PRODUCT DESCRIPTION

EuroProt+ DTRV

IED-EP+/DTRV

GENERATOR PROTECTION RELAY

PROTECTA HUNGARY

EUROPROT+ DTRV

GENERATOR 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 **DTRV** product type is especially designed for protection and control applications of power transformers and generators including generator-transformer blocks. Additionally the **DTRV** product type includes variety of versatile protection functions to meet the user's the most demanding requirements.

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:
  - DRE can store more than 64 records
  - 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
  - Event recorder can store more than 10,000 events
  - 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 on-line. 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:
  - Ethernet-based communication protocol: IEC61850, DNP3.0 TCP, IEC60870-5-104, Modbus TCP
  - 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** relay includes variety of versatile protection functions along with the main differential protection, such as overcurrent, over-/undervoltage, frequency protections. The other main function is the automatic generator synchronizer. The device contains several functions especially made for generator applications as well, e.g. thermal-based negative sequence overcurrent protection, voltage dependent overcurrent, inadvertent energizing protections, loss of excitation, 100% stator earth fault protection, rotor earth fault etc. It can be applied as a back-up protection relay for downstream equipment (e.g. feeders, cables etc.).

The **DTRV** relay can support the double breaker terminals at any side of the transformer such as breaker and a half, or ring bus topologies. Note that automatic synchronization is available to one bus in this device. To be able to switch between several buses with the synchronizer please use the standalone version of the automatic generator synchronizer (ASZKG of the DAUT type).

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

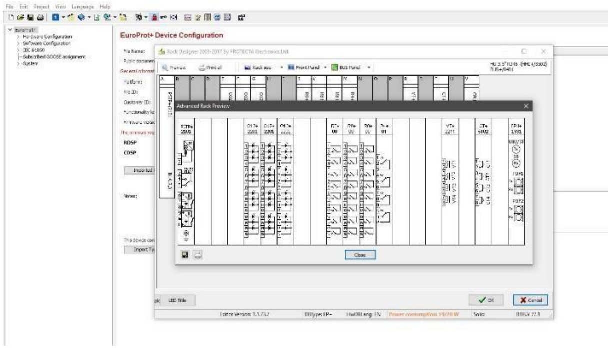
SCOPE OF APPLICATION

- Block differential protection with three ends:
  - Automatic phaseshift and turns ratio compensation
  - 2nd and 5th harmonics restraint for transformer inrush and overexcitation detection
  - CT of the auxiliary transformer can be at either side
- Automatic generator synchronizer:
  - Synchrocheck and synchroswitch with output signals for frequency and voltage control
  - User-configurable start/cancel conditions
- Protections specifically made for generator applications:
  - Voltage dependent overcurrent protections Interturn fault protection for larger generators (current or voltage based, depending on the winding)
  - Loss of excitation protection
  - Pole slipping (out-of-step) protection
  - Rotor earth fault protection for isolated/ungrounded or middle-grounded rotors
- Different kinds of 95% earth fault protections:
  - Residual overcurrent (can be sensitive depending on the CT)
  - Residual overvoltage
  - Restricted earth fault
- 100% Stator earth fault protections:
  - 3rd harmonic undervoltage
  - 3rd harmonic differential overvoltage by measuring the residual voltage in the neutral and the terminal point (two operation modes if generator CB is present)
- Restricted earth-fault protection
- The implemented protection functions provide back- up protection for downstream equipment (e.g. feeders, cables etc.).
- Independent trip logic and circuit supervision for each trip circuit (circuit breaker, excitation, turbine valve etc.)
- Support for the double breaker terminals such as breaker and a half, or ring bus topologies
- Supervision of current and voltage transformers Programmable interlocking schemes
- Optional external unit: Remote I/O unit (RIO)
- Optional transducer I/Os (RTD/mA)

