PRODUCT DESCRIPTION

EuroProt+ DTRV

IED-EP+/DTRV

TRANSFORMER DIFFERENTIAL PROTECTION RELAY

PROTECTA
HUNGARY

EUROPROT+ DTRV

TRANSFORMER DIFFERENTIAL PROTECTION RELAY

OVERVIEW

The **DTRV** product type is a member of the **EuroProt+** numerical protection relay, 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.

The members of the **DTRV** product type are configured to protect and control high voltage/medium voltage transformers.

GENERAL FEATURES

- Native IEC 61850 IED with Edition 1 & 2 compatibility
- Module layouts with options 42 or 84 HP 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
- Different HMI Types: advanced HMI with color touchscreen and black-and-white display with 4 tactile push buttons. An embedded web server and extended measuring, control and monitoring functions are also available for both types
- User configurable LCD user screens, which can display SLDs (Single Line Diagrams) with switchgear position indication and control as well as setting values, measurement values, event and fault information (timestamp, function block, fault phase, fault current...)
- 8 setting groups available as default. The number of setting groups can be up to 20 as user's requirement
- Enhanced breaker monitoring and control
- High capacity disturbance recorder (DRE) and event logging in non-volatile memory:
  o DRE can store more than 64 records.
  o Each DRE recording can be configured up to 32 analogue and 64 digital signal channels with duration up to 10s and sampling rate up to 2kHz
  o Event recorder can store more than 10,000 events
  o The records can be read out from IED in the standard COMTRADE file format (IEEE Std C37.111) via exist communication connection (such as IEC61850) or even examined online. Every single record stored in 3 files with the same name and the following extensions: .dat, .cfg, .inf
- 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:
  o Ethernet-based communication protocol: IEC61850, DNP3.0 TCP, IEC60870-5-104, Modbus TCP
  o Serial communication protocol: DNP3.0, IEC60870-5-101, IEC60870-5-103, MODBUS, SPA
- Legacy network based protocols via 100Base-FX and 10/100Base-TX (RJ45)
- Optional communication ports: Fiber Ethernet (MM/ST, SM/FC), RJ45, Serial POF, Serial glass fiber, RS-485/422
- Handling several communication protocols simultaneously
- Built-in self-monitoring to detect internal hardware or software errors
- Time synchronization protocol: NTP/SNTP, Minute pulse, Legacy protocol, IRIG-B
- Integrated advanced cyber security - Conformity with the Cyber Security requirements in accordance with NERC-CIP, IEEE 1686, BDEW Whitepaper and IEC 62351-8 standard and recommendation. Passwords are required when logging into the device for: access, control, setting, manage,...

APPLICATION

The **DTRV** is aligned for complex protection, control and monitoring functions of two or three-winding power transformers. The device also features an integrated voltage regulator (E3, E6 versions).

The **DTRV** relay provides a variety of versatile protection functions along with the main transformer differential protection, such as 3ph, Io and I2 overcurrent protection, overload protection, restricted earth-fault protection etc.

Sensitive restricted earth-fault protection (REF) is the final element in the overall differential protection system, which detects even single phase-to-ground faults close to the grounded neutral of the transformer.

The multiple instances of the implemented three- phase and residual overcurrent functions are provided for the segregated protection of both transformer windings. Furthermore, several voltage-based protection functions are available for the voltage controlled side of the transformer based on the three phase-

voltage measurement. It can be used as a back-up protection relay for downstream equipment (e.g. feeders, cables).

The **DTRV** transformer protection relay can support double-breaker terminals on any side of the transformer such as breaker and a half or ring bus topology. Automatic phase shift and turns ratio compensation for all types of transformer winding connections.

The IED includes a wide range of control and supervise functions, which provide full control and user-defined interlocking schemes for the primary switchgear at the substation.

SCOPE OF APPLICATION

- Two or three - winding transformer protection and control device with main transformer differential protection and several additional protection functions; voltage control is integrated in the device
- The versatile protections functions can provide back-up protection relay for downstream equipment (e.g. feeders, cables etc.).
- Protection for all kinds of power transformers (including auto-transformers)
- 1-/3-phase tripping and support for double breaker terminals such as breaker and a half or ring bus topologies
- Three-phase transformer differential protection:
  o Automatic phase shift and turns ratio compensation of the transformer.
  o 2nd and 5th harmonics restraint for transformer inrush and over-excitation detection.
  o Residual current elimination feature is available if there is a neutral grounding transformer in the protected zone on the secondary side of the transformer
- Sensitive restricted earth-fault protection
- Several voltage-based protection functions are available through the three-phase voltage measurement.
- Current unbalance detection of Current Transformers
- Voltage regulation with automatic tap changer controller:
  o For up to 4 parallel transformers depending on the minimum circulating current or master-slave principles,
  o Tap changer position reading via RTD, mA or Binary inputs
  o Type of binary input coding: binary, BCD, Grey. Interlocking schemes can be defined by the user
- Optional external units:
  o 28 input/ 5 output tap changer transcoder (TRCS)
  o Remote I/O unit (RIO)
- Optional transducer I/Os (RTD/mA)
- Optional impedance protection

EUROCAP CONFIGURATION TOOL

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 customisable.
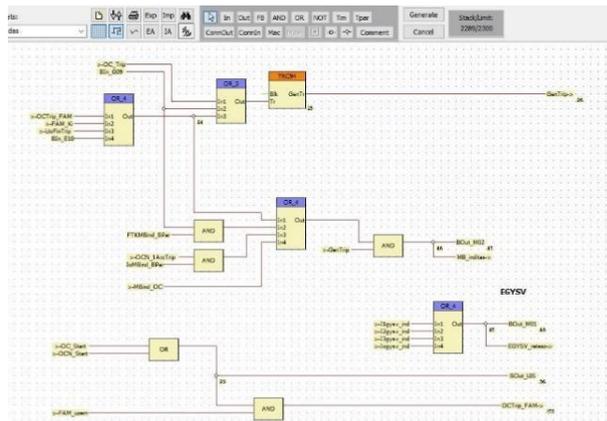
- **HW configuration**

  - View the exciting hardware configuration of the IED including card information and slot position
  - Modify (add or change) certain HW modules
 - Digital and analogue I/O signal definition
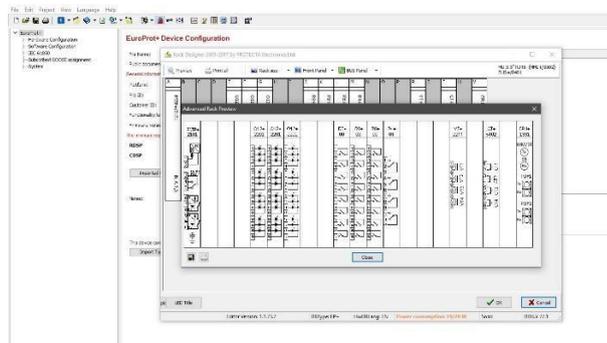
- **Logic editor**

  - Create/manage logical sheets
  - Factory pre-configured logical schemes to speed up the commissioning process


- **Communication configurator**

  - Set up IEC 61850, 101-104, 103, DNP3 communication protocols
  - Configure dataset, report and goose control block properties for IEC 61850 horizontal and vertical communication
  - GOOSE configuration between IEDs
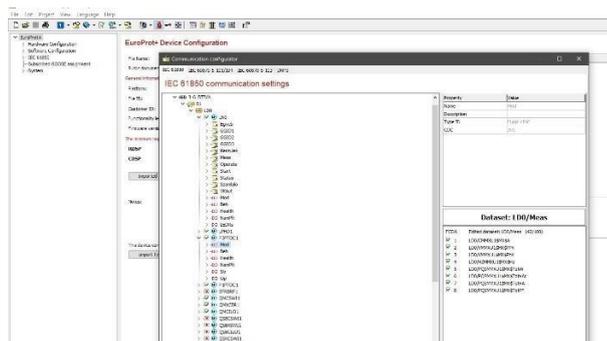
- **LCD configurator (available with color TFT displays)**

- Create/modify user screens with Single Line Diagrams, measuring or status values
- Icon library for effective configuration Own, user-defined symbols can be created as well
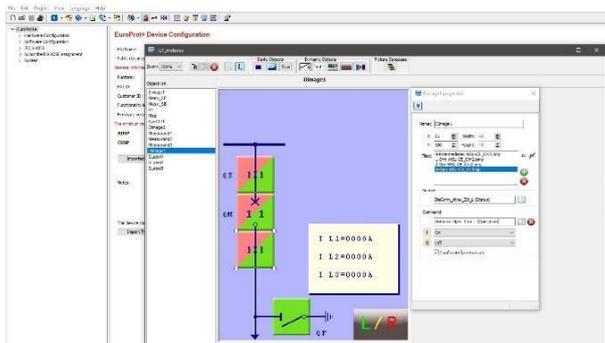
▪ **Feedback documentation**

Automatic documentation of the configured IED, which can contain the actual connection assignment, on-line measurements, all recorded event channels, all recorded disturbance channels, LED assignment, Logical sheets and the relevant communication settings and collect the protection, control and monitoring parameters.

▪ **Offline Parameter Set Editor**

- View, set, compare and save the setting of the IED parameters
- Import existing parameter settings into the Offline parameter set editor from the IED
- Import/Export parameters in xlsx format
- Generate and save parameters in RIO/XRIO format for relay tester

PROTECTION & CONTROL FUNCTIONS

▪ **Pre-defined configuration variants**

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

The main protection functions are transformer differential protection and restricted earth-fault protection functions. Based on the voltage measurement also the frequency is evaluated to realize frequency- based protection functions.
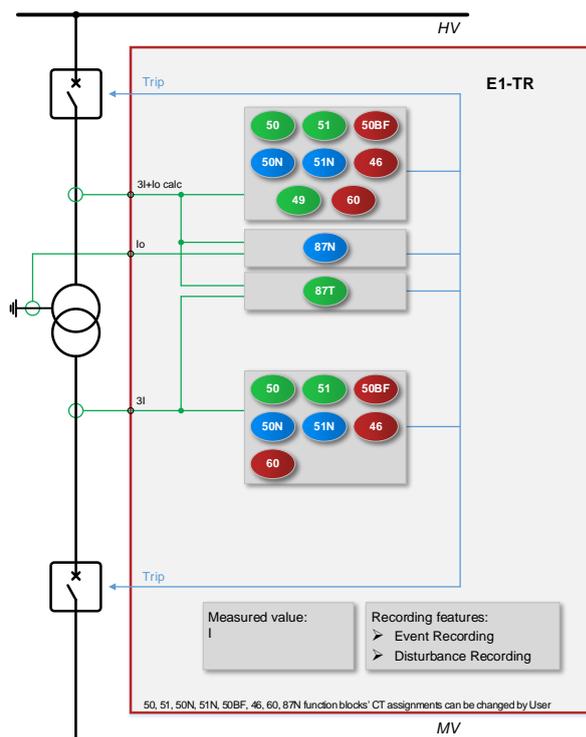
The number and the functionality of the members of each product type are put together according to the application philosophy, keeping in mind the possible main usages. The available configurations of the **DTRV** type for transformers are listed in the table below.

VARIANT	MAIN APPLICATION
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

- **E1-TR Two-winding transformer differential protection and control**

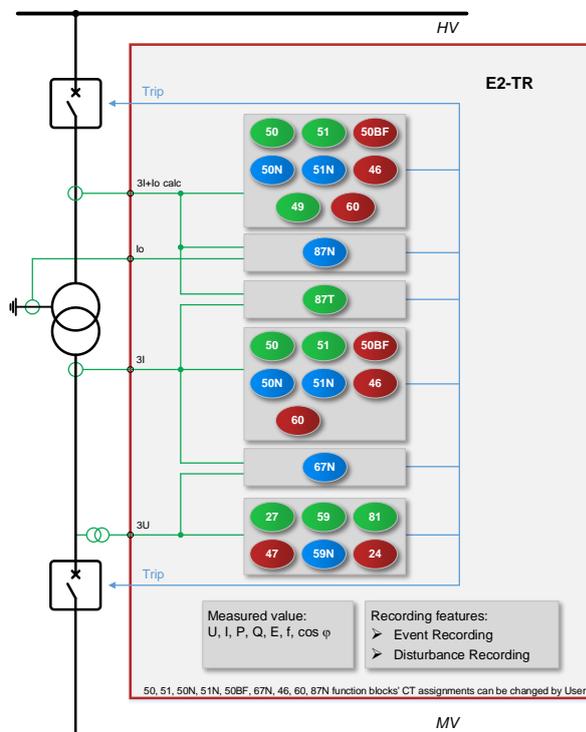| THE IMPLEMENTED PROTECTION & CONTROL FUNCTIONS	IEC	ANSI	*Inst.
Circuit breaker control (included interlocking function)			
Disconnector control (included interlocking function)			
Negative sequence overcurrent protection	I2 >	46	2
Thermal protection	T >	49	1
Three-phase instantaneous overcurrent protection	I >>>	50	2
Residual instantaneous overcurrent protection	Io >>>	50N	2
Breaker failure protection	CBFP	50BF	2
Three-phase time overcurrent protection	I >, I >>	51	4
Residual overcurrent protection	Io >, Io >>	51N	4
Current unbalance		60	2
Trip circuit supervision		74	1
Lockout trip logic function		86/94	1
Restricted earth-fault protection	REF	87N	2
Transformer differential protection (2W)	3IdT>	87T	1

*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.

- **E2-TR Two-winding transformer differential protection and control with voltage- based functions**

THE IMPLEMENTED PROTECTION & CONTROL FUNCTIONS	IEC	ANSI	*Inst.
Circuit breaker control (included interlocking function)			
Disconnector control (included interlocking function)			
Overexcitation protection	V/Hz	24	1
Definite time undervoltage protection	U <, U <<	27	2
Negative sequence overcurrent protection	I2 >	46	2
Negative sequence definite time overvoltage protection	U2 >	47	1
Thermal protection	T >	49	1
Three-phase instantaneous overcurrent protection	I >>>	50	2
Residual instantaneous overcurrent protection	Io >>>	50N	2
Breaker failure protection	CBFP	50BF	2
Three-phase time overcurrent protection	I >, I >>	51	4
Residual overcurrent protection	Io >, Io >>	51N	4
Definite time overvoltage protection	U >, U >>	59	2
Residual definite time overvoltage protection	Uo >, Uo >>	59N	2
Current unbalance		60	2
Directional residual time overcurrent protection	Io Dir >, Io Dir >>	67N	2
Trip circuit supervision		74	1
Overfrequency protection	f >, f >>	81O	2
Underfrequency protection	f <, f <<	81U	2
Rate of change of frequency protection	df/dt	81R	2
Lockout trip logic function		86/94	1
Restricted earth-fault protection	REF	87N	2
Transformer differential protection (2W)	3IdT>	87T	1

*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.

