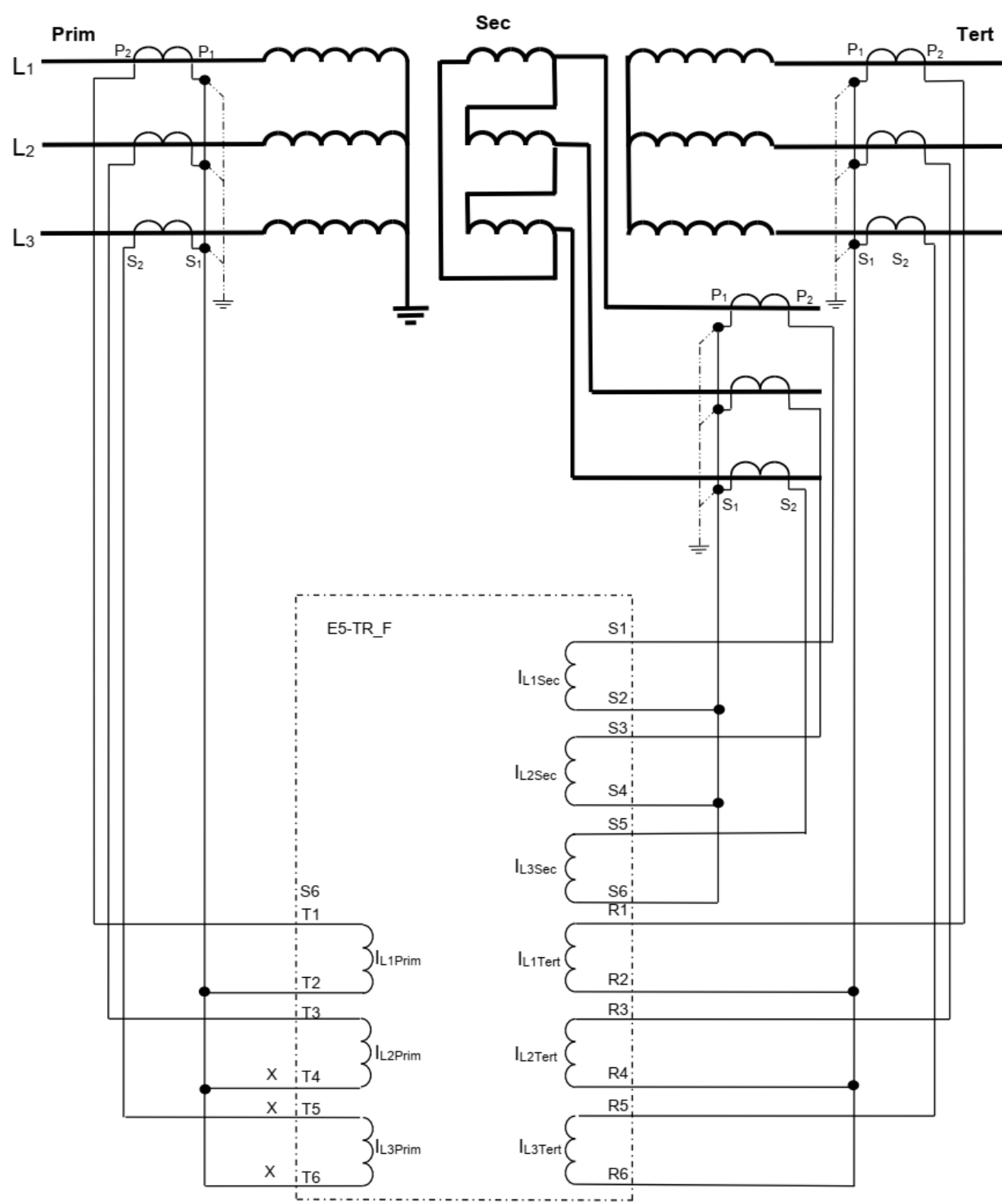


Figure 1-4 Connection diagram for the example

3.1.10.4.1. Setting the CT input function blocks

In the EuroProt+ devices the CT inputs are assigned to CT function blocks. They need parameter setting and also displaying functions are assigned to them. Parameters can be set in the parameter screen of a WEB browser, when there is Internet connection with the device. For details about this communication see the Protecta document “**Remote user interface description**” available in Protecta WEB site www.protecta.hu.

NOTE: the parameters can be set also using the local LCD touch-screen of the device, if no internet connection is available. For details about this communication see the Protecta document “**LCD touchscreen interface description**” available in Protecta WEB site www.protecta.hu.

The parameters of the current input function are explained in the following tables.

Enumerated parameters

Parameter name	Title	Selection range	Default
Rated secondary current of the first three input channels. 1A or 5A is selected by parameter setting, no hardware modification is needed.			
CT4_Ch13Nom_EPar_	Rated Secondary I1-3	1A,5A	1A
Rated secondary current of the fourth input channel. 1A or 5A (0.2A, 1A) is selected by parameter setting, no hardware modification is needed.			
CT4_Ch4Nom_EPar_	Rated Secondary I4	1A,5A (0.2A, 1A)	1A
Definition of the positive direction of the first three currents, given by location of the secondary star connection point			
CT4_Ch13Dir_EPar_	Starpoint I1-3	Line,Bus	Line
Definition of the positive direction of the fourth current, given as normal or inverted			
CT4_Ch4Dir_EPar_	Direction I4	Normal,Inverted	Normal

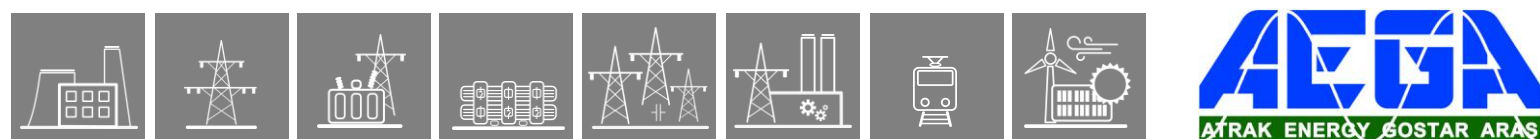
Table 2-1 The enumerated parameters of the current input function

Floating point parameters

Parameter name	Title	Dim.	Min	Max	Default
Rated primary current of channel1-3					
CT4_Pr13_FPar_	Rated Primary I1-3	A	100	4000	1000
Rated primary current of channel4					
CT4_Pr14_FPar_	Rated Primary I4	A	100	4000	1000

Table 2-2 The floating point parameters of the current input function

NOTE: The rated primary current of the channels is not needed for the current input function block itself. These values are passed on to the subsequent function blocks.



Using the information given in this example above, the following setting values are assigned:

Primary side and grounding CT:

Rated Secondary I1-3	1A	Selected, according to the CT applied at the primary side.
Rated Secondary I4	1A	Not applied, the value is not considered.
Starpoint I1-3	Line	"Line" in this case means "Toward protected object = Transformer"
Direction I4		Not applied, the value is not considered.
Rated Primary I1-3	1000	Setting, according to the CT applied at the primary side. This parameter is used for scaling the displayed values only
Rated Primary I4		Not applied, the value is not considered.

Secondary side:

Rated Secondary I1-3	1A	Selected, according to the CT applied at the secondary side.
Rated Secondary I4		Not applied, the value is not considered.
Starpoint I1-3	Line	"Line" in this case means "Toward protected object = Transformer"
Direction I4		Not applied, the value is not considered.
Rated Primary I1-3	500	Setting, according to the CT applied at the secondary side. This parameter is used for scaling the displayed values only
Rated Primary I4		Not applied, the value is not considered.

Tertiary side:

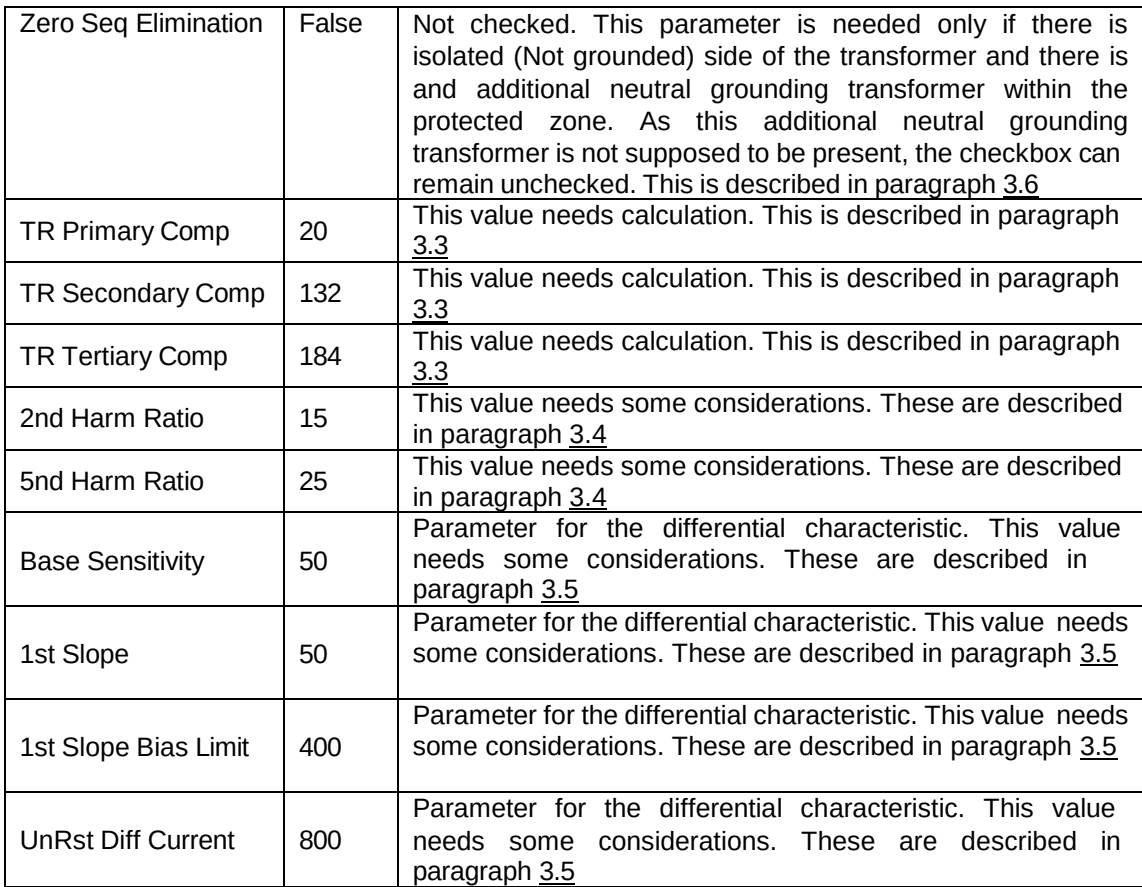
Rated Secondary I1-3	1A	Selected, according to the CT applied at the tertiary side.
Rated Secondary I4		Not applied, the value is not considered.
Starpoint I1-3	Line	"Line" in this case means "Toward protected object = Transformer"
Direction I4		Not applied, the value is not considered.
Rated Primary I1-3	600	Setting, according to the CT applied at the tertiary side. This parameter is used for scaling the displayed values only
Rated Primary I4		Not applied, the value is not considered.

Table 2-3 Summary of the CT parameter setting

3.1.10.4.2. Parameter setting for the differential function

The parameters with the selected settings for the example application for the differential protection function are summarized in [Table 3-1](#) below. Some parameters need basic considerations some of them need also calculation. This is explained in the paragraphs below:

Operation	On	Set this parameter to "On" for enabling the function. NOTE: In tests, when other protection functions are tested. Switch this parameter to "Off" to prevent false test results. The details see in paragraph 3.1
Pri-Sec VGroup	Yy6	This setting is selected according to the protected object. NOTE: see explanation in paragraph 3.2
Pri-Ter VGroup	Yd11	This setting is selected according to the protected object. (Example) NOTE: see explanation in paragraph 3.2



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3.1.10.4.2.1. Enabling the differential protection function

The DIF87 differential protection function can be applied as main protection for transformers, generators, large motors and also for protection of lines or cables on solidly grounded networks, or any combination of the mentioned protected objects.

The version DIF87_3w can be applied to protect transformers with three voltage levels. The simpler version DIF87_2w is designed to protect two winding transformers.

The parameter for enabling the differential protection function is shown in table below:

Parameter name	Title	Selection range	Default
Parameter to enable the differential protection function:			
DIF87_Op_EPar_	Operation	Off, On	Off

For enabling the function, set this Boolean parameter:

„Operation” = „On”

Additionally the differential protection function block has a binary input signal: „Blk”. In active state of this input signal the function is blocked. The conditions for blocking can be programmed using the graphic logic editor

3.1.10.4.2.2. Setting the vector compensation

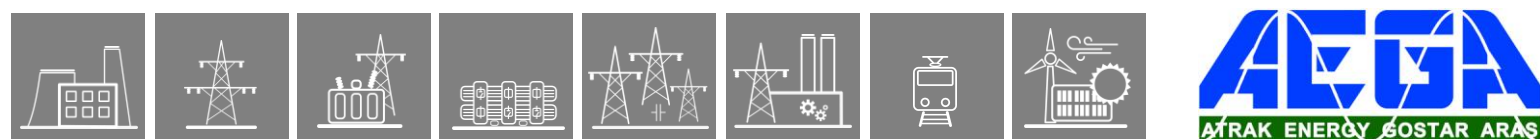
A three-phase transformer transforms the primary current to the secondary side according to the turn's ratio and the connection of the coils. The connection of the coils Y (star), D (delta) or Z (zig-zag) results phase shift of the current vectors. The numerical transformer differential protection function applies matrix transformation for the phase currents, according to the connection group to match them on all sides of the transformer.

The required matrix transformation is defined by correct selection of the transformer's connection group.

The transformer differential protection function in Protecta EuroProt+ devices transforms all currents to the delta side. This method is the numerical realization of the traditional principle: connect the secondary coils of the current transformers on the Y side of the transformer to delta, and apply y connection of the CT secondary coils on the delta side of the transformer. This transformation automatically eliminates also the problem caused by zero sequence current components.

Parameters for matching the vector group of the transformer are listed in the table below:

Parameter name	Title	Selection range	Default
Parameter to select connection group of the transformer coils in primary-secondary relation:			
DIF87_VGrSec_EPar_	Pri-Sec VGroup*	Dy1,Dy5,Dy7,Dy11,Dd0,Dd6,Dz0,Dz2,Dz4,Dz6,Dz8,Dz10,Yy0,Yy6,Yd1,Yd5,Yd7,Yd11,Yz1,Yz5,Yz7,Yz11	Dd0
Parameter to select connection group of the transformer coils in primary-secondary relation:			
DIF87_VGrTer_EPar_	Pri-Ter VGroup*	Dy1,Dy5,Dy7,Dy11,Dd0,Dd6,Dz0,Dz2,Dz4,Dz6,Dz8,Dz10,Yy0,Yy6,Yd1,Yd5,Yd7,Yd11,Yz1,Yz5,Yz7,Yz11	Dd0



* If the connection of the primary winding in primary-secondary and primary tertiary relation is selected in contradiction then the protection function is automatically disabled, and the function generates a warning signal.

The selection of these parameters is easy: select the real connection relationship of the protected transformer. For autotransformers select always Yy0.

If the protection function is applied to protect the unit of transformer-line or transformer-cable then the parameters should be selected as the connection group can be seen from the location of the protection. As an example: a transformer of Yd11 connection group is seen at the other side as a transformer Dy1.

3.1.10.4.2.3. Setting the magnitude matching

The basic principle is that in case of power transfer at rated current the currents to be compared should be the same, 100%. This means that in case of any external faults there will be no current difference, the differential function is balanced and stable.

For a two winding transformer, usually the rated current of the transformer is considered to be the base current, considered to be 100%. (NOTE: any other current value could also be selected for this reference current.) The ratio of the secondary and primary rated currents is the turn's ratio of the transformer. For the setting calculation, calculate the ratio of the transformer rated current and the CT rated primary current. These values expressed in % are the parameter values to be set for parameters „TR Primary Comp” and “TR Secondary Comp”.

For a three winding transformer in the example the rated power of the winding is not the same (40 MVA, 30 MVA and 20 MVA), consequently the ratio of rated currents for the windings do not match the turn's ratio of the coils. In this case the usual procedure is to consider the rated current of the primary side, and transform this current both for the secondary and to the tertiary side. These calculated currents should be related to the rated currents of the CT-s. These values expressed in % are the parameter values to be set for parameters „TR Primary Comp”, “TR Secondary Comp” and “TR Tertiary Comp”.

In the example:

The rated primary current is calculated from the transformer data above. This is the reference current.

$I_{1nprimary} = 192 \text{ A}$

$I_{2nprimary} = 471 \text{ A}$ based on the turn's ratio it is: 627 A

$I_{3nprimary} = 525 \text{ A}$ based on the turn's ratio it is: 1047 A

The calculation of the setting values is as follows

„TR Primary Comp”= $100 \cdot 192 \text{ A} / 1000 \text{ A} = 19.2\%$ It needs correction.

„TR Secondary Comp”= $100 \cdot 627 \text{ A} / 500 \text{ A} = 125.4\%$ It needs correction, using the same factor

„TR Tertiary Comp” = $100 \cdot 1047 \text{ A} / 600 \text{ A} = 174.5\%$ It needs correction, using the same factor

For the 120 kV side the setting of 19% is below the low limit of the parameter range. Select instead 20 %. Consequently the compensation values both for the secondary and tertiary sides should be multiplied by 20/19. Note this correction means only that not the rated current but a slightly different value is selected as the base current.

„TR Primary Comp”= 20 %

„TR Secondary Comp”= $20/19 \cdot 125.4 \% = 132 \%$

„TR Tertiary Comp” = $20/19 \cdot 174.5 \% = 184 \%$

3.1.10.4.2.4. Considerations, related to the harmonic restraint

When a transformer is energized then due to the asymmetric saturation of the iron core a high “inrush current” can flow from one side into the transformer. This is a pure differential current. To prevent unwanted operation of the differential protection the special waveform of the inrush current is identified. The principle is the detection of the second harmonic content, which is present in the inrush current, but its value can be neglected in any fault current. For the differential current, the second harmonic component in the evaluation is related to the value of the base harmonic. This is the parameter „2nd Harm Ratio”. If this ratio gets higher due to inrush current, the trip command is blocked.

When a transformer is overexcited then the iron core is saturated symmetrically, resulting high current peaks, distorting both the positive and the negative sinusoidal current shape. In this current shape the fifth harmonic is characteristic. To prevent mal-operation, this component of the differential current is analyzed and compared to the base harmonic. If the ratio is high, then the differential current is caused by the over-excitation, the trip command is blocked. If however the fifth harmonic content is low, then the high differential current, which is a fault current, results trip command. The ratio is the parameter „5th Harm Ratio”.

If no results of detailed harmonic analysis are available, apply the factory setting, which can be corrected later. The proposed setting values are:

$$\text{„2nd Harm Ratio”} = 15 \%$$

and

$$\text{„5th Harm Ratio”} = 25 \%$$

3.1.10.4.3. Considerations, related to the differential characteristic for the differential protection function

The differential characteristic is shown in *Figure 3-1*. If the calculated (I_{bias}, I_{diff}) operating point is above the characteristic, then the differential protection operates.

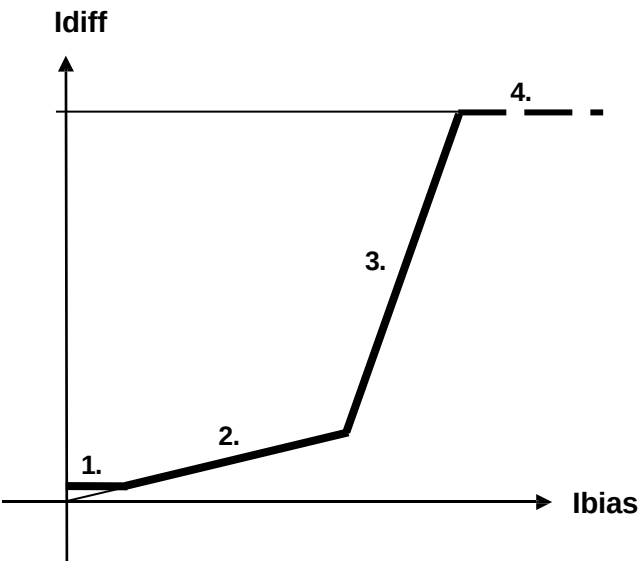
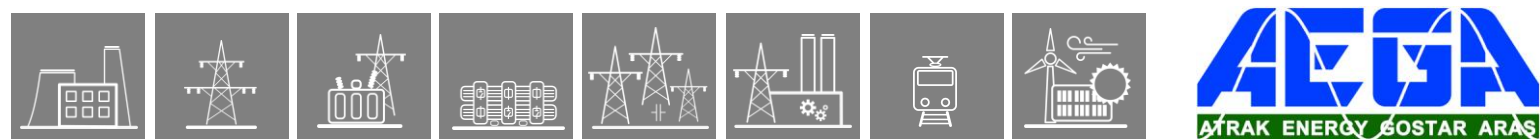


Figure 3-1 The differential characteristic

This characteristic has four sections; each of them is a straight line. The parameters define the position of these lines on the I_{diff} - I_{bias} plane.

The first parameter is “Base Sensitivity”. It defines the minimum differential current for the operation. Its role is to prevent mal-operation in case of current noises and measuring errors



for small currents. In this example the selected setting value is the less sensitive selection:

„Base Sensitivity” = 50 %,

This value can be tested easily: inject three phase symmetrical currents from one side only and increase its value. The operation is expected if this current gets above 50% of the reference current. (In this example it is $0.5 \cdot 0.87A$. NOTE: for asymmetrical fault current this value changes due to the matrix transformation.)

The second section of the characteristic is a line through the origin of the I_{diff} - I_{bias} plane. The slope of this line serves to compensate the not correct matching of the CT-s, e.g. due to the different tap-changer positions and the CT errors. Due to these causes the error current increases if the current flowing through the transformer increases. The parameter is “1st Slope”. The mathematical expression of the second section of the characteristic is

$$I_{diff} = \frac{1stSlope}{100} * I_{bias}$$

. The steps for getting the parameter value are as follows:

- Calculate the error in percent, due to not correct matching (To be calculated for all three voltage levels):

$$x\% = \left(1 - \left| \frac{I_{l \cdot required_matching}}{I_{l \cdot matching}} \right| \right) * 100$$

- The unbalance of the differential protection at top or bottom position of the tap changer in percent, related to the value of 0 position ($r_{max}\%$):

$$x\% = |r_{max}\%|$$

Select the biggest value of the calculated $x\%$ values above. The setting value is advised to be above this value.

Example: suppose the voltage control range to be $+18\%/-12\%$, and the reference position for current balancing is the 0 position, then the parameter value with 1,5x safety is:

$$„1st Slope” = 1,5 \cdot 18 = 27 \rightarrow 30 \%$$

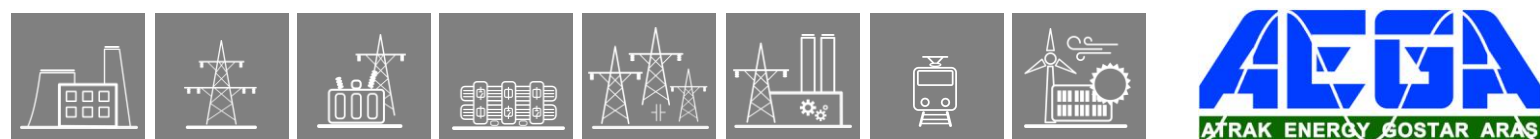
Another choice for calculation is the selection the mid-position of the tap-changer. This is in this example as follows: The full position range is $18 + 12 = 30\%$. The half value is 15% , accordingly the mid-position is $+3\%$. With this the voltage ratio of the transformer to be considered is to be increased by $118/115$, and the balancing of the current is to be determined for this voltage. In this case only $\pm 15\%$ tap position range can be considered, and the value of this parameter is decreased to:

$$„1st Slope” = 1,5 \cdot 15 = 22,5 \rightarrow 25 \%$$

The slope of the third section of the characteristic is higher. This is to compensate the increased CT error, due to the CT saturation at higher currents. This higher slope is a factory setting: 200%. The parameter “1st Slope Bias Limit” defines the intersection point of section 2 and 3.

This parameter value is influenced by the highest fault current in the protected object and the applied current transformer saturation point related to the rated value. If the current transformer is less over-dimensioned then select the parameter value for “1st Slope Bias Limit” low. The usual consideration is: for relatively high currents select 200 %, for low fault currents select 1000 %.

The fourth section of the characteristic is the unrestrained section. The related parameter is “UnRst Diff Current”. This parameter serves unrestrained fast operation if the high magnitude of the fault current indicates internal fault. The calculation determines the maximal external fault current, and the setting value should be above this current.



3.1.10.4.4. Considerations for zero sequence elimination

In solidly grounded high voltage networks, in case of external earth faults, the Y-delta transformers supply zero sequence current, which is present on the Y side only. No zero sequence current can flow on the delta side. When comparing the currents in the differential protection, this could cause unwanted operation.

The differential protection function in the Protecta EuroProt+ devices eliminates the Y side zero sequence current by matrix transformation (simulating the old type delta connected CT secondary behavior). This elimination is automatic, no additional solution is needed.

In several cases, however, there is additional neutral grounding transformer on the delta side of the transformer within the protected zone. Between the neutral point of this additional transformer an arc suppression Petersen coil, or a grounding resistor is connected. The Petersen coil minimizes the earth-fault current to some Amperes, the resistor limits the earth-fault current to 100 A (in some cases to 200 A).

If the neutral grounding transformer is not in the protected zone, it is outside the current transformers, then set:

„ZeroSeq Elimination” = „False” (Not checked)

In some cases, however, the neutral grounding transformer is closely connected to the main transformer's delta side terminals; it is in the protected zone. The advantage of this arrangement is that the energizing the transformer immediately solves the neutral grounding problems.

In case of external earth-fault the zero sequence current of the neutral grounding transformer is detected by the delta side current transformers. The zero sequence elimination is needed. In this case set

„ZeroSeq Elimination” = „True” (Checked)

3.1.10.4.5. Application of the binary signals

The binary output status signals are usually applied in the graphic logic editor as input signals. The logic relationship can be programmed freely.

The available binary output status signals of the differential protection function are listed in the table below:

Binary output signals	Signal title	Explanation
Restrained differential protection function		
DIF87_L1St_GrI_	Start L1	Start of the restrained differential protection function in phase L1 (after vector group compensation)
DIF87_L2St_GrI_	Start L2	Start of the restrained differential protection function in phase L2 (after vector group compensation)
DIF87_L3St_GrI_	Start L3	Start of the restrained differential protection function in phase L3 (after vector group compensation)
DIF87_GenSt_GrI	General Start	General start of the restrained differential protection function
Unrestrained differential protection function		
DIF87_UnRL1St_GrI_	Start L1 unrestr.	Start of the unrestrained differential protection function in phase L1 (after vector group compensation)
DIF87_UnRL2St_GrI_	Start L2 unrestr.	Start of the unrestrained differential protection function in phase L2 (after vector group compensation)
DIF87_UnRL3St_GrI_	Start L3 unrestr.	Start of the unrestrained differential protection function in phase L3 (after vector group compensation)
DIF87_UnRGenSt_GrI_	General Start unrestr	General start of the unrestrained differential protection function
Harmonic blocking		
DIF87_2HBlk_GrI	2.Harm Restr.	Restraint caused by high second harmonic content in any of the differential currents
DIF87_5HBlk_GrI	5.Harm Restr.	Restraint caused by high fifth harmonic content in any of the differential currents

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

Binary input signal	Explanation
DIF87_BlK_GrO	Output status of a graphic equation defined by the user to disable the differential 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.

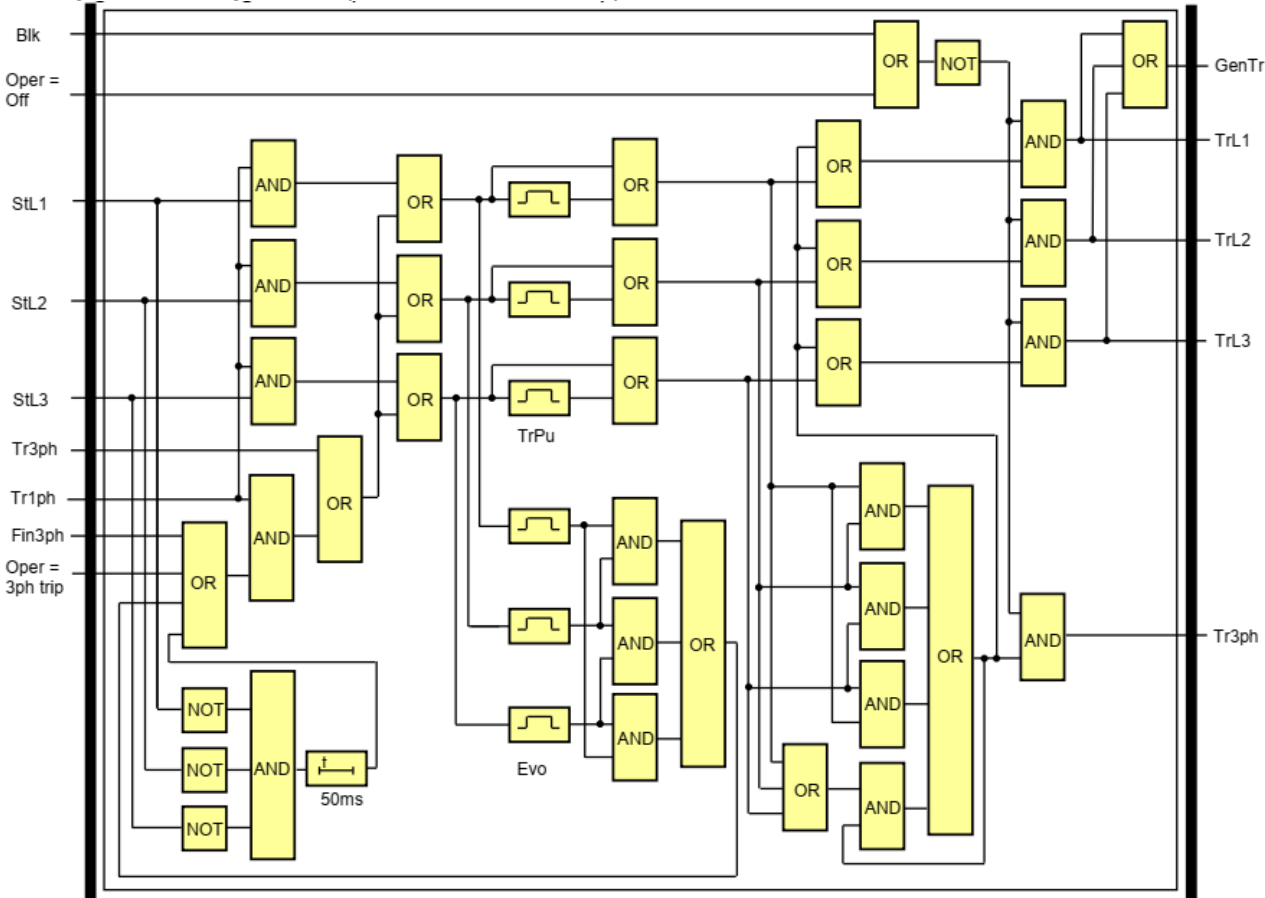


Figure 1-1 Logic scheme of the decision logic

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.

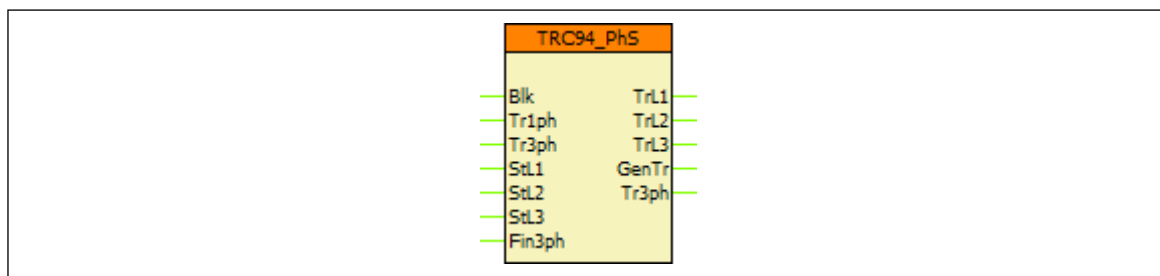


Figure 2-1 Graphic appearance of the function block of the phase-selective trip logic function

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).