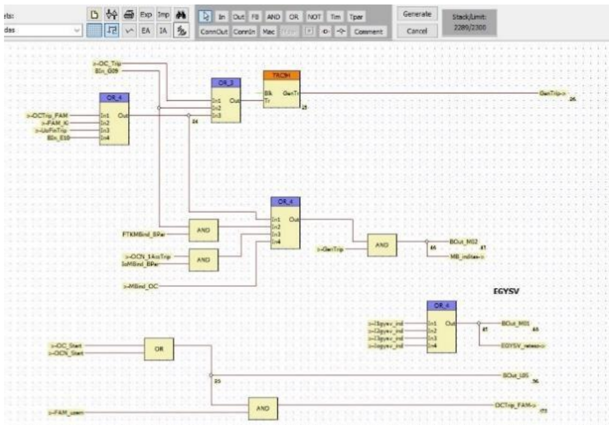
EUROCAP CONFIGURATION TOOL

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.

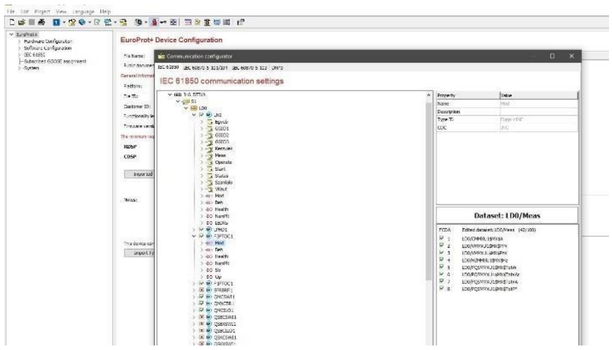
- **HW configuration**
  - View the exciting hardware configuration of the IED including card information and slot position
  - Modify (add or change) certain HW modules
  - Digital and analogue I/O signal definition



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

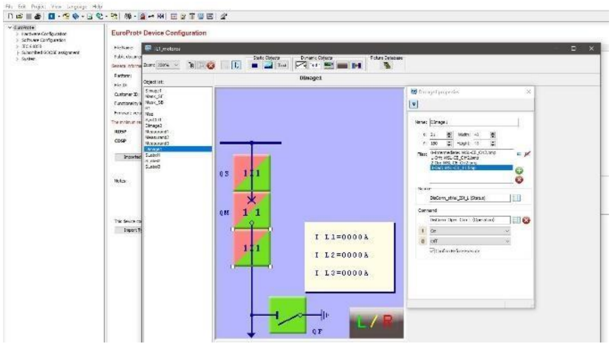


- **Communication configurator**
  - Set up IEC 61850, 101-104, 103, DNP3 communication protocols
  - Configure dataset, report and goose control block properties for IEC 61850 horizontal and vertical communication
  - GOOSE configuration between IEDs



- **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.

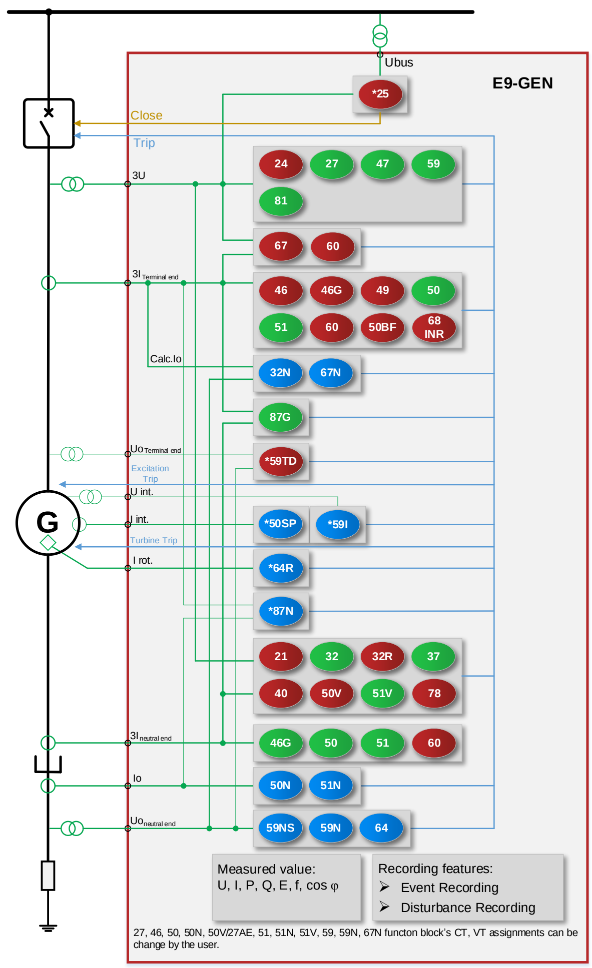
The number and the functionality of the members of each product type are put together according to the application philosophy, keeping in mind the possible main usages. The available configurations of the **DTRV** type for transformers are listed in the table below.