- **E3-TR Two-winding transformer differential protection and control with voltage- based functions and automatic voltage regulator / tap changer controller**
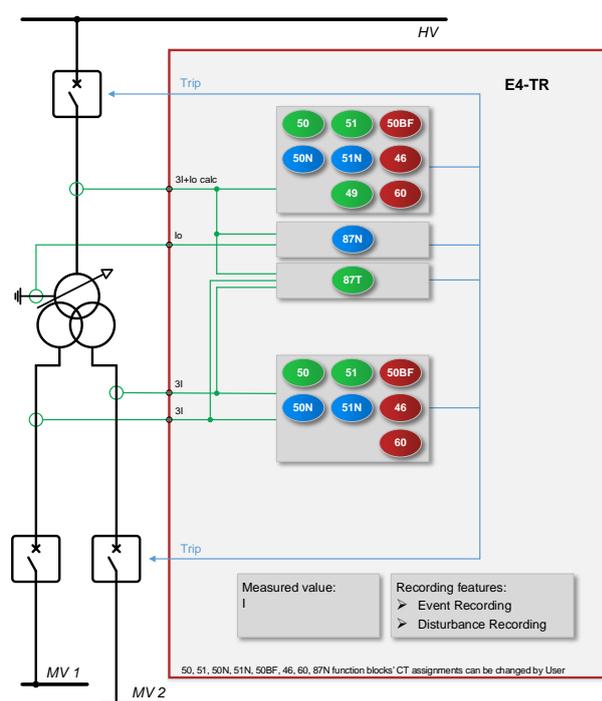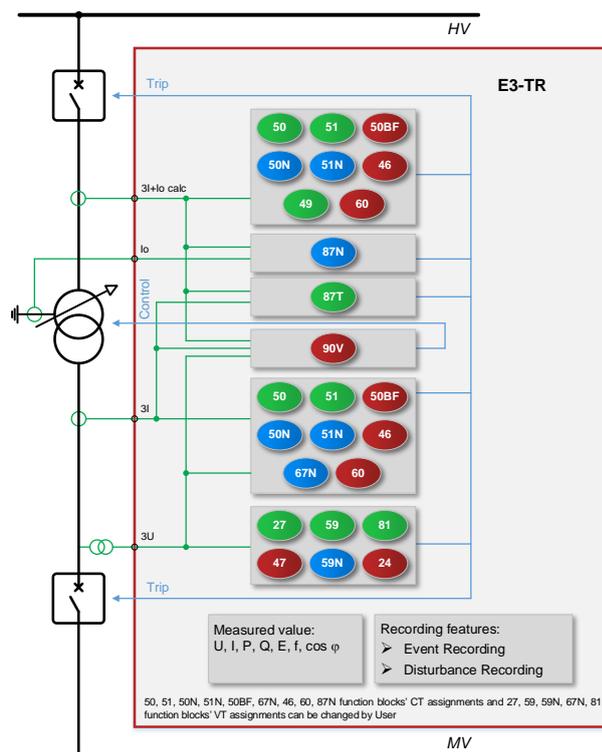
THE IMPLEMENTED PROTECTION & CONTROL FUNCTIONS	IEC	ANSI	*Inst.
Circuit breaker control (included interlocking function)			
Disconnector control (included interlocking function)			
Overexcitation protection	V/Hz	24	1
Definite time undervoltage protection	U <, U <<	27	2
Negative sequence overcurrent protection	I2 >	46	2
Negative sequence definite time overvoltage protection	U2 >	47	1
Thermal protection	T >	49	1
Three-phase instantaneous overcurrent protection	I >>>	50	2
Residual instantaneous overcurrent protection	Io >>>	50N	2
Breaker failure protection	CBFP	50BF	2
Three-phase time overcurrent protection	I >, I >>	51	4
Residual overcurrent protection	Io >, Io >>	51N	4
Definite time overvoltage protection	U >, U >>	59	2
Residual definite time overvoltage protection	Uo >, Uo >>	59N	2
Current unbalance		60	2
Residual directional overcurrent protection	Io Dir >, Io Dir >>	67N	2
Trip circuit supervision		74	1
Overfrequency protection	f >, f >>	81O	2
Underfrequency protection	f <, f <<	81U	2
Rate of change of frequency protection	df/dt	81R	2
Lockout trip logic function		86/94	1
Restricted earth-fault protection	REF	87N	2
Transformer differential protection (2W)	3IdT>	87T	1
Automatic tap-changer controller	ATCC	90V	1

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.

- **E4-Tr Three-winding transformer differential protection and control**

THE IMPLEMENTED PROTECTION & CONTROL FUNCTIONS	IEC	ANSI	*Inst.
Circuit breaker control (included interlocking function)			
Disconnector control (included interlocking function)			
Negative sequence overcurrent protection	I2 >	46	3
Thermal protection	T >	49	1
Three-phase instantaneous overcurrent protection	I >>>	50	3
Residual instantaneous overcurrent protection	Io >>>	50N	3
Breaker failure protection	CBFP	50BF	3
Three-phase time overcurrent protection	I >, I >>	51	6
Residual overcurrent protection	Io >, Io >>	51N	6
Current unbalance		60	3
Trip circuit supervision		74	1
Lockout trip logic function		86/94	1
Restricted earth-fault protection	REF	87N	3
Transformer differential protection (3W)	3IdT>	87T	1

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.

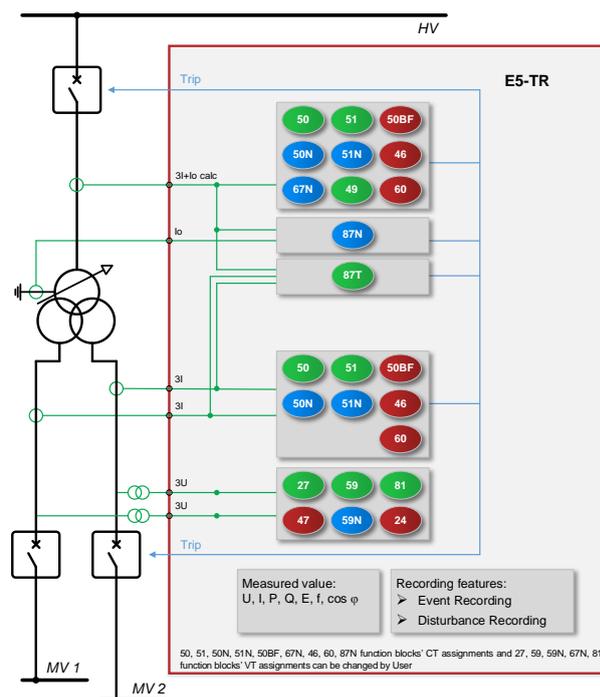▪ **E5-Tr Three-winding transformer differential protection and control with voltage- based functions**

| THE IMPLEMENTED PROTECTION & CONTROL FUNCTIONS	IEC	ANSI	*Inst.
Circuit breaker control (included interlocking function)			
Disconnector control (included interlocking function)			
Overexcitation protection	V/Hz	24	2
Definite time undervoltage protection	U <, U <<	27	2
Negative sequence overcurrent protection	I2 >	46	3
Negative sequence definite time overvoltage protection	U2 >	47	2
Thermal protection	T >	49	1
Three-phase instantaneous overcurrent protection	I >>>	50	3
Residual instantaneous overcurrent protection	Io >>>	50N	3
Breaker failure protection	CBFP	50BF	3
Three-phase time overcurrent protection	I >, I >>	51	6
Residual overcurrent protection	Io >, Io >>	51N	6
Definite time overvoltage protection	U >, U >>	59	2
Residual definite time overvoltage protection	Uo >, Uo >>	59N	2
Current unbalance		60	3
Residual directional overcurrent protection	Io Dir >, Io Dir >>	67N	2
Trip circuit supervision		74	1
Overfrequency protection	f >, f >>	81O	2
Underfrequency protection	f <, f <<	81U	2
Rate of change of frequency protection	df/dt	81R	2
Lockout trip logic function		86/94	1
Restricted earth-fault protection	REF	87N	3
Transformer differential protection function (3W)	3IdT>	87T	1

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.

- **E6-TR Three-winding transformer differential protection and control with voltage- based functions and automatic voltage regulator / tap changer controller**

THE IMPLEMENTED PROTECTION & CONTROL FUNCTIONS	IEC	ANSI	*Inst.
Circuit breaker control (included interlocking function)			
Disconnector control (included interlocking function)			
Overexcitation protection	V/Hz	24	2
Definite time undervoltage protection	U <, U <<	27	2
Negative sequence overcurrent protection	I2 >	46	3
Negative sequence definite time overvoltage protection	U2 >	47	2
Thermal protection	T >	49	1
Three-phase instantaneous overcurrent protection	I >>>	50	3
Residual instantaneous overcurrent protection	Io >>>	50N	3
Breaker failure protection	CBFP	50BF	3
Three-phase time overcurrent protection	I >, I >>	51	6
Residual overcurrent protection	Io >, Io >>	51N	6
Definite time overvoltage protection	U >, U >>	59	2
Residual definite time overvoltage protection	Uo >, Uo >>	59N	2
Current unbalance		60	3
Residual directional overcurrent protection	Io Dir >, Io Dir >>	67N	2
Trip circuit supervision		74	1
Overfrequency protection	f >, f >>	81O	2
Underfrequency protection	f <, f <<	81U	2
Rate of change of frequency protection	df/dt	81R	2
Lockout trip logic function		86/94	1
Restricted earth-fault protection	REF	87N	3
Transformer differential protection function (3W)	3IdT>	87T	1
Automatic tap-changer controller function	ATCC	90V	1

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.
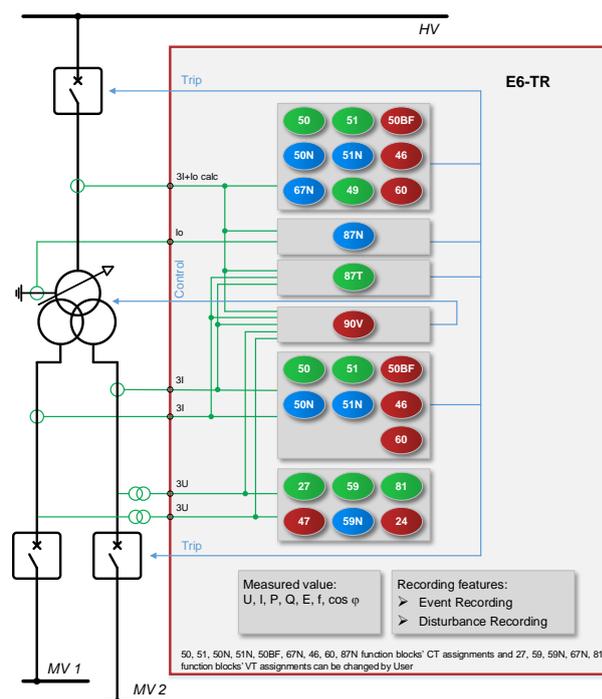
▪ **Circuit breaker control function block (CB1Pol)**

The Circuit breaker control function 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. Up to 32 Circuit breaker control function blocks can be configured.

The Circuit breaker control function 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" (enabled trip command) and "EnaOn" (enabled close command), 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:
  o Time limitation to execute a command
  o Command pulse duration
  o Filtering the intermediate state of the circuit breaker
  o Checking the synchro check and synchro switch times
  o 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 give commands to the CB). The combination is made graphically using the graphic equation editor
- Operation counter
- Event reporting

The Circuit breaker control function block has binary input signals. The conditions are defined by the user applying the graphic equation editor. The signals of the circuit breaker control are seen in the binary input status list.

▪ **Disconnector control function (DisConn)**

The Disconnector control function block can be used to integrate the disconnector or earthing switch control of the EuroProt+ device into the station control system and to apply active scheme screens of the local LCD of the device. Up to 32 Disconnector control function blocks can be configured.

The disconnector control function 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" (enabled trip command) and "EnaOn" (enabled close command), 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:
  o Time limitation to execute a command
  o Command pulse duration
  o Filtering the intermediate state of the disconnector
  o Controlling the individual steps of the manual commands
- Sending trip and close commands to the disconnector
- Operation counter
- Event reporting

The Disconnector control function block has binary input signals. The conditions are defined by the user applying the graphic equation editor. The signals of the disconnector control are seen in the binary input status list.

▪ **Overexcitation protection (24)**

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

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

The effect of high flux values is the symmetrical saturation of the iron core of the generator or that of the unit transformer. During saturation, the magnetizing current is high and distorted; high current peaks can be detected. The odd harmonic components of the current are of high magnitude and the RMS value of the current also increases. The high peak current values

generate high dynamic forces, the high RMS value causes overheating. During saturation, the flux leaves the iron core and high eddy currents are generated in the metallic part of the generator or transformer in which normally no current flows, and which is not designed to withstand overheating. The overexcitation protection is designed to prevent this long-term overexcited state

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

As the heating effect of the distorted current is not directly proportional to the flux value, the applied characteristic is of inverse type (so called IEEE type): If the overexcitation increases, the operating time decreases. To meet the requirements of application, a definite-time characteristic is also offered in this protection function as an alternative.

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

The effective frequency range includes all frequencies where the defined accuracy can be achieved. If the frequency is too small, then the time needed to find the peak values and to calculate the flux increases. In contrast, at high frequencies the accuracy of the detected peak value decreases. The frequency range monitored extends from 10 Hz to 70 Hz. The details are given among the technical data.

Similar to the frequency range, the voltage range is also limited. If the voltage is too small, the voltage measurement becomes inaccurate due to the sampling. In case of high voltage at low frequencies the voltage transformers may also saturate. Accordingly, the frequency range and the voltage range are closely related. The voltage range monitored extends from 10 V to 170 V. The details are given among the technical data.

The flux range is the combination of the voltage range and the frequency range. For overfluxing protection, the effective flux range extends from 0.5 to 1.5 UN/fN

- **Definite time undervoltage protection (27)**

The definite time undervoltage protection function measures the RMS values of the fundamental Fourier component of three phase voltages. The Fourier calculation inputs are the sampled values of the three phase voltages (UL1, UL2, UL3), and the outputs are the basic Fourier components of the analyzed voltages (UL1Four, UL2Four, UL3Four). They are not part of the TUV27 function; they belong to the preparatory phase.