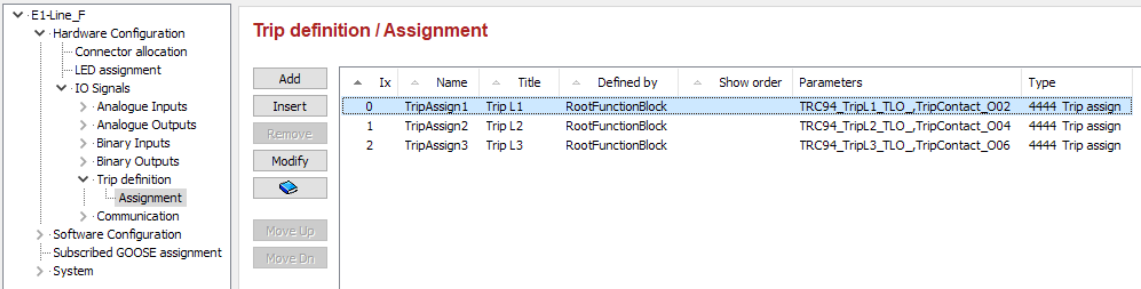


Figure 2-2 Trip assignment in EuroCAP

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:

$$\sum_{i=1}^n I_t^k = CycNum$$

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.

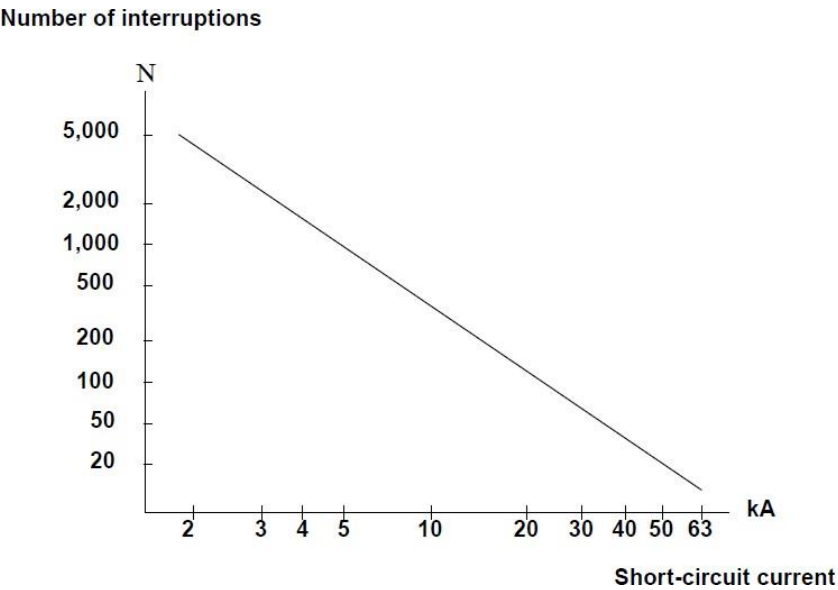
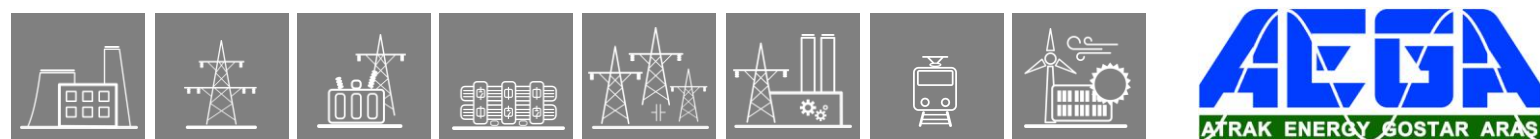


Figure 1-1 Example: Number of permitted interruptions as the function of the interrupted current

- 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_Blkc_GrO_	Blk	The programmed True state of this input disables the operation of the function
Open state of the circuit breaker		
CBWear_Open_GrO_	Open	The open state of the circuit breaker is needed to stop the procedure to find the maximum breaking current
Closed state of the circuit breaker		
CBWear_Closed_GrO_	Closed	The closed state of the circuit breaker is needed to perform the procedure to find the maximum breaking current
Trip command to the circuit breaker		



CBWear_Trip_GrO_	Trip	This signal starts the procedure to find the highest breaking current
Reset command		
CBWear_Reset_GrO_	Reset	If this input is programmed to logic True, at maintenance the weighted sum of the breaking currents can be set to 0

Table 1-6 The binary input signals of the circuit breaker wear monitoring function

3.2.2.2.5. The function block

The function block of the circuit breaker wear monitoring function is shown in [Figure 1-3](#). This block shows all binary input and output status signals that are applicable in the graphic equation editor.

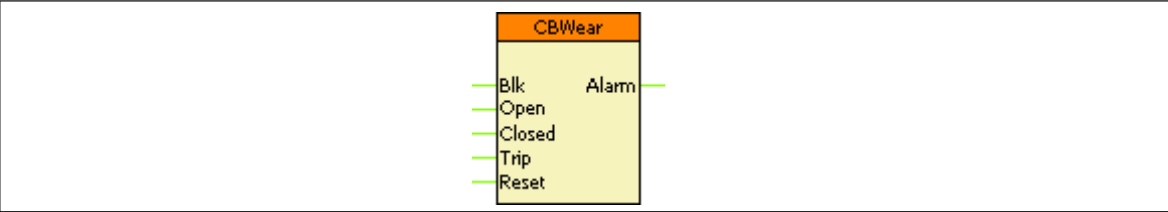
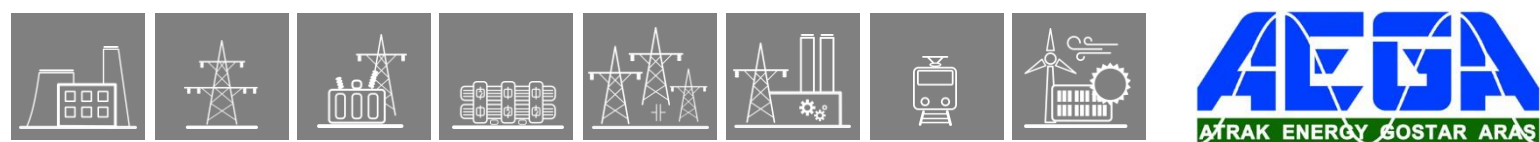


Figure 1-3 The function block of the circuit breaker wear monitoring function



3.2.3. Circuit breaker control function block

3.2.3.1. Application

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

3.2.3.1.1. Mode of operation

The circuit breaker control block receives remote commands from the SCADA system and local commands from the local LCD of the device, performs the prescribed checking and transmits the commands to the circuit breaker. It processes the status signals received from the circuit breaker and offers them to the status display of the local LCD and to the SCADA system.

Main features:

- Local (LCD of the device) and Remote (SCADA) operation modes can be enabled or disabled individually.
- The signals and commands of the synchro-check / synchro-switch function block can be integrated into the operation of the function block.
- Interlocking functions can be programmed by the user applying the inputs “EnaOff” and “EnaOn”, using the graphic equation editor.
- Programmed conditions can be used to temporarily disable the operation of the function block using the graphic equation editor.
- The function block supports the control models prescribed by the IEC 61850 standard.
- All necessary timing tasks are performed within the function block:
 - Time limitation to execute a command
 - Command pulse duration
 - Filtering the intermediate state of the circuit breaker
 - Checking the synchro-check and synchro-switch times
 - Controlling the individual steps of the manual commands
- Sending trip and close commands to the circuit breaker (to be combined with the trip commands of the protection functions and with the close command of the automatic reclosing function; the protection functions and the automatic reclosing function directly gives commands to the CB). The combination is made graphically using the graphic equation editor
- Operation counter
- Event reporting

3.2.3.2. Circuit Breaker control function overview

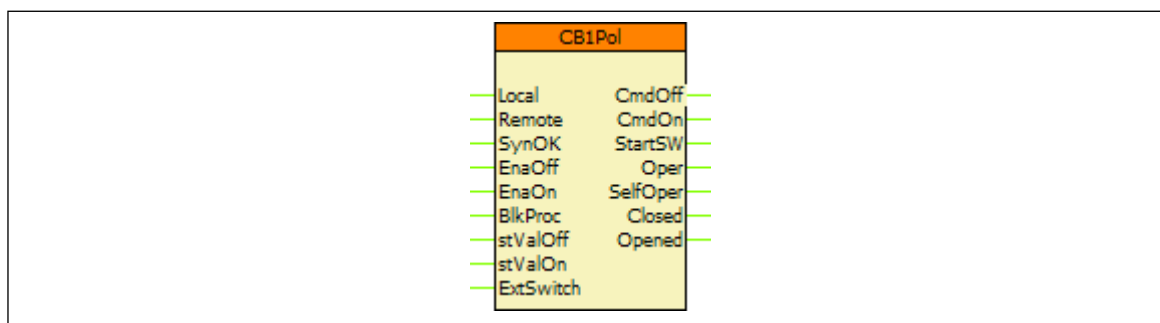


Figure 2-1 Graphic appearance of the function block of the circuit breaker control function

3.2.3.3. Settings

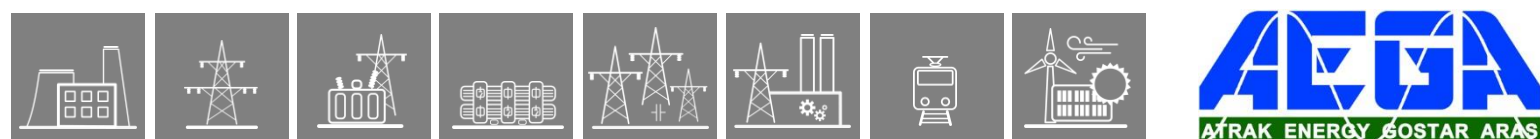
3.2.3.3.1. Parameters

TITLE	DIM	RANGE	STEP	DEFAULT	EXPLANATION
ControlModel	-	Direct normal, Direct enhanced, SBO enhanced	-	Direct normal	The control model of the circuit breaker node according to the IEC 61850 standard
Forced Check	-	FALSE, TRUE	-	TRUE	If true, then the check function cannot be neglected by the check attribute defined by the IEC 61850 standard
Max Operating Time	ms	10 – 1000	1	200	When either enhanced control model is selected, the status of the CB must change within this time after the issued command. At timeout an invalid-position error will be generated for the client.
Pulse Duration	ms	50 – 1000	1	300	Duration of the generated On and Off impulse*
Max Intermediate Time	ms	20 – 500	1	100	Waiting time for status signals, at expiry the CB is reported to be in intermediate state
Max SynCheck Time	ms	10 – 5000	1	1000	Length of the time period to wait for the conditions of the synchronous state. After expiry of this time, the synchro-switch procedure is initiated (see synchro-check/ synchro-switch function block description)
Max SynSW Time**	ms	0 – 60000	1	0	Length of the time period to wait for the synchro-switch impulse (see synchro-check/ synchro-switch function block description). After this time the function resets, no switching is performed
SBO Timeout	ms	1000 – 20000	1	5000	Duration of the waiting time between object selection and command selection. At timeout no command is performed

* If the input status signals (stValOff, stValOn) indicate the successful switching then the pulse is withdrawn, but the minimum duration is 100 ms (factory setting).

** If this parameter is set to 0, then the "StartSW" output is not activated

Table 2-1 Parameters of the circuit breaker control function



3.2.3.3.2. Function I/O

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

3.2.3.3.2.1. Binary input signals (graphed output statuses)

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

BINARY INPUT SIGNAL	EXPLANATION
CB1Pol_ Local _GrO_	If this input is active, the circuit breaker can be controlled using the local LCD of the device.
CB1Pol_ Remote _GrO_	If this input is active, the circuit breaker can be controlled via remote communication channels of the SCADA system or the device web page ('commands' menu)
CB1Pol_ SynOK _GrO_	This input indicates if the synchronous state of the voltage vectors at both sides of the circuit breaker enables the closing command. This signal is usually generated by the synchro check/ synchro switch function. If this function is not available, set the input to logic true.
CB1Pol_ EnaOff _GrO_	The active state of this input enables the opening of the circuit breaker. The state is usually generated by the <i>interlocking conditions defined graphically by the user</i> .
CB1Pol_ EnaOn _GrO_	The active state of this input enables the closing of the circuit breaker. The state is usually generated by the <i>interlocking conditions defined graphically by the user</i> .
CB1Pol_ BlkProc _GrO_	The active state of this input blocks the operation of the circuit breaker. The conditions are defined graphically by the user.
CB1Pol_ stValOff _GrO_	Off (Opened) state of the circuit breaker.
CB1Pol_ stValOn _GrO_	On (Closed) state of the circuit breaker.
CB1Pol_ ExtSwitch _GrO_	This signal is considered only when evaluating unintended operation (see "SelfOper" output in Chapter 2.2.2). It indicates that an external command has been issued to the circuit breaker (e.g. trip request from other protection device or external on/off command is given).

Table 2-2 The binary input signals of the circuit breaker control function

3.2.3.3.2.2. Binary output signals (graphed input statuses)

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

BINARY OUTPUT SIGNAL	SIGNAL TITLE	EXPLANATION
CB1Pol_ CmdOff _Grl_	Off Command	Off command impulse, the duration of which is defined by the parameter "Pulse duration"
CB1Pol_ CmdOn _Grl_	On Command	On command impulse, the duration of which is defined by the parameter "Pulse duration"
CB1Pol_ StartSW _Grl_	Start Synchro-switch	If the synchro check/synchro switch function is applied and the synchronous state conditions are not valid for the time defined by the parameter "Max.SynChk time", then this output triggers the synchro switch function (see synchro-check/synchro-switch function block description).
CB1Pol_ Oper _Grl_	Operation	An impulse with a duration of 150 ms at any operation of the circuit breaker
CB1Pol_ SelfOper _Grl_	Unintended Operation	This output is logic true if the status of the circuit breaker has changed without detected command from the SCADA system or on the input "ExtSwitch"
CB1Pol_ Closed _Grl_	Closed	The filtered status signal for closed state of the circuit breaker
CB1Pol_ Opened _Grl_	Opened	The filtered status signal for opened state of the circuit breaker

Table 2-3 The binary output signals of the circuit breaker control function

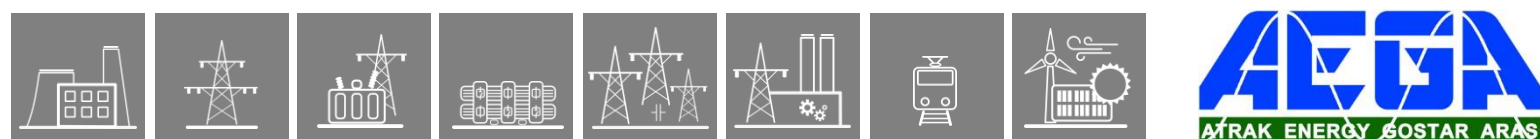
3.2.3.3.2.3. On-line data

Visible values on the on-line data page:

SIGNAL TITLE	DIMENSION	EXPLANATION
Status	-	State of the CB (see Chapter 2.2.6)
Off Command	-	Off command impulse, the duration of which is defined by the parameter "Pulse duration"
On Command	-	On command impulse, the duration of which is defined by the parameter "Pulse duration"
Operation	-	An impulse with a duration of 150 ms at any operation of the circuit breaker
Unintended Operation	-	This output is logic TRUE if the status of the circuit breaker has changed without detected command from the SCADA system or on the input "ExtSwitch"
Opened	-	The filtered status signal for opened state of the circuit breaker
Closed	-	The filtered status signal for closed state of the circuit breaker
Operation counter	-	Resettable* counter that increments every time the Operation (see above) output gets active

*The operation counter can be reset on the device web page on-line menu.

Table 2-4 On-line data of the circuit breaker control function



3.2.3.3.2.4. Events

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

EVENT	VALUE	EXPLANATION
Status	Intermediate,Off,On,Bad	CB state indication based on the received signals

Table 2-5 Event of the circuit breaker control function

3.2.3.3.2.5. Commands

The following table contains the issuable commands of the function block. The name of the command channel is used while working in the EuroCAP configuration tool, whereas the title is seen by the user on the device web page.

COMMAND CHANNEL	TITLE	RANGE	EXPLANATION
CB1Pol_Oper_Con_	Operation	Off,On	Issue open (off) or close (on) command on the corresponding outputs of the function block

Table 2-6 The command of the circuit breaker control function

3.2.3.3.2.6. Indication of the four states (Intermediate, On, Off, Bad)

To generate an active scheme on the local LCD, there is an internal status variable indicating the state of the circuit breaker. Different graphic symbols can be assigned to the values, the function block's events are generated also according to this status variable.

This integer status has four values based on the states of the **stValOn** and **stValOff** inputs of the function block.

INTEGER STATUS	TITLE	STVALON STATE	STVALOFF STATE	VALUE	EXPLANATION
CB1Pol_stVal_ISt_	Status	FALSE	FALSE	0: Intermediate	Integer status signal for indicating the state of the CB according to the corresponding inputs of the function block
		FALSE	TRUE	1: Off	
		TRUE	FALSE	2: On	
		TRUE	TRUE	3: Bad	

Table 2-7 State signals from the circuit breaker control function

3.2.3.3.3. Technical data

FUNCTION	VALUE	ACCURACY
Pulse time		< 3 ms

Table 2-8 The technical data of the circuit breaker control function

3.2.3.3.3.1. Notes for testing

If the commands get blocked from time to time during commissioning, it is advised to check how the conditions are fulfilled to issue commands on the function block. The following **three** conditions must be fulfilled at the same time:

- Local or Remote input is active appropriately
- The enabling input (EnaOff or EnaOn) of the issued command (off or on) is active
- (close/on command only) Synchro-check is OK (SynOK input is active)

If there are no conditions to be defined for any of these three (e.g. there is no synchro-check function present, so no valid signal can be provided to that input), the corresponding input can be connected to constant logical TRUE signal provided by the fixture output of the Common function block.

3.2.3.3.3.1.1. IEC 61850 commands

In several configurations the Interlocking and Control logical nodes may have the same prefix for CB and DC function blocks (**INTCILO#** and **SBwCSWI#** respectively where the '#' marks the instance number). This means that their instance number not necessarily corresponds to the actual function block:

- Example: if there are **2** DC and **1** CB function blocks in the same configuration where the former ones were added first, the instance number **#1** and **#2** will belong to the DC function blocks whereas number **#3** will belong to the CB function block even if it is the only CB control function in the device.
- Make sure to check which logical nodes belong to which function by checking the DOI description using the EuroCAP tool (right click the function block in the Logic editor)

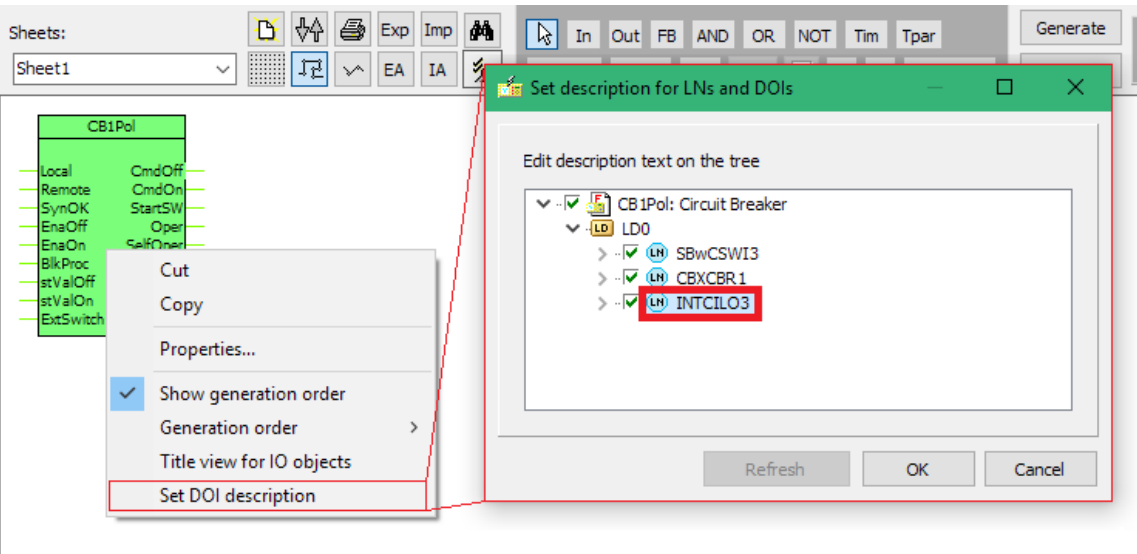
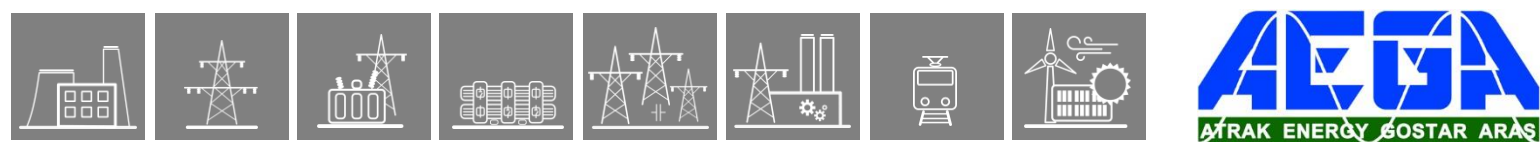


Figure 2-2 Checking the description of the Interlocking LN of the function block

In other cases, the two prefixes are given according to the type of the function block, so they are individual for each (i.e. **CBCILO#** and **CBwCSW#** for circuit breaker and **DCCILO#** and **DCCSW#** for disconnector).



3.2.4. Disconnecter control function

3.2.4.1. Application

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

3.2.4.1.1. Mode of operation

The disconnector control block receives remote commands from the SCADA system and local commands from the local LCD of the device, performs the prescribed checking and transmits the commands to the disconnector. It processes the status signals received from the disconnector and offers them to the status display of the local LCD and to the SCADA system.

Main features:

- Local (LCD of the device) and Remote (SCADA) operation modes can be enabled or disabled individually.
- Interlocking functions can be programmed by the user applying the inputs “EnaOff” and “EnaOn”, using the graphic equation editor.
- Programmed conditions can be used to temporarily disable the operation of the function block using the graphic equation editor.
- The function block supports the control models prescribed by the IEC 61850 standard.
- All necessary timing tasks are performed within the function block:
 - Time limitation to execute a command
 - Command pulse duration
 - Filtering the intermediate state of the disconnector
 - Controlling the individual steps of the manual commands
- Sending open and close commands to the disconnector
- Operation counter
- Event reporting

3.2.4.2. Disconnecter control function overview

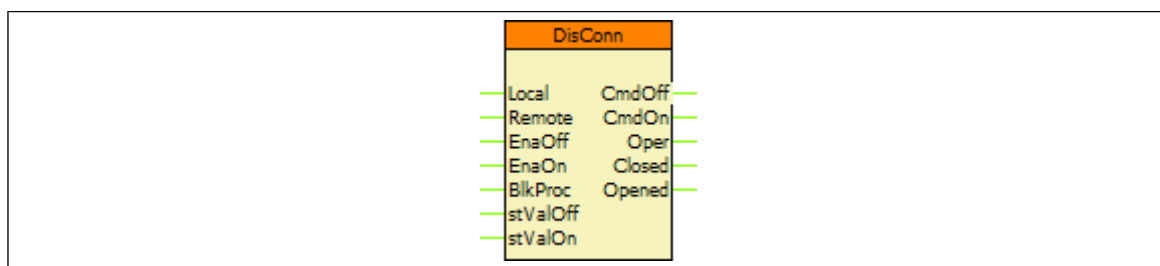


Figure 2-1 Graphic appearance of the function block of the disconnector control function

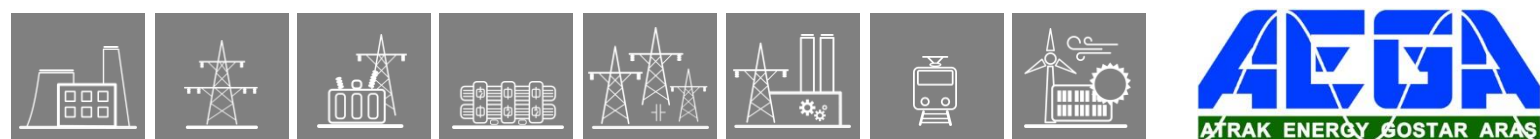
3.2.4.2.1. Settings

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, Disconnecter, Earthing Switch, HS Earthing Switch	-	Disconnecter	
Forced Check	-	FALSE, TRUE	-	TRUE	If true, then the check function cannot be neglected by the check attribute defined by the IEC 61850 standard
Max Operating Time	ms	10 – 60000	1	10000	When either enhanced control model is selected, the status of the DC must change within this time after the issued command. At timeout an invalid-position error will be generated for the client.
Pulse Duration	ms	100 – 60000	1	1000	Duration of the generated On and Off impulse*
Max Intermediate Time	ms	20 – 60000	1	10000	Waiting time for status signals, at expiry the DC is reported to be in intermediate state
SBO Timeout	ms	1000 – 20000	1	5000	Duration of the waiting time between object selection and command selection. At timeout no command is performed

* If the input status signals (stValOff, stValOn) indicate the successful switching then the pulse is withdrawn, but the minimum duration is 1000 ms (factory setting).

Table 2-1 Parameters of the 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 <i>interlocking conditions defined graphically by the user</i> .
DisConn_ EnaOn _GrO_	The active state of this input enables the closing of the disconnector. The state is usually generated by the <i>interlocking conditions defined graphically by the user</i> .
DisConn_ BlkProc _GrO_	The active state of this input blocks the operation of the disconnector. The conditions are defined <i>graphically by the user</i> .
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 (**INTCILO#** and **SBwCSWI#** respectively where the '#' marks the instance number). This means that their instance number not necessarily corresponds to the actual function block:

- Example: if there are **1** CB and **1** DC function blocks in the same configuration where the former was added first, the instance number **#1** will belong to the CB function block whereas number **#2** will belong to the DC function block even if it is the only DC control function in the device.
- Make sure to check which logical nodes belong to which function by checking the DOI description using the EuroCAP tool (right click the function block in the Logic editor)

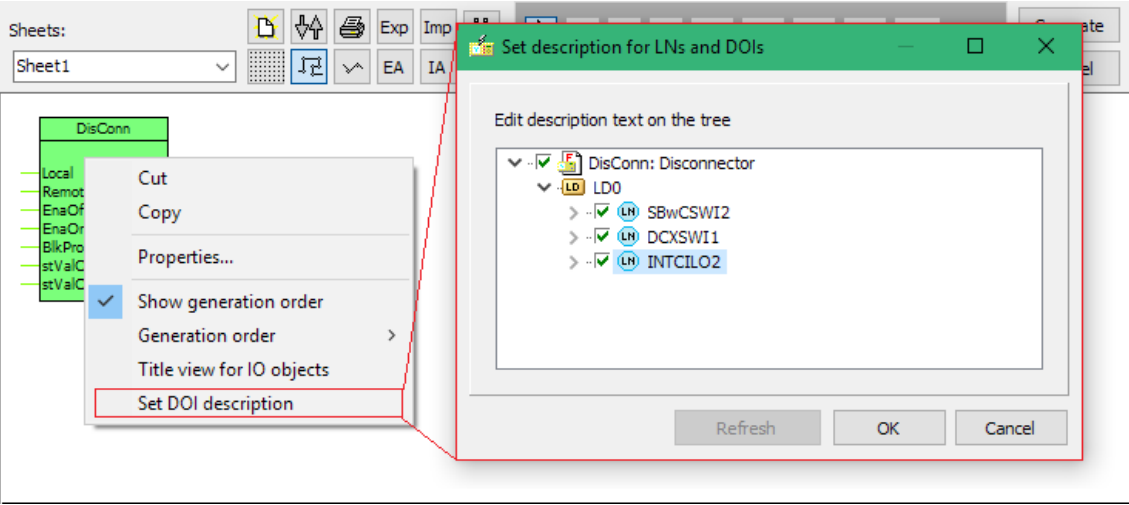


Figure 2-2 Checking the description of the Interlocking LN of the function block

In other cases, the two prefixes are given according to the type of the function block, so they are individual for each (i.e. **DCCILO#** and **DCCSW#** for disconnecter 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.

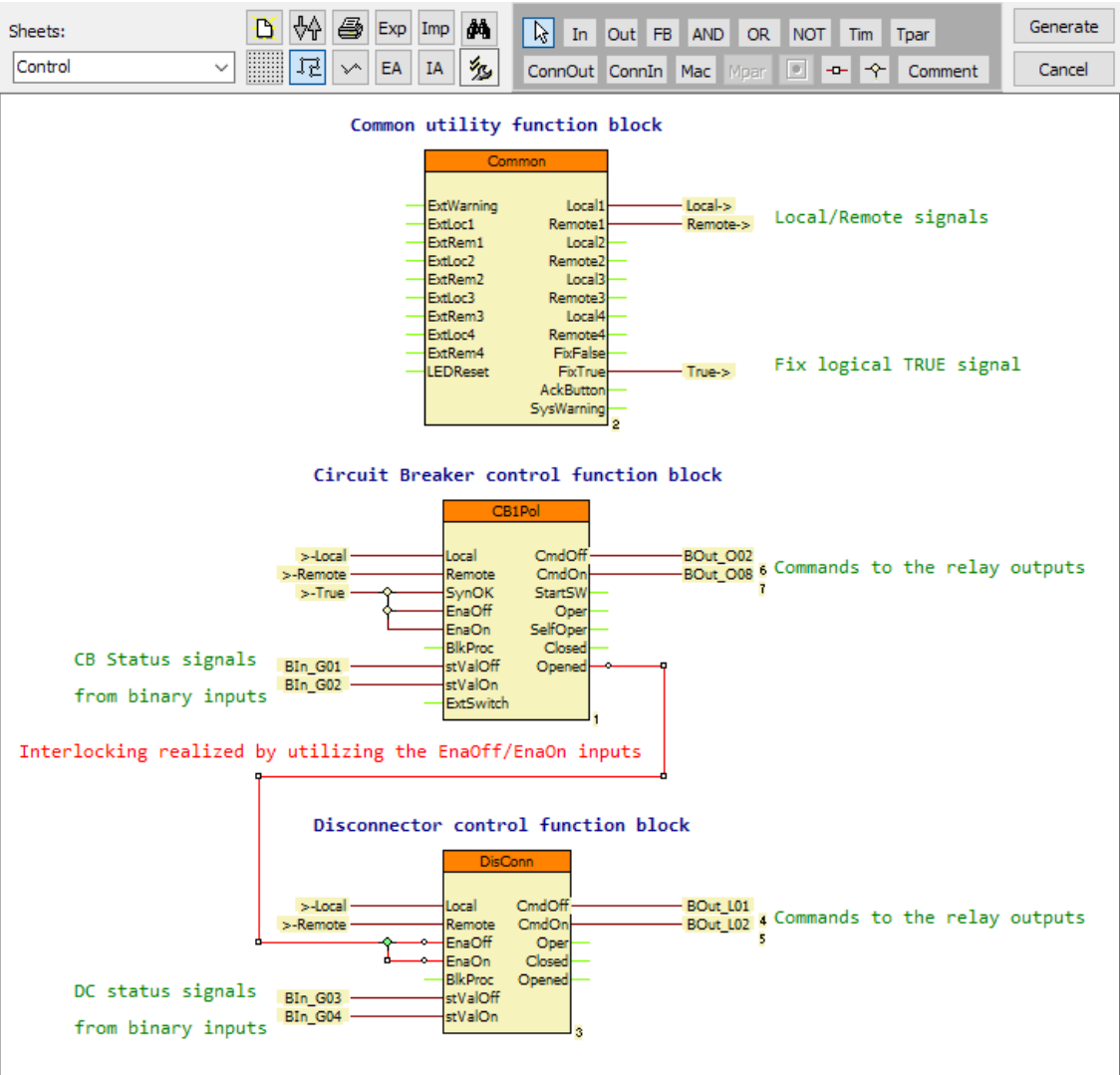
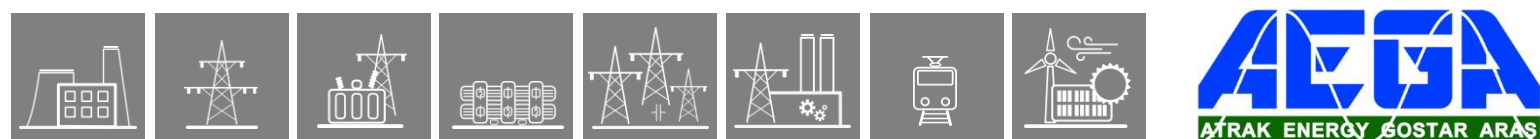


Figure 3-1 Inserting the disconnector function block into the logic (example)



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.

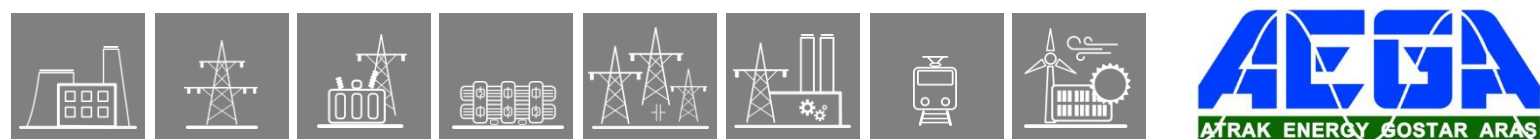
When further indications are needed or the signals of the statuses (such as events, logic signals for the user logic, LEDs etc.), the Ethernet Links function block makes these available for the user.