VARIANT	MAIN APPLICATION
E9-GEN	Generator protection
E10-GEN	Generator protection with automatic synchronizer
E11-GEN	Generator – Transfomrer block protection with three ends
E12-GEN	Generator – Transformer block protection with three ends and automatic synchronizer

- **E9-Gen Generator protection**

THE IMPLEMENTED PROTECTION & CONTROL FUNCTIONS	IEC	ANSI	*Inst.
Circuit breaker control (included interlocking function)			
Disconnector control (included interlocking function)			
Impedance protection with compounded circular characteristic	Z<	21	1
Overexcitation protection	V/Hz	24	1
Synchro check synchro switch	SYNC	25	1 (op.)
Definite time undervoltage protection	U <, U <<	27	2
Directional overpower protection	P>	32	2
Directional residual wattmetric earth-fault protection	Po>	32N	1
Directional underpower protection	P<	37	1
GGIORTD temperature measurement		38/49T	4 (op.)
Loss of excitation protection (Version 40Q)	X<	40Q	2
Loss of excitation protection (Version 40Z)	Z<	40Z	2 (op.)
Negative sequence overcurrent protection	I2>	46	1
Negative sequence overcurrent protection for generators	I2>	46G	1
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/ 50Ns	2
Breaker failure protection	CBFP	50BF	1
Interturn fault protection (split phase/current based)	Ii>	50SP	1 (op.)
Generator inadvertent energizing protection	I>>> U<	50V/ 27AE	1
Three-phase time overcurrent protection	I >, I >>	51	2
Residual overcurrent protection	Io >, Io >>	51N/ 51Ns	2
Voltage dependent overcurrent protection	I> U<	51V	1
Definite time overvoltage protection	U>, U>>	59	2
Definite time overvoltage protection	Uo>, Uo>>	59N	2
Residual start-up overvoltage protection function	UNs>	59Ns	1
Interturn fault protection function (voltage based)	Ui>	59I	1 (op.)
Third harmonic differential overvoltage protection	U3hd>	59TD/ 64TN	1 (op.)
Current transformer supervision		60	2
Voltage transformer supervision and dead line detection		60	1
Third harmonic undervoltage protection	U3h<	64/ 27TN	1 (op.)
Rotor earth fault function and hardware description for isolated rotors/middle-grounded rotors		64R	1 (op.)
Directional three-phase overcurrent protection	I Dir>, I Dir>>	67	2
Directional residual time overcurrent protection	Io Dir>, Io Dir>>	67N/ 67Ns	2
Inrush current detection	I2h >	68	1
Trip circuit supervision		74	1
Pole slipping protection	ΔZ/Δt	78	1
Overfrequency protection	f>, f>>	81O	2
Underfrequency protection	f<, f<<	81U	2
Rate of change of frequency	df/dt	81R	2
Lockout trip logic function		86/94	1
Generator differential protection	3IdG >	87G/ 87M	1
Restricted earth-fault protection	REF	87N	2 (op.)
Differential protection	3IdT >	87T	1 (op.)