The function generates start signals for the phases individually. The general start signal is generated if the voltage is below the preset starting level parameter setting value and above the defined blocking level. The function generates a trip command only if the definite time delay has expired and the parameter selection requires a trip command as well.

The operation mode can be chosen by the type selection parameter. The function can be disabled, and can be set to "1 out of 3", "2 out of 3", and "All".

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

- **Negative sequence overcurrent protection (46)**

The negative sequence overcurrent protection function (46) 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. The definite (independent) time characteristic has a fixed delaying time when the current is above the starting current Gs previously set as a parameter. The negative phase sequence components calculation is based on the Fourier components of the phase currents.

The binary output status signals of the negative sequence overcurrent protection function are the general starting and the general trip command of the function.

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.

- **Negative sequence definite time overvoltage protection (47)**

The definite time negative sequence overvoltage protection function measures three voltages and calculates the negative sequence component. If the negative sequence component is above the level defined by parameter setting, then a start signal is generated. The function generates a start signal. The general start signal is generated if the negative sequence voltage component is above the level defined by parameter setting value. The function generates a trip command only if the time delay has expired and the parameter selection requires a trip command as well.

The function can be disabled by parameter setting or by an external signal, edited by the graphic logic editor.

- **Thermal protection (49)**

Basically, 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 "over temperature", meaning the temperature above the ambient temperature. Accordingly, the temperature of the protected object is the sum of the calculated "over temperature" and the ambient temperature.

If the calculated temperature (calculated "over temperature" + ambient temperature) is above the threshold values, alarm, trip and restart blocking status signals are generated.

▪ **Three-phase instantaneous overcurrent protection (50)**

The three-phase instantaneous overcurrent protection function (50) operates immediately if the phase currents are higher than the setting value. The setting value is a parameter, and it can be doubled by graphic programming of the dedicated input binary signal defined by the user. The function is based on peak value selection or on the RMS values of the Fourier basic harmonic calculation, according to the parameter setting. The fundamental Fourier components are results of an external function block.

Parameter for type selection has selection range of Off, Peak value and Fundamental value. 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.

The function generates trip commands without additional time delay if the detected values are above the current setting value. The function generates trip commands for the three phases individually and a general trip command as well.

The 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.

▪ **Breaker failure protection (50BF)**

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 breakers which are a priori expected to open. The breaker failure protection function can be applied to perform this task.

The starting signal of the breaker failure protection function is usually the trip command of any other protection function. Dedicated timer starts at the rising edge of the general start signal for the backup trip command. During the running time of the timer 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 an enumerated parameter.

If current supervision is selected by the user then the current limit values must be set correctly. The binary input indicating the status of the circuit breaker has no meaning.

If contact supervision is selected by the user then the current limit values have no meaning. The binary input indicating the status of the circuit breaker must be programmed correctly using the graphic equation editor.

If the parameter selection 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.

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 pulse duration of the trip command is not shorter than the time defined by setting the parameter Pulse length.

The breaker failure protection function can be disabled by setting the enabling parameter to "Off".

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

▪ **Residual instantaneous overcurrent protection (50N/50Ns)**

The residual instantaneous overcurrent protection function operates immediately if the residual current (3Io) is above the setting value. The setting value is a parameter, and it can be doubled by a dedicated binary input signal defined by the user applying the graphic programming. The function is based on peak value selection or on the RMS values of the Fourier basic harmonic component of the residual current, according to the parameter setting. The fundamental Fourier component calculation is not part of the 50N/50Ns function. Parameter for type selection has selection range of Off, Peak value and Fundamental value.

The function generates a trip commands without additional time delay if the detected values are above the current setting value.

If the relay is equipped with the current transformer module with a sensitive channel (4th channel), the function will be considered as sensitive residual instantaneous overcurrent protection for use in applications where the fault current magnitude may be very low.

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.

▪ **Three-phase time overcurrent protection (51)**

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. The definite (independent) time characteristic has a fixed time delay when the current is above the starting current is previously set as a parameter.

The binary output status signals of the three-phase overcurrent protection function are starting signals of the three phases individually, a general starting signal and a general trip command.

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.

▪ **Residual overcurrent protection (51N/51Ns)**

The residual delayed overcurrent protection function can realize definite time or inverse time characteristics according to IEC or IEEE standards, based on the RMS value of the fundamental Fourier component of a single measured current, which can be the measured residual current at the neutral point (3Io) or the calculated zero sequence current component. The characteristics are harmonized with IEC 60255-151, Edition 1.0, 2009-08. The definite (independent) time characteristic has a fixed time delay when the current is above the starting current Is previously set as a parameter.

The binary output status signals of the residual overcurrent protection function are the general starting signal and the general trip command if the time delay determined by the characteristics expired.

If the relay is equipped with the current transformer module with a sensitive channel (4th channel), the function will be considered as sensitive residual overcurrent protection (51Ns) for use in applications where the fault current magnitude may be very low.

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.

▪ **Definite time overvoltage protection (59)**

The definite time overvoltage protection function measures three voltages. The measured values of the characteristic quantity are the RMS values of the basic Fourier components of the phase voltages. The Fourier calculation inputs are the sampled values of the three phase voltages (UL1, UL2, UL3), and the outputs are the basic Fourier components of the analyzed voltages (UL1Four, UL2Four, UL3Four). They are not part of the 59 function; they belong to the preparatory phase.

The function generates start signals for the phases individually. The general start signal is generated if the voltage in any of the three measured voltages is above the level defined by parameter setting value. The function generates a trip command only if the definite time delay has expired and the parameter

selection requires a trip command as well.

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

▪ **Residual definite time overvoltage protection (59N)**

The residual definite time overvoltage protection function operates according to definite time characteristics, using the RMS values of the fundamental Fourier component of the zero sequence voltage (UN=3Uo). The Fourier calculation inputs are the sampled values of the residual or neutral voltage (UN=3Uo) and the outputs are the RMS value of the basic Fourier components of those.

The function generates start signal if the residual voltage is above the level defined by parameter setting value. The function generates a trip command only if the definite time delay has expired and the parameter selection requires a trip command as well.

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

▪ **Current unbalance function (60)**

The current unbalance protection function (60) can be applied to detect unexpected asymmetry in current measurement. The applied method selects maximum and minimum phase currents (RMS value 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 Fourier calculation modules calculate the RMS value of the basic Fourier current components of the phase currents individually. They are not part of the VCB60 function; they belong to the preparatory phase.

The decision logic module combines the status signals to generate the starting signal and the trip command of the function. The trip command is generated after the defined time delay if trip command is enabled by the Boolean parameter setting.

The function can be disabled by parameter setting, and by an input signal programmed by the user with the graphic programming tool.

▪ **Residual directional overcurrent protection (67N/67Ns)**

The main application area of the directional residual delayed overcurrent protection function is an earth-fault protection.

The inputs of the function are the RMS value of the Fourier basic harmonic components of the zero sequence current (IN=3Io) and those of the zero sequence voltage (UN=3Uo).

The block of the directional decision generates a signal of TRUE value if the $U_N=3U_o$ zero sequence voltage and the $I_N=3I_o$

zero sequence current are above the limits needed for correct directional decision, and the angle difference between the vectors is within the preset range. The decision enables the output start and trip signal of an overcurrent protection function block (51N/51Ns). This non- directional residual overcurrent protection function block is described in a separate document. The directional decision module calculates the phase angle between the residual voltage and the residual current. The reference signal is the residual voltage according to the Figure.
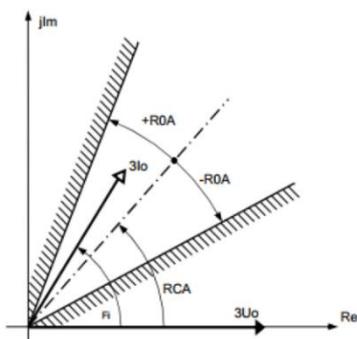
The output of the directional decision module is OK, namely it is TRUE if the phase angle between the residual voltage and the residual current is within the limit range defined by the preset parameter OR if non-directional operation is selected by the preset parameter (Direction=NonDir).

If the relay is equipped with the current transformer module with a sensitive channel (4th channel), the function will be considered as sensitive residual directional overcurrent protection (67Ns) for use in applications where the fault current magnitude may be very low.

- **Trip circuit supervision (74)**

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.)

- **Over-frequency protection (81O)**

The deviation of the frequency from the rated system frequency indicates unbalance between the generated power and the load demand. If the available generation is large compared to the consumption by the load connected to the power system, then the system frequency is above the rated value. The over-frequency protection function is usually applied to decrease generation to control the system frequency. Another possible application is the detection of unintended island operation of distributed generation and some consumers. In the island, there is low probability that the power generated is the same as consumption; accordingly, the detection of high frequency can be one of the indication of island operation.

The over-frequency protection function generates a start signal if at least five measured frequency values are above the preset level. Time delay can also be set.

The function can be enabled/disabled by a parameter.

The over-frequency protection function has a binary input signal. The conditions of the input signal are defined by the user, applying the graphic equation editor. The signal can block the under-frequency protection function.

- **Underfrequency protection (81U)**

The deviation of the frequency from the rated system frequency indicates unbalance between the generated power and the load demand. If the available generation is small compared to the consumption by the load connected to the power system, then the system frequency is below the rated value. The under-frequency protection function is usually applied to increase generation or for load shedding to control the system frequency. Another possible application is the detection of unintended island operation of distributed generation and some consumers. In the island, there is low probability that the power generated is the same as consumption; accordingly, the detection of low frequency can be one of the indications of island operation. Accurate frequency measurement is also the criterion for the synchro-check and synchro- switch functions.

The under-frequency protection function generates a start signal if at least five measured frequency values are below the setting value.Time delay can also be set.

The function can be enabled/disabled by a parameter.

The under-frequency protection function has a binary input signal. The conditions of the input signal are defined by the user, applying the graphic equation editor. The signal can block the under-frequency protection function.

- **Rate of change of frequency protection (81R)**

The deviation of the frequency from the rated system frequency indicates unbalance between the generated power and the load demand. If the available generation is large compared to the consumption by the load connected to the power system, then the system frequency is above the rated value, and if it is small, the frequency is below the rated value. If the unbalance is large, then the frequency changes rapidly. The rate of change of frequency protection function is usually applied to reset the balance between generation and consumption to control the system frequency. Another possible application is the detection of unintended island operation of distributed generation and some consumers. In the island, there is low probability that the power generated is the same as consumption; accordingly, the detection of a high rate of change of frequency can be an indication of island operation.

The rate of change of frequency protection function generates a start signal if the df/dt value is above the setting value. The rate of change of frequency is calculated as the difference of the frequency at the present sampling and at three periods earlier. Time delay can also be set.

The function can be enabled/disabled by a parameter.

The rate of change of frequency protection function has a binary input signal. The conditions of the input signal are defined

by the user, applying the graphic equation editor. The signal can block the rate of change of frequency protection function.

- **Lockout trip logic (86/94)**

The lockout version of the simplified trip logic function operates according to the functionality required by the IEC 61850 standard for the "Trip logic logical node". Its output can be set to lockout and be reset externally.

This simplified software module can be applied if only three-phase trip commands are required, that is, phase selectivity is not applied.

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 operation can be normal or lockout. In normal mode, the output remains energized at least for a given pulse time and drops off as soon as the trip input drops off. The aim of this decision logic is to define a minimal impulse duration even if the protection functions detect a very shorttime fault.

In lockout mode the output stays active until the function gets a reset signal on its reset input.

The trip requirements and the reset signal are programmed by the user, using the graphic equation editor.
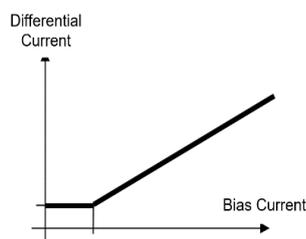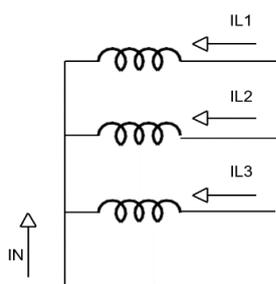
- **Restricted earth fault protection (87N)**

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 protect one side winding of transformers with grounded neutral against single-phase-to-earth fault (see Figure).

IL1
IL2
IL3
IN

The function compares the measured neutral current at the star point (IN) and the calculated zero sequence current component of the phase currents (IL1, IL2, IL3) and generates a trip command if the difference of these currents is above the characteristics.

The function performs the necessary calculations for the evaluation of the "percentage differential characteristics", and decides to trip if the differential current is above the characteristic curve of the zero sequence differential protection

Differential Current

Bias Current

function. This curve is the function of the restraint (Bias) current, which is the maximum of the phase currents and the current of the neutral point.

Additionally, the function 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.

A Boolean parameter of the restricted earth-fault protection function serves to enable the directional checking of the measured and calculated zero sequence currents. 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 by the directional decision. Additionally, the operation of the function is enabled by parameter setting. The conditions of enabling are defined by the user applying the graphic equation editor.

- **Transformer differential protection (87T)**

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

The three-phase power transformers transform the primary current to the secondary side according to the turns 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 secondary sides causes the vector shift of the currents. The numerical differential protection function applies matrix transformation of the directly measured currents of one side of the transformer to match them with the currents of the other side.

In Protecta's transformer differential protection the target of the matrix transformation is the delta (D) side. Thus the problem of zero sequence current elimination in case of an external ground fault is also solved.

The method of the matrix transformation is defined by the "Code" parameter identifying the transformer vector group connection.

The differential current can be high during the transients of transformer energizing (inrush current) due to the current distortion caused by the transformer iron core asymmetrical saturation. In this case, the second harmonic content of the differential current is applied to disable the false operation of the differential protection function.

The differential current can be high in case of the over-excitation of the transformer due to the current distortion caused by the transformer iron core symmetrical saturation. In this case, the fifth harmonic content of the differential current is applied to disable the false operation of the differential protection function.

The harmonic analysis 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. Third harmonic is eliminated in the algorithm's transformation matrix without individual settings like 2nd or 5th harmonics.

The software modules evaluate and compare the result with the parameter values set for the second and fifth harmonic. If the harmonic content relative to the basic harmonic component of the differential currents is high, a restraint signal is generated immediately and a timer is started at the same time. If the

duration of the active status is at least 25 ms, then the resetting of the restraint signal is delayed by an additional 15 ms.