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.

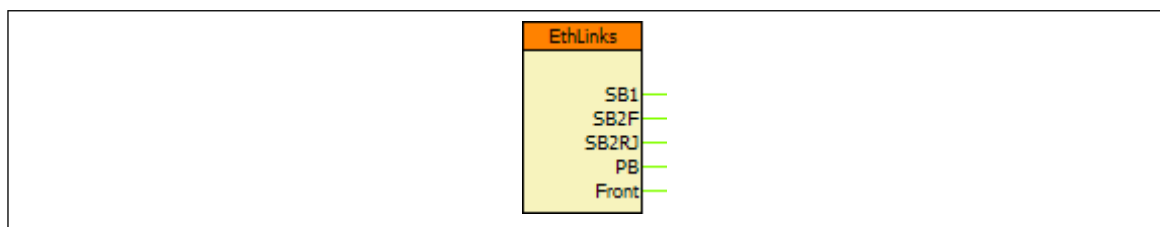


Figure 2-1 Graphic appearance of the function block of the ethernet links function

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

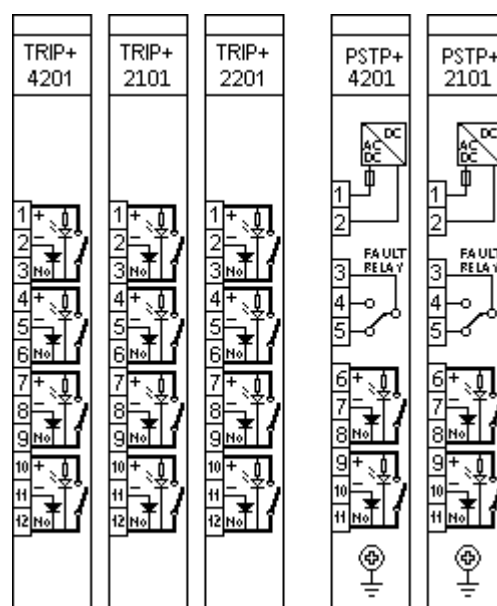


Figure 1-1 I/O arrangement of the modules with TCS

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 – Trip Circuit Supervision function is active with both methods.



The voltage of the "No" contact is maximized at 15 V by a Zener-diode. Make sure that the voltage caused by the resistance of the circuit breaker and the injected current from the TRIP+ module does not reach 10 V. In case of PSTP+ modules, this voltage is 8 V (PSTP+/4201) and 13 V (PSTP+/2101).



Our TRIP+ modules are made to switch DC circuits. **Using reversed polarity or AC voltage can cause the damage of the internal circuits.**

3.2.6.2.1.1. 3-wire TRIP+ wiring methods

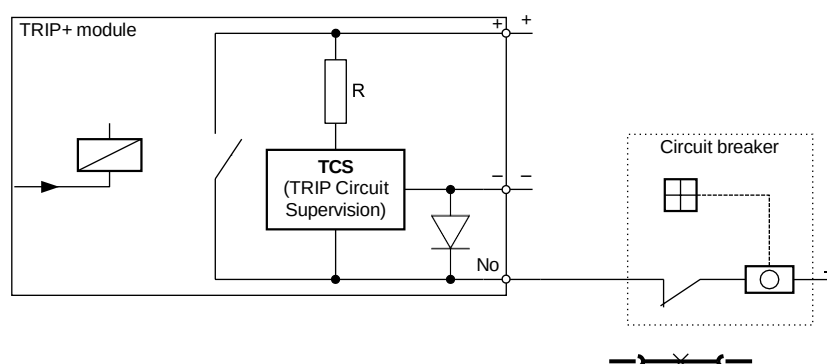


Figure 2-1 3-wire TRIP+ wiring

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

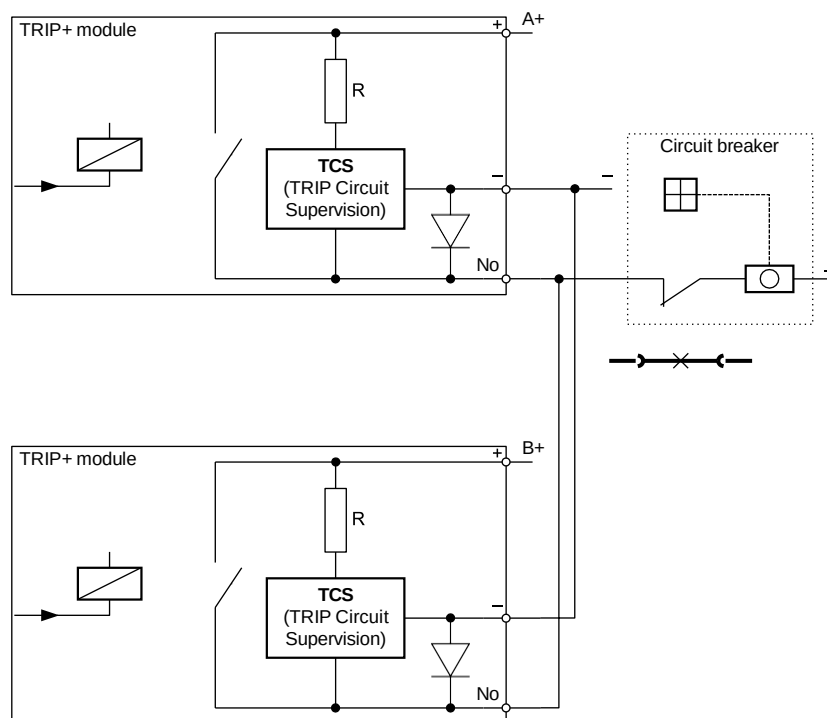


Figure 2-2 3-wire TRIP+ wiring using parallel connected TRIP+ modules

3.2.6.2.1.2. **2-wire TRIP+ wiring methods**

If it is necessary, you can also wire the TRIP+ modules using only the “+” and the “No” contacts.

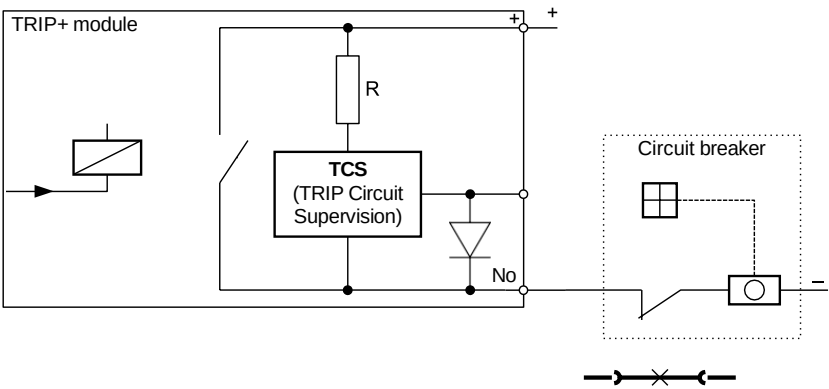


Figure 2-3 2-wire TRIP+ wiring

It is possible to use parallel connected TRIP+ modules.

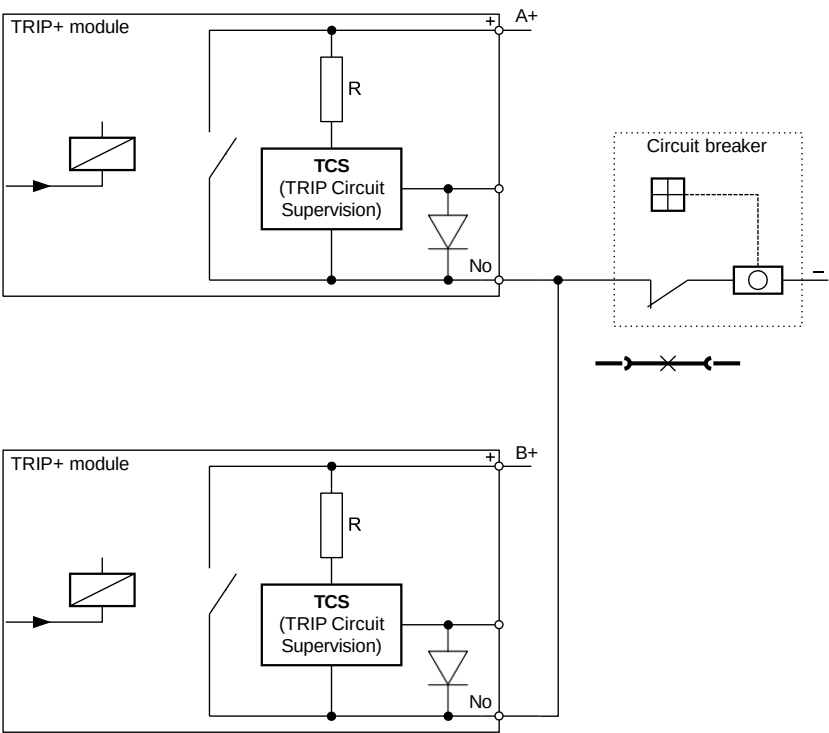


Figure 2-4 2-wire TRIP+ wiring using parallel connected TRIP+ modules

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

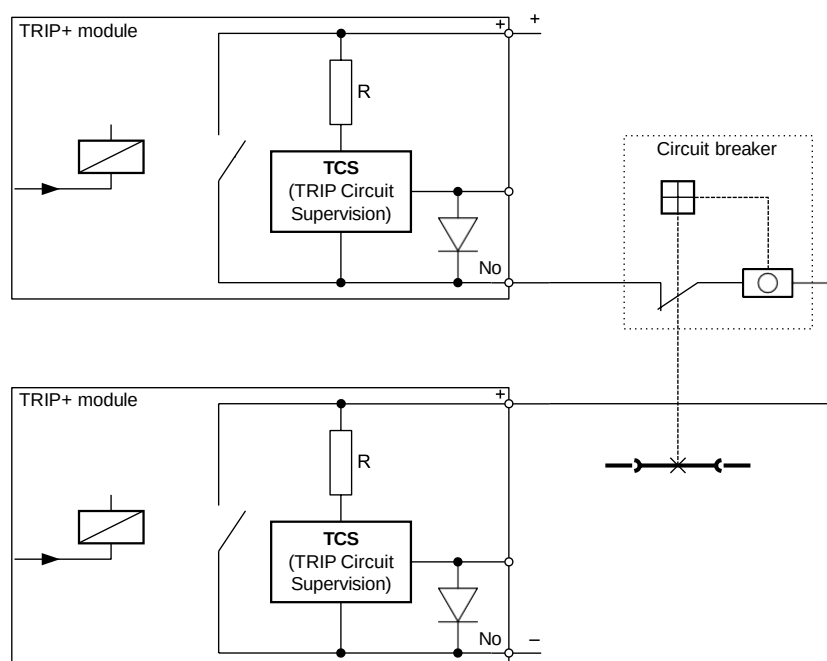


Figure 2-5 2-wire TRIP+ wiring using series connected TRIP+ modules

3.2.6.2.2. TCS signal handling

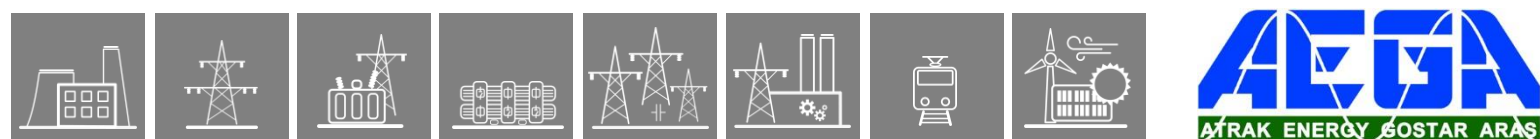
The Trip Circuit Supervision detects broken trip circuit if the current flowing through the trip coil is below 1 mA or (in case of 3-wire wirings) the voltage on it is above 8-10-13 V (depending on the module).

In Chapter [2.3](#) there are calculated maximum values for the resistance of the trip coil. If these values are exceeded, the TCS might consider the trip circuit broken even if it is intact.

To solve this, there are two ways:

- Using the 2-wire wiring method*:** leaving out/disconnecting the DC- part of the TRIP wiring may solve the issue.
Note that in this case the voltage is not maximized on 15 V, so **the used voltage (up to 220 Vdc) will appear on the “NO” pin**. Caution is advised when touching the wiring in this case.
- Usage of modules without TCS:** if the TCS is not a requirement (e.g. in backup protections), it can be simply left out by opting for the appropriate modules (such as PSTP+/2131 or TRIP+/21F1) while ordering.

**The inputs of some relay testers might sense the states of the Trip contacts active even if they are not. In such cases the “-” pin must be wired in for the tests.*



3.2.6.2.3. Technical data

The following tables contain information according to the wiring connections described in Chapter 2.1.

Table 2-1 Technical data for the TRIP+ modules

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

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.

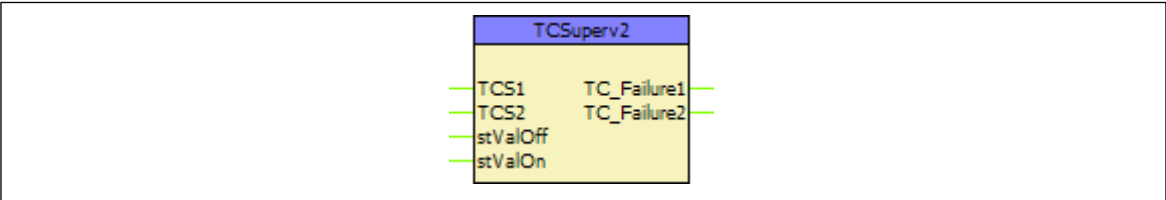


Figure 3-1 Graphic appearance of the Trip Circuit Supervision macro



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).

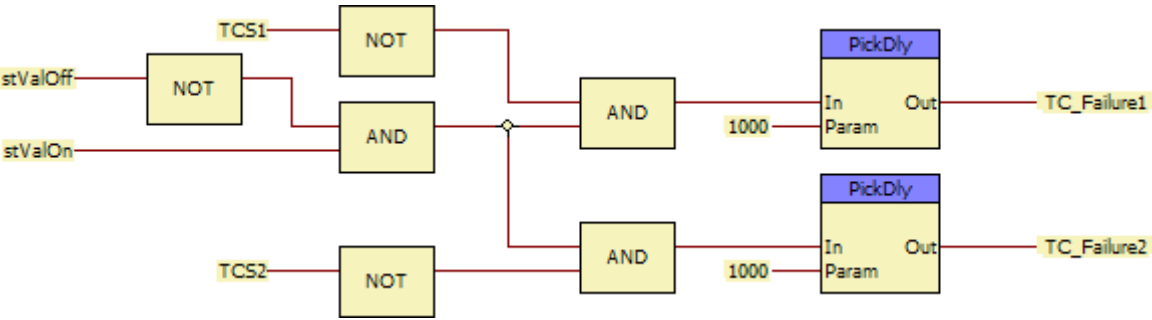
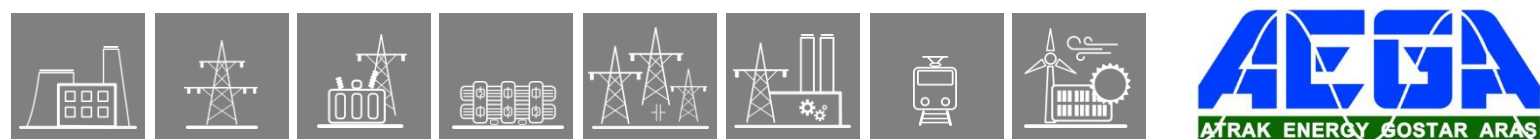


Figure 3-2 Internal logic of the Trip Circuit Supervision macro



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

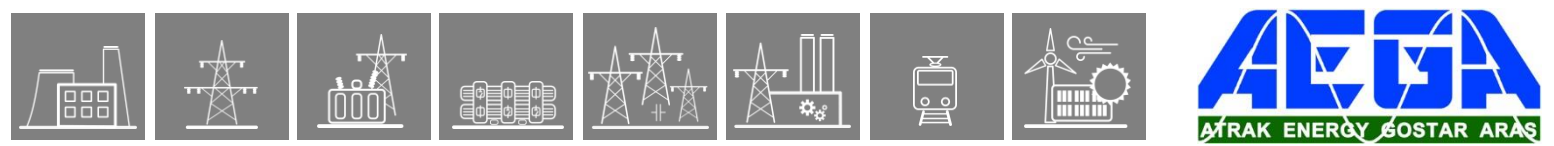
3.2.6.3.2.2. Binary output signals

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. Dead Line Detection Function

3.2.7.1. Application

The “Dead Line Detection” (DLD) function generates a signal indicating the dead or live state of the line. Additional signals are generated to indicate if the phase voltages and phase currents are above the pre-defined limits.

3.2.7.1.1. Mode of Operation

The task of the “Dead Line Detection” (DLD) function is to decide the Dead line/Live line state.

Criteria of “Dead line” state: all three phase voltages are below the voltage setting value AND all three currents are below the current setting value.

Criteria of “Live line” state: all three phase voltages are above the voltage setting value.

3.2.7.1.2. Structure of the Algorithm

Figure 1-1 shows the structure of the dead line detection algorithm.

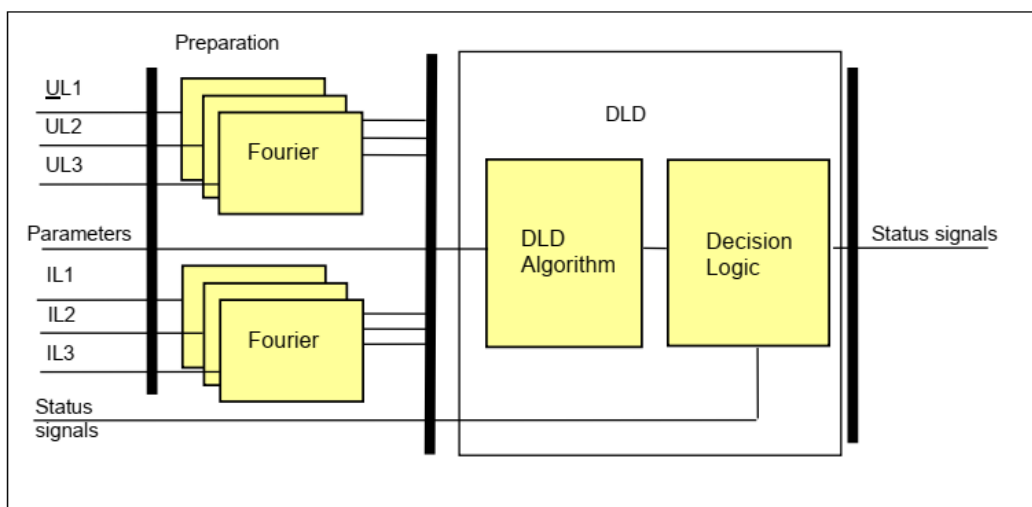


Figure 1-1 Structure of the dead line detection algorithm

For the preparation phase:

The **inputs** are

- the sampled values of the three phase voltages (UL1, UL2, UL3) and three phase currents (IL1, IL2, IL3),
- parameters.

The **outputs** are

- the fundamental Fourier components of the three phase voltages (UL1, UL2, UL3) and three phase currents (IL1, IL2, IL3).

For the DLD function:

The **inputs** are

- the fundamental Fourier components of the three phase voltages (UL1, UL2, UL3) and three phase currents (IL1, IL2, IL3),
- parameters,
- status signals.

The **software modules** of the dead line detection function are:

Fourier calculations

These modules calculate the basic Fourier components of the phase currents and phase voltages individually. These modules belong to the preparation phase.

Dead Line Detection

This module decides if the “Live line condition” (Line_OK) or the “DeadLine condition” is fulfilled.

Decision logic

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

The following description explains the details of the individual components.

3.2.7.1.3. The Fourier Calculation (Fourier)

These modules calculate the basic Fourier current components of the phase voltages and phase currents individually. These modules belong to the preparation phase.

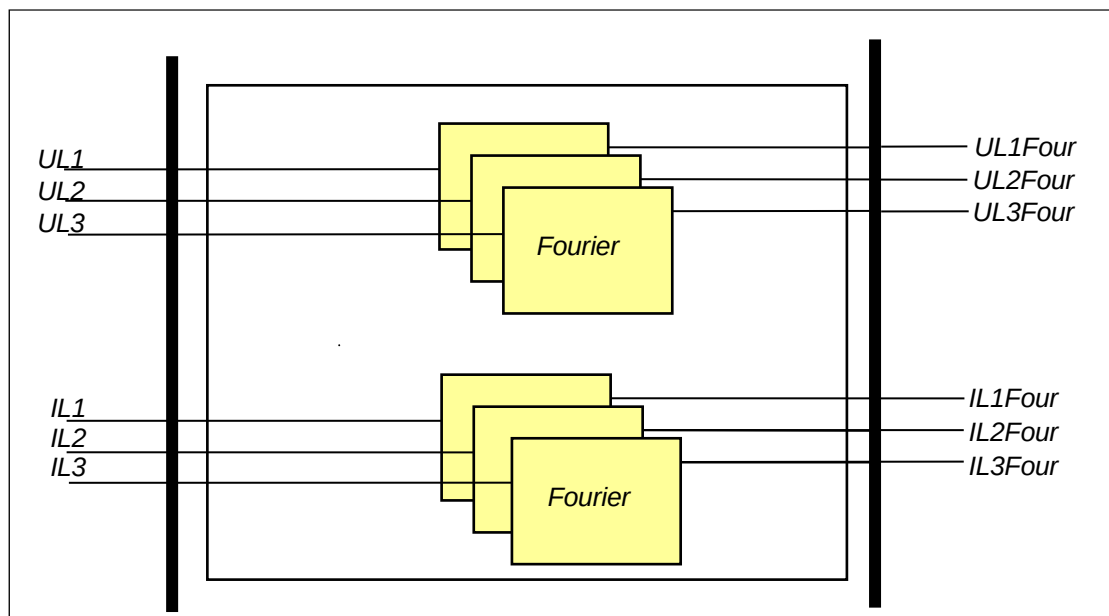


Figure 1-2 Principal scheme of the Fourier calculation

The **inputs** are the sampled values of:

- the three phase voltages (UL1, UL2, UL3)
- the three phase currents (IL1, IL2, IL3)

The **outputs** are:

- the basic Fourier components of the analyzed voltages (UL1Four, UL2Four, UL3Four),
- the basic Fourier components of the analyzed currents (IL1Four, IL2Four, IL3Four).

3.2.7.1.4. The Dead Line Detection Algorithm (Dead Line Detection)

This module decides if the “Live line condition” (Line_OK) or the “DeadLine condition” is fulfilled.

The **inputs** are

- the basic Fourier components of the phase voltages (UL1Four, UL2Four, UL3Four),
- the basic Fourier components of the phase currents (IL1Four, IL2Four, IL3Four),
- status signals,
- parameters.

The **outputs** are the internal status signals of the function. These indicate the “DeadLine condition” or the “Live line condition” (Line_OK) state.

Criteria of “Dead line” state: all three phase voltages are below the voltage setting value AND all three currents are below the current setting value.

Criteria of “Live line” state: all three phase voltages are above the voltage setting value.

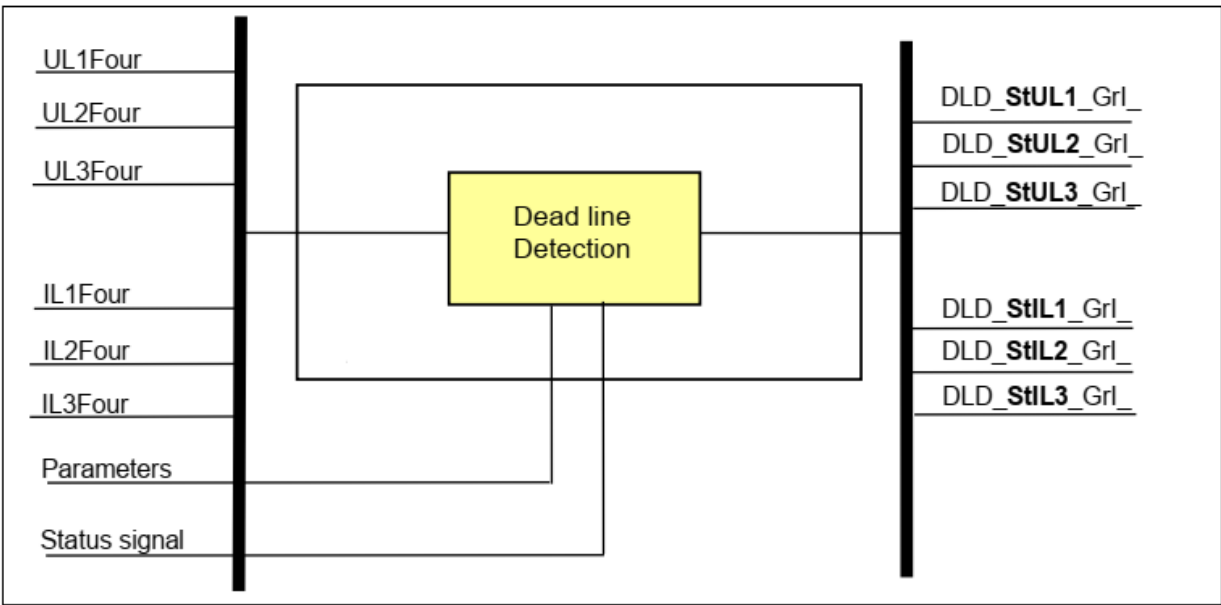


Figure 1-3 Principal scheme of the dead line detection function

Enumerated parameters

Table 1-1 The enumerated parameters of the dead line detection function

TITLE	DIM	RANGE	STEP	DEFAULT	EXPLANATION
Operation	-	Off, On	-	Off	Parameter for enabling the function

Integer parameters

Table 1-2 The integer parameters of the dead line detection function

TITLE	DIM	RANGE	STEP	DEFAULT	EXPLANATION
Min Operate Voltage	%	10 – 100	1	60	Voltage setting for “Dead line” state criteria.
Min Operate Current	%	2 – 100	1	10	Current setting for “Dead line” state criteria.

Binary status signals

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

Table 1-3 The binary input signal of the dead line detection function

BINARY STATUS SIGNAL	SIGNAL TITLE	EXPLANATION
DLD_ Blk _GrO_	Block	Input used to disable the function

The **binary output status signals** of the residual dead line detection function are listed in [Table 1-4](#).

Table 1-4 The binary output status signals of the dead line detection function

BINARY OUTPUT SIGNAL	SIGNAL TITLE	EXPLANATION
DLD_ StUL1 _GrI_	Start UL1	The voltage of phase L1 is above the setting limit
DLD_ StUL2 _GrI_	Start UL2	The voltage of phase L2 is above the setting limit
DLD_ StUL3 _GrI_	Start UL3	The voltage of phase L3 is above the setting limit
DLD_ StIL1 _GrI_	Start IL1	The current of phase L1 is above the setting limit
DLD_ StIL2 _GrI_	Start IL2	The current of phase L2 is above the setting limit
DLD_ StIL3 _GrI_	Start IL3	The current of phase L3 is above the setting limit

3.2.7.1.5. The Decision Logic (Decision logic)

The decision logic module combines status signals, binary and enumerated parameters to generate the dead line or live line status signals.

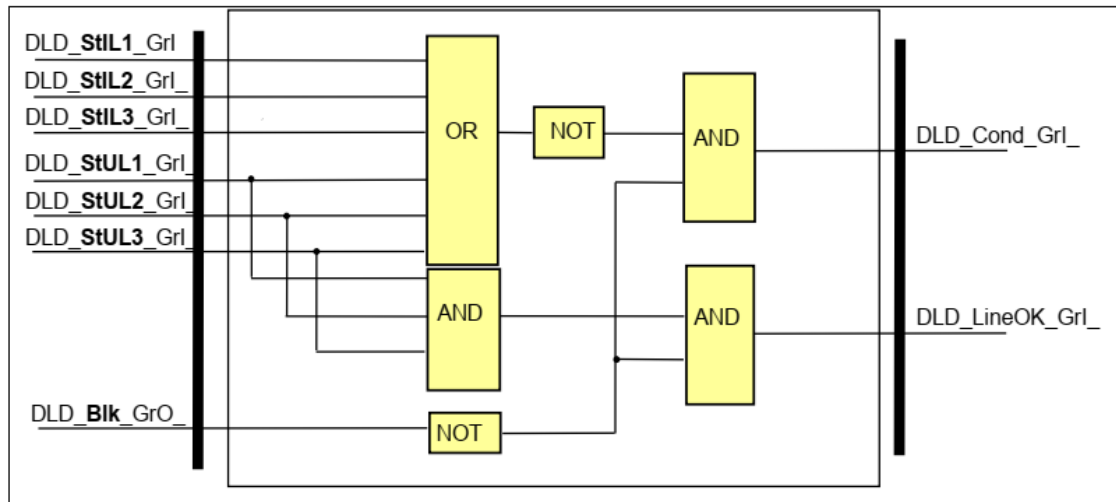


Figure 1-4 The logic scheme of the decision logic

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

BINARY INPUT SIGNAL	SIGNAL TITLE	EXPLANATION
DLD_StUL1_GrI_	Start UL1	The voltage of phase L1 is above the setting limit
DLD_StUL2_GrI_	Start UL2	The voltage of phase L2 is above the setting limit
DLD_StUL3_GrI_	Start UL3	The voltage of phase L3 is above the setting limit
DLD_StIL1_GrI_	Start IL1	The current of phase L1 is above the setting limit
DLD_StIL2_GrI_	Start IL2	The current of phase L2 is above the setting limit
DLD_StIL3_GrI_	Start IL3	The current of phase L3 is above the setting limit

Binary status signals

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

Table 1-6 The binary input signal of the dead line detection function

BINARY STATUS SIGNAL	SIGNAL TITLE	EXPLANATION
DLD_BlK_GrO_	Block	Input for disabling the function

Table 1-7 The binary output status signals of the dead line detection function

BINARY OUTPUT SIGNAL	SIGNAL TITLE	EXPLANATION
DLD_DeadLine_GrI_	DeadLine condition	The requirements of "DeadLine condition" are fulfilled
DLD_LineOK_GrI_	LineOK condition	The requirements of "Live line condition" (LineOK) are fulfilled

3.2.7.2. DeadLine Detection Function Overview

The graphic appearance of the dead line detection function block is shown in [Figure 2-1](#). This block shows all binary input and output status signals that are applicable in the graphic equation editor.

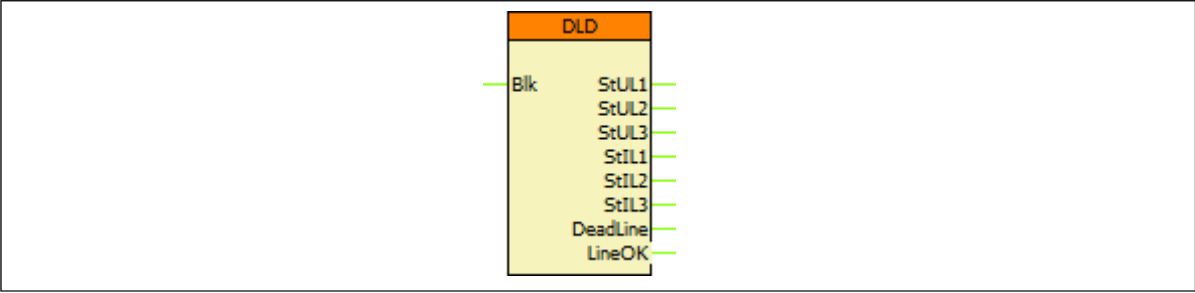


Figure 2-1 The function block of the residual instantaneous overcurrent protection

3.2.7.2.1. Settings

3.2.7.2.1.1. Parameters

The available parameters are listed below in order of their appearance in the *parameters* menu. If the setting range of a parameter should be extended, contact Protecta Support.

Table 2-1 Parameters of the dead line detection function

TITLE	DIM	RANGE	STEP	DEFAULT	EXPLANATION
Operation	-	Off, On	-	Off	Parameter for enabling the function
Min Operate Voltage	%	10 – 100	1	60	Voltage setting for “Dead line” state criteria.
Min Operate Current	%	2 – 100	1	10	Current setting for “Dead line” state criteria.

3.2.7.2.2. Function I/O

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

3.2.7.2.2.1. Analogue inputs

The analog inputs are the sampled values of the three phase voltages and the three phase currents.

3.2.7.2.2.2. Binary input signals (graphed output statuses)

The conditions of the binary inputs are defined by the user, applying the graphic equation editor (*Logic Editor*). Parts written in **bold** are seen on the left side of the function block in the Logic editor.

Table 2-2 The binary input signals of the dead line detection function

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

3.2.7.2.2.3. Binary output signals (graphed input statuses)

These signals can be used in EuroCAP to assign to LED, user LCD object etc. Parts written in **bold** are seen on the right side of the function block in the *Logic Editor*.