**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.*



- **E10-Gen Generator protection with automatic synchronizer**

THE IMPLEMENTED PROTECTION & CONTROL FUNCTIONS	IEC	ANSI	*Inst.
Circuit breaker control (included interlocking function)			
Disconnector control (included interlocking function)			
Impedance protection with compounded circular characteristic	Z<	21	1
Overexcitation protection	V/Hz	24	1
Automatic generator synchronizer function	SYN	25G	1
Synchro check synchro switch	SYNC	25	1
Definite time undervoltage protection	U <, U <<	27	2
Directional overpower protection	P>	32	2
Directional residual wattmetric earth-fault protection	Po>	32N	1
Directional underpower protection	P<	37	1
GGIORTD temperature measurement		38/49T	4 (op.)
Loss of excitation protection (Version 40Q)	X<	40Q	2
Loss of excitation protection (Version 40Z)	Z<	40Z	2 (op.)
Negative sequence overcurrent protection	I2>	46	1
Negative sequence overcurrent protection for generators	I2>	46G	1
Negative sequence definite time overvoltage protection	U2 >	47	1
Thermal protection	T >	49	1
Three-phase instantaneous overcurrent protection	I >>>	50	3
Residual instantaneous overcurrent protection	Io >>>	50N/ 50Ns	3
Breaker failure protection	CBFP	50BF	1
Interturn fault protection (split phase/current based)	Ii>	50SP	1 (op.)
Generator inadvertent energizing protection	I>>> U<	50V/ 27AE	1
Three-phase time overcurrent protection	I >, I >>	51	2
Residual overcurrent protection	Io >, Io >>	51N/ 51Ns	2
Voltage dependent overcurrent protection	I> U<	51V	1
Definite time overvoltage protection	U>, U>>	59	2
Residual definite time overvoltage protection	Uo>, Uo>>	59N	2
Interturn fault protection function (voltage based)	Ui>	59I	1 (op.)
Third harmonic differential overvoltage protection	U3hd>	59TD/ 64TN	1 (op.)
Current transformer supervision		60	2
Voltage transformer supervision and dead line detection		60	1
Third harmonic undervoltage protection	U3h<	64/ 27TN	1 (op.)
Rotor earth fault function and hardware description for isolated rotors/middle-grounded rotors		64R	1 (op.)
Directional three-phase overcurrent protection	I Dir>, I Dir>>	67	2
Directional residual time overcurrent protection	Io Dir>, Io Dir>>	67N/ 67Ns	2
Inrush current detection	I2h >	68	1
Trip circuit supervision		74	1
Pole slipping protection	ΔZ/Δt	78	1
Overfrequency protection	f>, f>>	81O	2
Underfrequency protection	f<, f<<	81U	2
Rate of change of frequency	df/dt	81R	2
Lockout trip logic function		86/94	1
Generator differential protection	3IdG >	87G/ 87M	1
Restricted earth-fault protection	REF	87N	2 (op.)
Differential protection	3IdT >	87T	1 (op.)