The decision logic module decides if the differential current of the individual phases is above the characteristic curve of the differential protection function. It compares the magnitudes of the differential currents and those of the restraint currents for evaluation of the "percentage differential characteristics". This curve is the function of the restraint current, which is calculated based on the sum of the magnitude of the phase-shifted phase currents (see Figure below).
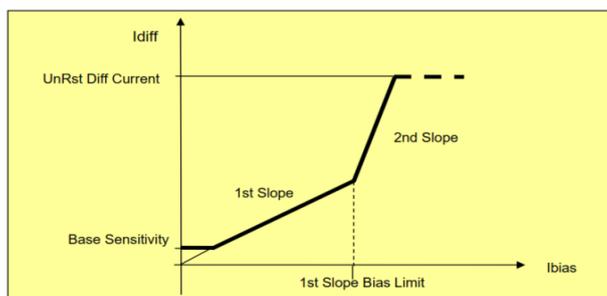
The characteristic curve has four sections. The first section is the base sensitivity, the second one serves to compensate the turns ratio deviation e.g. due to the operation of the on-load tap changer, the third is to eliminate false operation caused by the CT saturation and the fourth one is the unrestricted differential function.

The differential 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.

▪ **Automatic tap-changer controller (90V)**

One criterion for power quality is to keep the voltage of selected points of the networks within the prescribed limits. The most common mode of voltage regulation is the application of transformers with on-load tap changers. When the transformer is connected to different taps, its turns ratio changes and supposing constant primary voltage, the secondary voltage can be increased or decreased as required.

Voltage control can take the actual load state of the transformer and the network into consideration. As a result, the voltage of a defined remote point of the network is controlled assuring that neither consumer near the busbar nor consumers at the far ends of the network get voltages out of the required range.

The voltage control function can be performed automatically or, in manual mode of operation, the personnel of the substation can set the network voltage according to special requirements.

The automatic tap changer controller function can be applied to perform this task. The automatic tap changer controller function receives the following analog inputs:

- UL1L2 Line-to-line voltage of the controlled secondary side of the transformer
- IL1L2   Difference of the selected line currents of the

secondary side of the transformer for voltage drop compensation
- IHV Maximum of the phase currents of the primary side of the transformer for limitation purposes

The parameter "U Correction" permits fine tuning of the measured voltage. The function performs the following internal checks before control operation (see Figure below):
- If the voltage of the controlled side UL1L2 is above the value set by the parameter "U High Limit", then control to increase the voltage is disabled.
- If the voltage of the controlled side UL1L2 is below the value set by the parameter "U Low Limit", then control to decrease the voltage is disabled.
- If the voltage of the controlled side UL1L2 is below the value set by the parameter "U Low Block", then the transformer is considered to be de-energized and automatic control is completely disabled.
- If the current of the supply side IHV is above the limit set by the parameter "I Overload", then both automatic and manual controls are completely disabled. This is to protect the switches inside the tap changer

There are two modes for Automatic tap-changer controller function:
- Automatic control mode
- Manual control mode

MEASUREMENT FUNCTIONS

▪ **Measurement functions**

Based on the hardware inputs the measurements listed in table below are available.

Measurement functions	E1-TR	E2-TR	E3-TR	E4-TR	E5-TR	E6-TR
Current (I1, I2, I3, I4, Iseq (I0, I1, I2))	X	X	X	X	X	X
Voltage (U1, U2, U3, U4, U12, U23, U31, Useq (U0, U1, U2)) and frequency		X	X		X	X
Circuit breaker wear	X	X	X	X	X	X
Supervised trip contacts (TCS)	X	X	X	X	X	X

The measurement functions of the DTRV configuration

▪ **Monitoring functions**

The **DTRV** product type can monitor and detect current and voltage harmonics and short duration system disturbances such as:

- Harmonics contents of each voltage and current channel (order 1st to order 19th)
- Current total demand distortion (TDD)
- Voltage total harmonic distortion (THD)
- Sags (Dips), Swells and Interrupts

HMI AND COMMUNICATION TASKS

- **Embedded WEB-server:** Allows remote access via Ethernet port of device

  - Firmware upgrade possibility
  - Modification of user parameters
  - Events list and disturbance records
  - Password management
  - Online data measurement
  - Commands
  - Administrative tasks
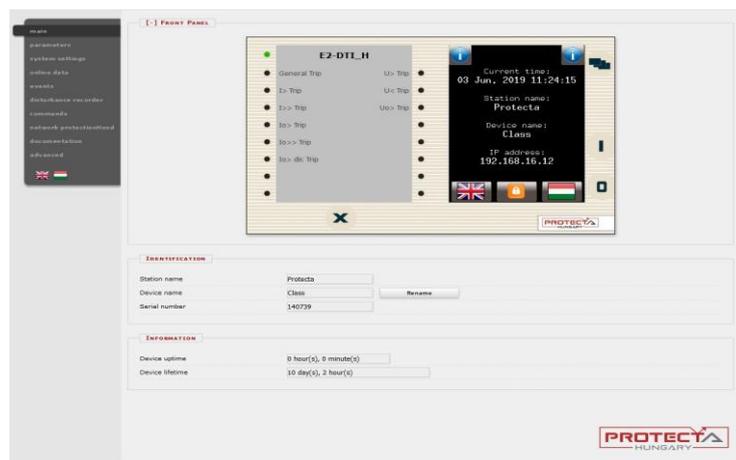
- **Front panel TFT display handling:** the interactive menu set is available through the TFT and the touchscreen interface.

- **User keys:** capacitive touch keys on front panel
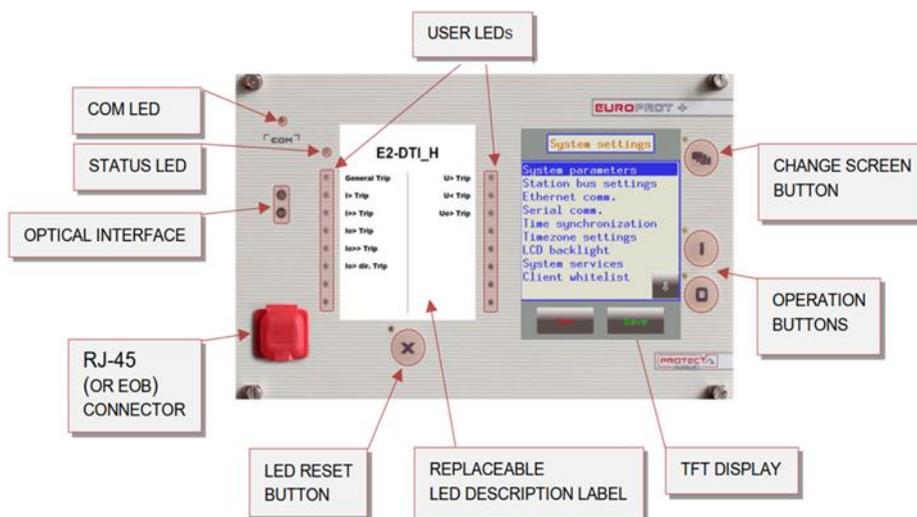
- **Communication:**

  - The built-in 5-port Ethernet switch allows EuroProt+ to connect to IP/Ethernet-based network. The following Ethernet ports are available:

    - Station bus (100Base-FX Ethernet) SBW
    - Redundant station bus (100Base-FX Ethernet) SBR
    - Process bus (100Base-FX Ethernet)
    - EOB or EOB2 (Ethernet Over Board) or RJ-4 Ethern user interface on front panel
    - Optional 10/100Base-T port via RJ-45 connector

  - PRP/HSR seamless redundancy for Ethernet networking (100Base-FX Ethernet; 10/100Base-TX Ethernet)
  - Redundancy RJ-45 for Ethernet networking (10/100Base-TX Ethernet)
  - Other communication:
    - RS422/RS485 interfaces (galvanic interface to support legacy or other serial protocols, ASIF)
    - Plastic or glass fiber interfaces to support legacy protocols, ASIF
    - Proprietary process bus communication controller on COM+ module

FUNCTIONAL PARAMETERS

Circuit breaker control function block (CB1Pol)

ControlModel	Direct normal, Direct enhanced, SBO enhanced
Forced check	If true, then the check function cannot be neglected by the check attribute defined by the IEC 61850 standard
Max.Operating time	10-1000ms in 1ms steps
Pulse length	50-500ms in 1ms steps
Max.Intermediate time	20-30000ms in 1ms steps
Max.SynChk time	10-5000ms in 1ms steps
Max.SynSW time	0-60000ms in 1ms steps
SBO Timeout	1000-20000ms in 1ms steps

Disconnector control function (DisConn)

ControlModel	Direct normal, Direct enhanced, SBO enhanced
Type of switch	N/A, Load break, Disconnector, Earthing Switch, HS Earthing Switch
Forced check	If true, then the check function cannot be neglected by the check attribute defined by the IEC 61850 standard
Max.Operating time	10-20000ms in 1ms steps
Pulse length	50-30000ms in 1ms steps
Max.Intermediate time	20-30000ms in 1ms steps
SBO Timeout	1000-20000ms in 1ms steps

Overexcitation protection function (24)

Operation	Off, Definite Time, IEEE
Start U/f LowSet	80-140% in 1% steps
Start U/f HighSet	80-140% in 1% steps
Time Multiplier	1-100 in 1 steps
Min Time Delay	0.50-60.00s in 0.01s steps
Max Time Delay	300.00-8000.00s in 0.01s step
Cooling Time	60.00-8000.00s in 0.01s step

Definite time undervoltage protection (27)

Operation	Off, 1 out of 3, 2 out of 3, All
Start Voltage	30-130% in 1% steps
Block Voltage	0-20% in 1% steps
Reset Ratio	1-10% in 1% steps
Time Delay	50-60000ms in 1ms steps

Negative sequence overcurrent protection (46)

Operation	Off, DefiniteTime, IEC Inv,IEC VeryInv, IEC ExtInv,IEC LongInv, ANSI Inv, ANSI ModInv, ANSI VeryInv, ANSI ExtInv, ANSI LongInv, ANSI LongVeryInv, ANSI LongExtInv
Start Current	5-3000% in 1% steps
Time Multiplier	0.05-999 in 0.01 steps
Minimal time delay for the inverse char.	0-60000ms in 1ms steps
Definite time delay	0-60000ms in 1ms steps
Reset time delay for the inverse char	0-60000ms in 1ms steps

Negative sequence overvoltage protection (47)

Operation	Off, On
Start Voltage	2-40% in 1% steps
Time Delay	50-60000ms in 1ms steps

Thermal protection (49)

Operation	Off, Pulsed, Locked
Alarm Temperature	60-200deg in 1deg steps
Trip Temperature	60-200deg in 1deg steps
Rated Temperature	60-200deg in 1deg steps
Base Temperature	0-40deg in 1deg steps
Unlock Temperature	20-200deg in 1deg steps
Ambient Temperature	0-40deg in 1deg steps
Startup Term	0-60% in 1% steps
Rated Load Current	20-150% in 1% steps
Time Constan	1-999min in 1min step

Three-phase instantaneous overcurrent protection (50)

Operation	Off, Peak value, Fundamental value
Start current	5-3000% in 1% steps

Breaker failure protection (50BF)

Operation	Off, Current, Contact, Current/Contact
Retrip	Off, On
Start Ph Current	20-200% in 1% steps
Start Res Current	10-200% in 1% steps
Retrip Time Delay	0-1000ms in 1ms steps
Backup Time Delay	100-60000ms in 1ms steps
Pulse Duration	0-60000ms in 1ms steps

Residual instantaneous overcurrent protection (50N/50Ns)

Operation	Off, Peak value, Fundamental value
Start Current	5-3000% in 1% steps

Three-phase time overcurrent protection (51)

Operation	Off, Definite Time, IEC Inv, IEC VeryInv, IEC ExtInv, IEC LongInv, ANSI0.95 Inv, ANSI ModInv, ANSI VeryInv, ANSI ExtInv, ANSI LongInv, ANSI LongVeryInv, ANSI LongExtInv
Start current	5-3000% in 1% steps
Time Multiplier	0.05-999 in 0.01 steps
Minimum time delay for the inverse char.	40-60000ms in 1ms steps
Definite time delay for definite type char.	40-60000ms in 1ms steps
Reset time delay for the IEC type inverse char.	60-60000ms in 1ms steps

Residual time overcurrent protection (51N/51Ns)

Operation	Off, DefiniteTime, IEC Inv,IEC VeryInv, IEC ExtInv,IEC LongInv, ANSI Inv, ANSI ModInv, ANSI VeryInv, ANSI ExtInv, ANSI LongInv, ANSI LongVeryInv, ANSI LongExtInv
Start current	
In = 1A or 5A	5-3000% in 1% steps
In = 200mA or 1A	5-3000% in 1% steps
Time Multiplier	0.05-999 in 0.01 steps

Minimum time delay for the inverse char.	40-60000ms in 1ms steps
Definite time delay for definite type char.	40-60000ms in 1ms steps
Reset time delay for the inverse char.	60-60000ms in 1ms steps

Definite time overvoltage protection (59)

Operation	Off, On
Start Voltage	30-130% in 1% steps
Reset Ratio	1-10% in 1% steps
Time Delay	0-60000ms in 1ms steps

Residual overvoltage protection (59N)

Operation	Off, On
Start Voltage	2-60% in 1% steps
Time Delay	0-60000ms in 1ms steps

Current unbalance protection (60)

Operation	Off, On
Start Signal Only	False, True
Start Current Diff	10-90% in 1% steps
Time Delay	100-60000ms in 1ms steps

Residual directional overcurrent protection (67N/67Ns)

Direction	NonDir, Forward - Angle, Backward Angle, Forward I*cos(fi), Backward- Angle, Forward-I*cos(fi), Backward - I*sin(fi), Forward-I*sin(fi+45), Backward - I*sin(fi+45)
Operation	Off, DefiniteTime, IEC Inv,IEC VeryInv, IEC ExtInv,IEC LongInv, ANSI Inv, ANSI ModInv, ANSI VeryInv, ANSI ExtInv, ANSI LongInv, ANSI LongVeryInv, ANSI LongExtInv
Start Current	5-3000% in 1% steps
URes Min	1-20% in 1% steps
IRes Min	1-50% in 1% steps
Operating Angle	30-85º in 1º steps
Characteristic Angle	-180-180º in 1º steps
Time Multiplier	0.05-999 in 0.01 step
Minimal time delay for the inverse char.	30-60000ms in 1ms steps
Definite time delay	30-60000ms in 1ms steps
Reset time delay for the inverse char.	30-60000ms in 1ms steps

Overfrequency protection (81O)
Undefrequency protection (81U)

Operation	Off, On
Start signal only	False, True
Start frequency	40-70Hz in 0.01Hz steps
Time Delay	0-60000ms in 1ms steps
Voltage limit	0.3-1.0 Un