Table 2-3 The binary output signals of the dead line detection function

BINARY OUTPUT SIGNAL	SIGNAL TITLE	EXPLANATION
DLD_ StUL1 _GrI_	Start UL1	The voltage of phase L1 is above the setting limit
DLD_ StUL2 _GrI_	Start UL2	The voltage of phase L2 is above the setting limit
DLD_ StUL3 _GrI_	Start UL3	The voltage of phase L3 is above the setting limit
DLD_ StIL1 _GrI_	Start IL1	The current of phase L1 is above the setting limit
DLD_ StIL2 _GrI_	Start IL2	The current of phase L2 is above the setting limit
DLD_ StIL3 _GrI_	Start IL3	The current of phase L3 is above the setting limit
DLD_ DeadLine _GrI_	DeadLine condition	The requirements of "DeadLine condition" are fulfilled
DLD_ LineOK _GrI_	LineOK condition	The requirements of "Live line condition" (LineOK) are fulfilled

3.2.7.2.2.4. Online data

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

Table 2-4 Online data of the dead line detection function

SIGNAL TITLE	DIMENSION	EXPLANATION
DeadLine condition	-	The requirements of "DeadLine condition" are fulfilled
LineOK condition	-	The requirements of "Live line condition" are fulfilled



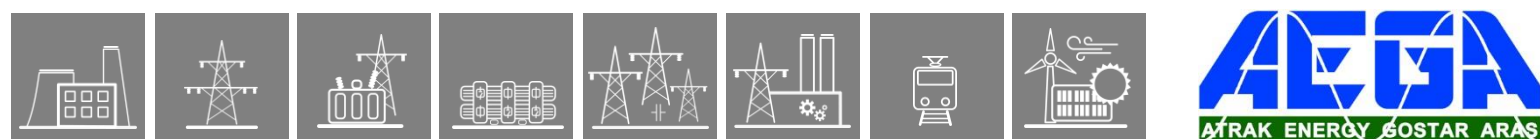
3.2.7.2.2.5. **Events**

There are no events generated for this function block.

3.2.7.2.3. **Technical Data**

Table 2-5 Technical data of the dead line detection function

FUNCTION	VALUE	ACCURACY
Pick-up voltage		1%
Operation time	< 20 ms	
Reset ratio	0.95	



3.2.8. Voltage transformer supervision function

The voltage transformer supervision function generates a signal to indicate an error in the voltage transformer secondary circuit. This signal can serve, for example, as a warning, indicating disturbances in the measurement, or it can disable the operation of the distance protection function if appropriate measured voltage signals are not available for a distance decision.

The voltage transformer supervision function is designed to detect faulty asymmetrical states of the voltage transformer circuit caused, for example, by a broken conductor in the secondary circuit.

(Another method for detecting voltage disturbances is the supervision of the auxiliary contacts of the miniature circuit breakers in the voltage transformer secondary circuits. This function is not described here.)

The user has to generate graphic equations for the application of the signal of this voltage transformer supervision function.

This function is interconnected with the “dead line detection function”. Although the dead line detection function is described fully in a separate document, the explanation necessary to understand the operation of the VT supervision function is repeated also in this document.

3.2.8.1. Mode of operation

3.2.8.1.1. “Dead line detection” (DLD) function - modes of operation

The voltage transformer supervision function is based on the “Dead line detection” (DLD) function, the task of which is to decide the Dead line/Live line state.

Criteria of “Dead line” state: all three phase voltages are below the preset voltage value AND all three currents are below the preset current value.

Criteria of “Live line” state: all three phase voltages are above the preset voltage value.

The dead line detection function is described in a separate document.

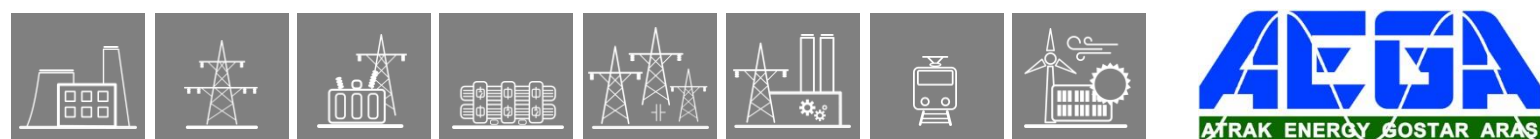
3.2.8.1.2. “Voltage transformer supervision” (VTS) function - modes of operation

The voltage transformer supervision function can be used in three different modes of application:

Zero sequence detection (for typical applications in systems with grounded neutral): “VT failure” signal is generated if the residual voltage ($3U_0$) is above the preset voltage value AND the residual current ($3I_0$) is below the preset current value.

Negative sequence detection (for typical applications in systems with isolated or resonant grounded (Petersen) neutral): “VT failure” signal is generated if the negative sequence voltage component (U_2) is above the preset voltage value AND the negative sequence current component (I_2) is below the preset current value.

Special application: “VT failure” signal is generated if the residual voltage ($3U_0$) is above the preset voltage value AND the residual current ($3I_0$) AND the negative sequence current component (I_2) are below the preset current values.



3.2.8.1.3. Activating the VTS function

The voltage transformer supervision function can be activated if “Live line” status is detected for at least 200 ms. This delay avoids mal-operation at line energizing if the poles of the circuit breaker make contact with a time delay. The function is set to be inactive if “Dead line” status is detected.

If the conditions specified by the selected mode of operation are fulfilled (for at least 4 milliseconds) then the voltage transformer supervision function is activated and the operation signal is generated. (When evaluating this time delay, the natural operating time of the applied Fourier algorithm must also be considered.)

NOTE: For the operation of the voltage transformer supervision function the “Dead line detection function” must be operable as well: it must be enabled by binary parameter setting, and its blocking signal may not be active.

3.2.8.1.4. Resetting the VTS function

If, in the active state, the conditions for operation are no longer fulfilled, the resetting of the function depends on the mode of operation of the primary circuit:

- If the “Live line” state is valid, then the function resets after approx. 200 ms of time delay. (When evaluating this time delay, the natural operating time of the applied Fourier algorithm must also be considered.)
- If the “Dead line” state is started and the “VTS Failure” signal has been continuous for at least 100 ms, then the “VTS failure” signal does not reset; it is generated continuously even when the line is in a disconnected state. Thus, the “VTS Failure” signal remains active at reclosing.
- If the “Dead line” state is started and the “VTS Failure” signal has not been continuous for at least 100 ms, then the “VTS failure” signal resets.

3.2.8.2. Structure of the voltage transformer supervision algorithm

Fig.1-1 shows the structure of the voltage transformer supervision (VTS) algorithm.

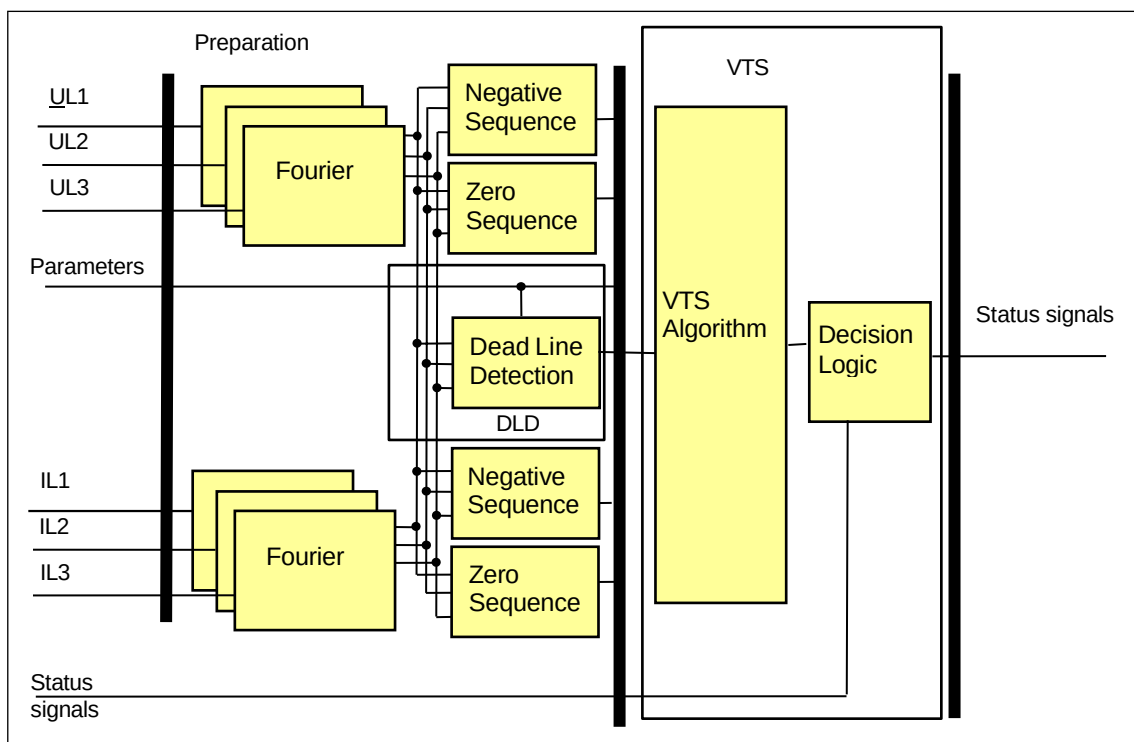


Figure 1-1 Structure of the voltage transformer supervision algorithm

For the preparation phase:

The **inputs** are

- the sampled values of the three phase voltages (UL1, UL2, UL3) and three phase currents (IL1, IL2, IL3),
- parameters.

The **outputs** are

- negative and zero sequence voltage and current components.
- signals indicating the “Live line” or “Dead line” condition.

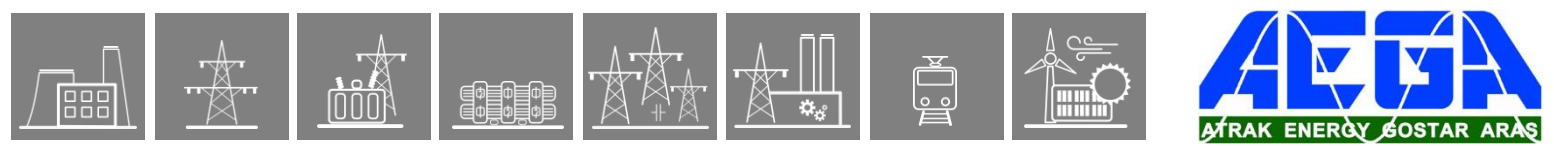
For the VTS function:

The **inputs** are

- negative and zero sequence voltage and current components.
- signals indicating the “Live line” or “Dead line” condition,
- parameters,
- status signals.

The **outputs** are

- the binary output status signal indicating a failure of the voltage transformer secondary circuit,
- signals indicating the “Live line” or “Dead line” condition.



The **software modules** of the voltage transformer supervision function and those of the preparation phase:

Fourier calculations

These modules calculate the basic Fourier current components of the phase voltages and currents. These modules belong to the preparation phase.

Negative sequence

This module calculates the basic Fourier current components of the negative sequence voltage and current, based on the Fourier components of the phase voltages and currents. This module belongs to the preparation phase.

Zero sequence

This module calculates the basic Fourier voltage and current components of the residual voltage ($3U_0$) and current ($3I_0$), based on the Fourier components of the phase voltages and currents. This module belongs to the preparation phase.

Dead Line Detection

This module decides if the “Line_OK condition” or the “DeadLine condition” is fulfilled. This module belongs to the preparation phase.

VTS algorithm

This module decides if the “VTS_FAIL” conditions are fulfilled according to the conditions specified for the selected mode.

Decision logic

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

The following description explains the details of the individual components.

3.2.8.3. The Fourier calculation (Fourier)

These modules calculate the basic Fourier current components of the phase voltages and phase currents individually. These modules belong to the preparation phase.

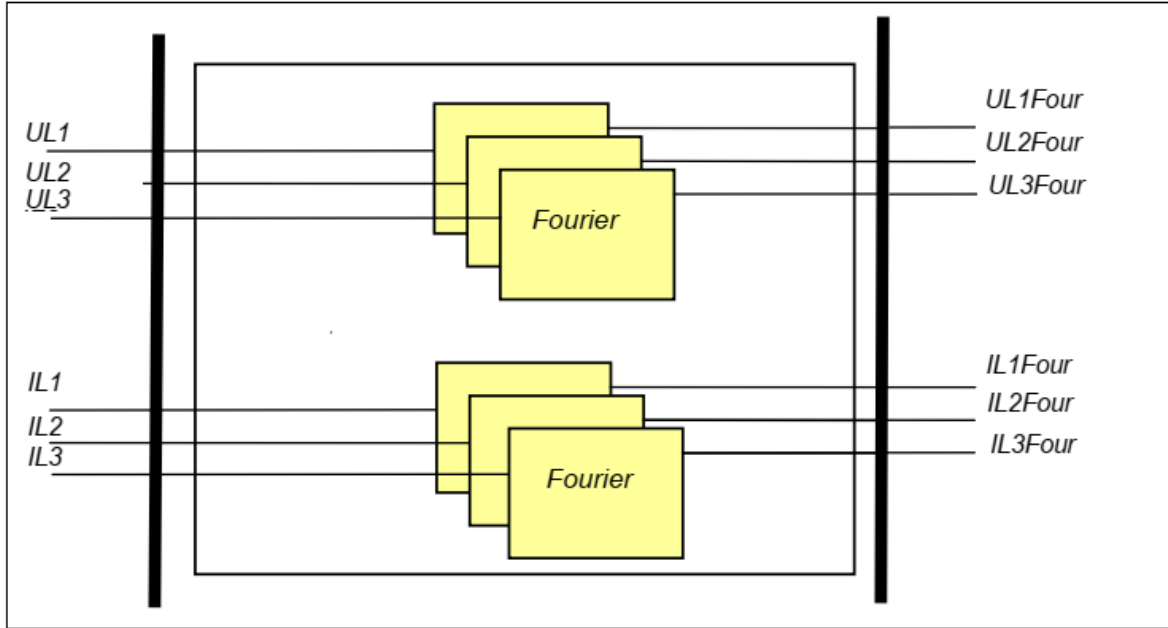


Figure 1-2 Principal scheme of the Fourier calculation

The **inputs** are the sampled values of:

- the three phase voltages (UL1, UL2, UL3)
- the three phase currents (IL1, IL2, IL3)

The **outputs** are

- the basic Fourier components of the analyzed voltages (UL1Four, UL2Four, UL3Four),
- the basic Fourier components of the analyzed currents (IL1Four, IL2Four, IL3Four).

3.2.8.4. The negative phase sequenc calculation (Negative sequence)

This module calculates the negative phase sequence components based on the Fourier components of the phase voltages and phase currents. These modules belong to the preparation phase.

The **inputs** are the basic Fourier components of the phase voltages and phase currents (UL1Four, UL2Four, UL3Four, IL1Four, IL2Four, IL3Four).

The **outputs** are

- the basic Fourier components of the negative sequence voltage component (UNegFour),
- the basic Fourier components of the negative sequence current component (INegFour).

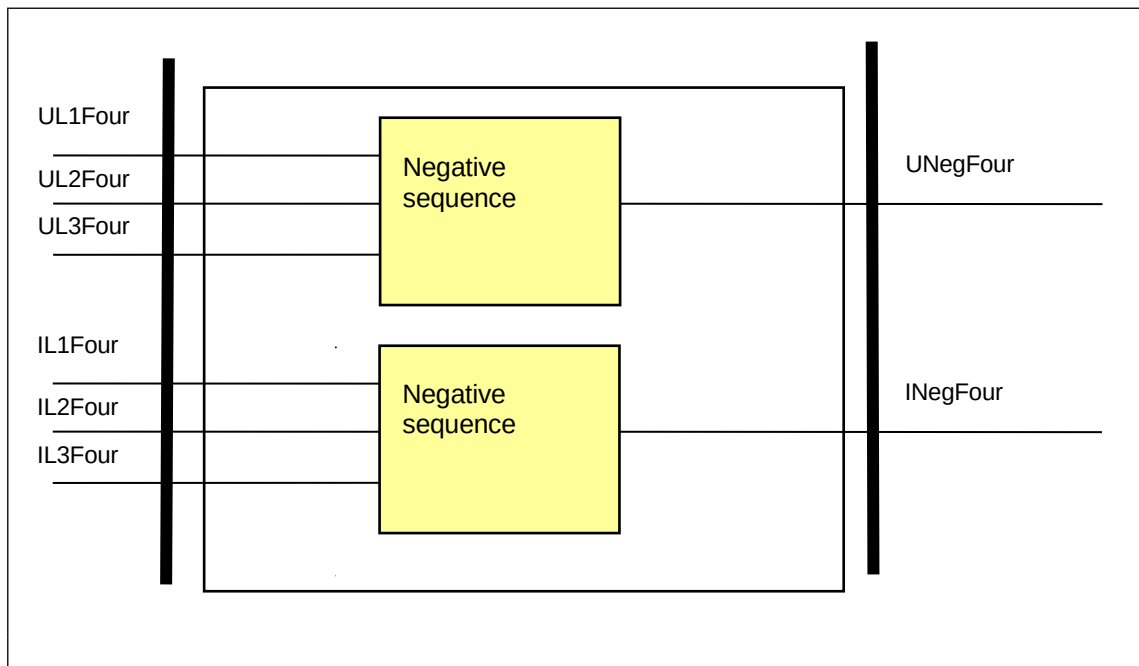


Figure 1-3 Schema of the negative sequence component calculation

3.2.8.5. The residual voltage and current calculation (Zero sequence)

This module calculates the residual voltage ($U_{ZerFour}$) and current ($I_{ZerFour}$) based on the Fourier components of the phase voltages and currents. These modules belong to the preparation phase.

The **inputs** are

- the basic Fourier components of the phase voltages ($UL1Four$, $UL2Four$, $UL3Four$),
- the basic Fourier components of the phase currents ($IL1Four$, $IL2Four$, $IL3Four$).

The **outputs** are

- the basic Fourier components of the residual voltage ($U_{ZerFour}$),
- the basic Fourier components of the residual current ($I_{ZerFour}$).

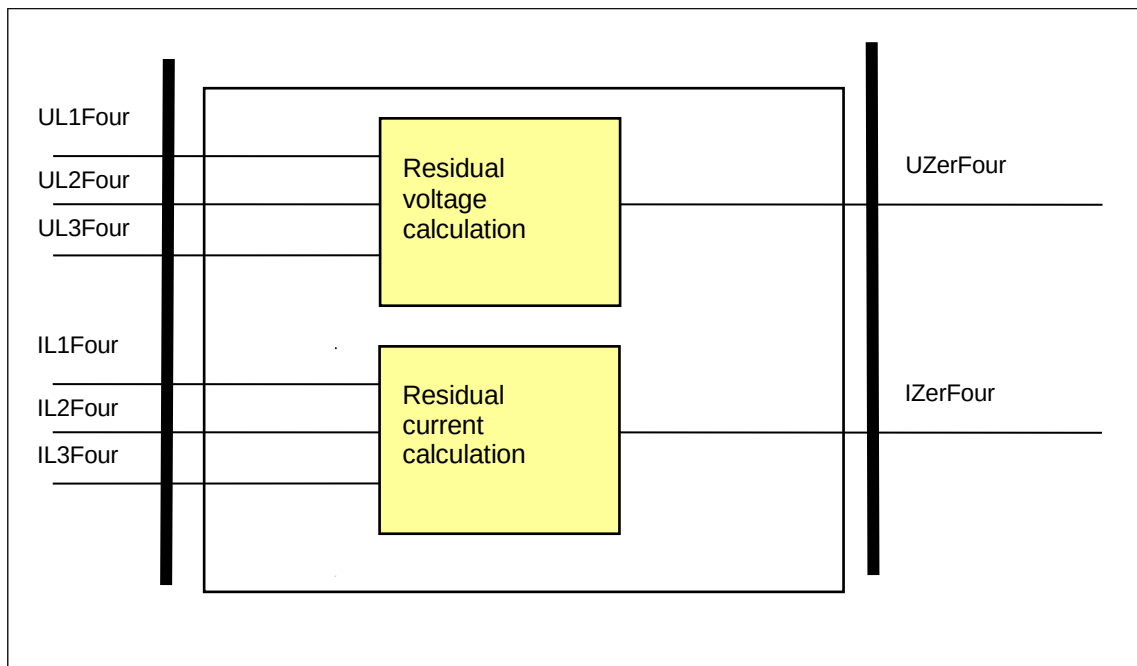
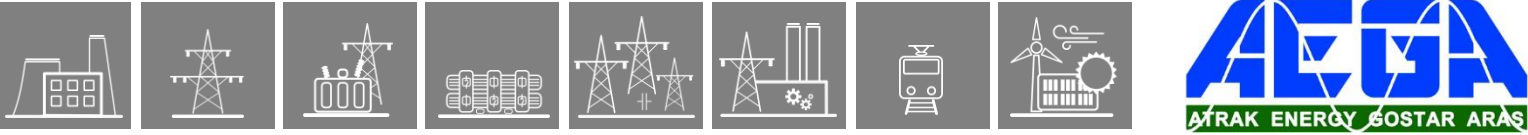


Figure 1-4 Schema of the residual voltage and current calculation



3.2.8.6. The dead line detection algorithm (Dead Line Detection)

This module decides if the “Line_OK condition” or the “DeadLine condition” is fulfilled. This module belongs to the preparation phase.

The **inputs** are

- the basic Fourier components of the phase voltages (UL1Four, UL2Four, UL3Four),
- the basic Fourier components of the phase currents (IL1Four, IL2Four, IL3Four),
- parameters.

The **outputs** are the internal status signals of the function. These indicate the “DeadLine condition state” or the “Line_OK conditions” state. This module belongs to the preparation phase.

Criteria of “Dead line” state: all three phase voltages are below the voltage setting value AND all three currents are below the current setting value.

Criteria of “Live line” state: all three phase voltages are above the voltage setting value.

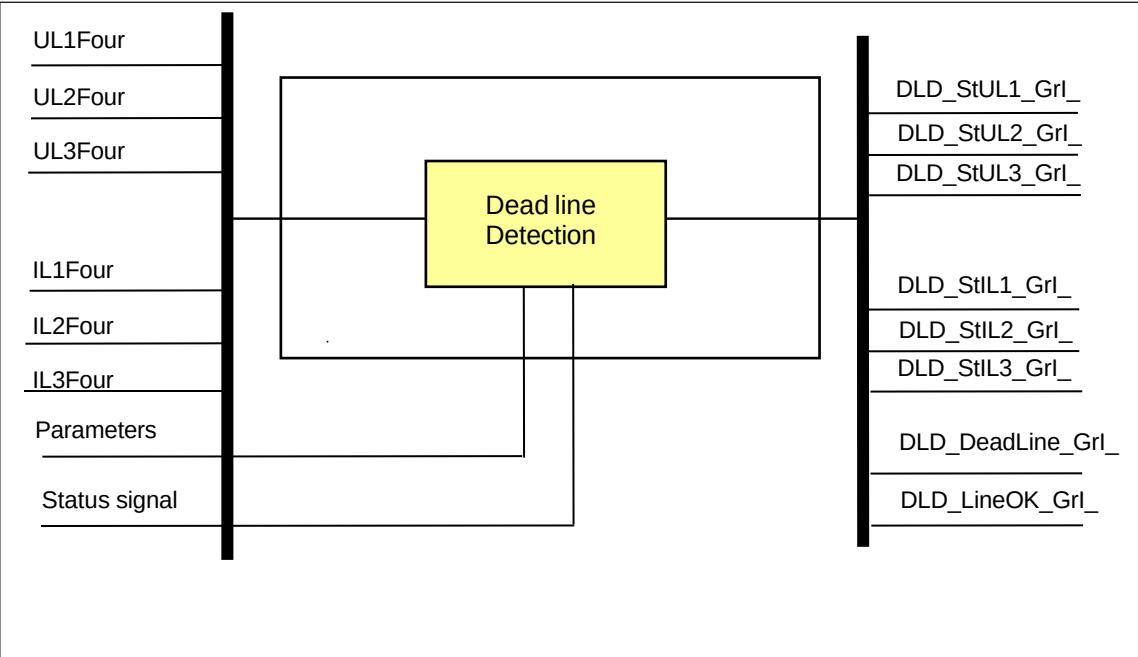


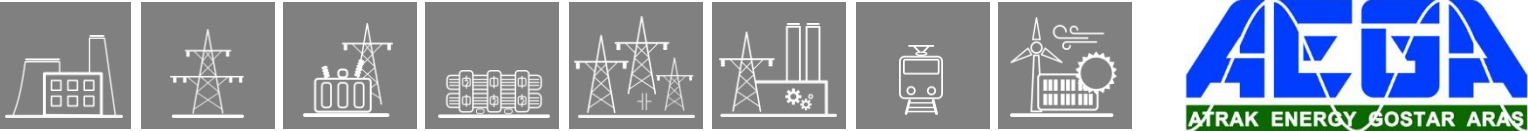
Figure 1-5 Principal scheme of the dead line detection function

The parameters of the dead line detection function are listed in [Table 1-1](#).

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Integer parameters of the dead line detection function						
DLD_ULev_IPar_	Min Operate Voltage	%	10	100	1	60
DLD_ILev_IPar_	Min Operate Current	%	2	100	1	10

Table 1-1 The integer parameters of the dead line detection function



Binary status signals

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

Binary status signal	Explanation
DLD_BlK_GrO_	Output status of a graphic equation defined by the user to disable the dead line detection function.

Table 1-2 The binary input signal of the dead line detection function

The **binary output status signals** of the dead line detection function are listed in Table 1-3.

Binary output signals	Signal title	Explanation
DLD_StUL1_GrI_	Start UL1	The voltage of phase L1 is above the preset parameter value
DLD_StUL2_GrI_	Start UL2	The voltage of phase L2 is above the preset parameter value
DLD_StUL3_GrI_	Start UL3	The voltage of phase L3 is above the preset parameter value
DLD_StIL1_GrI_	Start IL1	The current of phase L1 is above the preset parameter value
DLD_StIL2_GrI_	Start IL2	The current of phase L2 is above the preset parameter value
DLD_StIL3_GrI_	Start IL3	The current of phase L3 is above the preset parameter value
DLD_DeadLine_GrI_	DeadLine condition	The criteria for dead line condition are fulfilled
DLD_LineOK_GrI_	LineOK condition	The criteria for line OK condition are fulfilled

Table 1-3 The binary output status signals of the dead line detection function

3.2.8.7. Voltage transformer supervision (VTS algorithm)

The voltage transformer supervision function can be used in three different modes of operation:

Zero sequence detection (for typical applications in systems with grounded neutral): “VT failure” signal is generated if the residual voltage ($3U_0$) is above the preset voltage value AND the residual current ($3I_0$) is below the preset current value.

Negative sequence detection (for typical applications in systems with isolated or resonant grounded (Petersen) neutral): “VT failure” signal is generated if the negative sequence voltage component (U_2) is above the preset voltage value AND the negative sequence current component (I_2) is below the preset current value.

Special application: “VT failure” signal is generated if the residual voltage ($3U_0$) is above the preset voltage value AND the residual current ($3I_0$) AND the negative sequence current component (I_2) are below the preset current values.

The task of this module is to detect if the conditions of the “VTS FAIL” state are fulfilled, according to the conditions defined for the selected mode of operation.

The **inputs** are

- the basic Fourier components of the residual voltage ($U_{ZerFour}$) and current ($I_{ZerFour}$),
- the negative sequence components of the voltage ($U_{NegFour}$) and current ($I_{NegFour}$),
- binary signals from the dead line detection function,
- parameters.

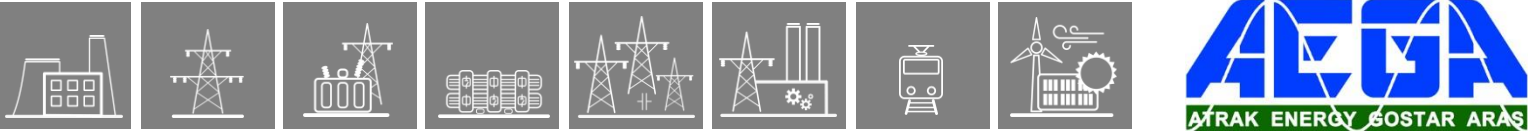
NOTE: For the operation of the voltage transformer supervision function the “Dead line detection function” must be operable as well: it must be enabled by binary parameter setting, and its blocking signal may not be active.

The **output** is the internal status signal of the function. This internal signal indicates if the “VTS_FAIL_int” condition is fulfilled.

Binary output signals	Signal title	Explanation
VTS_FAIL_int	VTS_FAIL_int	Internal status signal indicating the fulfillment of conditions. This status signal is not available for the users.

Table 1-4 The binary internal status signals of the voltage transformer supervision algorithm

The parameters of the voltage transformer supervision algorithm are listed in [Table 1-5](#) and in [Table 1-6](#).



Enumerated parameter

Parameter name	Title	Selection range	Default
Parameter for type selection			
VTS_Oper_EPar_	Operation	Off, Zero sequence, Neg sequence, Special	Zero sequence

Table 1-5 The enumerated parameters of the voltage transformer supervision function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Starting voltage and current parameter for residual and negative sequence detection:						
VTS_Uo_IPar_	Start URes	%	5	50	1	30
VTS_Io_IPar_	Start IRes	%	10	50	1	10
VTS_Uneg_IPar_	Start UNeg	%	5	50	1	10
VTS_Ineg_IPar_	Start INeg	%	10	50	1	10

Table 1-6 The integer parameters of the voltage transformer supervision algorithm

Binary status signals

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

Binary status signal	Explanation
VTS_BlK_GrO_	Output status of a graphic equation defined by the user to disable the voltage transformer supervision function.

Table 1-8 The binary input signal of the decision logic

Binary output signals	Signal title	Explanation
DLD_DeadLine_GrI_	DeadLine condition	The requirements of “DeadLine condition” are fulfilled
DLD_LineOK_GrI_	LineOK condition	The requirements of “LineOK condition” are fulfilled
VTS_Fail_GrI	VT Failure	Failure status signal of the VTS function

Table 1-9 The binary output status signals of the decision logic

3.2.8.9. Technical summary

3.2.8.9.1. Technical data

Function	Value	Accuracy
Pick-up voltage I ₀ =0A I ₂ =0A		<1% <1%
Operation time	<20ms	
Reset ratio	0.95	

Table 1-10 Technical data of the voltage transformer supervision function

3.2.8.9.2. The parameters

Integer parameters

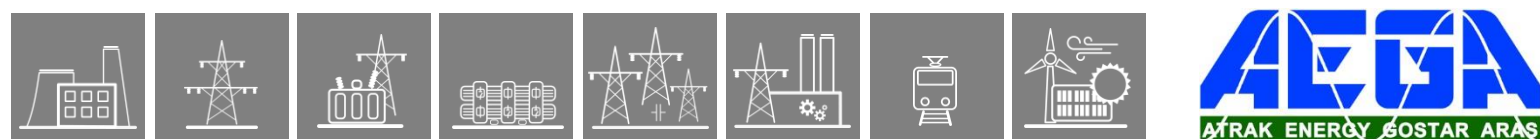
Parameter name	Title	Unit	Min	Max	Step	Default
Integer parameters of the dead line detection function						
DLD_ULev_IPar_	Min Operate Voltage	%	10	100	1	60
DLD_ILev_IPar_	Min Operate Current	%	2	100	1	10
Starting voltage and current parameter for residual and negative sequence detection:						
VTS_Uo_IPar_	Start URes	%	5	50	1	30
VTS_Io_IPar_	Start IRes	%	10	50	1	10
VTS_Uneg_IPar_	Start UNeg	%	5	50	1	10
VTS_Ineg_IPar_	Start INeg	%	10	50	1	10

Table 1-11 The integer parameters of the voltage transformer supervision function

Enumerated parameter

Parameter name	Title	Selection range	Default
Parameter for type selection			
VTS_Oper_EPar_	Operation	Off, Zero sequence, Neg. sequence, Special	Zero sequence

Table 1-12 The enumerated parameter of the voltage transformer supervision function



3.2.8.9.3. The binary input status signals

Binary status signals

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

Binary status signal	Explanation
VTS_BlK_GrO_	Output status of a graphic equation defined by the user to disable the voltage transformer supervision function.

Table 1-13 The binary input signal of the voltage transformer supervision function

3.2.8.9.4. Binary output status signals

The **binary output status signals** of the voltage transformer supervision function are listed in Table 1-14.

Binary output signals	Signal title	Explanation
DLD function		
DLD_StUL1_Grl_	Start UL1	The voltage of phase L1 is above the preset parameter value, signal of the DLD function
DLD_StUL2_Grl_	Start UL2	The voltage of phase L2 is above the preset parameter value, signal of the DLD function
DLD_StUL3_Grl_	Start UL3	The voltage of phase L3 is above the preset parameter value, signal of the DLD function
DLD_StIL1_Grl_	Start IL1	The current of phase L1 is above the preset parameter value, signal of the DLD function
DLD_StIL2_Grl_	Start IL2	The current of phase L2 is above the preset parameter value, signal of the DLD function
DLD_StIL3_Grl_	Start IL3	The current of phase L3 is above the preset parameter value, signal of the DLD function
DLD_DeadLine_Grl_	DeadLine condition	The requirements of "DeadLine condition" are fulfilled, signal of the DLD function
DLD_LineOK_Grl_	LineOK condition	The requirements of "LineOK condition" are fulfilled, signal of the DLD function
VTS function		
VTS_Fail_Grl	VT Failure	Failure status signal of the VTS function

Table 1-14 The binary output signals of the voltage transformer supervision function

3.2.8.9.5. **The function block**

The function block of the dead line detection and voltage transformer supervision function is shown in Figure 1-7. This block shows all binary input and output status signals that are applicable in the graphic equation editor.