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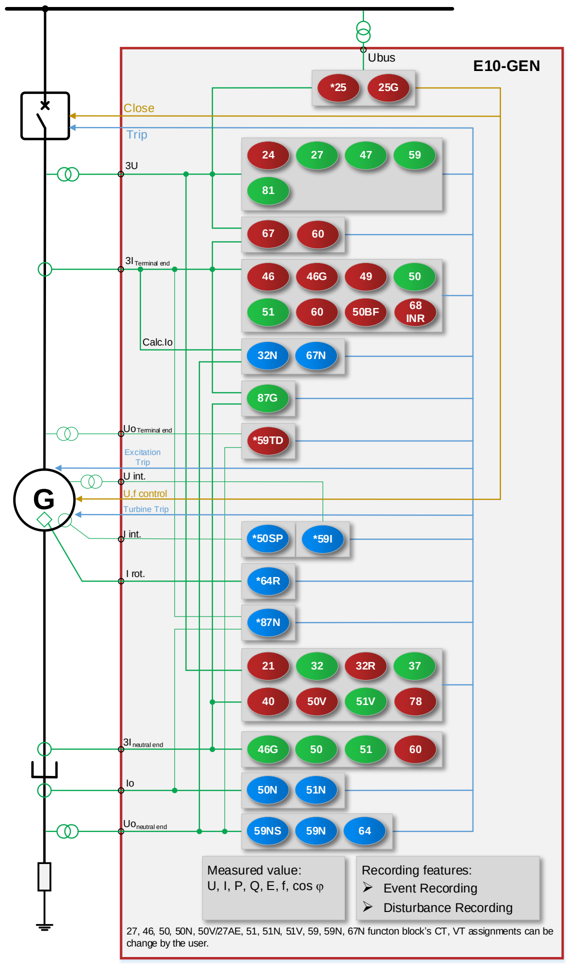
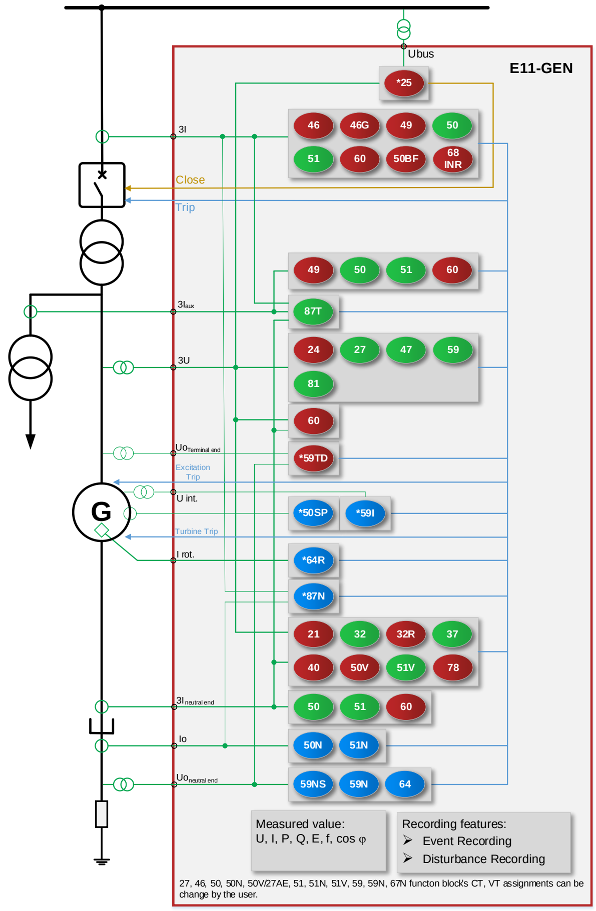


- **E11-Gen Generator – Transfomrer block protection with three ends**

THE IMPLEMENTED PROTECTION & CONTROL FUNCTIONS	IEC	ANSI	*Inst.
Circuit breaker control (included interlocking function)			
Disconnector control (included interlocking function)			
Impedance protection with compounded circular characteristic	Z<	21	1
Overexcitation protection	V/Hz	24	1
Synchro check synchro switch	SYNC	25	1 (op.)
Definite time undervoltage protection	U <, U <<	27	2
Directional overpower protection	P>	32	2
Directional underpower protection	P<	37	1
GGIORTD temperature measurement		38/49T	4 (op.)
Loss of excitation protection (Version 40Q)	X<	40Q	2
Loss of excitation protection (Version 40Z)	Z<	40Z	2 (op.)
Negative sequence overcurrent protection	I2>	46	1
Negative sequence overcurrent protection for generators	I2>	46G	1
Negative sequence definite time overvoltage protection	U2 >	47	1
Thermal protection	T >	49	1
Three-phase instantaneous overcurrent protection	I >>>	50	3
Residual instantaneous overcurrent protection	Io >>>	50N/ 50Ns	3
Breaker failure protection	CBFP	50BF	1
Interturn fault protection (split phase/current based)	Ii>	50SP	1 (op.)
Generator inadvertent energizing protection	I>>> U<	50V/ 27AE	1
Three-phase time overcurrent protection	I >, I >>	51	2
Residual overcurrent protection	Io >, Io >>	51N/ 51Ns	2
Voltage dependent overcurrent protection	I> U<	51V	1
Definite time overvoltage protection	U>, U>>	59	2
Definite time overvoltage protection	Uo>, Uo>>	59N	2
Interturn fault protection function (voltage based)	Ui>	59I	1 (op.)
Third harmonic differential overvoltage protection	U3hd>	59TD/ 64TN	1 (op.)
Current transformer supervision		60	3
Voltage transformer supervision and dead line detection		60	1
Third harmonic undervoltage protection	U3h<	64/ 27TN	1 (op.)
Rotor earth fault function and hardware description for isolated rotors/middle-grounded rotors		64R	1 (op.)
Inrush current detection	I2h >	68	1
Trip circuit supervision		74	1
Pole slipping protection	ΔZ/Δt	78	1
Overfrequency protection	f>, f>>	81O	2
Underfrequency protection	f<, f<<	81U	2
Rate of change of frequency	df/dt	81R	2
Lockout trip logic function		86/94	1
Restricted earth-fault protection	REF	87N	2 (op.)
Differential protection	3IdT >	87T	1