Rate of change of frequency protection (81R)

Operation	Off, On
Start signal only	False, True
Start df/dt	-5.00-5.00Hz/s in 0.01Hz/s steps
Time Delay	0-60000ms in 1ms steps

Lockout trip logic (86/94)

Operation	Off, On, Lockout
Min pulse duration	50-60000ms in 1ms steps

Rectricted earth fault protection (87N)

Operation	Off, On
Directional check	False, True
Io Primary Match	20-500% in 1% steps
Neutral Match	100-1000% in 1% steps
Base Sensitivity	10-50% in 1% steps
Slope	50-100% in 1% steps
Base Sens Bias Limit	100-200% in 1% steps

Transformer differential protection (87T)

Operation	Off, On
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
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
Zero Seq Elimination	False, True
TR Primary Comp	20-500% in 1% step
TR Secondary Comp	20-500% in 1% step
TR Tertiary Comp	20-200% in 1% step
2nd Harm Ratio	5-50% in 1% step
5th Harm Ratio	5-50% in 1% step
Base Sensitivity	10-50% in 1% step
1st Slope	10-50% in 1% step
1st Slope Bias Limit	200-2000% in 1% step
UnRst Diff Current	800-2500% in 1% step

Automatic tap-changer controller function (90V)

ControlModel	Direct normal, Direct enhanced, SBO enhanced
sboClass	Operate-once, Operate-many
Operation	Off, On
T1 Delay Type	Definite, Inverse, 2powerN
Compensation	Off, AbsoluteComp, ComplexComp
TC Supervision	Off, TCDrive, Position, Both
CodeType	Binary, BCD, Gray
Fast Higher Enable	Enable, Disable
Fast Lower Enable	Enable, Disable
Min Position	1-32 in 1 steps
Max Position	1-32 in 1 steps
Max Operating Time	1000-30000ms in 1ms steps
Pulse Duration	100-10000ms in 1ms steps
Position Filter	1000-30000ms in 1ms steps
SBO Timeout	1000-20000ms in 1ms steps
U Correction	0.950-1.050 in 0.001 steps
U Set	80.0-115.0% in 0.1% steps
U Deadband	0.5-9.0% in 0.1% steps
Deadband Hysteresis	60-90% in 1% steps
(R) Compound Factor	0.0-15.0% in 0.1% steps
X Compound Factor	0.0-15.0% in 0.1% steps
Voltage Reduction 1	0.0-10.0% in 0.1% steps

Voltage Reduction 2	0.0-10.0% in 0.1% steps
I Comp Limit	0-150% in 1% steps
I Overload	50-150% in 1% steps
U High Limit	90.0-120.0% in 0.1% steps
U Low Limit	70.0-110.0% in 0.1% steps
U Low Block	50.0-110.0% in 0.1% steps
Time delay for first command	1.0-600.0s in 0.1 steps
Time delay for second command	1.0-100.0s in 0.1 steps
Min Delay	1.0-100.0s in 0.1 steps
Reclaim Time	1.0-100.0s in 0.1 steps
Disturbance recorder	
Operation	Off, On
Resolution	1/1.2 kHz; 2/2.4kHz
Prefault	100-1000ms in 1ms steps
PostFault	100-10000ms in 1ms steps
Max Recording Time	500-10000ms in 1ms steps

TECHNICAL DATA

HARDWARE	
Analog Inputs (Current & Voltage Input Modules)	
Rated current In	1A or 5A (selectable)
Rated voltage Vn	110V (± 10%)
Rated frequency	50Hz or 60Hz
Overload rating	
Current inputs	20A continuous, 175A for 10s, 500A for 1s, 1200A for 10ms
Voltage inputs	250V continuous, 275V for 1s
Burden	
Phase current inputs	0.01VA at In = 1A, 0.25VA at In = 5A
Voltage inputs	0.61VA at 200V, 0.2VA at 100V
Power Supply	
Rated auxiliary voltage	24/48/60VDC (Operative range: 19.2 - 72VDC)
	110/220VDC (Operative range: 88 - 264VDC or 80-250VAC)
Power consumption	20W, 25W, 30W, 60W (Depend on type of power supply module)
Binary Inputs	
Input circuit DC voltage	24VDC (Thermal withstand voltage: 72VDC)
	48VDC (Thermal withstand voltage: 100VDC)
	110VDC (Thermal withstand voltage: 250VDC)
	220VDC (Thermal withstand voltage: 320VDC)
Pickup voltage	0.8Un
Drop voltage	0.64Un
Power consumption	max. 1.6 mA per channel at 220VDC
	max. 1.8 mA per channel at 110VDC
	max. 2 mA per channel at 48VDC
	max. 3 mA per channel at 24VDC
Binary Outputs	
Rated voltage	250VAC/DC
Continuous carry	8A
Maximum switching voltage	400VAC
Breaking capacity	0.2A at 220VDC, 0.3A at 110VDC (L/R=40ms)
	2000VA max
Short time carrying capacity	35A for 1s
Operating time	Typically 10ms
Trip Contacts	
Rated voltage	24VDC/48VDC/110VDC/220VDC
Continuous carry	8A
Thermal withstand voltage	72VDC (Rated voltage: 24VDC or 48VDC)
	150VDC (Rated voltage: 110VDC)
	242VDC (Rated voltage: 220VDC)
Breaking capacity	4A (L/R=40ms)
Making capacity	30A for 0.5s
Operating time	With pre-trip 0.5 ms, without pre-trip typically 10 ms
Mechanical Design	

Installation	Flush mounting
Case	42 or 84 HP (height:3U)
Protection class	IP41 from front side, IP2x from rear side
	IP54 Rated mounting kit

Key & LED

Device keys	Capacitive touch keys
Capacitive touch key LEDS	4 pcs yellow, 3 mm circular LEDs indicating touch key actions
Number of configurable LED	16
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

Local Interface

Service port on front panel	10/100-Base-T interface with RJ-45 type connector

System Interface

10/100-Base-TX	IP56 rated with RJ-45 connector
100Base-FX	MM/ST 1300 nm, 50/62.5/125 µm connector, (up to 2 km) fiber
	MM/LC 1300 nm, 50/62.5/125 µm connector, (up to 2 km) fiber
	SM/FC 1550 nm, 9/125 µm connector, (up to 120 km), with max. 32 dB link attenuation
	SM/FC 1550 nm, 9/125 µm connector, (up to 50 km), with max. 27 dB link attenuation
Serial Interface	Plastic optical fiber (ASIF-POF)
	Glass with ST connector (ASIF-GS)
	Galvanic RS485/422 (ASIF-G)

PROTECTION & CONTROL FUNCTIONS

Circuit breaker control function block (CB1Pol)

Operate time accuracy	±5% or ±15 ms, whichever is greater

Disconnector control function (DisConn)

Operate time accuracy	±5% or ±15 ms, whichever is greater

Overexcitation protection (24)

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

Definite time undervoltage protection (27)

Pick-up starting accuracy	< ± 0,5 %
Reset time	
U> → Un	50 ms
U> → 0	40 ms
Operate time accuracy	< ± 20 ms
Minimum operate time	50 ms

Negative sequence overcurrent protection (46)

Operating accuracy	<2% (when $20 \leq G_S \leq 1000$)
Operate time accuracy	±5% or ±15 ms, whichever is greater
Reset ratio	0.95
Reset time	
Dependent time char.	Dependent time char.
Definite time char.	Approx 60 ms
Reset accuracy time	< 2% or ±35 ms, whichever is greater
Transient overreach	< 2 %
Pickup time *	< 40 ms
Overshot time	
Dependent time char.	25 ms
Definite time char.	45 ms
Influence of time varying value of the input current (IEC 60255-151) accuracy	< 4 %

Negative sequence overvoltage protection (47)

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

Thermal protection (49)

Operate time at I>1.2*Itrip accuracy	<3 % or <+ 20 ms

Three-phase instantaneous overcurrent protection (50)

Using peak value calculation

Operating characteristic	Instantaneous, accuracy < 6 %
Reset ratio	0.85
Operate time at 2*I_S	<15 ms
Reset time	<40 ms
Transient overreach	90%

Using Fourier basic harmonic calculation

Operating characteristic	Instantaneous, accuracy < 2 %
Reset ratio	0.85
Operate time at 2*I_S	<25 ms
Reset time	<60 ms
Transient overreach	15%

Breaker failure protection (50BF)

Pick-up starting accuracy	<2 %
Operating time accuracy	±5% or ±15 ms, whichever is greater
Retrip time	approx. 15 ms
Reset ratio	0.9
Current reset time	16-25ms

Residual instantaneous overcurrent protection (50N/50Ns)

Using peak value calculation

Operating characteristic (I>0.1 In)	Instantaneous, accuracy <6%
Reset ratio	0.85
Operate time at $2*I_S$	< 15 ms
Reset time *	< 45 ms
Transient overreach	85 %

Using Fourier basic harmonic calculation	
Operating characteristic (I>0.1 In)	Instantaneous, accuracy <6%
Reset ratio	0.85
Operate time at $2*I_S$	< 25 ms
Reset time *	< 60 ms
Transient overreach	15 %

Three-phase time overcurrent protection (51)

Operating accuracy	<2% (when $20 \leq G_S \leq 1000$)
Operate time accuracy	±5% or ±15 ms, whichever is greater
Reset ratio	0.95
Reset time	
Dependent time char.	Dependent time char.
Definite time char.	Approx 60 ms
Reset time accuracy	< 5% or ±35 ms, whichever is greater
Transient overreach	< 2 %
Pickup time *	< 40 ms
Overshot time	
Dependent time char.	30 ms
Definite time char.	50 ms
Influence of time varying value of the input current (IEC 60255-151)	< 4 %

Residual time overcurrent protection (51N/51Ns)

Operating accuracy	<3% (when $20 \leq G_S \leq 1000$)
Operate time accuracy	±5% or ±15 ms, whichever is greater
Reset ratio	0.95
Reset time	
Dependent time char.	Dependent time char.
Definite time char.	Approx 60 ms
Reset accuracy time	< 5% or ±35 ms, whichever is greater
Transient overreach	< 2 %
Pickup time *	≤ 40 ms
Overshot time	
Dependent time char.	30 ms
Definite time char.	50 ms
Influence of time varying value of the input current (IEC 60255-151) accuracy	< 4 %

Definite time overvoltage protection (59)

Pick-up starting accuracy	< ± 0,5 %
Reset time	
U> → Un	60 ms
U> → 0	50 ms
Operate time accuracy	< ± 20 ms
Minimum operate time	50 ms

Residual overvoltage protection (59N)	
Pick-up starting accuracy	
2 – 8 %	< ± 2 %
8 – 60 %	< ± 1.5 %
Reset time	
U> → Un	60 ms
U> → 0	50 ms
Operate time	50 ms
Operate time accurracy	< ± 20 ms

Current unbalance protection (60)	
Pick-up starting accuracy at In	Pick-up starting accuracy at In
Reset ratio	0.95
Operate time	70 ms

Residual directional overcurrent protection (67N/67Ns)	
Operating accuracy	< ±2 %
Operating accuracy	±5% or ±15 ms, whichever is greater 0.95
Accuracy in minimum time range	±35 ms
Reset ratio	0.95
Reset time	Approx 50 ms
Reset time accuracy	±35 ms
Transient overreach	< 2 %
Pickup time	±35 ms
Angular accuracy	<3º
$Io \leq 0.1\ In$	<±10º
$Io \leq 0.1\ In$	<±5º
$Io \leq 0.1\ In$	<±2º
Angular reset ratio	
Forward and backward	10º
All other selection	5º

Overfrequency protection (81O) Undefrequency protection (81U)	
Min. operate voltage	0.1 Un
Operate range	40 - 60 Hz (50 Hz system)
	50 - 70 Hz (60 Hz system)
Effective range	45 - 55 Hz (50 Hz system)
	55 - 65 Hz (60 Hz system)
Accuracy	± 3 mHz
Minimum operate time	93ms (50 Hz system)
	73ms Hz (60 Hz system)
Minimum operate time accuracy	± 32 ms (50 Hz system)
	± 27 ms (60 Hz system)
Accuracy when time delay:	
140 – 60000 ms	± 4 ms
<140 ms (50 Hz system)	± 32 ms
<140 ms (60 Hz system)	± 27 ms
Reset frequency	[Start freq.] – 101 mHz, accuracy: ± 1 mHz
Reset time	98 ms (50 Hz)
	85 ms (60 Hz)
Reset time accuracy	± 6 ms

Rate of change of frequency protection (81R)	
Min. operate voltage	0.1 Un
Operate range	± 10 Hz/s, accuracy: ± 50 mHz/s
Effective range	± 5 Hz/s, accuracy: ± 15 mHz/s
Minimum operate time	191 ms (50 Hz system), accuracy: ± 40 ms
	159 ms (60 Hz system), accuracy: ± 39 ms
	200 – 60000 ms (50 Hz), accuracy: ± 2 ms
Time delay (at 0.2 Hz/s)	± 1 mHz
Reset ratio (drop/pick in absolute values)	0.92 (>0.5 Hz/s), accuracy: -0.03
	0.999 (<0.5 Hz/s), accuracy: -0.072
Reset time	187 ms (50Hz), accuracy: ±44ms
	157 ms (60Hz), accuracy: ±38 ms

Lockout trip logic (86/94)	
Pulse time	<3 ms

Rectricted earth fault protection (87N)	
Operating characteristic	1 breakpoint
Reset ratio	0.95
Characteristic accuracy	<2%
Opera time, restrained	Typically 20ms
Reset time, restrained	Typically 25ms

Transformer differential protection (87T)	
Operating characteristic	2 breakpoints
Reset ratio	0.95
Characteristic accuracy	<2%
Operate time, unrestrained	Typically 20 ms
Reset time, unrestrained	Typically 25 ms
Operate time, restrained	Typically 30 ms
Reset time, restrained	Typically 25 ms

Automatic tap-changer controller function (90V)	
Voltage measurement	50 % < U < 130 %, accuracy: <1%
Definite time delay accuracy	<2% or ±20 ms, whichever is greater
Inverse and "2powerN" time delay accuracy	
12 % < U < 25%	<5%
25 % < U < 50%	<2% or ±20 ms, whichever is greater