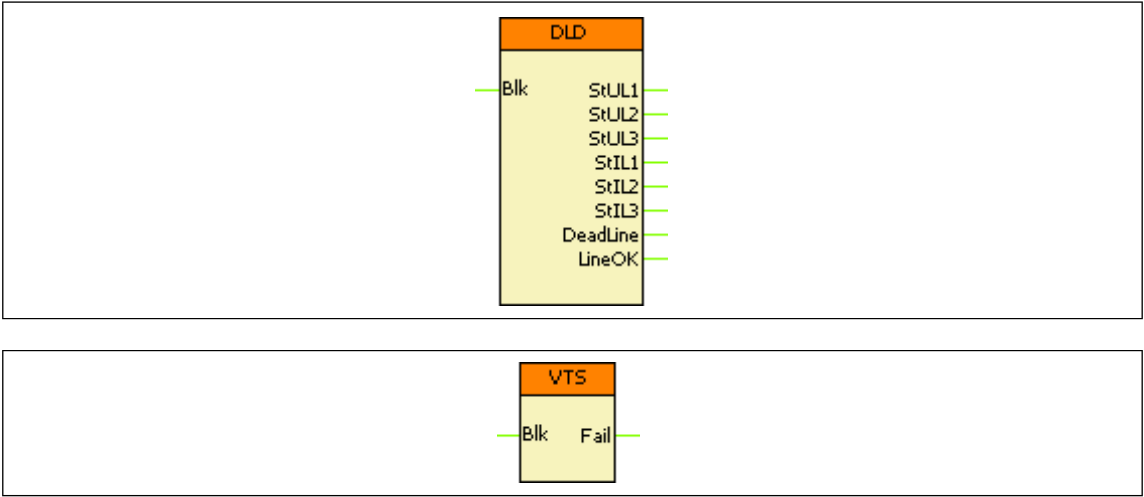


Figure 1-7 The function block of the dead line detection and voltage transformer supervision function

3.2.9. Current unbalance function

3.2.9.1. Application

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

3.2.9.1.1. Mode of operation

The applied method selects maximum and minimum phase currents (RMS values of the fundamental Fourier components). If the difference between them is above the setting limit, the function generates a start signal. It is a necessary precondition of start signal generation that the maximum of the currents be above 10 % of the rated current and below 150% of the rated current.

The function can be disabled by parameter setting, and by an input signal programmed by the user with the graphic programming tool.

The trip command is generated after the defined time delay if trip command is enabled by parameter setting.

3.2.9.1.2. Operation principles

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

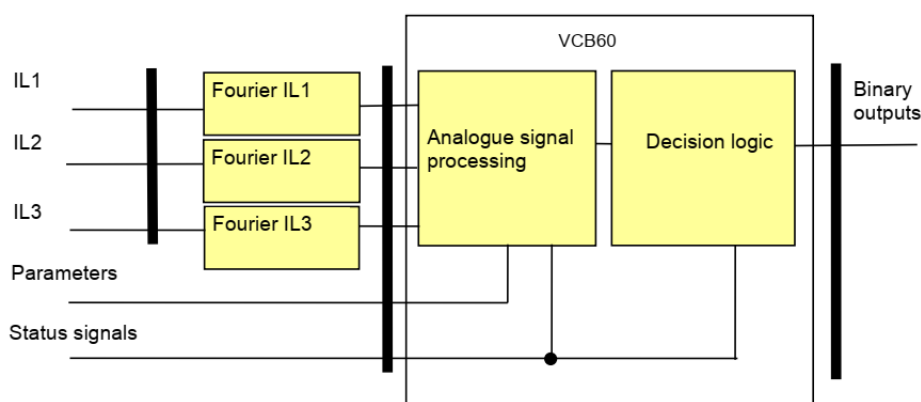


Figure 1-1 Structure of the current unbalance protection algorithm

The **inputs** of the preparatory phase are

- the three phase currents,

The **outputs** of the preparatory phase are

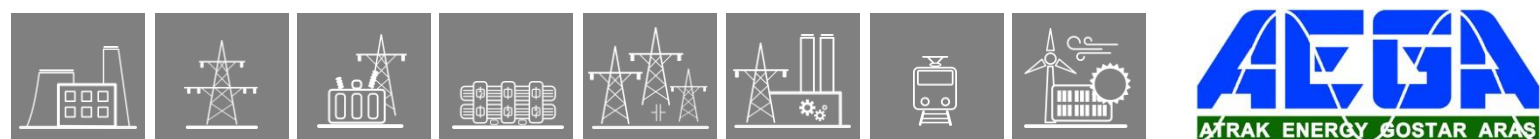
- the RMS values of the fundamental Fourier component of three phase currents.

The **inputs** of the current unbalance function are

- the RMS values of the fundamental Fourier component of three phase currents,
- parameters,
- status signals.

The **outputs** are

- the binary output status signals.



The **software modules** of the current unbalance function:

Fourier calculations

These modules calculate the RMS values of the basic Fourier current components of the phase currents individually (not part of the VCB60 function).

Analogue signal processing

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

Decision logic

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

The following description explains the details of the individual components.

3.2.9.1.3. The Fourier calculation (Fourier)

These modules calculate the RMS values of the fundamental Fourier components of the phase currents individually. They are not part of the VCB60 function; they belong to the preparatory phase.

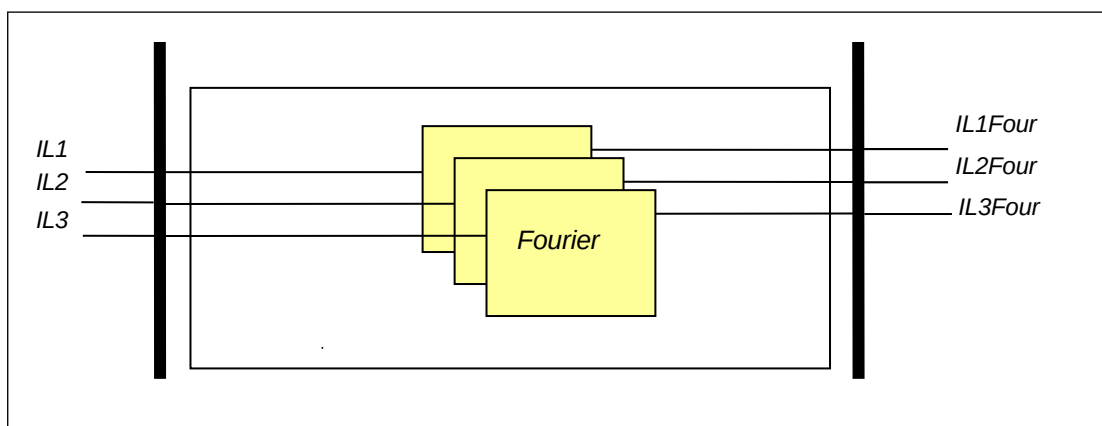


Figure 1-2 Principal scheme of the Fourier calculation

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

The **outputs** are the RMS values of the fundamental Fourier components of the phase currents (IL1Four, IL2Four, IL3Four).

3.2.9.1.4. The Analogue signal processing

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

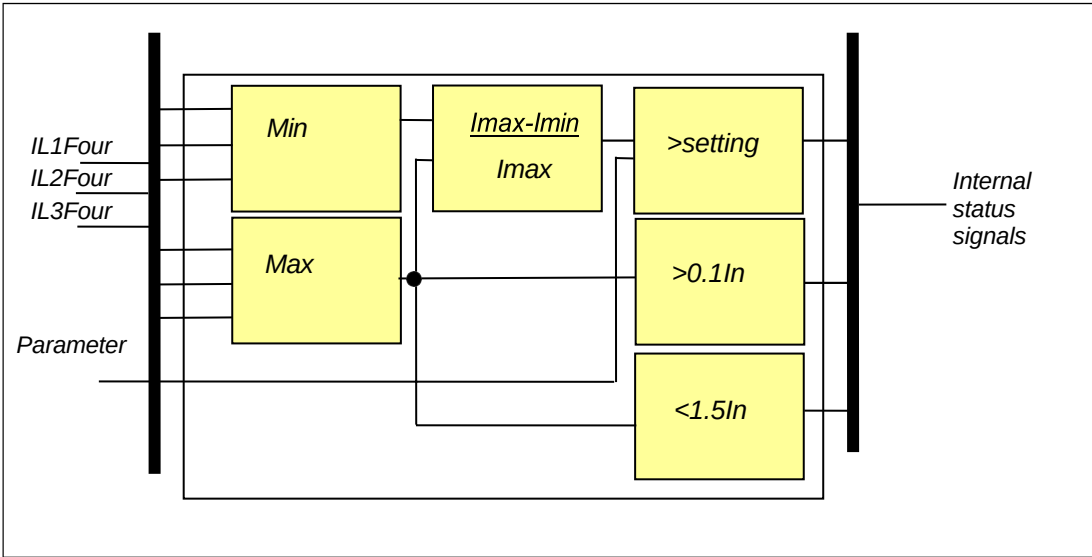


Figure 1-3 Principal scheme of the analogue signal processing

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

The **outputs** are internal binary signals:

- $\Delta I >$ The difference between the maximum and minimum of the RMS values of the fundamental Fourier components of the phase currents as a percentage of the maximum of these values is above the limit defined by the preset parameter "Start current";
- $I_{max} > 0.1 I_n$ The maximum of the RMS values of the fundamental Fourier components of the phase currents is sufficient for evaluation;
- $I_{max} < 1.5 I_n$ The maximum of the RMS values of the fundamental Fourier components of the phase currents is not considered as a fault current.

3.2.9.1.5. The decision logic (Decision logic)

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

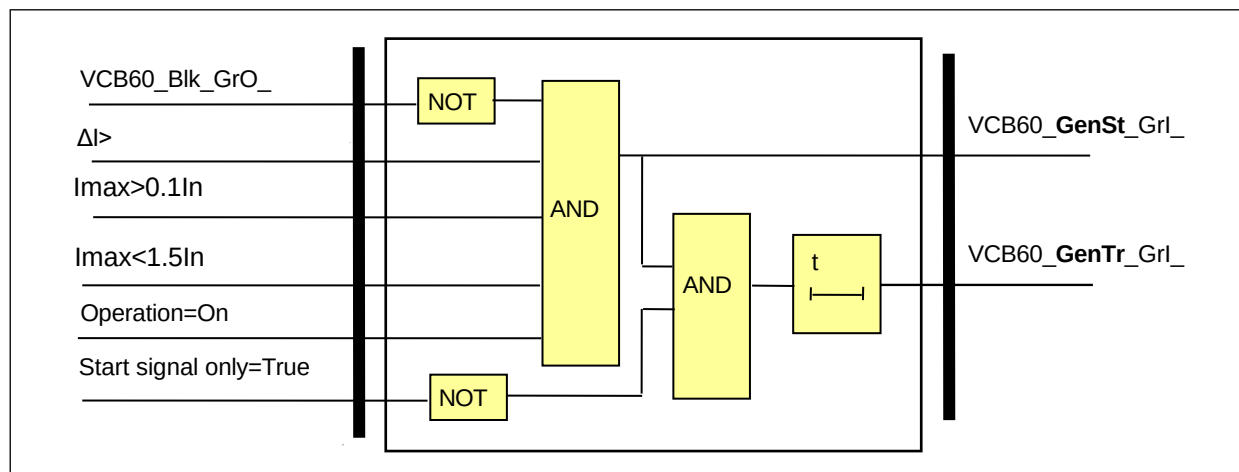


Figure 1-4 The logic scheme of the current unbalance function

The **inputs** are internal binary signals:

- $\Delta I >$ the difference between the maximum and minimum of the RMS values of the fundamental Fourier components of the phase currents as a percentage of the maximum of these values is above the limit defined by parameter setting "Start Current Diff";
- $I_{max} > 0.1 I_n$ the maximum of the RMS values of the fundamental Fourier components of the phase currents is sufficient for evaluation;
- $I_{max} < 1.5 I_n$ the maximum of the RMS values of the fundamental Fourier components of the phase currents is not considered as a fault current.

3.2.9.2. Current unbalance protection function overview

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

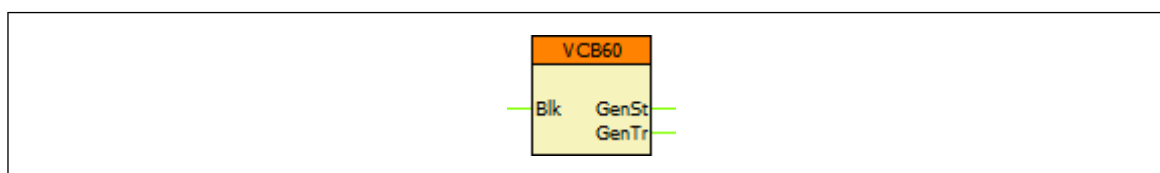


Figure 2-1 Graphic appearance of the function block of the current unbalance protection function



3.2.9.2.2.5. Events

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

Table 2-5 Generated events of the current unbalance protection function

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

3.2.9.2.3. Technical data

Table 2-6 Technical data of the current unbalance protection function

FUNCTION	VALUE	ACCURACY
Pick-up starting accuracy at In		< 2 %
Reset ratio	0,95	
Operate time	70 ms	

3.2.9.2.4. Notes for testing

Normally in the EuroProt+ devices the trip contacts are assigned to the Trip Logic function block, and not to the protection function blocks. Because of this, the testing personnel must make sure that the Trip Logic is switched on ('Operation' parameter is set to other than 'Off') before starting the tests, otherwise there will be no physical trip on the relay.

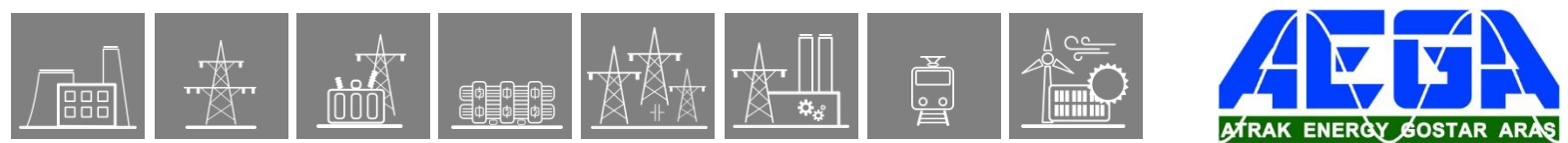
Note that the time delay parameter incorporates the algorithm time as well, so the time delay *does not mean the time difference between the appearance of the start and trip signals* of the function. In other words: it is not the delay between the detection of the fault and the trip that follows it. This should be taken into consideration when checking the disturbance records.

Instead the time delay parameter defines the elapsed time from the appearance of the faulty state to the trip. Because of this, while testing, the delay measurement should start *from the moment of the fault injection* until the trip signal.

3.3. 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*
<i>Distance protection function (DIS21_HV)</i>	
Fault location	Measured distance to fault
Fault react.	Measured reactance in the fault loop
L1N loop R	Resistive component value of impedance in L1-N loop
L1N loop X	Reactive component value of impedance in L1-N loop
L2N loop R	Resistive component value of impedance in L2-N loop
L2N loop X	Reactive component value of impedance in L2-N loop
L3N loop R	Resistive component value of impedance in L3-N loop
L3N loop X	Reactive component value of impedance in L3-N loop
L12 loop R	Resistive component value of impedance in L12 loop
L12 loop X	Reactive component value of impedance in L12 loop
L23 loop R	Resistive component value of impedance in L23 loop
L23 loop X	Reactive component value of impedance in L23 loop
L31 loop R	Resistive component value of impedance in L31 loop
L31 loop X	Reactive component value of impedance in L31 loop



<i>Synchrocheck function (SYN25)</i>	
Voltage Diff	Voltage different value
Frequency Diff	Frequency different value
Angle Diff	Angle different value
<i>Line measurement (MXU_L) (here the displayed information means primary value)</i>	
Active Power – P	Three-phase active power
Reactive Power – Q	Three-phase reactive power
Apparent Power – S	Three-phase power based on true RMS voltage and current measurement
Current L1	True RMS value of the current in phase L1
Current L2	True RMS value of the current in phase L2
Current L3	True RMS value of the current in phase L3
Voltage L1	True RMS value of the voltage in phase L1
Voltage L2	True RMS value of the voltage in phase L2
Voltage L3	True RMS value of the voltage in phase L3
Voltage L12	True RMS value of the voltage between phases L1 L2
Voltage L23	True RMS value of the voltage between phases L2 L3
Voltage L31	True RMS value of the voltage between phases L3 L1
Frequency	Frequency
<i>Metering (MTR)</i>	
Forward MWh	Forward MWh
Backward MWh	Backward MWh
Forward MVarh	Forward MVarh
Backward MVarh	Backward MVarh
<i>Line thermal protection (TTR49L)</i>	
Calc. Temperature	Calculated line temperature

* The reference angle is the phase angle of “Voltage Ch - U1”

Table 3-146 Measured analog values



3.3.1. Current input function

3.3.1.1. Application of the current input function

The application of the current inputs depends on the correct connection of the hardware terminals and also on the correct parameter setting for the CT4 function block. This guide describes examples, based on which any other combinations can be realized.

In the applications of the current transformer hardware module, the first three current inputs (terminals 1-2, 3-4, 5-6) receive the three phase currents (IL1, IL2, IL3), the fourth input (terminals 7-8) is reserved for zero sequence current, for the zero sequence current of the parallel line or for any additional currents. Accordingly, the first three inputs have common parameters while the fourth current input needs individual setting.

The CT4 function block is an independent module in the sense that:

- It has independent parameters to be set, associated to the current inputs,
- It delivers the sampled current values for protection, measurement function blocks and for disturbance recording and for on-line displaying,
- It provides parameters for the subsequent functions blocks for scaling the measured currents.
- It performs the basic calculations
 - Fourier basic harmonic magnitude and angle,
 - True RMS value.

3.3.1.1.1. Parameter setting

3.3.1.1.1.1. Summary of the parameters

The parameters of the current input function are explained in the following tables.

Enumerated parameters

Parameter name	Title	Selection range	Default
Rated secondary current of the first three input channels. 1A or 5A is selected by parameter setting, no hardware modification is needed.			
CT4_Ch13Nom_EPar_	Rated Secondary I1-3	1A,5A	1A
Rated secondary current of the fourth input channel. 1A or 5A (0.2A, 1A) is selected by parameter setting, no hardware modification is needed.			
CT4_Ch4Nom_EPar_	Rated Secondary I4	1A,5A (0.2A, 1A)	1A
Definition of the positive direction of the first three currents, given by location of the secondary star connection point			
CT4_Ch13Dir_EPar_	Starpoint I1-3	Line,Bus	Line
Definition of the positive direction of the fourth current, given as normal or inverted			
CT4_Ch4Dir_EPar_	Direction I4	Normal,Inverted	Normal

Table 1-1 The enumerated parameters of the current input function

Floating point parameters

Parameter name	Title	Dim.	Min	Max	Default
Rated primary current of channel1-3					
CT4_PrI13_FPar_	Rated Primary I1-3	A	100	4000	1000
Rated primary current of channel4					
CT4_PrI4_FPar_	Rated Primary I4	A	100	4000	1000

Table 1-2 The floating point parameters of the current input function



NOTE: The rated primary current of the channels is not needed for the current input function block itself. These values are passed on to the subsequent function blocks.

3.3.1.1.1.2. Setting the rated secondary current

The scaling of the currents (even hardware scaling) depends on parameter setting.

Rated Secondary I1-3 and Rated Secondary I4

Select the rated secondary current according to the nominal data of the main current transformer. The options to choose from are 1A or 5A (in special applications, 0.2A or 1A). This parameter influences the internal number format and, naturally, accuracy. (A small current is processed with finer resolution if 1A is selected.) The first parameter is common for the first three channels and the second one is applied for the fourth channel.

NOTE: when selecting from the available choice, no hardware modification is needed.

3.3.1.1.1.3. Setting the positive direction of the currents

The positive direction of the currents influences the correct operation of directionality (e.g. distance protection, directional overcurrent protection, power calculation, etc.) If needed, the currents can be inverted by setting parameters. This is equivalent to interchanging the two wires, connecting the currents to the inputs.

Starpoint I1-3 and Direction I4.

Starpoint I1-3 applies to each of the channels IL1, IL2 and IL3. The example of Figure 1-1 below shows the connection and the correct parameter setting for Starpoint I1-3=Line. The current L1 is connected to terminal No1 of the CT input, the current L2 to No3, and the current L3 to No5. The common point of the CT inputs is the connected No2-No4-No6. This point leads the residual current to the input No7. The connection point No8 is connected with the fourth wire to the star-point of the CTs. This application of the fourth channel is the "Normal" direction.

If the currents are connected not this way then change the parameter values accordingly.

3.3.1.1.1.4. Setting the rated primary current

These parameters are needed only to display the currents (and powers) in primary scale. The protection function apply secondary values, these parameters are not needed for protection functions.

Rated Primary I1-3 and Rated Primary I-4

Select the rated primary currents according to the nominal data of the main current transformers. The first parameter (Rated Primary I1-3) is common for the first three channels and the second (Rated Primary I-4) is for the fourth channel.



3.3.1.1.2. Application of the on-line measurements in commissioning

The **measured values** of the current input function block are listed and explained in the Table below.

Measured value	Dim.	Explanation
Current Ch - I1	A(secondary)	Fourier basic component of the current in channel IL1
Angle Ch - I1	degree	Vector position of the current in channel IL1
Current Ch - I2	A(secondary)	Fourier basic component of the current in channel IL2
Angle Ch - I2	degree	Vector position of the current in channel IL2
Current Ch - I3	A(secondary)	Fourier basic component of the current in channel IL3
Angle Ch - I3	degree	Vector position of the current in channel IL3
Current Ch - I4	A(secondary)	Fourier basic component of the current in channel IL4
Angle Ch - I4	degree	Vector position of the current in channel IL4

Table 1-3 The measured analogue values of the current input function

NOTE1: The scaling of the Fourier basic component is such that if pure sinusoid 1A RMS of the rated frequency is injected, the displayed value is 1A.

NOTE2: The reference of the vector position depends on the device configuration. If a voltage input module is included, then the reference vector (vector with angle 0 degree) is the vector calculated for the first voltage input channel of the first applied voltage input module. If no voltage input module is configured, then the reference vector (vector with angle 0 degree) is the vector calculated for the first current input channel of the first applied current input module. (The first input module is the one, located closer to the CPU module.)



3.3.1.1.3. Examples

When the vector position of the currents are relevant (e.g. distance protection, directional overcurrent protection, power measurement, etc.) then mind the correct connection of the instrument transformers and the related parameter setting. If the wires of the secondary cables are interchanged then change also the related parameter values.

3.3.1.1.3.1. Residual current measurement

Figure 1-1 shows a connection example with 3I₀ measurement. The star-point of the CT-s is towards the line, L1 is connected to terminal No1 of the CT input, L2 to No3, L3 to No5.

The common point of the CT inputs is the connected No2-No4-No6. This point leads the residual current to the input No7. The connection point No8 is connected with the fourth wire to the star-point of the CTs.

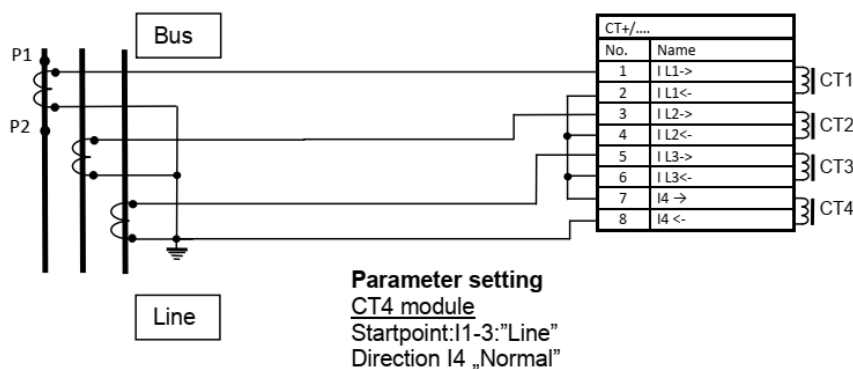


Figure 1-1 Example: CT connection with 3I₀ measurement

The related proposed parameter setting is the screen-shot of Figure 1-2. Parameter “Starpoint I1-3” is set to “Line”, indicating that the star-point is toward the protected object (line). The parameter “Direction I4” is set to “Normal”, indicating that the residual current flows in to terminal No7 and the star point of the primary current transformer is toward the protected object (line).

	Device value (Default_set_1)	New value	
Rated Secondary I1-3	1A	1A	
Rated Secondary I4	1A	1A	
Starpoint I1-3	Line	Line	
Direction I4	Normal	Normal	
Rated Primary I1-3	1000	1000	A (100 - 4000 / 1)
Rated Primary I4	1000	1000	A (100 - 4000 / 1)

Figure 1-2 Example: Parameter setting, according to Figure 1-1

In case of normal operation of the network, the correct connection of the CT-s and the related parameter setting can be checked using the “On-line” measurements. Disconnect one phase of the protected line, e.g. L1. The expected result is shown in Figure 1-3. The current is missing in phase L1 (Current Ch-I1 = 0) and the measured 3I₀ value is the vector sum of the remaining I₂+I₃. (Value of “Current Ch - I4” with the related “Angle - I4”.

NOTE: If in this test, only the secondary current is disclosed using a short measuring cable, then the measured current in this phase is usually not zero, due to the current distribution between the low-impedance input and the impedance of the measuring cable. For correct result, additionally to the short-circuit, also the disconnection of this input is needed. In this example the reference vector is the vector of the first voltage channel (not shown in the screenshot).

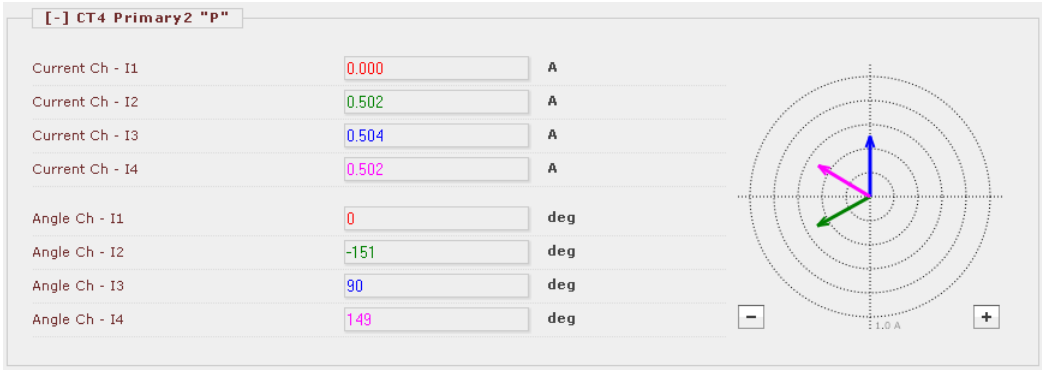


Figure 1-3 Example: Checking the current connection

3.3.1.1.3.2. Application of core-balanced CT

Figure 1-4 shows a connection example with 3I₀ measurement. The star-point of the CT-s is towards the line, L1 is connected to terminal No1 of the CT input, L2 to No3, L3 to No5. The common point of the CT inputs is the connected No2-No4-No6. The separately measured residual current is connected with the same polarity to terminals 7-8.

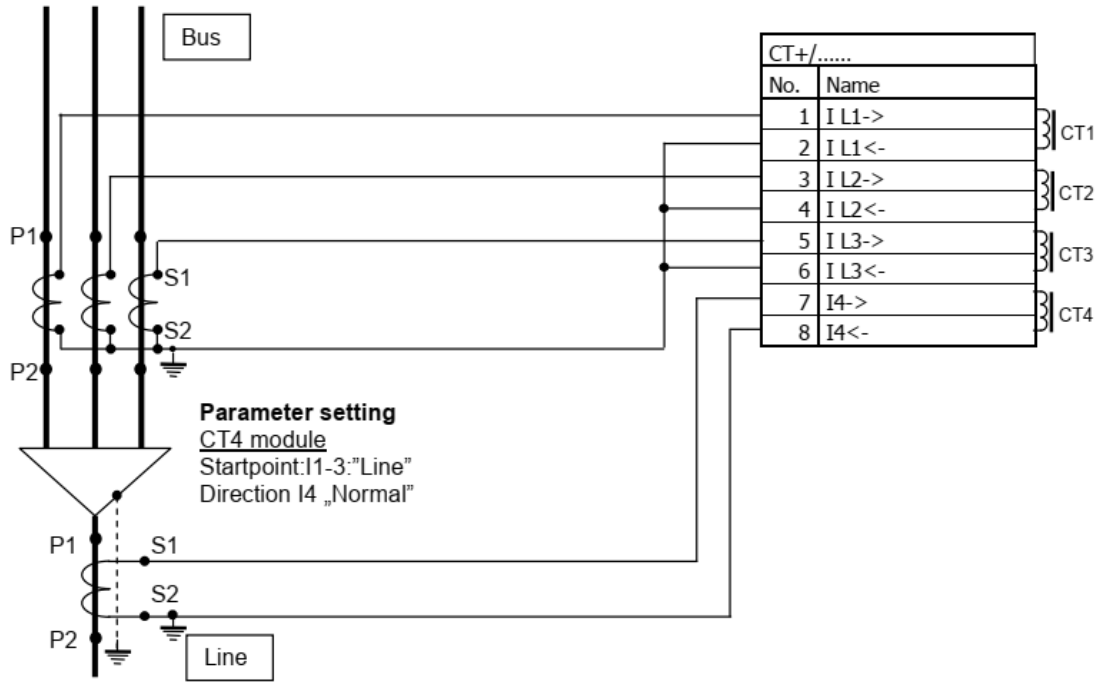


Figure 1-4 Example: CT connection with core-balance CT application

This figure also indicates the proposed parameter values for this connection. The checking is similar to that, shown in Figure 1-3.

3.3.2. AIC current input function

3.3.2.1. Application of the AIC current input function

If the factory configuration includes an AIC input hardware module, the AIC current input function block is automatically configured among the software function blocks. Separate current input function blocks are assigned to each AIC current input hardware module.

The AIC current input module accepts transducers current outputs. The AIC module has four channels, they can measure unipolar and bipolar current values in wide ranges. (See EuroProt+ hardware description document.) The transducer converts any physical quantity to DC current values.

The transmitters can be connected by wiring methods, shown in Figure 1–1, Figure 1–2 and Figure 1–3.

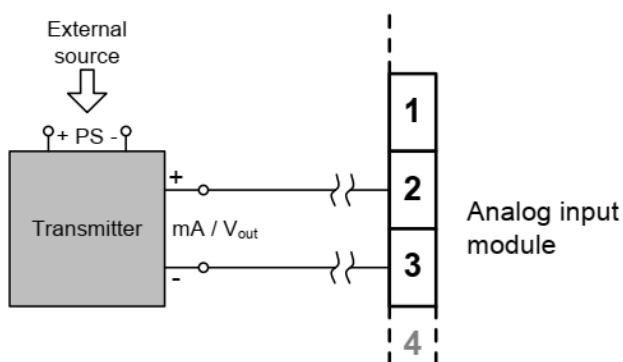


Figure 1–1 2-wire AIC wiring without 12 V excitation

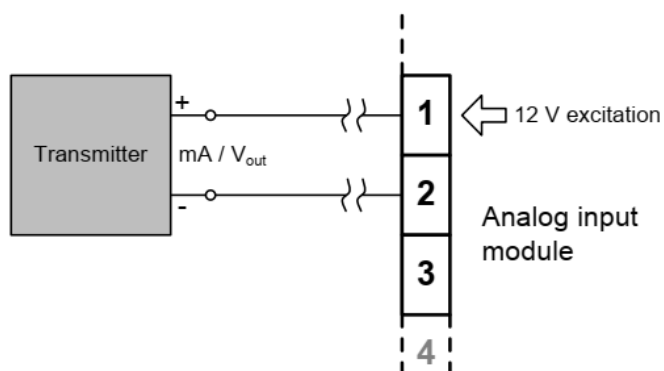


Figure 1–2 2-wire AIC wiring with 12 V excitation

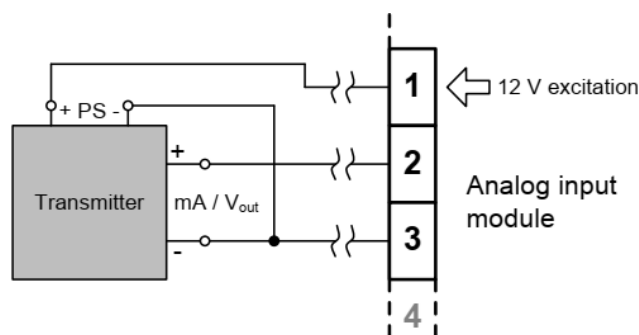


Figure 1-3 3-wire AIC wiring with 12 V excitation

The channels of the module are independent of each other. To each channel a dedicated measuring module is assigned. These measuring modules are described in a separate document: **"GGIOmA current measurement module function block description"**.