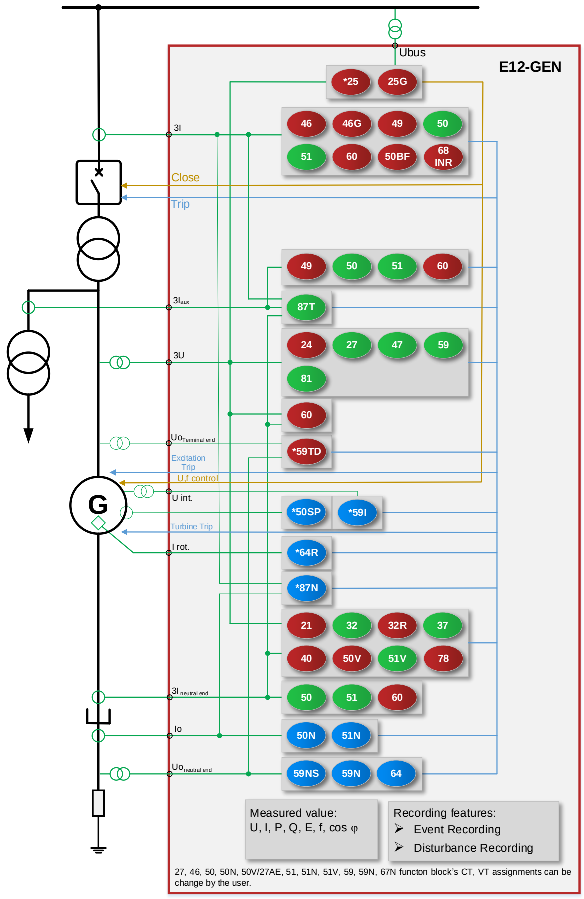
**The Inst. column contains the numbers of the pre-configured function blocks in the factory configuration. These numbers may be different in order to meet the user's requirements.*



- **E12-Gen Generator – Transformer block protection with three ends and automatic synchronizer**