MEASUREMENT FUNCTION	
Current	
With CT+/5151; CT+/5153 (Channel 1-3)	Range: 0.05 – 20 In, accuracy: ±0.5%, ±1 digit
With CT+/1500	Range: 0.02 – 2 In, accuracy: ±0.2%, ±1 digit
Voltage	
With VT+/2211	Range: 0.05 – 1.5 Un, accuracy: ±0.5%, ±1 digit
Power (P,Q,S, PF)	
With CT+/5151; CT+/5153 (Channel 1-3)	Range: 0.05 – 20 In, accuracy: ±0.5%, ±1 digit
With CT+/1500	Range: 0.02 – 2 In, accuracy: ±0.2%, ±1 digit
Frequency	
	Range: 40 – 60 Hz (50Hz system); accuracy: ±2mHz
	Range: 50 – 70 Hz (60Hz system); accuracy: ±2mHz

ENVIRONMENTAL PERFORMANCE

Atmospheric Environment		
Temperature	IEC 60068-2-1 IEC 60068-2-2 IEC 60068-2-14	Storage temperature: - 40 ºC … + 70 ºC Operation temperature: - 20 ºC … + 55 ºC
Humidity	IEC 60255-1 IEC 60068-2-78 IEC 60068-2-30	Humidity: 10 % ... 93 %
Enclosure protection	IEC 60529	IP41 from front side, IP2x from rear side IP54 Rated mounting kit
Mechanical Environment		
Vibration	IEC 60255-21-1	Class I
Shock and bump	IEC 60255-21-2	Class I
Seismic	IEC 60255-21-3	Class I
Electrical Environment		
Dielectric withstand	IEC 60255-27	Test levels: 2 kV AC 50 Hz (0.705 kV DC for transducer inputs)
High voltage impulse	IEC 60255-27	Test levels: 5 kV (1 kV for transducer and temperature measuring inputs)
Insulation resistance	IEC 60255-27	Insulation resistance > 15 GΩ
Voltage dips, interruptions, variations and ripple on dc supply	IEC 60255-26	Voltage dips: 40 % (200 ms), 70 % (500ms), 80 % (5000 ms)
Thermal short time	IEC 60255-27	
Electromagnetic Environment		
Electrostatic discharge	IEC 61000-4-2 IEC 60255-26	Test voltages: 15 kV air discharge, 8 kV contact discharge
Radiated radio frequency electromagnetic field immunity	IEC 61000-4-3 IEC 60255-26	Test field strength: 10 V/m
Electrical fast transient	IEC 61000-4-4 IEC 60255-26	Test voltage: 4 kV, 5kHz
Surge immunity	IEC 61000-4-5 IEC 60255-26	Test voltages: 4 kV line-to-earth, 2 kV line-to-line
Immunity to conducted disturbances, induced by radio-frequency fields	IEC 61000-4-6 IEC 60255-26	Frequency sweep: 150kHz…80 MHz Spot frequencies: 27 MHz, 68 MHz Test voltage: 10 V
Power frequency magnetic field immunity	IEC 61000-4-8 IEC 60255-26	Test field field strength: 100 A/m continuous, 1000 A/m for 3 s
Damped oscillatory wave immunity	IEC 61000-4-18 IEC 60255-26	Test frequency: 100 kHz, 1 MHz Test voltage: 2.5 kV in common mode, 1 kV in differential mode

DIMENSION AND PANEL CUT-OUT

▪ **Flush mounting**
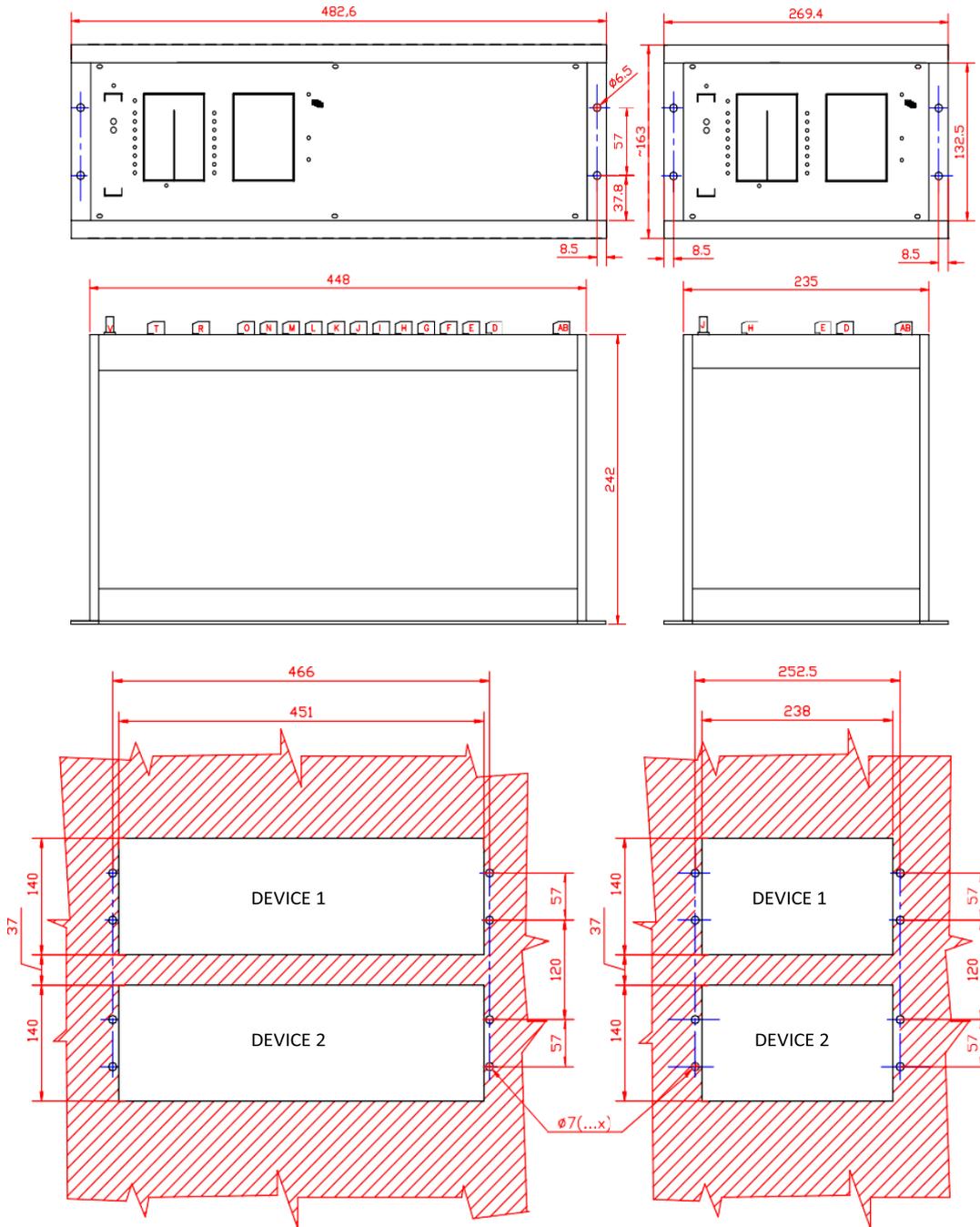
Dimension and panel cut-out for DTRV devices (Flush mounting type)

- **Rack mounting**

When rack mounting is used the devices do not have a cover profile fit on. So it is possible to mount them in a 19" rack
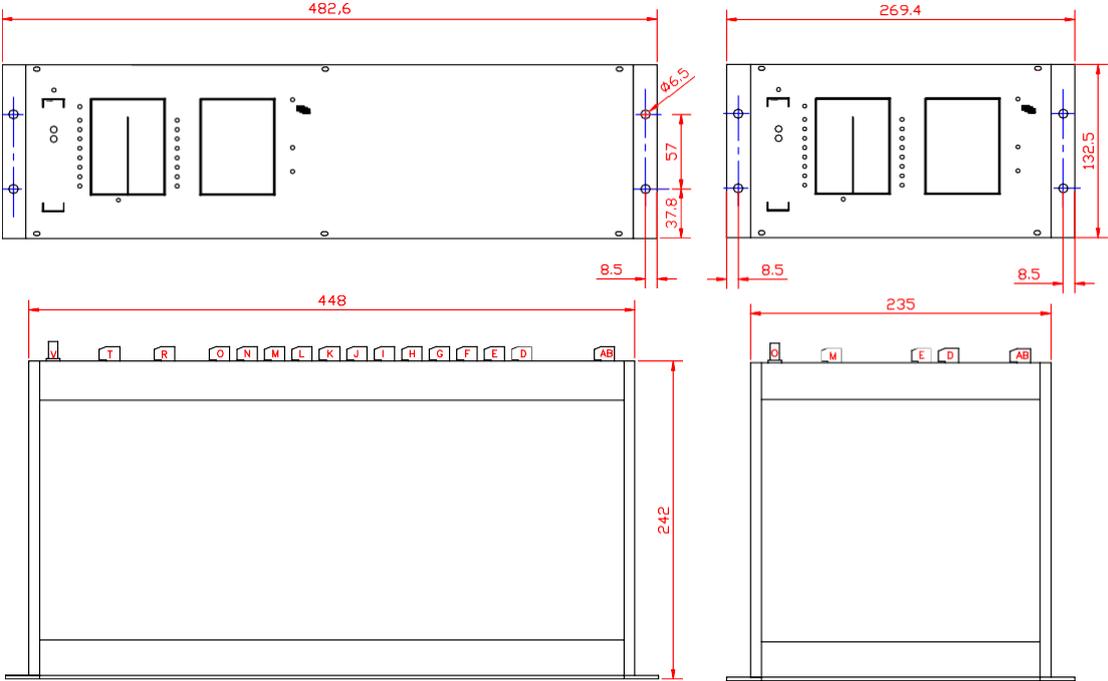
Dimension and panel cut-out for DTRV devices (Rack mounting type)
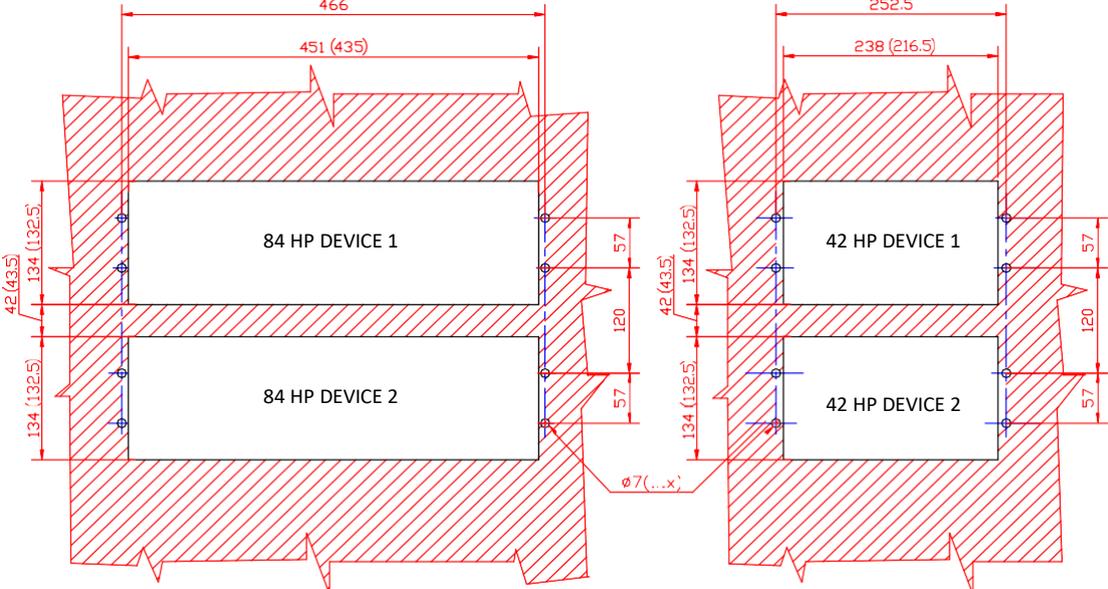
Note that rack mounting type devices can also be mounted in a cut-out (e.g. on a switchgear door). It is possible to mount them from the front or from the back of the cut-out. The dimensions for rack mounting cut-outs are in the figure below. Dimensions in brackets are applicable in case of mounting from the back.

HARDWARE CONFIGURATION

- **I/O configuration**

   The standard number of inputs and outputs of each variant are listed in the table below.

Hardware configuration	E1-TR	E2-TR	E3-TR	E4-TR	E5-TR	E6-TR
Current inputs (4th channel can be sensitive)	8	8	8	12	12	4
Voltage inputs	-	4	4	-	4	4
Binary inputs	12	12	12	12	12	12
Binary outputs	8	8	8	8	8	8
Fast trip outputs	4	4	4	4	4	8

   The maximum number of inputs and outputs of each variant are listed in the table below.