3.3.2.2. Technical summary

3.3.2.2.1. Technical data

The technical data of the AIC analog current input module are related to the hardware module. This is described in the document **"EuroProt+ Hardware description, Chapter 11: analog input module"**.

3.3.2.2.2. Summary of the parameters

The parameters of the AIC analog current input function are explained in the following table.

Enumerated parameters

Parameter name	Title	Selection range	Default
Polarity of Channel 1			
AIC_Ch1Dir_EPar_1	Direction - Ch1	Normal,Inverted*	Normal
Polarity of Channel 2			
AIC_Ch2Dir_EPar_1	Direction – Ch2	Normal,Inverted*	Normal
Polarity of Channel 3			
AIC_Ch3Dir_EPar_1	Direction – Ch3	Normal,Inverted*	Normal
Polarity of Channel 4			
AIC_Ch4Dir_EPar_1	Direction – Ch4	Normal,Inverted*	Normal

*Figures 1-1, 1-2 and 1-3 show "Normal" connection polarity

Table 1-1 The enumerated parameters of the current input function

NOTE: The function block has no input and output binary signals, the graphic logic editor does not show this function block.



3.3.3. Voltage input function

3.3.3.1. Application of the voltage input function

The application of the voltage inputs depends on the correct connection of the hardware terminals and also on the correct parameter setting for the VT4 function block. This guide describes examples, based on which any other combinations can be realized.

In the applications of the voltage transformer hardware module, the first three voltage inputs receive the three phase voltages (UL1, UL2, UL3), the fourth input is reserved for zero sequence voltage, for the busbar voltage if synchronized switching is applied or for any additional voltages. Accordingly, the first three inputs have common parameters while the fourth voltage input needs individual setting.

The VT4 function block is an independent module in the sense that:

- It has independent parameters to be set, associated to the voltage inputs,
- It delivers the sampled voltage values for protection, measurement function blocks and for disturbance recording,
- It provides parameters for the subsequent functions blocks for scaling the measured voltages.
- It performs the basic calculations
 - Fourier basic harmonic magnitude and angle,
 - True RMS value.

3.3.3.1.1. Parameter setting

3.3.3.1.1.1. Summary of the parameters

The parameters of the voltage input function are explained in the following tables.

Enumerated parameters

Parameter name	Title	Selection range	Default
Rated secondary voltage of the input channels. 100 V or 200V is selected by parameter setting, no hardware modification is needed.			
VT4_Type_EPar_	Range	Type 100, Type 200	Type 100
Connection of the first three voltage inputs (main VT secondary)			
VT4_Ch13Nom_EPar_	Connection U1-3	Ph-N, Ph-Ph, Ph-N-Isolated	Ph-N
Selection of the fourth channel input: phase-to-neutral or phase-to-phase voltage			
VT4_Ch4Nom_EPar_	Connection U4	Ph-N, Ph-Ph	Ph-Ph
Definition of the positive direction of the first three input channels, given as normal or inverted			
VT4_Ch13Dir_EPar_	Direction U1-3	Normal, Inverted	Normal
Definition of the positive direction of the fourth voltage, given as normal or inverted			
VT4_Ch4Dir_EPar_	Direction U4	Normal, Inverted	Normal

Table 1-1 The enumerated parameters of the voltage input function

Integer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Voltage correction						
VT4_CorrFact_IPar_	VT correction	%	100	115	1	100

Table 1-2 The integer parameter of the voltage input function



Floating point parameters

Parameter name	Title	Dim.	Min	Max	Default
Rated primary voltage of channel 1, 2, 3					
VT4_PriU13_FPar	Rated Primary U1-3	kV	1	1000	100
Rated primary voltage of channel 4					
VT4_PriU4_FPar	Rated Primary U4	kV	1	1000	100

Table 1-3 The floating point parameters of the voltage input function

NOTE: The rated primary voltage of the channels is not needed for the voltage input function block itself. These values are passed on to the subsequent function blocks.

3.3.3.1.1.2. Setting the rated secondary voltage

The scaling of the voltage depends on parameter setting.

Range

There are basically two standard voltage transformer types: one with secondary rated voltage 100 V, the other with 200 V. Select the parameter value respectively: Type 100, Type 200. No hardware modification is needed. This parameter influences the internal number format and, naturally, accuracy. (A small voltage is processed with finer resolution if 100V is selected.)

VT correction

In some cases the rated secondary of the voltage transformers is not 100V but e.g. 110 V. This parameter is to correct this difference, if the rated secondary voltage of the main voltage transformer does not match the rated input of the device. As an example: if the rated secondary voltage of the main voltage transformer is 110V, then select Type 100 for the parameter "Range" and the required value to set here is 110%.

3.3.3.1.1.3. Setting the connection and the positive direction of the voltages

The connection and direction parameters of the first three VT secondary windings must be set to reflect actual physical connection of the main VTs.

Connection U1-3.

The selection can be: "Ph-N", "Ph-Ph" or "Ph-N-Isolated".

The *Ph-N* option is applied in solidly grounded networks, where the measured phase voltage is never above $1.5 \cdot U_n$. In this case the primary rated voltage of the VT must be the value of the rated PHASE-TO-NEUTRAL voltage.

The *Ph-N-Isolated* option is applied in compensated or isolated networks, where the measured phase voltage can be above $1.5 \cdot U_n$ even in normal operation. In this case the primary rated voltage of the VT must be the value of the rated PHASE-TO-PHASE voltage.

The *Ph-Ph* option is to be selected if phase-to-phase voltage is connected to the VT input of the device. Here, the primary rated voltage of the VT must be the value of the rated PHASE-TO-PHASE voltage. This option must not be selected if the distance protection function or



directional overcurrent protection function is supplied from the VT input.

Connection U4

The fourth input is reserved for zero sequence voltage or for a voltage from the other side of the circuit breaker for synchronized switching. Accordingly, the connected voltage must be identified with parameter setting Connection U4. Here, phase-to-neutral or phase-to-phase voltage can be selected: “Ph-N”, “Ph-Ph”

Direction U1-3

If needed, the phase voltages can be inverted by setting the parameter Direction U1-3. This selection applies to each of the channels UL1, UL2 and UL3. The primary/secondary connection of the VT windings is generally star/star connected and the phase voltages signed with • are connected to the VT4 terminals 1-3-5. In this case the parameter setting is „Normal”. Select “Inverted” to the parameter Direction U1-3 in case of inverted connection of phase voltages.” (See also Figure 1-1 in setting example.)

Direction U4

This parameter applies to the channel UL4. If the voltage signed with • is connected to the VT4 terminal 7 the parameter setting is „Normal”. Select “Inverted” to the parameter Direction U4 in case of inverted connection of the voltage. This inversion may be needed in protection functions such as distance protection or for any functions with directional decision, or for checking the voltage vector positions.

Figure 1-1 shows an example with harmonized connection and parameter setting.

If the voltages are connected not this way then change the parameter values accordingly.

3.3.3.1.1.4. Setting the rated primary voltage

These parameters are needed only to display the voltages (and powers) in primary scale. The protection functions apply secondary values, these parameters are not needed for protection functions.

Rated Primary U1-3 and Rated Primary U-4

Select the rated primary voltages according to the nominal data of the main voltage transformers. The two parameters are: common for the first three channels and one for the fourth channel respectively.



3.3.3.1.2. Application of the on-line measurements in commissioning

The performed basic calculation results the Fourier basic harmonic magnitude and angle value of the voltages. These results are processed by subsequent protection function blocks and they are available for on-line displaying as well.

3.3.3.1.2.1. Summary of the on-line measurements

The **measured values** of the voltage input function block.

Measured value	Dim.	Explanation
Voltage Ch - U1	V(secondary)	Fourier basic component of the voltage in channel UL1
Angle Ch - U1	degree	Vector position of the voltage in channel UL1
Voltage Ch – U2	V(secondary)	Fourier basic component of the voltage in channel UL2
Angle Ch – U2	degree	Vector position of the voltage in channel UL2
Voltage Ch – U3	V(secondary)	Fourier basic component of the voltage in channel UL3
Angle Ch – U3	degree	Vector position of the voltage in channel UL3
Voltage Ch – U4	V(secondary)	Fourier basic component of the voltage in channel U4
Angle Ch – U4	degree	Vector position of the voltage in channel U4

Table 1-4 The measured analogue values of the voltage input function

NOTE1: The scaling of the Fourier basic component is such that if pure sinusoid 57V RMS of the rated frequency is injected, the displayed value is 57V.

NOTE2: The reference vector (vector with angle 0 degree) is the vector calculated for the first voltage input channel of the first applied voltage input module. (The first voltage input module is the one, configured closer to the CPU module.)



3.3.3.1.3. Examples

When the vector position of the voltages are relevant (e.g. distance protection, directional overcurrent protection, power measurement, synchrocheck, etc.) then mind the correct connection of the instrument transformers and the related parameter setting. If the wires of the secondary cables are interchanged then change also the related parameter values.

3.3.3.1.3.1. Phase voltage and residual voltage measurement

Figure 1-1 shows the phase voltage measurement and also the residual voltage measurement e.g. for residual directional overcurrent protection function. In this example the residual voltage is measured in open delta of the VT secondary coils. The network is supposed to be compensated. This figure also indicates the proposed parameter values.

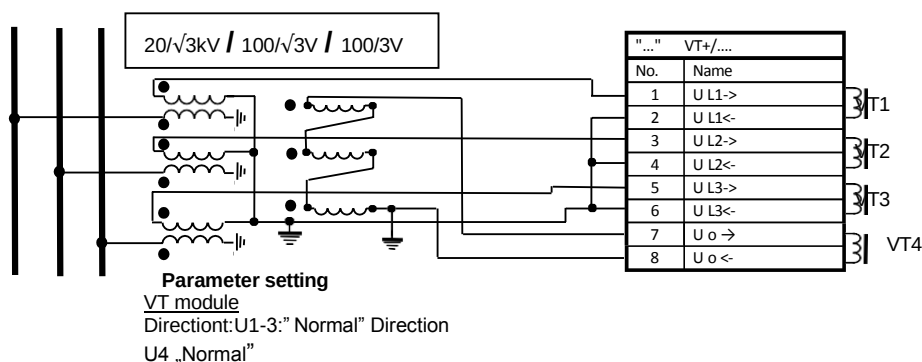
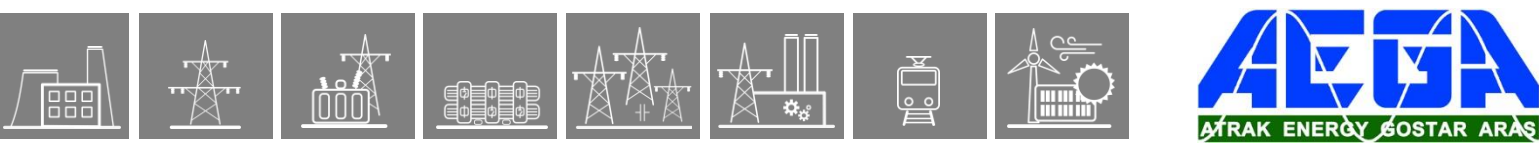


Figure 1-1 Example: Phase voltage and residual voltage measurement

Range	Type 100	The type indicates the rated secondary voltage of the VT. This can be 100 V (in this example) or 200V
Connection U1-3	Ph-N-Isolated	This indicates that the VT primary is connected between the conductor and the ground (in this example in compensated network). This could be Ph-N or Ph-Ph in other application. (NOTE: If the neutral of the system is not grounded, select Ph-N-Isolated)
Connection U4	Ph-Ph	In case of earth fault the open delta measures 100 V. This corresponds to the phase-to-phase value
Direction U1-3	Normal	Figure 1-1 shows the normal VT connection, i.e. the signed • phase wires are connected to the terminals 1-3-5. (Select "Inverted" in case of inverted connection.)
Direction U4	Normal	Figure 1-1 shows the normal VT connection, i.e. the signed • wire of the open delta of VT-s is connected to the terminal 7. (Select "Inverted" in case of inverted connection.)
VT correction	100	If the rated secondary value of the VT is e.g. 110 V then select this correction value to 110%.
Rated Primary U1-3	20	Setting, according to the VT rated voltage, applied at the primary side. This parameter is used for scaling the displayed values only.
Rated Primary U4	11.55	This parameter is used for scaling the displayed values only. In case of earth fault, the open delta measures 100 V. In primary value it is displayed as the phase voltage in the 20 kV network.

Table 1-5 Example parameters for the voltage input function



3.3.3.1.3.2. Syncrocheck using phase-to neutral voltage

Figure 1-2 shows the application of the fourth voltage input of the VT module for syncrocheck function. Here UL2 of the busbar voltage is used for this purpose.

NOTE: Among syncrocheck parameters set “Voltage select” parameter to “L2-N.

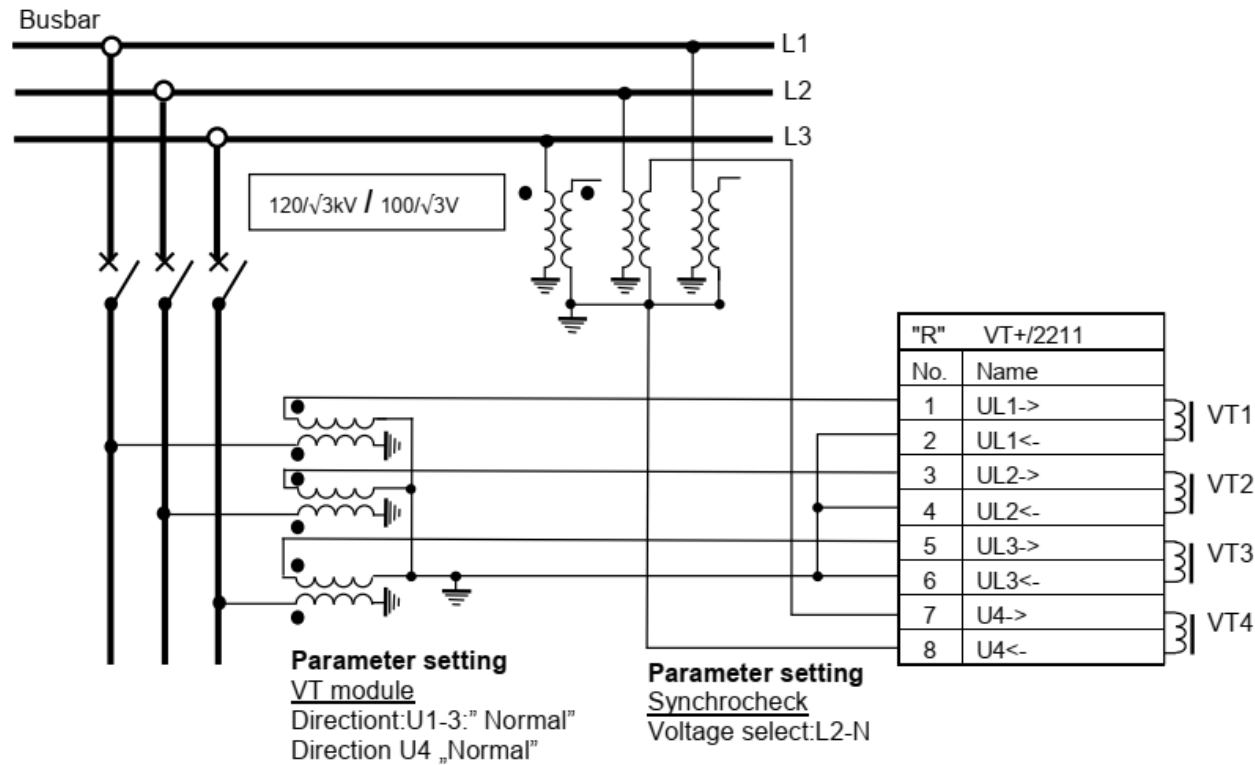


Figure 1-2 Example: Syncrocheck, using phase-to-neutral voltage

Figure 1-3 shows the screenshot indicating the proposed parameter values.

[-] VT4 module "U"

	Device value (Default_set_1)	New value	
Range	Type 100	Type 100	
Connection U1-3	Ph-N	Ph-N	
Connection U4	Ph-N	Ph-N	
Direction U1-3	Normal	Normal	
Direction U4	Normal	Normal	
VT correction	100	100	% (100 - 115 / 1)
Rated Primary U1-3	69.28	69.28	kV (1.00 - 1000.00 / 0.01)
Rated Primary U4	69.28	69.28	kV (1.00 - 1000.00 / 0.01)

Figure 1-3 Example:Parameters for syncrocheck, using phase-to-neutral voltage

The “On-line window” of the VT4 input module shows the checking the correct voltage vector position. When the line is connected to the busbar, i.e. the CB is closed, in this example the U4 voltage is expected to have the same value and position as U2. See Figure 1-4.



Figure 1-4 Example: On-line measurement for syncrocheck, using phase-to-neutral voltage

3.3.3.1.3.3. Syncrocheck using phase-to-phase voltage

Figure 1-5 shows the application of the fourth voltage input of the VT module for syncrocheck function. Here UL1-UL3 line-to-line signal of the busbar voltage is used for this purpose.

NOTE: Among syncrocheck parameters set "Voltage select" parameter to "L3-L1". This selection is opposite to that, of the connected voltage. This can be corrected selecting the "Direction U4" parameter value to "Inverse".

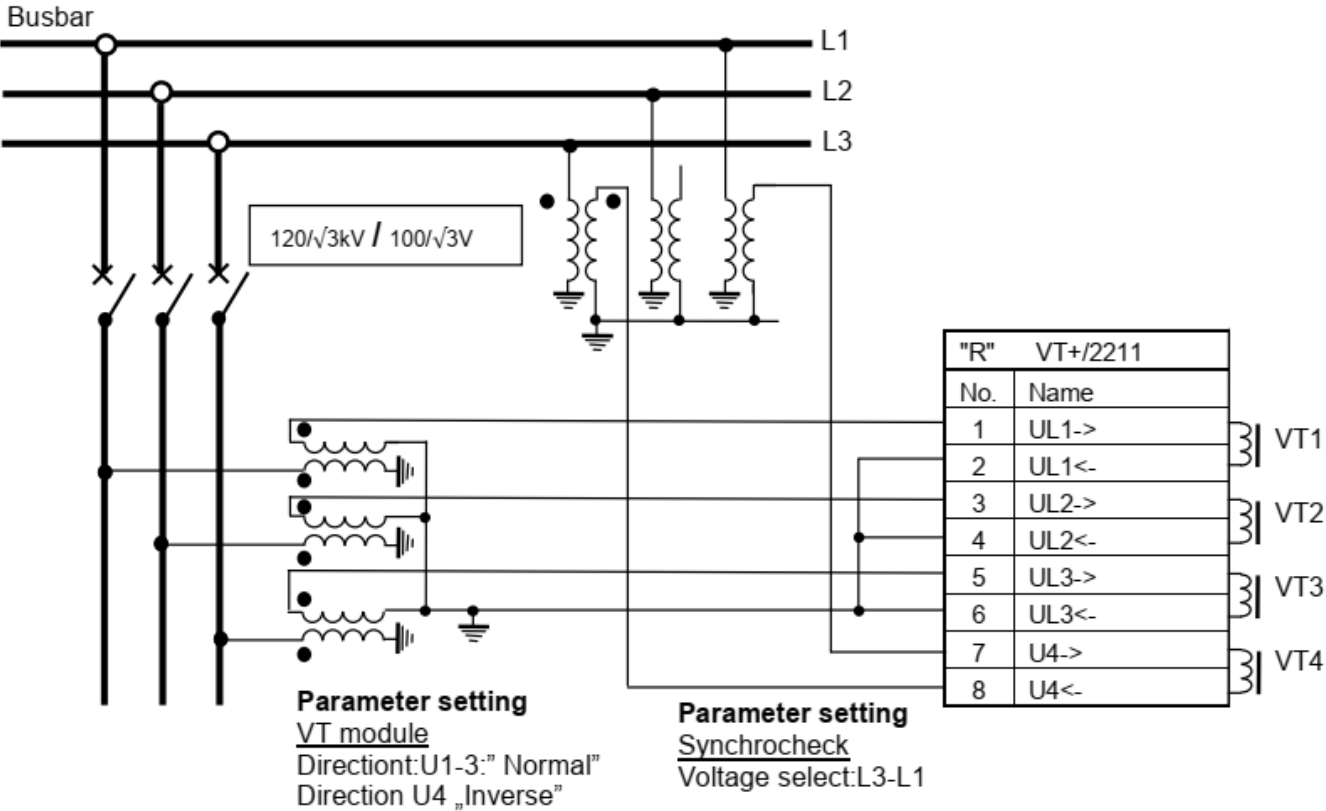


Figure 1-5 Example: Syncrocheck, using phase-to-phase voltage

Figure 1-6 shows the proposed parameter values for the connection shown above.

[-] VT4 module "U"

	Device value (Default_set_1)	New value		
Range	Type 100	Type 100		
Connection U1-3	Ph-N	Ph-N		
Connection U4	Ph-Ph	Ph-Ph		
Direction U1-3	Normal	Normal		
Direction U4	Inverted	Inverted		
VT correction	100	100	%	(100 - 115 / 1)
Rated Primary U1-3	69.28	69.28	kV	(1.00 - 1000.00 / 0.01)
Rated Primary U4	120.00	120.00	kV	(1.00 - 1000.00 / 0.01)

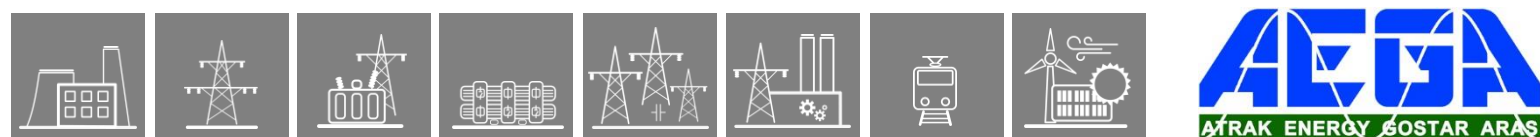
Figure 1-6 Example:Parameters for syncrocheck, using phase-to-phase voltage

The “On-line window” of the VT4 input module shows the checking the correct voltage vector position. When the line is connected to the busbar, i.e. the CB is closed, in this example the U4 voltage is expected to have a vector identical with the voltage difference U3-U1. See Figure 1-7.



Figure 1-7 Example:On-line measurement for syncrocheck, using phase-to-phase voltage

NOTE that due to the reverse connection of the voltage difference and the parameter setting also reverted by “Inverse” setting, the indicated U4 vector corresponds to the parameter “Voltage select=L3-L1” among syncrocheck parameters.



3.3.4. Line and frequency measurement functions

3.3.4.1. Application

The input values of the EuroProt+ devices are the secondary signals of the voltage transformers and those of the current transformers when they are available in the actual configuration.

These signals are pre-processed by the “VT4 module” voltage input function block and by “CT4 module” the current input function block. These function blocks are described in separate documents. The pre-processed values include the Fourier basic harmonic phasors of the voltages and currents and the true RMS values. Additionally, it is in these function blocks that parameters are set concerning the voltage ratio of the primary voltage transformers and current ratio of the current transformers.

Based on the pre-processed values and the measured transformer parameters, the measurement function blocks calculate - depending on the hardware and software configuration - the primary RMS values of the voltages and currents and some additional values such as active and reactive power, symmetrical components of voltages and currents. These values are available as primary quantities and they can be displayed on the on-line screen of the device or on the remote user interface of the computers connected to the communication network and they are available for the SCADA system using the configured communication system.

3.3.4.2. Mode of operation

The **inputs** of the line measurement function are

- the Fourier components and true RMS values of the measured voltages and currents,
- frequency measurement,
- parameters.

The **outputs** of the line measurement function are

- displayed measured values,
- reports to the SCADA system.

NOTE: the scaling values are entered as parameter setting for the “Voltage transformer input” function block and for the “Current transformer input” function block.

3.3.4.3. The measurement

3.3.4.3.1. The measured values; variants of the function

There are six variants of the MXU function, based on their **measured values**. Parameters and measurements are alike for each. The **type of the variant** is shown in the *function block name*:

- Line Measurement (*MXU_LM*)
- Frequency Measurement (*MXU_F*)
- Voltage measurement (*MXU_V*)
- Voltage measurement (*MXU_V1*) (single voltage)
- Current measurement (*MXU_C*)
- Current measurement (*MXU_C1*) (single current)

Table 1-1 Measured values of each variant

ON-LINE MEASURED VALUE	EXPLANATION	MXU FUNCTION BLOCK VARIANT					
		LM	F	V	V1	C	C1
MXU_P_OLM_	Active Power – P (Fourier base harmonic value)	X					
MXU_Q_OLM_	Reactive Power – Q (Fourier base harmonic value)	X					
MXU_S_OLM_	Apparent Power – S (Fourier base harmonic value)	X					
MXU_Fi_OLM_	Power factor	X					
MXU_I1_OLM_	Current L1	X				X	X
MXU_I2_OLM_	Current L2	X				X	
MXU_I3_OLM_	Current L3	X				X	
MXU_Ipos_OLM_	Calculated positive seq. current	X				X	
MXU_Ineg_OLM_	Calculated negative seq. current	X				X	
MXU_3Io_OLM_	Calculated 3Io	X				X	
MXU_U1_OLM_	Voltage L1	X		X	X		
MXU_U2_OLM_	Voltage L2	X		X			
MXU_U3_OLM_	Voltage L3	X		X			
MXU_U12_OLM_	Voltage L12	X		X			
MXU_U23_OLM_	Voltage L23	X		X			
MXU_U31_OLM_	Voltage L31	X		X			
MXU_Upos_OLM	Calculated positive seq. voltage	X		X			
MXU_Uneg_OLM_	Calculated negative seq. voltage	X		X			
MXU_3Uo_OLM_	Calculated 3Uo	X		X			
MXU_f_OLM_	Frequency		X	X			

3.3.4.3.2. The measurement modes

Regarding the power measurements there are two possibilities for the measurement modes. The first one is the “ThreePhase”-method, where all three measured voltages and currents are considered in the power calculation. The second one is the “Aron”-method, where two phase-to-phase voltages and two phase currents are taken into the calculation. This method has correct results only in case when the voltages and currents are symmetrical. The user can choose the mode with the “Measurement mode” parameter. For the “Aron”-method there are three options:

Table 1-2 Explanation for the Aron measurement modes

Measurement mode	Used phase-currents	Used phase-to-phase voltages
Aron L2-L3	L2, L3	L1-L2, L3-L1
Aron L3-L1	L1, L3	L1-L2, L2-L3
Aron L1-L2	L1, L2	L2-L3, L3-L1



If the “Connection U1-3” parameter of the VT4 module function block is set to “Ph-Ph”, the “ThreePhase”-method cannot be used for the power measurements here, so either of the “Aron” methods must be set for it. Otherwise, the device will provide a warning signal (yellow Status LED, “General param. error” message).

3.3.4.4. Reporting the measured values and the changes

It is usual for the SCADA systems that they sample the measured and calculated values in regular time periods and additionally they receive the changed values as reports at the moment when any significant change is detected in the primary system. The “Line measurement” function block performs such reporting for the SCADA system. Three parameters define this reporting:

- *Report Deadband* for choosing the type of reporting, or disabling the reporting
- *Deadband Value* for defining the deadband width
- *Range (value)* for evaluating the “out-of-range” condition

The usage of these parameters is explained in the following chapters.

3.3.4.4.1. “Amplitude” mode of reporting

If the “Amplitude” mode is selected for reporting, a report is generated if the measured value leaves the deadband around the previously reported value. As an example, [Figure 1-1](#) shows that the current becomes higher than the value reported in “report1” PLUS the Deadband value, this results “report2”, etc.

For this mode of operation, the Deadband parameters are explained in the figure below.

NOTE: The “Range” parameters are needed to evaluate a measurement as “out-of-range”.

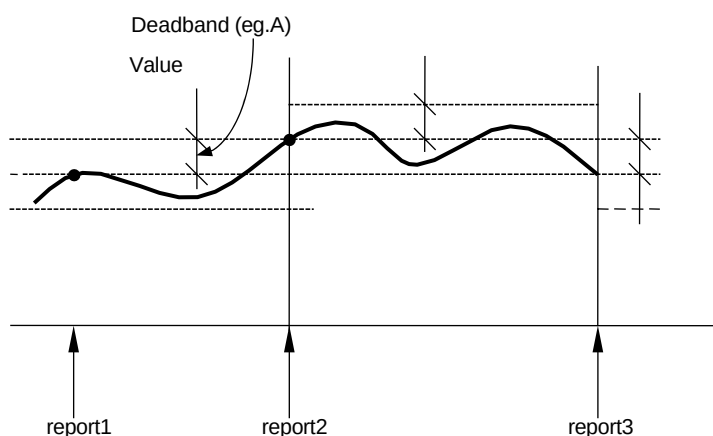


Figure 1-1 Reporting if “Amplitude” mode is selected

3.3.4.4.2. “Integrated” mode of reporting

If the “Integrated” mode is selected for reporting, a report is generated if the time integral of the measured value since the last report gets becomes larger, in the positive or negative direction, then the (deadband*1sec) area. As an example, [Figure 1-2](#) shows that the integral of the current in time becomes higher than the Deadband value multiplied by 1sec, this results “report2”, etc.

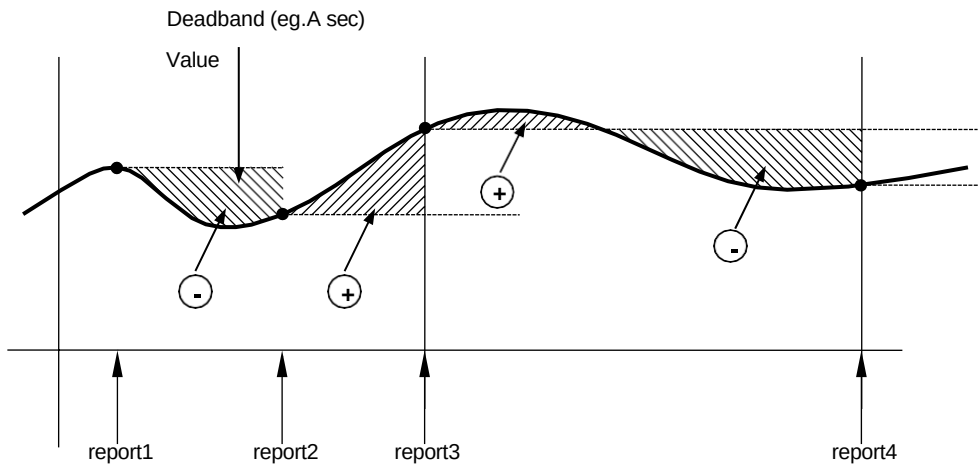


Figure 1-2 Reporting if “Integrated” mode is selected

3.3.4.4.3. Periodic reporting

Periodic reporting is generated independently of the changes of the measured values when the defined time period elapses. If the reporting time period is set to 0, then no periodic reporting is performed for this quantity.

Applying periodic reporting and setting up its interval is done by using the **Communication configurator**, a part of the **EuroCAP** software (see its description for detailed information).

Once the “Trigger period” property is set to “True”, the “Integrity period” setting becomes available to set (in milliseconds). As an example, see the picture below.