THE IMPLEMENTED PROTECTION & CONTROL FUNCTIONS	IEC	ANSI	*Inst.
Circuit breaker control (included interlocking function)			
Disconnector control (included interlocking function)			
Impedance protection with compounded circular characteristic	Z<	21	1
Overexcitation protection	V/Hz	24	1
Automatic generator synchronizer function	SYN	25G	1
Synchro check synchro switch	SYNC	25	1
Definite time undervoltage protection	U <, U <<	27	2
Directional overpower protection	P>	32	2
Directional underpower protection	P<	37	1
GGIORTD temperature measurement		38/49T	4 (op.)
Loss of excitation protection (Version 40Q)	X<	40Q	2
Loss of excitation protection (Version 40Z)	Z<	40Z	2 (op.)
Negative sequence overcurrent protection	I2>	46	1
Negative sequence overcurrent protection for generators	I2>	46G	1
Negative sequence definite time overvoltage protection	U2 >	47	1
Thermal protection	T >	49	1
Three-phase instantaneous overcurrent protection	I >>>	50	3
Residual instantaneous overcurrent protection	Io >>>	50N/ 50Ns	3
Breaker failure protection	CBFP	50BF	1
Interturn fault protection (split phase/current based)	Ii>	50SP	1 (op.)
Generator inadvertent energizing protection	I>>> U<	50V/ 27AE	1
Three-phase time overcurrent protection	I >, I >>	51	2
Residual overcurrent protection	Io >, Io >>	51N/ 51Ns	2
Voltage dependent overcurrent protection	I> U<	51V	1
Definite time overvoltage protection	U>, U>>	59	2
Residual definite time overvoltage protection	Uo>, Uo>>	59N	2
Interturn fault protection function (voltage based)	Ui>	59I	1 (op.)
Third harmonic differential overvoltage protection	U3hd>	59TD/ 64TN	1 (op.)
Current transformer supervision		60	3
Voltage transformer supervision and dead line detection		60	1
Third harmonic undervoltage protection	U3h<	64/ 27TN	1 (op.)
Rotor earth fault function and hardware description for isolated rotors/middle-grounded rotors		64R	1 (op.)
Inrush current detection	I2h >	68	1
Trip circuit supervision		74	1
Pole slipping protection	ΔZ/Δt	78	1
Overfrequency protection	f>, f>>	81O	2
Underfrequency protection	f<, f<<	81U	2
Rate of change of frequency	df/dt	81R	2
Lockout trip logic function		86/94	1
Restricted earth-fault protection	REF	87N	2 (op.)
Differential protection	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.*



- **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:
  - 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 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:
  - 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 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.

- **Impedance protection with compounded circular characteristic (21)**

This impedance protection function can be applied as impedance protection with an offset circular characteristic or as a loss-of-field protection function for synchronous machines.

A full-scheme system provides continuous measurement of impedances in the six possible fault loops. The calculation is performed in the phase-to-phase loops based on the line-to-line voltages and the difference of the affected phase currents, while in the phase-to-earth loops the phase voltage is divided by the phase current compounded with the zero sequence current. The result of this calculation is the positive sequence impedance of the fault loop, including the positive sequence fault resistance at the fault location.

The separation of the two types of equations is based on the presence or absence of the earth (zero sequence) current. A biased characteristics are applied.

Complex earth fault compensation factor is applied.

Impedance calculation is conditional on the values of phase currents being sufficient.

The impedance calculation is dynamically based on:

- Measured loop voltages if they are sufficient for decision,
- Moltages stored in the memory if they are available,
- Optionally, the decision can be non-direction; in that case, the center of the circle is not shifted away from the origin.

The operate decision is based on offset circle characteristics

- **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

- **Synchro check, synchro switch (25)**

Several problems can occur in the electric power system if the circuit breaker closes and connects two systems operating asynchronously. The high current surge can cause damage in the interconnecting elements, the accelerating forces can overstress the shafts of rotating machines or, at last, the actions taken by the protective system can result in the unwanted separation of parts of the electric power system. To prevent such problems, this function checks whether the systems to be interconnected are operating synchronously. If yes, then the close command is transmitted to the circuit breaker. In case of asynchronous operation, the close command is delayed to wait for the appropriate vector position of the voltage vectors on both sides of the circuit breaker. If the conditions for safe closing cannot be fulfilled within an expected time, then closing is declined.

There are three modes of operation:

- Energizing check:
  - Dead bus, live line,
  - Live bus, dead line,
  - Any Energizing Case (including Dead bus, dead line).
- Synchro check (Live line, live bus)
- Synchro switch (Live line, live bus)

The function can be started by the switching request signals initiated both the automatic reclosing and the manual closing. The binary input signals are defined by the user, applying the graphic equation editor.

Blocking signal of the function are defined by the user, applying the graphic equation editor. Blocking signal of the voltage transformer supervision function for all voltage sources are defined by the user, applying the graphic equation editor.

Signal to interrupt (cancel) the automatic or the manual switching procedure are defined by the user, applying the graphic equation editor.