Hardware configuration	E1-TR	E2-TR	E3-TR	E4-TR	E5-TR	E6-TR
Binary inputs (Max)	112	112	112	100	100	88
Binary outputs (Max)	60	60	60	60	60	60
Fast trip outputs (Max)	12	12	12	12	12	12

- **Module arrangement**

   - **E1-TR Variant**
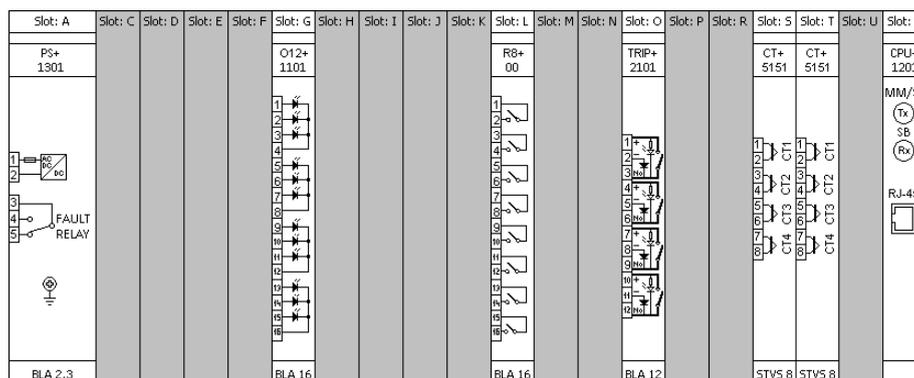
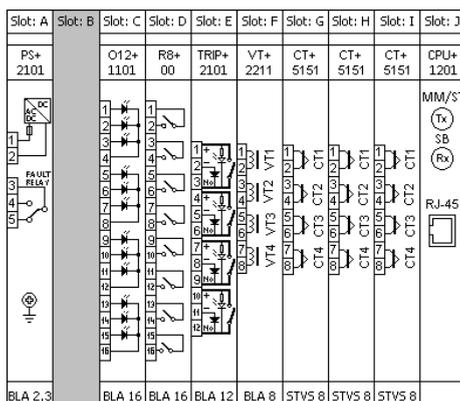*Basic module arrangement of the E1-TR configuration (84TE, rear view)*
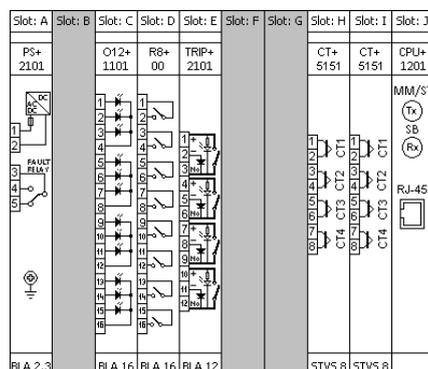
Basic module arrangement of the E1-TR configuration (42TE, rear view)

- **E2-TR Variant**
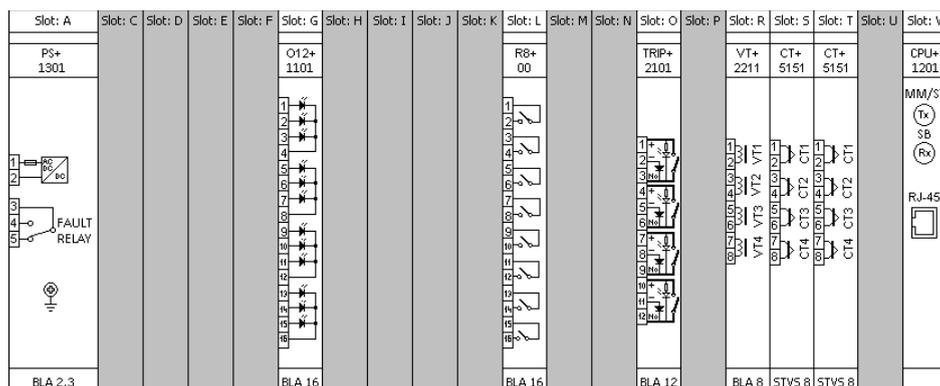
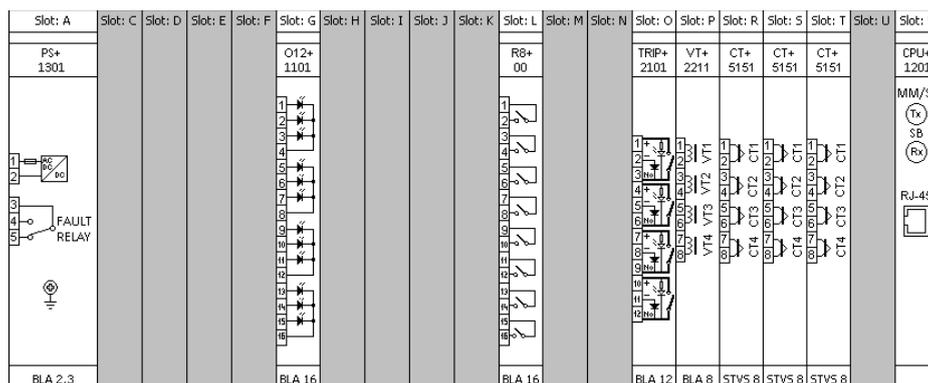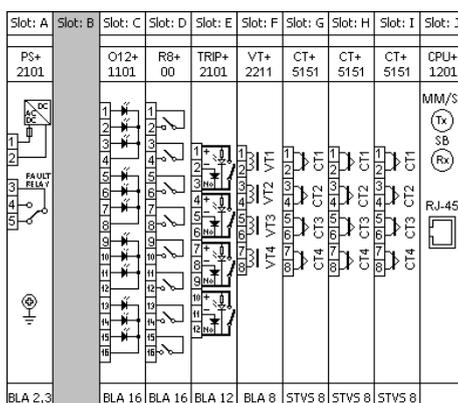*Basic module arrangement of the E2-TR configuration (84TE, rear view)*
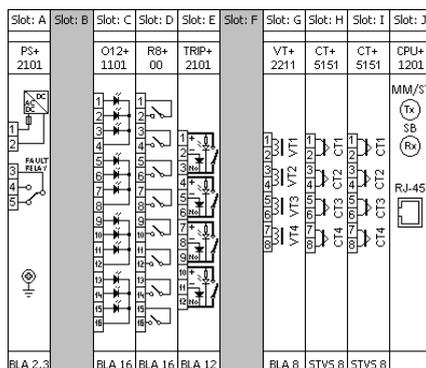
Basic module arrangement of the E2-TR configuration (42TE, rear view)

- **E3-TR Variant**
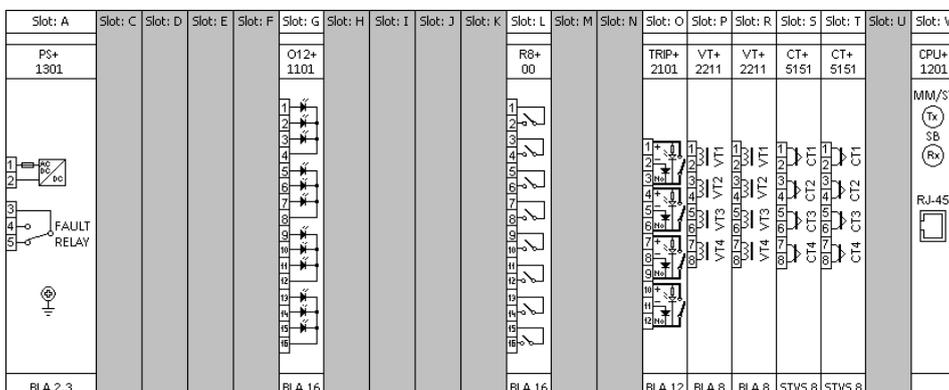
Basic module arrangement of the E3-TR configuration (84TE, rear view)
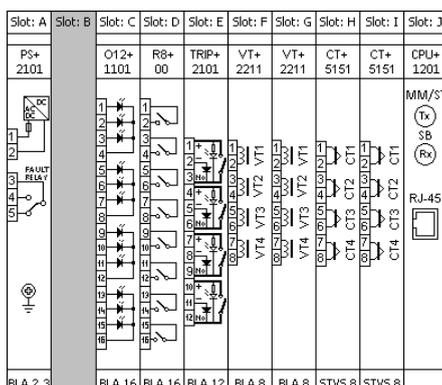
*Basic module arrangement of the E3-TR configuration (42TE, rear view)*

- **E4-TR Variant**
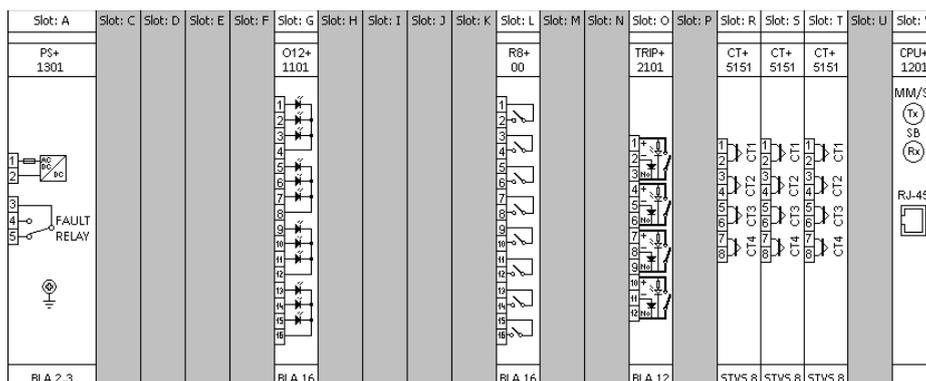
Basic module arrangement of the E4-TR configuration (84TE, rear view)
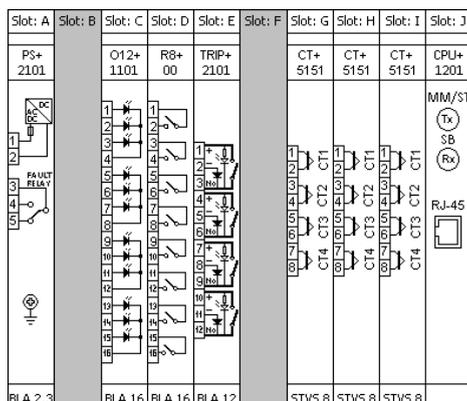
Basic module arrangement of the E4-TR configuration (42TE, rear view)

- **E5-TR Variant**
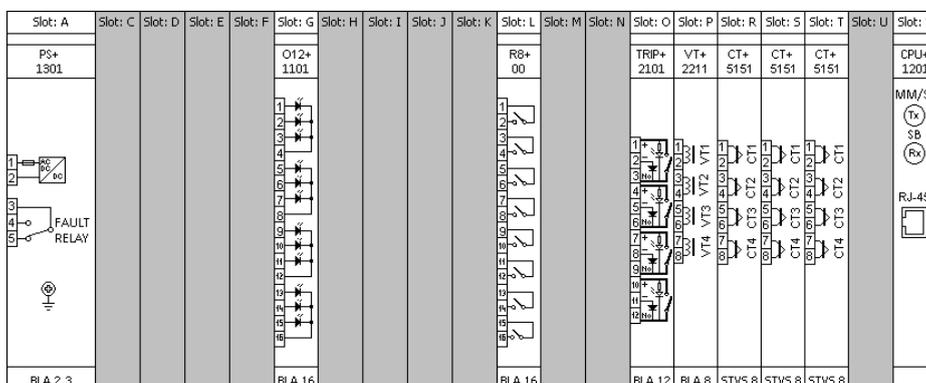
Basic module arrangement of the E5-TR configuration (84TE, rear view)

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

- **E6-TR Variant**

Basic module arrangement of the E6-TR configuration (84TE, rear view)

Basic module arrangement of the E6-TR configuration (42TE, rear view)