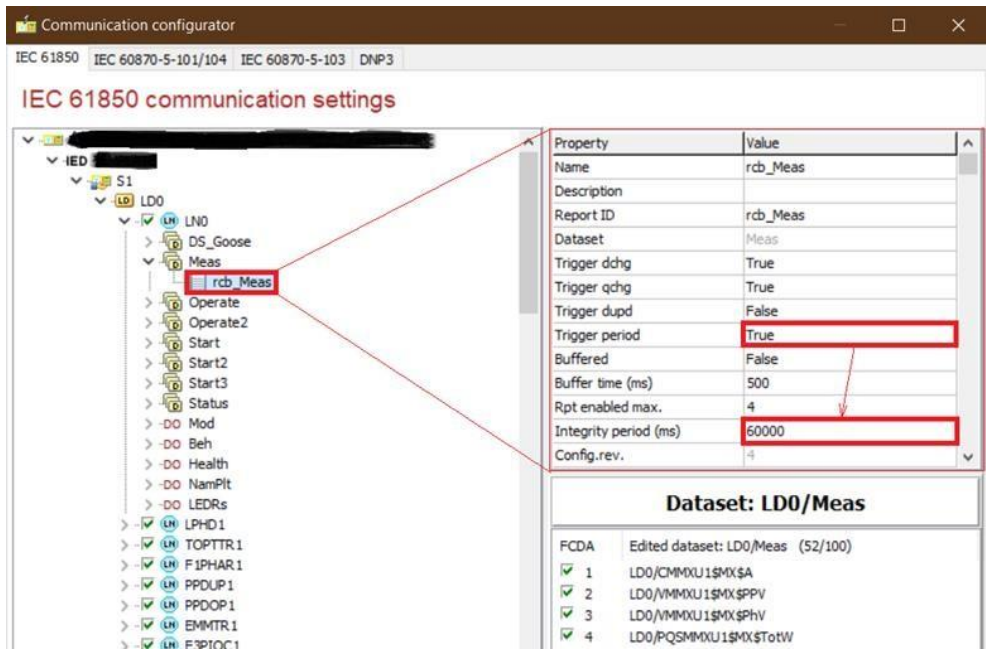
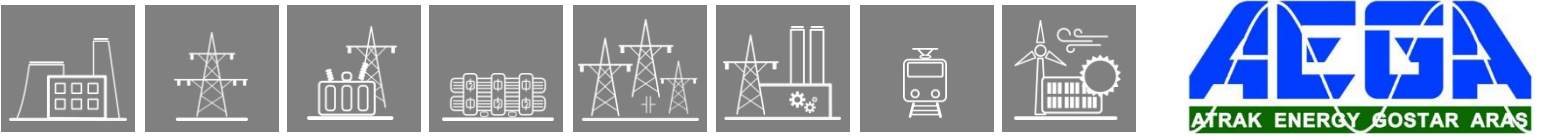


Figure 1-3 Setting up periodic reporting in EuroCAP



3.3.4.4.4. **Zero-point clamping**

A measured value under the zero-point clamping limit is cut off to zero.

- Three-phase current measurement 0.2% of nominal (I_n)
- Three-phase voltage measurement 2% of nominal (U_n)
- Residual current measurement 0.2% of nominal (I_n)
- Residual voltage measurement 2% of nominal (U_n)
- Phase sequence current measurement 0.2% of the nominal (I_n)
- Phase sequence voltage measurement 2% of the nominal (U_n)
- Three-phase power and energy measurement 0.23% of the nominal (S_n)

3.3.4.5. Line and frequency measurement functions overview

3.3.4.5.1. Settings

3.3.4.5.1.1. Parameters

The following parameters are the parameters of the Line Measurement and Frequency measurement function blocks (LM and F variants). The other functions' parameters follow the pattern of the corresponding measured values.

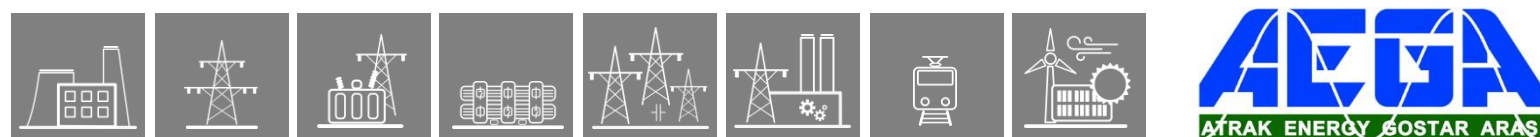
Table 2-1 Parameters of the line measurement function

TITLE	DIM	RANGE**	STEP	DEFAULT	EXPLANATION
Measurement mode	-	Aron L2-L3, Aron L3-L1, Aron L1-L2, ThreePhase	-	ThreePhase	Measurement mode
Report Deadband - U	-	Off, Amplitude, Integrated	-	Amplitude	Selection of the reporting mode for voltage measurement
Deadband Value - Uph-N	kV*	0.10 – 100.00	0.01	5	Deadband value for the phase-to-neutral voltage
Range Value - Uph-N	kV*	1.0 – 1000.0	0.1	231	Range value for the phase-to-neutral voltage
Deadband Value Uph-ph	kV*	0.10 – 100.00	0.01	5	Deadband value for the phase-to-phase voltage
Range Value - Uph-ph	kV*	1.0 – 1000.0	0.1	400	Range value for the phase-to-neutral voltage
Deadband Value - U Res	kV*	0.10 – 100.00	0.01	5	Deadband value for the residual voltage
Range Value - U Res	kV*	1.0 – 1000.0	0.1	20	Range value for the residual voltage
Deadband Value - Uneg	kV*	0.10 – 100.00	0.01	5	Deadband value for the negative seq. voltage
Range Value - Uneg	kV*	1.0 – 1000.0	0.1	231	Range value for the negative seq. voltage
Deadband Value - Upos	kV*	0.10 – 100.00	0.01	5	Deadband value for the positive seq. voltage
Range Value - Upos	kV*	1.0 – 1000.0	0.1	231	Range value for the positive seq. voltage
Report Deadband - I	-	Off, Amplitude, Integrated	-	Amplitude	Selection of the reporting mode for current measurement
Deadband Value - I	A	1 – 2000	1	10	Deadband value for the current
Range Value - I	A	1 – 5000	1	500	Range value for the current
Deadband Value - I Res	A	1 – 500	1	10	Deadband value for the residual current
Range Value - I Res	A	1 – 1000	1	100	Range value for the residual current
Deadband Value - Ineg	A	1 – 2000	1	10	Deadband value for the negative seq. current
Range Value - Ineg	A	1 – 5000	1	500	Range value for the negative seq. current
Deadband Value - Ipos	A	1 – 2000	1	10	Deadband value for the positive seq. current

Range Value - Ipos	A	1 – 5000	1	500	Range value for the positive seq. current
Report Deadband - P	-	Off, Amplitude, Integrated	-	Amplitude	Selection of the reporting mode for active power measurement
Deadband Value - P	kW*	0.10 – 10000.00	0.01	10	Deadband value for the active power
Range Value - P	kW*	1.00 – 100000.00	0.01	500	Range value for the active power
Report Deadband - Q	-	Off, Amplitude, Integrated	-	Amplitude	Selection of the reporting mode for reactive power measurement
Deadband Value - Q	kVAr*	0.10 – 10000.00	0.01	10	Deadband value for the reactive power
Range Value - Q	kVAr*	1.00 – 100000.00	0.01	500	Range value for the reactive power
Report Deadband - S	-	Off, Amplitude, Integrated	-	Amplitude	Selection of the reporting mode for apparent power measurement
Deadband Value - S	kVA*	0.10 – 10000.00	0.01	10	Deadband value for the apparent power
Range Value - S	kVA*	1.00 – 100000.00	0.01	500	Range value for the apparent power
Report Deadband	Hz	Off, Amplitude, Integrated	-	Amplitude	Selection of the reporting mode for frequency measurement
Deadband Value	Hz	0.01 – 1.00	0.01	0.03	Deadband value for the frequency
Range Value	Hz	0.05 – 10.00	0.01	5	Range value for the frequency

**the prefixes can change (i.e. kW → MW, kV → V etc.) depending on the configuration; changing these is done by Protecta personnel*

***if the setting range is to be extended, contact Protecta personnel*



3.3.4.5.2. Function I/O

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

3.3.4.5.2.1. Analogue inputs

The analogue inputs of the measurement functions are

- the Fourier components and true RMS values of the measured and calculated secondary voltages
- the Fourier components and true RMS values of the measured secondary currents,

3.3.4.5.2.2. Analogue outputs (measurements)

See the next chapter (On-line data) for the listing of all measurements. Note again, that the measured values depend on the type of the actual measurement function block, see Chapter [1.3.1](#)

3.3.4.5.2.3. On-line data

The **on-line data** of the line measurement function depend on the available analogue values which are referring to the applied hardware configuration.

Visible values on the on-line data page:

Table 2-2 On-line data of the line measurement function

SIGNAL TITLE	DIMENSION	EXPLANATION
Power - P	kW*	Calculated three-phase active power
Reactive Power - Q	kVar*	Calculated three-phase reactive power
Apparent Power - S	kVA*	Calculated three-phase apparent power
Power factor	-	Calculated power factor
Current L1	A	Measured primary current L1 based on the nominal values of the CT4 current input function
Current L2	A	Measured primary current L2 based on the nominal values of the CT4 current input function
Current L3	A	Measured primary current L3 based on the nominal values of the CT4 current input function
Positive sequence current	A	Calculated positive sequence current from the three phase currents
Negative sequence current	A	Calculated negative sequence current from the three phase currents
Calculated 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*

3.3.4.5.3. Technical data

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

POWER MEASUREMENT (P, Q, S)*	RANGE	ACCURACY
HW MODULES		
CT+/5115	0,002 – 0,01 In	±3%, ±1 digit
	0,01 – 0,03 In	±1%, ±1 digit
	0,03 – 5 In (max. 5 In for measurement purposes)	±0,5%, ±1 digit
CT+/1500**	0,002 – 0,005 In	±1,5%, ±1 digit
	0,005 – 0,02 In	±0,5%, ±1 digit
	0,02 – 2 In	±0,2%, ±1 digit
CT+/5151** CT+/5153 (Channel 1-3)	0,02 – 0,05 In	±3%, ±1 digit
	0,05 – 20 In	±0,5%, ±1 digit

* By using VT+/2211 with nominal voltage.

** The defined accuracy regarding the CT+/1500 and CT+/5151 modules are valid from 2020/Q2 or on customer request. For the values before this date, see [Table 2-7](#) in the next chapter.

Table 2-4 Technical data of the line measurement function (currents)

CURRENT MEASUREMENT (PHASE AND SEQUENTIAL)	RANGE	ACCURACY
HW MODULES		
CT+/5115	0,002 – 0,01 In	±3%, ±1 digit
	0,01 – 0,03 In	±1%, ±1 digit
	0,03 – 5 In (max. 5 In for measurement purposes)	±0,5%, ±1 digit
CT+/1500*	0,002 – 0,005 In	±1,5%, ±1 digit
	0,005 – 0,02 In	±0,5%, ±1 digit
	0,02 – 2 In	±0,2%, ±1 digit
CT+/5151* CT+/5153 (Channel 1-3)	0,02 – 0,05 In	±3%, ±1 digit
	0,05 – 20 In	±0,5%, ±1 digit

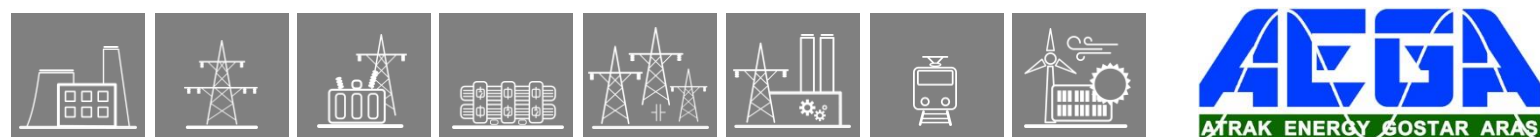
* The defined accuracy regarding the CT+/1500 and CT+/5151 modules are valid from 2020/Q2 or on customer request. For the values before this date, see [Table 2-7](#) in the next chapter.

Table 2-5 Technical data of the line measurement function (voltages)

VOLTAGE MEASUREMENT (PHASE, PHASE-TO-PHASE, SEQUENTIAL)	RANGE	ACCURACY
HW MODULES		
VT+/2211	0,05 – 1,5 Un	±0,5%, ±1 digit

Table 2-6 Technical data of the frequency measurement function

FREQUENCY MEASUREMENT	VALUE	ACCURACY
Frequency	40 - 60 Hz (50 Hz system) 50 - 70 Hz (60 Hz system)	± 2 mHz



3.3.4.5.3.1. Notes for testing

If there are no measurements seen on the SCADA software, check the Report Deadband parameter and/or the settings of the periodic reporting in the Communication Configurator. The former's default value is 'Off', and the latter's is 'False', which means that by default, the reporting is disabled. It must be enabled first.

The **periodic reporting** is defined in the device configuration file (.epc/.epcs) using EuroCAP. See Chapter [1.4.3](#). This also means that changing the properties of this will require loading a new configuration file to the device (hence a full device restart).

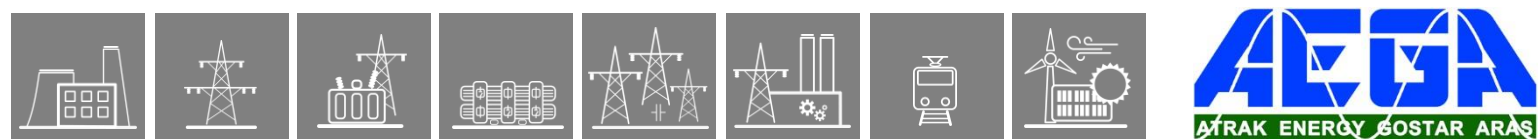


If the "Connection U1-3" parameter of the *VT4 module* function block is set to "Ph-Ph", the "ThreePhase"-method cannot be used for the power measurements here, so either of the "Aron" methods must be set for it. Otherwise, the device will provide a warning signal (yellow Status LED, "General param. error" message).

For the devices shipped with modules manufactured before 2020/Q2, the technical data table is different:

Table 2-7 Technical data of the line measurement function

HARDWARE MODULE	RANGE	ACCURACY
CT+/5151 or CT+/5102	0,2 In – 0,5 In	±2%, ±1 digit
	0,5 In – 20 In	±1%, ±1 digit
CT+/1500	0,03 In – 2 In	±0,5%, ±1 digit



3.3.5. Average and maximum measurement function

3.3.5.1. The measurement

The input values of the EuroProt+ devices are the secondary signals of the voltage transformers and those of the current transformers.

These signals are pre-processed by the “Voltage transformer input” function block and by the “Current transformer input” function block. These function blocks are described in separate documents. The pre-processed values include the Fourier basic harmonic phasors of the voltages and currents and the true RMS values. Additionally, it is in these function blocks that parameters are set concerning the voltage ratio of the primary voltage transformers and current ratio of the current transformers.

Based on the pre-processed analog signals, several function blocks perform additional calculation, e.g.: active and reactive power, frequency, temperature, impedances, higher harmonics, symmetrical components, etc.

The “Average and maximum” function block calculates average values and locates maximum values of the assigned (measured and calculated) analog signals.

3.3.5.2. Operation of the function block

The **input** of the function can be:

- Any single calculated analog value: active and reactive power, frequency, temperature, impedances, higher harmonics, symmetrical components, etc. depending on the assignment in the configuration.

The **outputs** of the function are:

- Average of the analog value,
- Maximum of the analog value.

The average and the maximum values are automatically reported to the SCADA system. The maximum is logged and is sent automatically to the HMI, the average however is logged only if a binary input of the function block enables this activity.

3.3.5.3. Reporting the values

The average calculation needs a time span for calculation; this is given as a parameter value, set in minutes (or the function is switched off). When the timer expires, the calculated average is reported automatically to the SCADA system. Depending on the requirements, this value is also logged and is sent to the local HMI. This activity is controlled by a binary input of the function block.

The identification of the maximum value needs also a time span; this is given as a parameter value, set in days. When the timer expires, the found maximum value is reported automatically to the SCADA system. Additionally this value is also logged and is sent to the local HMI.

The starting of the timer is controlled by the internal real-time clock of the device. The moment of time for the starting of the processing cycles is set by a parameter value.

3.3.5.4. Parameters of the function block

Enumerated parameter

Parameter name	Title	Selection range	Default
Time window for averaging			
MXU_TimWin_EPar_T _	Average TimeWindow	Off,5min,10min,15min,30min,60min	Off

Table 1-1 The enumerated parameters of the average and maximum measurement function

Integer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Time window for finding the maximum value						
MXU_MaxResInt_IPar_T	MaxReset Interval	day	0	365	1	1
Moment of time for reporting and reset						
MXU_MaxResTime_IPar_T	MaxReset Time	hour	0	23	1	12

Table 1-2 The integer parameters of the average and maximum measurement function

3.3.5.5. Status signals of the function block

The average and maximum measurement function block has **binary input signals**, which serve the purpose of resetting the values and enabling logging the average value. **The conditions are defined by the user, applying the graphic equation editor.**

Binary status signal	Explanation
MXU_Reset_GrO_IL1 *	This signal resets both the calculated average and the found maximum value. At the end of the running cycles, the values found during the shortened cycle will be processed.
MXU_DemHMIEna_GrO_IL1	During the active state of this signal also the calculated average value is logged

* Note: In this example “IL1” is indicating that in the instant of the function block processes the RMS value of the current in line 1

Table 1-3 The binary input signal for the average and maximum measurement function block

The average and maximum measurement function block **has no binary output signals**.

3.3.5.6. The function block

The function block of the average and maximum measurement function is shown in Figure 1-1. This block shows all binary input (and output) status signals that are applicable in the graphic equation editor.

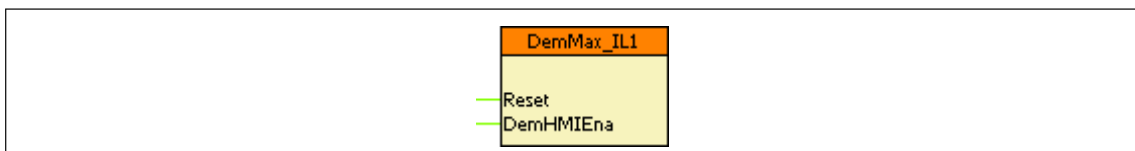
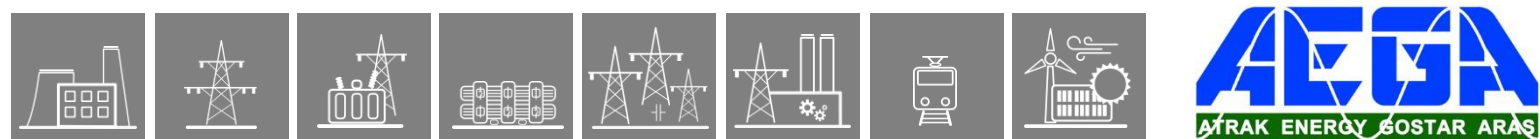


Figure 1-1 The function block of the average and maximum measurement function block



3.3.6. Metering

3.3.6.1. Application

The metering function can be applied to calculate the active and reactive energy supply and demand values based on the own measurement of the device or the energy meter impulses.

3.3.6.1.1. Mode of operation

There is an “Input selection” parameter to select the input of energy the calculation “Measurement” or “Impulse”. Chapter 1.1.1 and Chapter 1.1.2 describe the difference of operation.

3.3.6.1.2. Measurement mode

The input values of the EuroProt+ devices are the secondary signals of the voltage transformers and those of the current transformers.

These signals are pre-processed by the “Voltage transformer input” function block and by the “Current transformer input” function block. These function blocks are described in separate documents. The pre-processed values include the Fourier basic harmonic phasors of the voltages and currents. Additionally, it is in these function blocks that parameters are set concerning the voltage ratio of the primary voltage transformers and current ratio of the current transformers.

Based on the pre-processed values and the transformer parameters, the “Line measurement” function block calculates “P” and “Q” values in every process cycle and based on these values the “Metering” function block calculates the active and reactive power supply and demand. These values are accumulated to obtain, separately:

- Active power demand,
- Active power supply,
- Reactive power demand.
- Reactive power supply,

This means that the positive and negative values are accumulated separately.

The time period of the accumulation is defined by parameter setting. It can be selected in a broad range. The start of the accumulation is based on the integrated real-time clock of the device. For example, for the “Time Interval” setting of 15min, the trigger is: at 0h0min, 0h15min, 0h30min, 0h45 min, 1h0min, etc.

When the accumulation time is over, the calculated values are reported to the SCADA system. The displayed values change continuously.

The calculated values are available as primary quantities, and they can be displayed on the on-line screen of the device or on the webpage of the device and they are available for the SCADA system using the configured communication system.

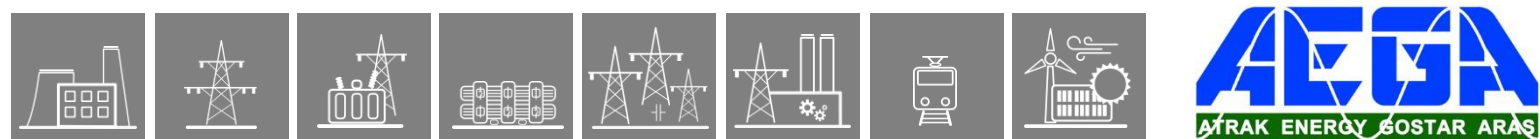
The **inputs** of the metering function are:

- the Fourier components of the measured voltages and currents,
- parameters.

The **output** of the metering function is:

- displayed measured values.

NOTE: the scaling values are entered as parameter setting for the “Voltage transformer input” function block and for the “Current transformer input” function block.



3.3.6.1.3. Impulse mode

Based on the external energy meter impulses. These impulse outputs of the meter connect as binary inputs. Metering function block calculates the active and reactive power supply and demand. These values are accumulated to obtain, separately:

- Active power demand,
- Active power supply,
- Reactive power demand.
- Reactive power supply,

Impulse scaling values are entered as parameters named “Active pulse scale” and “Reactive pulse scale”.

The time period of the accumulation is defined by parameter setting. It can be selected in a broad range. The start of the accumulation is based on the integrated real-time clock of the device. For example, for the “Time Interval” setting of 15min, the trigger is: at 0h0min, 0h15min, 0h30min, 0h45 min, 1h0min, etc.

When the accumulation time is over, the calculated values are reported to the SCADA system. The displayed values change continuously.

The calculated values are available as primary quantities and they can be displayed on the on-line screen of the device or on the webpage of the device and they are available for the SCADA system using the configured communication system

The **inputs** of the metering function are:

- the impulses of energy meter,
- parameters.

The **output** of the metering function is:

- displayed measured values.

3.3.6.1.4. Cumulation mode

“Cumulation mode” parameter defines the mode of operation. It can be “TRUE” or “FALSE”.

In “FALSE” mode the values set to zero after the values are reported to the SCADA system, based on the “Time Interval” settings.

In “TRUE” mode the values are cumulated after the report is sent to the SCADA system.

Maximum cumulated value depends on the CT module of IED and the primary nominals of CT and VT.

“Nominal primary power” = “Rated Primary U1-3” setting of VT module multiplied by “Rated Primary I1-3” setting of CT module. Unit prefix (kilo- or Mega) depends on the configuration, the “Line measurement” function uses the same unit prefix as Metering.

Maximum cumulated power value with CT+/1500 module = 3 259 602 multiplied by “Nominal primary power”

Maximum cumulated power value with CT+/5151 module = 65 192 055 multiplied by “Nominal primary power”

Maximum cumulated power value with CT+/5115 module = 8 149 006 multiplied by “Nominal primary power”

User can reset cumulated value to zero either by initiating the reset input of Metering function block or by restarting the device.

3.3.6.1.5. The measurement

3.3.6.1.5.1. Reference direction

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

3.3.6.1.5.2. The measured values

Unit prefix of the **measured values** of the metering function depends on the configuration: it can be kilo or Mega. The “Line measurement” function uses the same unit prefix as the Metering.

MEASURED VALUE	EXPLANATION
MTR_PosP_OLM_	Demand kWh – active power consumption
MTR_NegP_OLM_	Supply kWh – active power supply
MTR_PosQ_OLM_	Demand kVArh – reactive power consumption
MTR_NegQ_OLM_	Supply kVArh – reactive power supply

Table 1-1 Measured values of the metering function

The measured values available are shown as on-line information, see the figure below.

[-] METERING		
Demand kWh	400.0	kWh
Supply kWh	300.0	kWh
Demand kVArh	500.0	kVArh
Supply kVArh	2500.0	kVArh

Figure 1-1 Measured values of the metering function

3.3.6.1.6. Parameter setting

The time period of accumulation is defined by parameter setting. This can be selected in a broad range, as it is shown in Table 1-2.

Enumerated parameter

PARAMETER NAME	TITLE	SELECTION RANGE	DEFAULT
Selection of the time period for power metering			
MTR_TimInt_EPar_	Time Interval	Off, 5min, 10min, 15min, 30min, 60min	30min

Table 1-2 The enumerated parameter of the metering function

3.3.6.2. Metering function overview

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

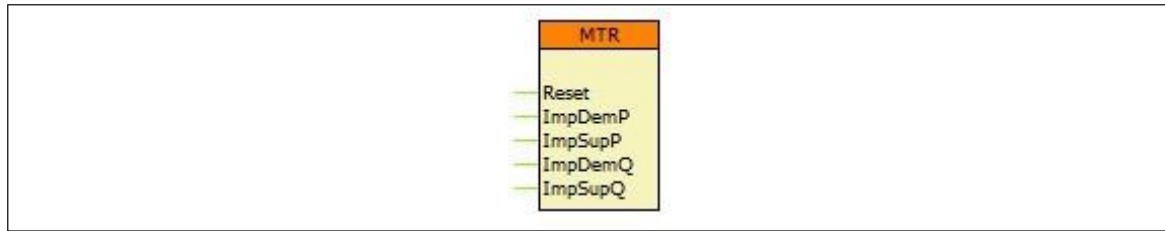


Figure 2-1 Graphic appearance of the function block of the metering function

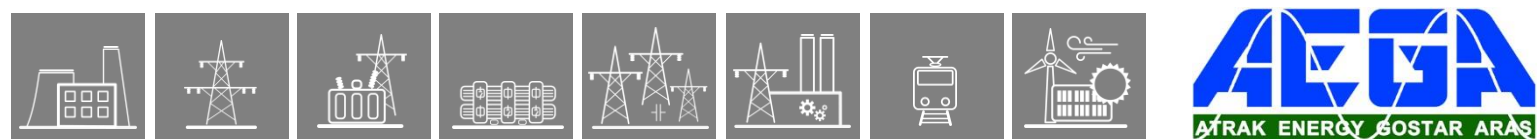
3.3.6.2.1. Settings

3.3.6.2.1.1. Parameters

The available parameters are listed below in order of their appearance in the *parameters* menu. If the setting range of a parameter should be extended, contact Protecta Support.

Table 2-1 The available parameters of the metering function

TITLE	DIM.	RANGE	STEP	DEFAULT	EXPLANATION
Time Interval	-	Off, 5min (On), 10min , 15min , 30min , 60min	-	30min	Time period of accumulation parameter for general operation of the function:
Input selection	-	Measurement, Impulse,	-	Measurement	Input selection of energy calculation
Cumulation mode		FALSE,TRUE		FALSE	Cumulation mode is used
Reference direction	-	Demand, Supply	-	Demand	Energy direction reference selection.
Active pulse scale	kWh/ pulse	1 - 10000	1	100	One impulse of energy meter is equal to this setting
Reactive pulse scale	kVarh/ pulse	1 - 10000	1	100	One impulse of energy meter is equal to this setting



3.3.6.2.2. Function I/O

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

3.3.6.2.2.1. Analogue inputs

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

3.3.6.2.2.2. Analogue outputs (measurements)

The measured values of the metering function are listed in the table below.

Table 2-2 The measured analogue values of the metering function

MEASURED VALUE	DIMENSION	EXPLANATION
Demand P	kWh	<i>Demand P. Unit prefix can be kilo- or mega-, depends on the configuration</i>
Supply P	kWh	<i>Supply P. Unit prefix can be kilo- or mega-, depends on the configuration</i>
Demand Q	kVarh	<i>Demand Q. Unit prefix can be kilo- or mega-, depends on the configuration</i>
Supply Q	kVarh	<i>Supply Q. Unit prefix can be kilo- or mega-, depends on the configuration</i>

3.3.6.2.2.3. Binary input signals (graphed output statuses)

The conditions of the binary inputs are defined by the user, applying the graphic equation editor (*Logic Editor*). Parts written in **bold** are seen on the left side function block in the Logic editor.

Table 2-3 The binary input signal of the metering function

BINARY OUTPUT SIGNAL	EXPLANATION
MTR_ Reset _GrO_	Reset input of the function has meaning only in cumulation mode
MTR_ ImpDemP _GrO_	Demand P impulse of external energy meter input of the function has meaning only in impulse input mode
MTR_ ImpSupP _GrO_	Supply P impulse of external energy meter input of the function has meaning only in impulse input mode
MTR_ ImpDemQ _GrO_	Demand Q impulse of external energy meter input of the function has meaning only in impulse input mode
MTR_ ImpSupQ _GrO_	Supply Q impulse of external energy meter input of the function has meaning only in impulse input mode

3.3.6.2.2.4. Events

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

Table 2-4 Generated events of the metering function

EVENT	DIMENSION	EXPLANATION
Demand P	Wh	<i>Demand P value</i>
Supply P	Wh	<i>Supply P value</i>
Demand Q	Varh	<i>Demand Q value</i>
Supply Q	Varh	<i>Supply Q value</i>

3.3.6.2.3. Technical data

Table 2-5 Technical data of the metering function

FUNCTION	RANGE	ACCURACY
Power accuracy	$I > 15\%I_n$	$\pm 3\%$

3.3.6.2.4. Notes for testing

Time period of the accumulation is defined by parameter setting.

Starting accumulation is based on the integrated real-time clock of the device.

For example, for a “Time Interval” setting of 15min, the trigger is: at 0h0min, 0h15min, 0h30min, 0h45 min, 1h0min, etc.

Parameter changing resets the accumulation. Using the settings of the example above, setting new parameters at 0h07min will result in the following:

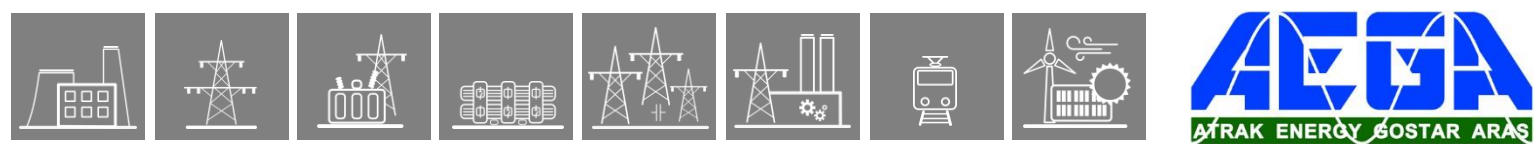
- 4 the accumulated values are reset to zero,
- 5 the new accumulation starts at 0h15min,
- 6 the first report is sent at 0h30min. Measured values in Events list will also refresh at 0h30min.

3.3.6.2.5. 61850 LN

Instance number of Logical Node is not mentioned in the table below.

Table 2-6 Logical Node and Data Objects of the metering function

LN NAME	DO NAME	DA NAME	FC	EXPLANATION
EMMTR	DmdVArhPV	mag.f	MX	Demand VArh value
		q	MX	quality
		t	MX	timestamp
	DmdWhPV	mag.f	MX	Demand Wh value
		q	MX	quality
		t	MX	timestamp
	SupVArhPV	mag.f	MX	Supply VArh value
		q	MX	quality
		t	MX	timestamp
	SupWhPV	mag.f	MX	Supply Wh value
		q	MX	quality
		t	MX	timestamp



3.3.7. Voltage selection function block

3.3.7.1. Application

In several substation configurations with double busbar, there is no voltage measurement in the bays, but voltage transformers are connected to the busbars only.

If the protection functions configured in the bay devices apply voltage measurement then the correct selection of the voltage sources is needed. The role of the voltage selection is that the protection functions get the voltage of the busbar section to which the feeder or the transformer is connected.

To solve this problem the device gets both three-phase voltages of both busbar sections, and a binary signal decides which one is valid for the protection function.

The "Voltage selection" function block assigns the correct voltages to the protection functions.

3.3.7.2. Mode of operation

The voltage selection is decided by a binary signal. **The conditions are defined by the user applying the graphic equation editor.**

If this input signal is FALSE then the voltages of the voltage input module configured as default input are assigned to the protection functions.

If however this input signal is TRUE then the voltages of the other voltage input module are assigned to the protection functions.

3.3.7.3. The binary status signals

The voltage selection function block has a binary input signal. **The conditions are defined by the user applying the graphic equation editor.**

The **binary input status signal** of the voltage selection function block is shown in Table 1-1.

Binary status signal	Title	Explanation
SelectVolt_USelect_GrO_	USelect	Binary signal controlling the voltage selection

Table 1-1 The binary input status signal of the voltage selection function block

The **binary output status signals** of the voltage selection function block.

The voltage selection function block has no binary output status signals.

3.3.7.4. The parameters

The voltage selection function block has no parameters.

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

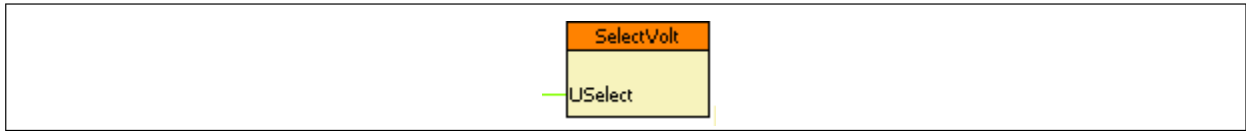


Figure 1-1 The function block of the voltage selection function block

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

3.3.7.6. Example

In this simple example the channel No.1 of the binary input module in position “F” is used as the signal controlling the selection.

If this input signal is FALSE then the voltages of the voltage input module configured as default input are assigned to the protection functions.

If however this input signal is TRUE then the voltages of the other voltage input module are assigned to the protection functions.