EXTERNAL CONNECTION DIAGRAM
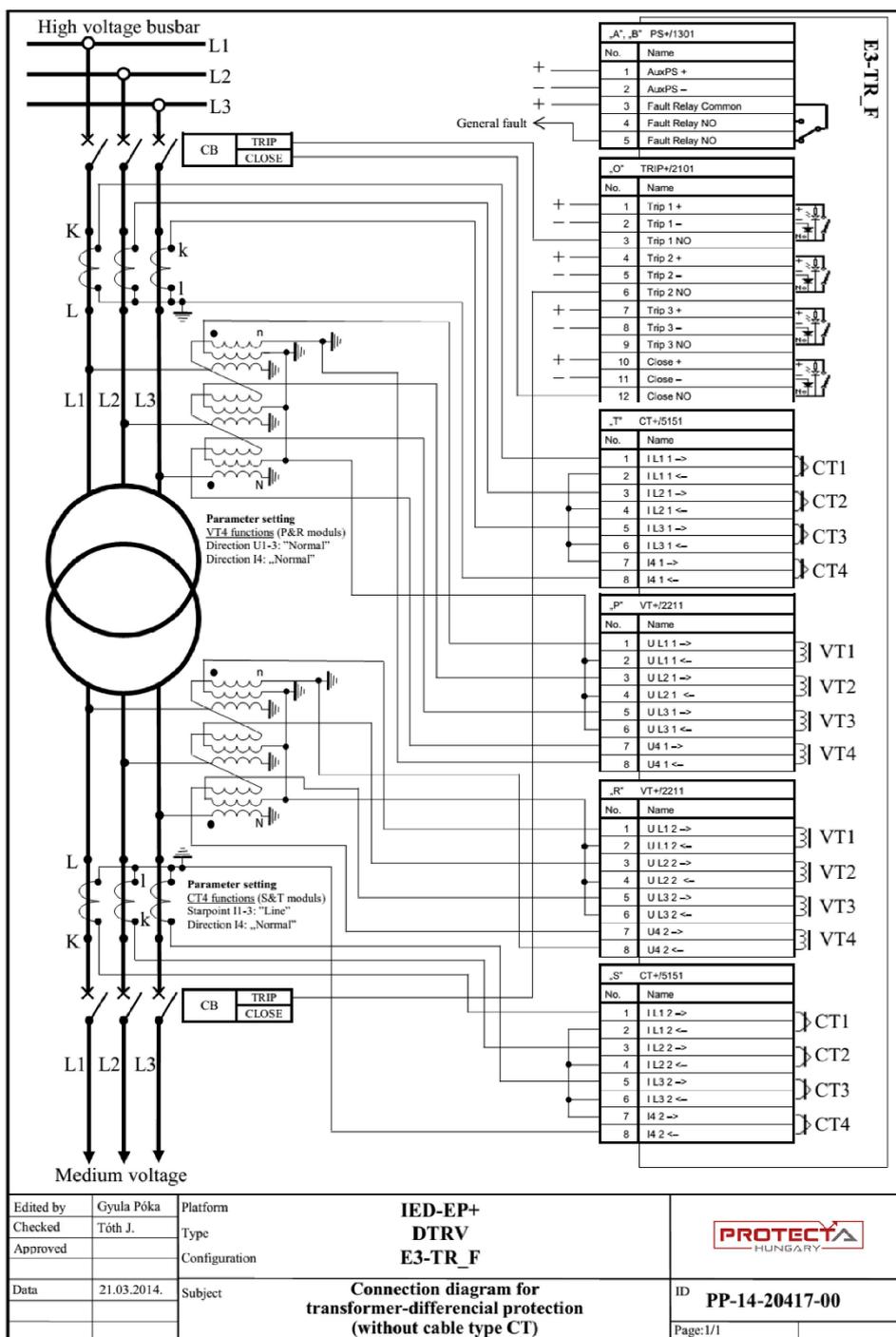
- **E1-TR Variant**
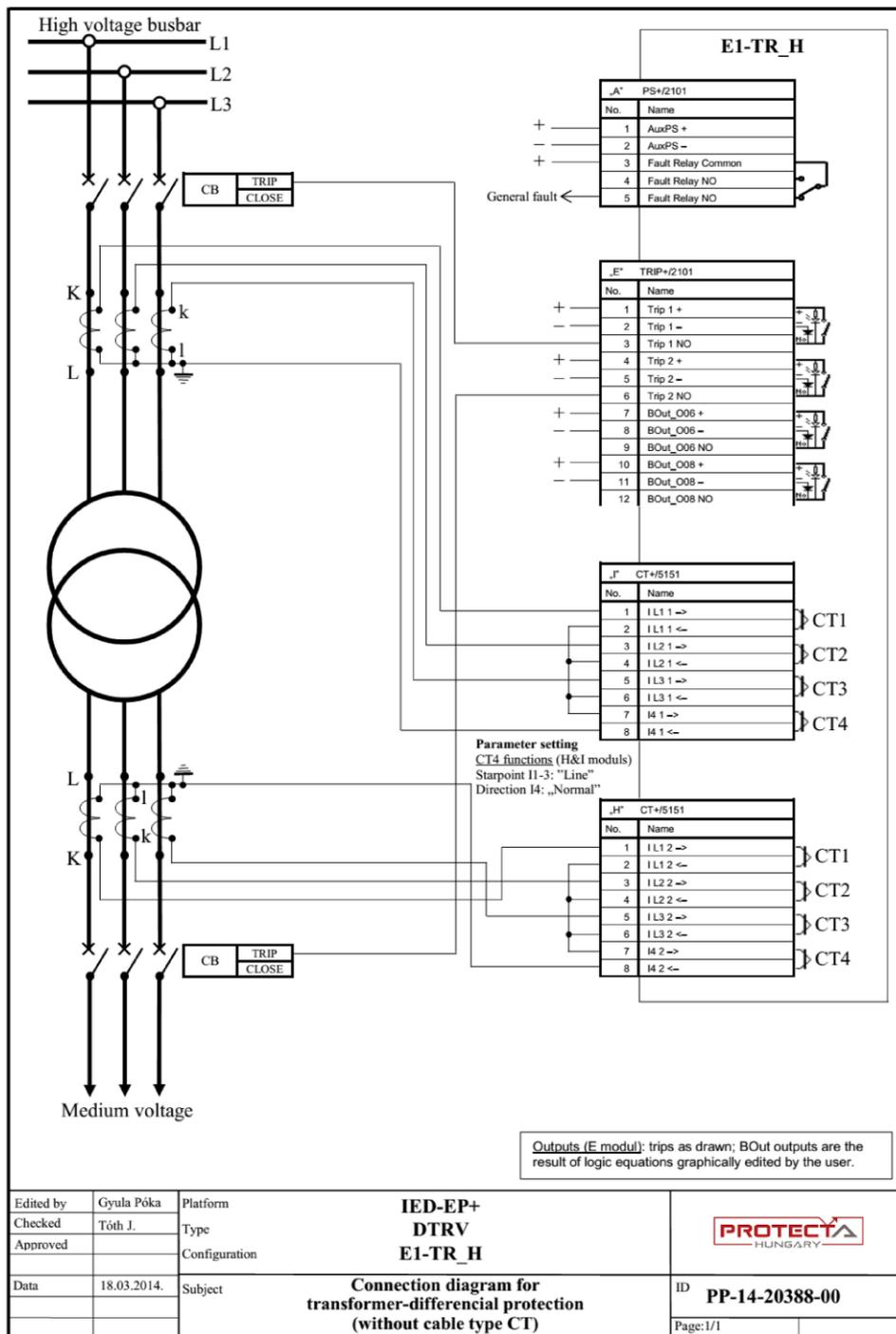
Typical connection diagram for E1-TR transformer differential protection
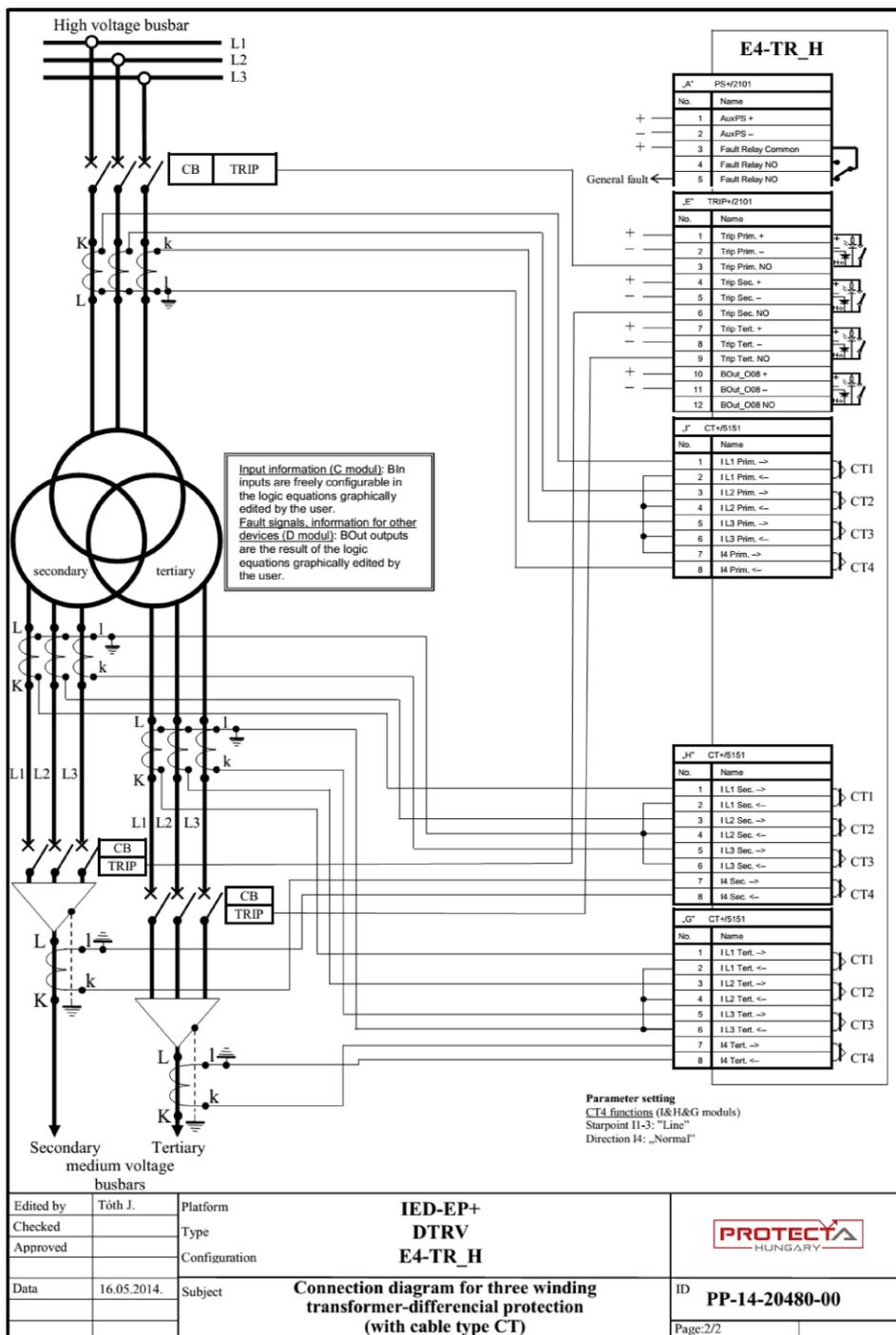
▪ **E2-TR Variant**
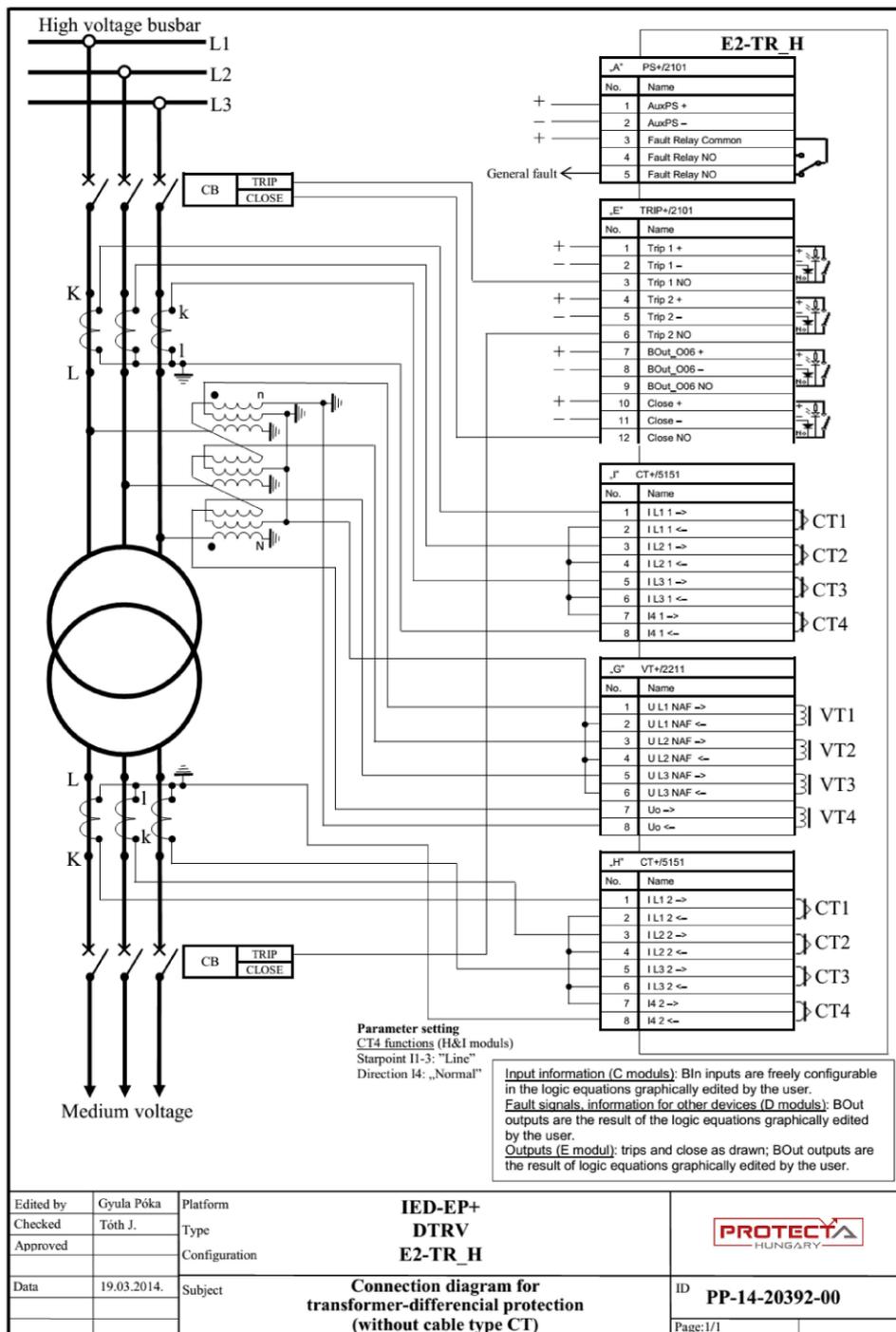
Typical connection diagram for E2-TR transformer differential protection
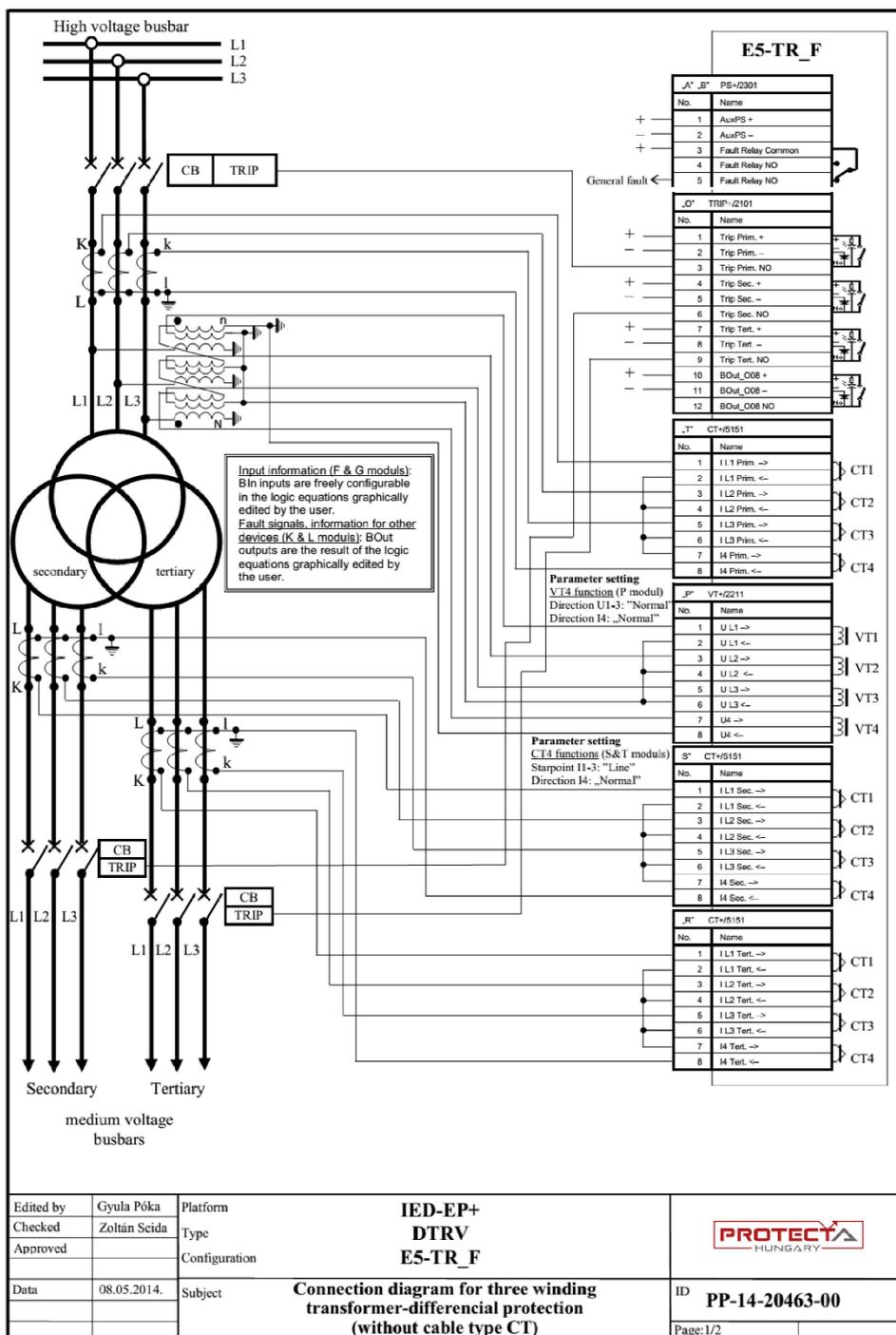
- **E3-TR Variant**

Typical connection diagram for E3-TR transformer differential protection

▪ **E4-TR Variant**

Typical connection diagram for E4-TR transformer differential protection

- **E5-TR & E6-TR Variant**

Typical connection diagram for E5-TR & E6-TR transformer differential protection

CONTACT

For more information, please refer to the **DTRV** configuration description document or contact us:

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