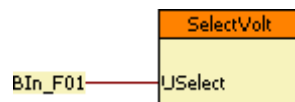
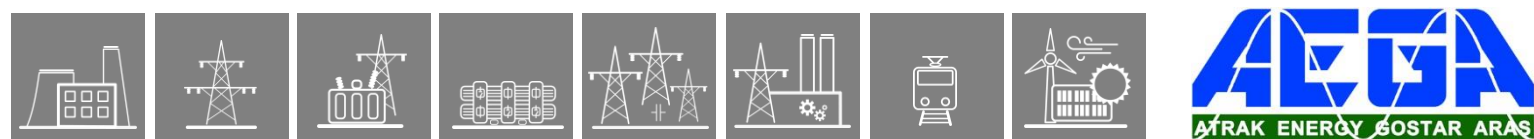


Figure 2-1 Example The simple application of the voltage selection function block



3.3.8. Trip Value Recorder

3.3.8.1. Application

For quick evaluating of network faults, it is very useful to see in the event list of the protection device the measured primary analog values (currents, voltages) before and during the fault state. The Trip value recorder function serves this purpose.

This function is not a default element of any configuration, but it can be acquired (please contact Protecta Support team).

3.3.8.1.1. The measurement

The input values of the EuroProt+ devices are the secondary signals of the voltage transformers and those of the current transformers.

These signals are pre-processed by the “Voltage transformer input” function block and by the “Current transformer input” function block. These function blocks are described in separate documents. The pre-processed values include the Fourier basic harmonic phasors of the voltages and currents and the true RMS values. Additionally, it is in these function blocks that parameters are set concerning the voltage ratio of the primary voltage transformers and current ratio of the current transformers.

Based on the pre-processed analogue signals, several function blocks perform additional calculation, e.g.: active and reactive power, frequency, temperature, impedances, higher harmonics, symmetrical components, etc.

The Trip value recorder function calculates the primary values from its three input secondary signals (currents or voltages) and uses them as described in the following chapter.

3.3.8.1.2. Operation principles

The Trip value recorder has two binary inputs: “Start” and “Trip”.

When the “Start” binary input receives a rising edge signal, the function stores the 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.

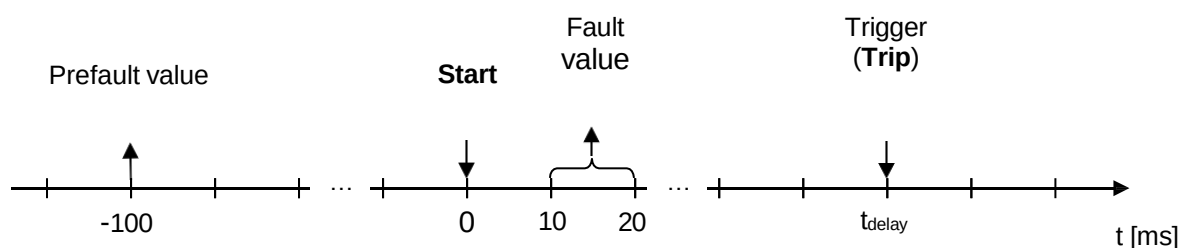


Figure 1-1 Time diagram of the trip recording behaviour

3.3.8.2. Trip value recorder function overview

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

Usually, the collected general start signal of the protection functions is assigned to the “Start” input and the general trip signal of trip logic function is connected to the “Trip” input.

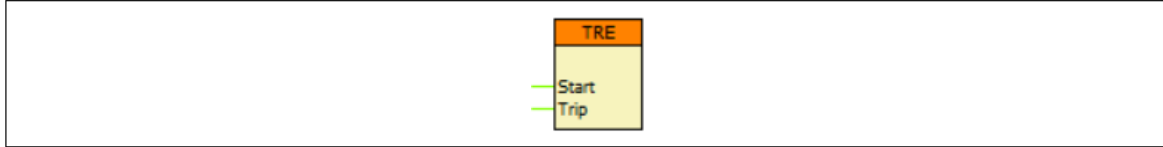


Figure 2-1 Graphic appearance of the function block of the trip value recorder function

3.3.8.2.1. Settings

3.3.8.2.1.1. Parameters

The Trip value recorder function does not have any parameters.

3.3.8.2.2. Function I/O

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

3.3.8.2.2.1. Analogue inputs

The function uses the sampled values of a current input or voltage input. Moreover, calculated analogue signals i.e.: symmetrical values, differential/bias current values can be used as inputs.

The following table contains the available input channels of the trip value recorder function.

Table 2-1 Available analogue inputs of the trip value recorder function

ANALOGUE INPUTS	RELATED FUNCTION BLOCK
Phase current, phase-to-phase, symmetrical, residual currents	CT4, CalcCurr
Voltage in phase, phase-to-phase, and symmetrical; Reference (busbar) voltages	VT4, CalcVolt
Calculated Idiff/Ibias current of transformer differential protection	DIF87T
Calculated Idiff/Ibias current of busbar differential protection for each bus section	DIF87B

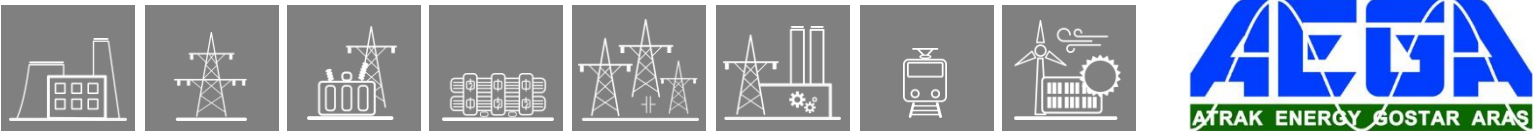
NOTE: Displaying the fault current values of the line differential protection Idiff/Ibias current and the restricted earth fault protection Idiff/Ibias current are integrated into the protection function, thus not need additional trip value functions to display the trip values.

3.3.8.2.2.2. Binary input signals (graphed output statuses)

The conditions of the binary inputs are defined by the user, applying the graphic equation editor (Logic Editor). Parts written in **bold** are seen on the left side function block in the Logic editor.

Table 2-2 The binary input signal of the trip value recorder function

BINARY OUTPUT SIGNAL	EXPLANATION
TRE_ Start _GrO_	Dedicated input of the function to receive the start signal of the selected protection functions
TRE_ Trip _GrO_	Dedicated input of the function to receive the trip signal of the selected protection functions



3.3.8.2.2.3. **Binary output signals (graphed input statuses)**

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

3.3.8.2.2.4. **Online data**

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

3.3.8.2.2.5. **Events**

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

Table 2-3 Generated events of the trip value recorder function

EVENT	VALUE	EXPLANATION
... Prefault*	according to the applied input	Prefault value of the applied signal
... Fault*	according to the applied input	Fault value of the applied signal

**The event text may vary according to the actual device configuration (.epcs)*



3.3.9. RTD temperature input function

3.3.9.1. Application of the RTD input

If the factory configuration includes an RTD temperature input hardware module, the temperature input function block is automatically configured among the software function blocks. Separate temperature input function blocks are assigned to each temperature input hardware module.

The RTD+1100 temperature input hardware module is equipped with four special input channels, the RTD+ 0200 has a single channel only. (See EuroProt+ hardware description document.) To each channel, a temperature sensor can be connected. The temperature is measured as the resistance value of the sensor, which depends upon the temperature.

The sensors can be connected by wiring methods, shown in Figure 1–1, Figure 1–2 and Figure 1–3. The connection mode is identified also by parameter setting.

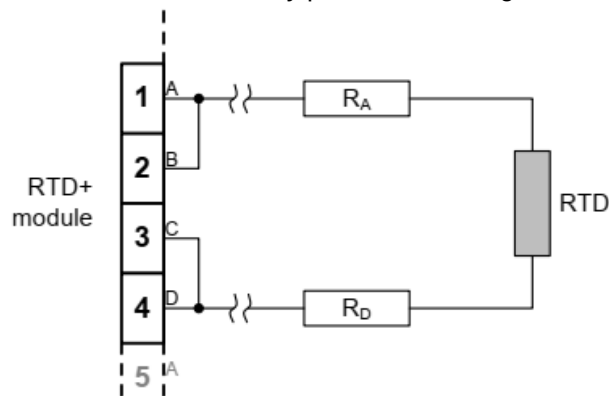


Figure 1–1 2-wire RTD wiring

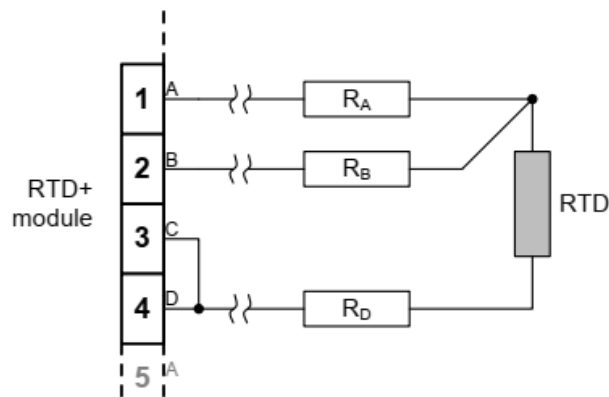
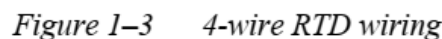


Figure 1–2 3-wire RTD wiring

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



- Pt100/Ni100
- Ni120/Ni120US
- Pt250/Ni250
- Pt1000/Ni1000
- Cu10
- Service-Ohm (60 Ω ... 1.6 k Ω)

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3.3.9.2. Technical summary

3.3.9.2.1. Technical data

The technical data of the temperature input module are related to the hardware module. This is described in the document “**EuroProt+ Hardware description**, Chapter 10: RTD input module”.

3.3.9.2.2. Summary of the parameters

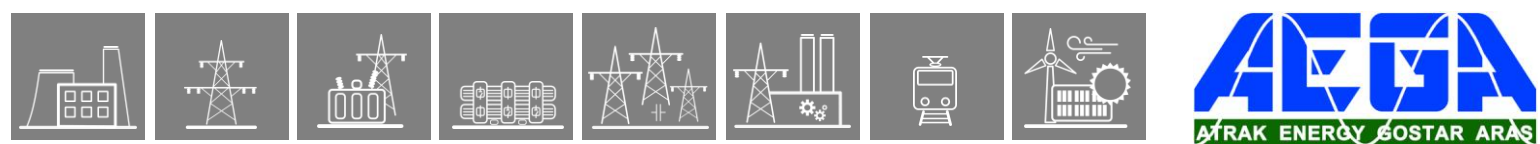
The parameters of the temperature input function are explained in the following table.

Enumerated parameters

Parameter name	Title	Selection range	Default
Connection mode of Channel 1			
RTD_Ch1RangeOfMAn03_EPar_	Channel 01	3wire, 4wire, 2wire	3wire
Connection mode of Channel 2			
RTD_Ch2Range2OfMAn03_EPar_	Channel 02	3wire, 4wire, 2wire	3wire
Connection mode of Channel 3			
RTD_Ch3RangeOfMAn04_EPar_	Channel 03	3wire, 4wire, 2wire	3wire
Connection mode of Channel 4			
RTD_Ch4Range2OfMAn04_EPar_	Channel 04	3wire, 4wire, 2wire	3wire

Table 1-1 The enumerated parameters of the voltage input function

NOTE: The function block has no input and output binary signals, the graphic logic editor does not show this function block.



3.4. Disturbance recorder function

3.4.1. Operation principle

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.

3.4.1.1. 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.

Depending on the type of the CPU module it has 64 or 128 MB memory. The available memory for disturbance records is 12 MB which is reserved from the whole 64 or 128 MB memory of the CPU module. The disturbance records are stored in the non-volatile flash memory and because of it the disturbance records remain in this memory after IED restarts, they will not be deleted.

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.*

The sizes of each record may vary depending on the number of the recorded signals and the length of the record. One analog channel takes up about 7 kB and a binary channel 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(seconds),
*where **n** and **m** are the number of analog and binary channels, respectively.*

As an example, for 50 Hz, if the duration of the record is 2000 ms (= 2 sec) and there are 4 current channels (4 analogue channels, n = 4) and 10 binary channels (m = 10), the size of the record is:

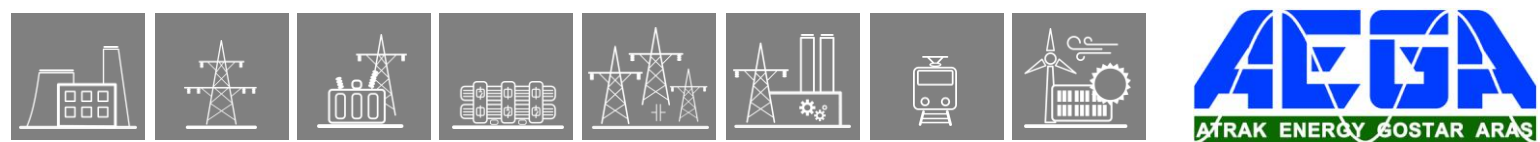
$$(4*7 + 10*2)*1 = (28+20)*2 = 96 \text{ kB}$$

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.



3.4.1.2. Format of recording

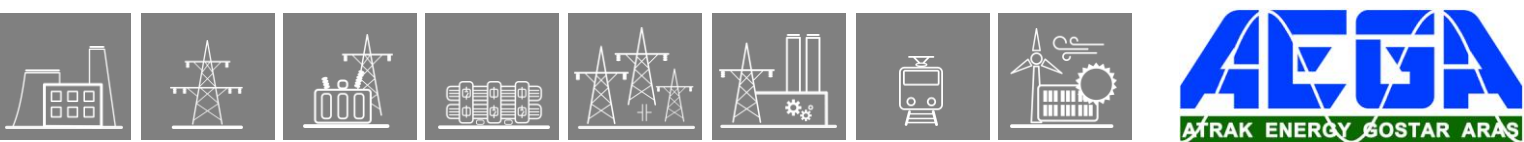
The records are stored in standard COMTRADE (C37.111-1999) format.

- 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.

3.4.1.3. 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.



3.4.2. Disturbance recorder function overview

The two function blocks of the disturbance recorder function are shown in Figure 2-1. 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.

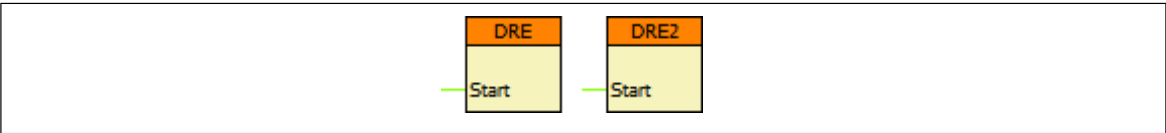


Figure 2-1 The function block of the disturbance recorder function

3.4.2.1. Settings

3.4.2.1.1. Parameters

Table 2-1 Parameters of the disturbance recorder function

TITLE	DIM	RANGE	STEP	DEFAULT	EXPLANATION
Operation	-	Off, On	-	Off	Parameter for activation
Resolution	kHz	1/1.2, 2/2.4	-	1/1.2	Sampling rate selection
PreFault	msec	100 - 1000	1	200	Pre-fault time
PostFault	msec	100 - 1000	1	200	Post-fault time
Max Recording Time	msec	500 - 10000	1	1000	Overall-fault time limit

NOTE: The device goes automatically in “Warning” state and sends a warning message (see Figure 2-2) 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.”

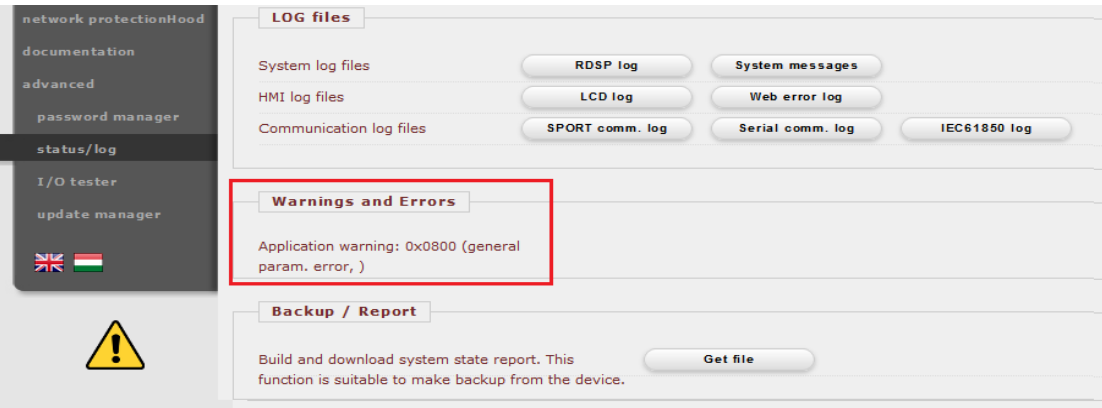
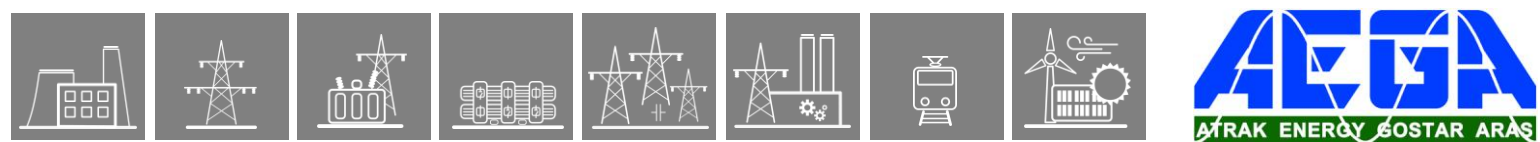


Figure 2-2 Warning message if the settings are invalid



3.4.2.2. Function I/O

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

3.4.2.2.1. Analogue inputs

The function doesn't use analogue inputs.

3.4.2.2.2. Binary output signals (graphed input statuses)

This function block doesn't have binary output signal.

3.4.2.2.3. Binary input signals (graphed output statuses)

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 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.

Table 2-2 The binary input status signals of the disturbance recorder function

BINARY INPUT SIGNAL	EXPLANATION
DRE_Start_GrO_	Output status of a graphic equation defined by the user to start the disturbance recorder function.

3.4.2.2.4. On-line data

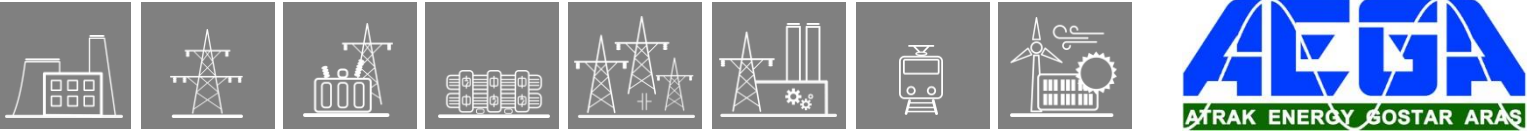
Visible values on the on-line data page:

Table 2-3 On-line data of the disturbance recorder function

SIGNAL TITLE	DIMENSION	EXPLANATION
DR Start	-	If the disturbance recorder starts, this signal becomes on

3.4.2.2.5. Events

No events belong to this function block.



3.4.2.3. 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.

3.4.2.3.1. Notes for testing

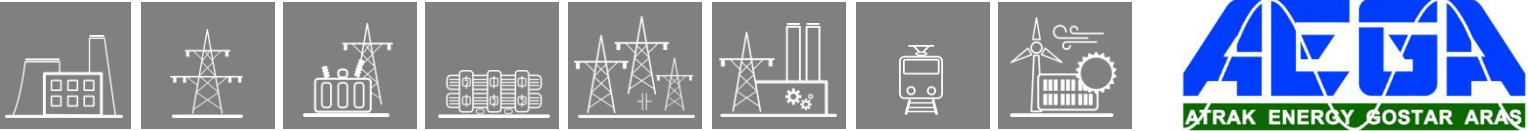
During special tests such as characteristic tests depending on the test method it could occur that due to frequently repeated starting of disturbance recorder leads to the stop of the function. After this kind of stops some test cases will not be recorded by the disturbance recorder. It is not a fault of the function or IED it is only the result of not well constructed test environment or not properly configured IED. Take this phenomenon into consideration before creating a test environment and prepare the configuration of the IED.

3.4.2.4. 61850 LN

Instance number of Logical Node is not mentioned in the table below.

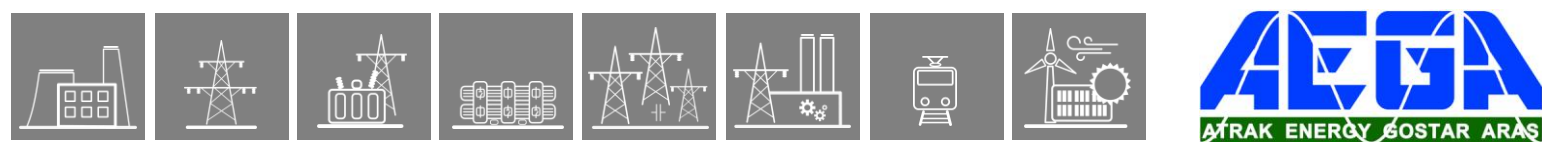
Table 2-4 Logical Node and Data Objects of the metering function

LN NAME	DO NAME	DA NAME	FC	EXPLANATION
DRDRE	RcdMade	stVal	ST	<i>A new record made in the IED</i>
		q	ST	<i>quality</i>
		t	ST	<i>timestamp</i>
	FltNum	stVal	ST	<i>Fault number is the number of recorded COMTRADE file</i>
		q	ST	<i>quality</i>
		t	ST	<i>timestamp</i>



3.5. **Event recorder**

The events of the device and those of the protection functions are recorded with a time stamp of 1 ms time resolution. This information with indication of the generating function can be checked on the touch-screen of the device in the “Events” page, or using an Internet browser of a connected computer



4. Maintenance guide for EuroProt+ devices

4.1. Foreword

The EuroProt+ devices are designed with the most up-to-date and durable components available, to keep appliances in continuous operation for decades. For this range, the only type of components that can age and lead to equipment failure are the power supply capacitors. Therefore, this document, in addition to suggesting some general steps for planned inspections, contains important information on the inspection of power supply modules.

4.2. Safety precautions

The EP+ protection-family, depending on the type, operates at dangerous power supply voltages (220 VDC, 230 VAC, 60 VDC, 48 VDC).



In all cases where the connections of the appliance are to be installed or opened, the work must be carried out by a suitably qualified person.

In all cases, the first step of activity should be to switch off the power



The EuroProt+ protection family has a high operating internal temperature. Operations carried out immediately after operation may lead to dangerous burns.



The hardware and software of the EP+ protection family form a complex system. Setting, modifying, and mounting the individual components may severely affect the operation of the whole system.

In all cases where the device is to be operated or maintained, the activity must be carried out by qualified personnel only

4.2.1. General guidelines for a scheduled maintenance of EP+ devices

1. As a first step, it is recommended to send an email attaching a report.zip file to the Protecta Application Department on the email address application@protecta.hu. In the report file, the logs contain information that can indicate abnormal operation of a module before it causes an operational fault. Based on this information, Protecta can make recommendations for the replacement or repair of the modules concerned.



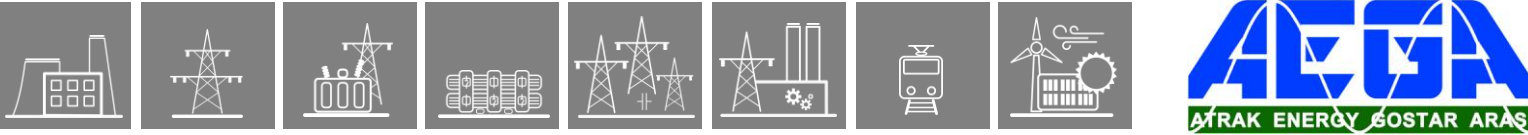
The report.zip file can be downloaded from the device's web interface, in the Backup / Report section of the Advanced / Status / Log menu, by pressing the "Get file" button. Attention! The file size should be about 700kB. If the downloaded file size is significantly smaller than this, please try again or contact Protecta's Application Department via our web-based support system (<https://support.protecta.hu/?language=English>)!

2. It is usually recommended to update the firmware of the devices during scheduled maintenance. Information about the new firmware releases can be found in the [Release Notes on the Protecta homepage](#). The information here can be used to consider upgrading the basic software for a single device, or all devices in a substation.



Before starting the upgrade, always contact the Protecta Application Department or submit a ticket in the web-based support system from the following link: <https://support.protecta.hu/>

For more details on the firmware update, please refer to Chapter 4.2.10.4 of the [EuroProt+ Operating Manual](#).



4.3. Power supply maintenance

Power supplies are designed with the longest possible life electrolytic capacitors. Their expected lifetime depends significantly on the environmental conditions of the device. During a scheduled inspection, we recommend visual inspection of the power supply for any abnormalities in the capacitors. The most common phenomena are: bloating, electrolyte leakage, discoloration, which typically occurs on capacitors, but can also occur on the surface of the PCB board due to leakage. In case of abnormality, the capacitors should be replaced. In such a case, please contact Protecta's Application Department via our support page (<https://support.protecta.hu/>)!

The following figures illustrate the different capacitor states in several photos.



Figure 4-1 The capacitor on the right is already discolored

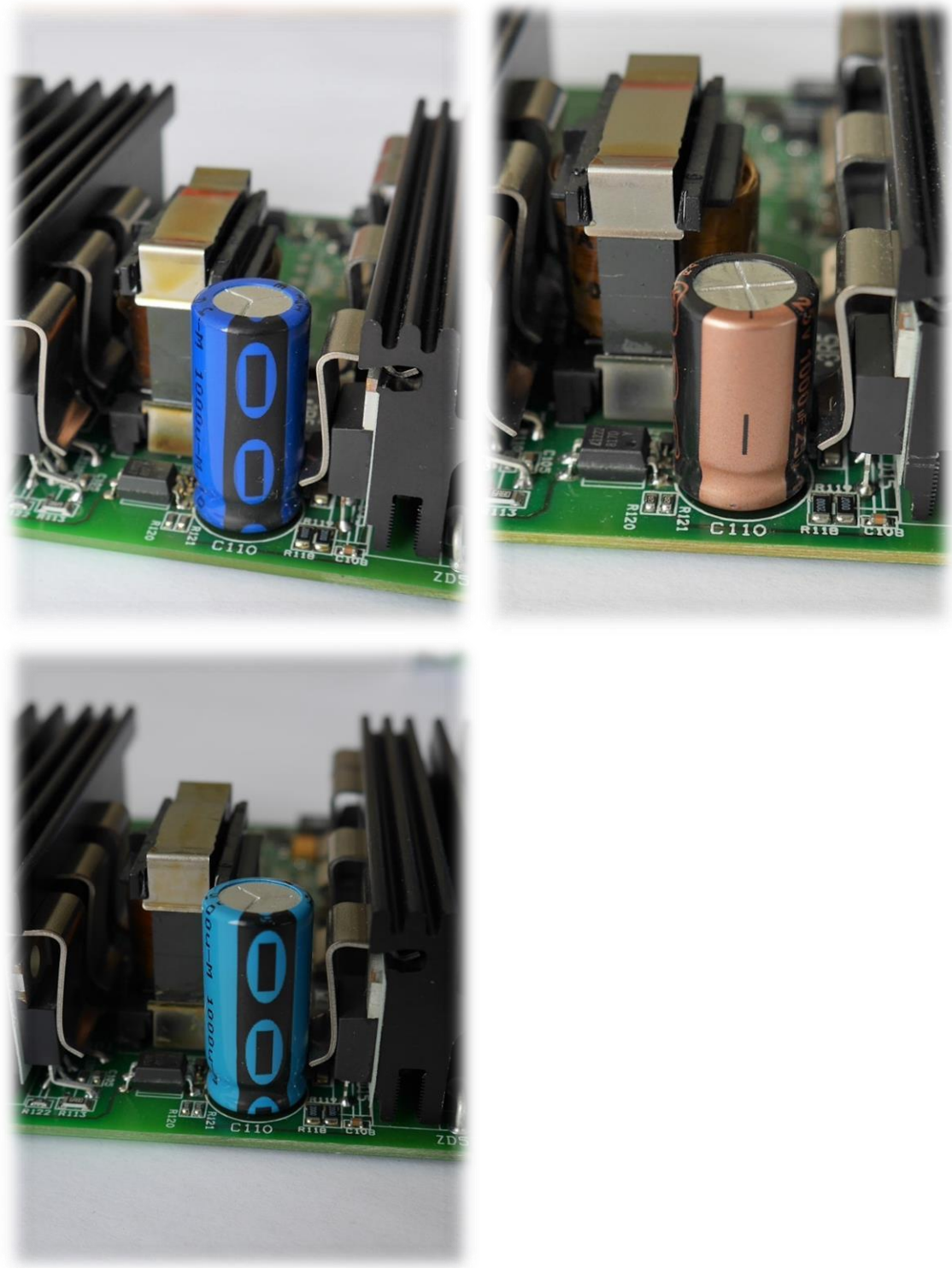


Figure 4-2 Healthy capacitors on visual inspection

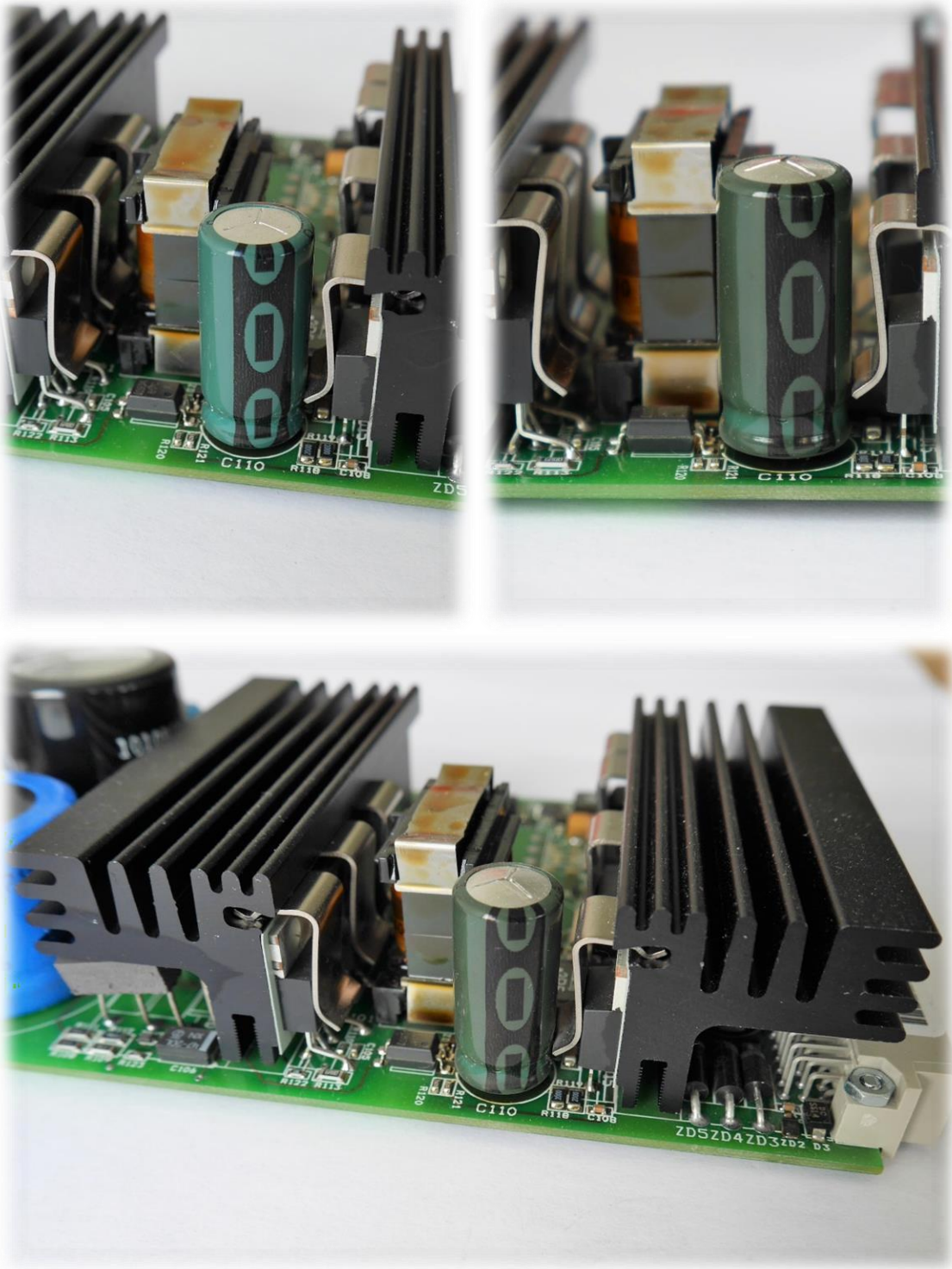


Figure 4-3 Faulty capacitances on visual inspection. The discoloration compared to the original blue color is clearly visible, bloating can be seen on 2 of them

4.4. Elements and Batteries

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

5. External connections