- **Automatic generator synchronizer function (25G)**

The 25G generator synchronizer function automatically controls the procedure to connect a generator to the network. The voltage and the speed of the generator is regulated to match the voltage and the frequency of the network. During this procedure, the voltage magnitude, the frequency and the phase angle of the generator and those of the network are continuously evaluated. If the voltage and frequency difference between the network and the generator is within the defined limits, then the close command to the circuit breaker is generated in the right moment, considering the closing time of the circuit breaker, to connect the generator to the system with minimal phase angle difference.

The function is based on the SYN25 synchro-check/synchro-switch function (the description is the document "Synchro check, synchro switch function block description"). The applied mode is "synchro switch" mode. This function is extended with command function to increase/decrease voltage and speed of the generator. These commands are generated to meet the basic switching requirements.

- **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".

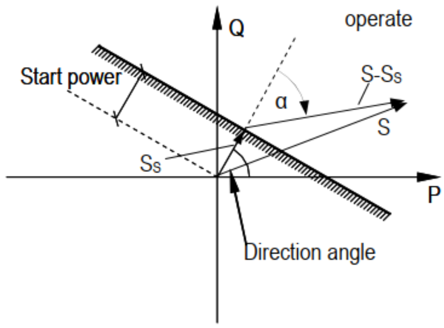
The overvoltage protection function has a binary input signal, which serves the purpose of disabling the function. The conditions of disabling are defined by the user, applying the graphic equation editor.

- **Directional over-power protection (32)**

The directional over-power protection function can be applied to protect any elements of the electric power system mainly generators if the active and/or reactive power has to be limited.

The inputs of the function are the Fourier basic harmonic components of the three phase currents and those of the three phase voltages. Based on the measured voltages and currents, the block calculates the three-phase activeand reactive power (point S) and compares the P-Q coordinates with the defined characteristics on the power plane. The characteristic is defined as a line laying on the point SS and perpendicular to the direction of SS. The SS point is defined by the "Start power" magnitude and the "Direction angle". The over-power function operates if the angle of the S-SS vector related to the directional line is below 90 degrees and above -90 degrees.

At operation, the "Start power" value is decreased by a hysteresis value.



- **Directional residual wattmetric earth-fault protection (32N)**

The decision in the directional residual wattmetric earth-fault protection function is based on calculated active power of the residual voltage and current. The application area is to detect earth-faults mainly in compensated networks, where the direction of the reactive power depends on the degree of compensation, the direction of the fault is indicated only by the active component of the power. For this application the characteristic angle setting is 180°. If the function is applied e.g. in isolated networks, the optimal setting of the characteristic angle is -90° degrees (valid for standard connection and factory setting). With this setting the function detects the faulty bay.

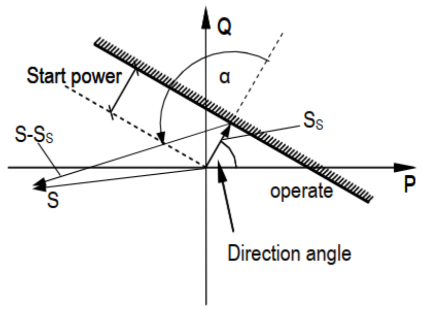
The function operates with definite time characteristic. The operation can be blocked by parameter setting and also by external blocking signal.

- **Directional under-power protection (37)**

The directional under-power protection function can be applied mainly to protect any elements of the electric power system, mainly generators, if the active and/or reactive power has to be limited in respect of the allowed minimum power.

The inputs of the function are the Fourier basic harmonic components of the three phase currents and those of the three phase voltages. Based on the measured voltages and currents, the block calculates the three-phase active and reactive power (point S) and compares the P-Q coordinates with the defined characteristics on the power plane. The characteristic is defined as a line laying on the point SS and perpendicular to the direction of SS. The SS point is defined by the “Start power” magnitude and the “Direction angle”. The under-power function operates if the angle of the S-SS vector related to the directional line is above 90 degrees or below -90 degrees, i.e. if the point S is on the “Operate” side of the P-Q plane.

At operation, the “Start power” value is increased by a hysteresis value.



- **GGIORTD temperature measurement (38/49T)**

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 (thermocouple) can be connected. The temperature is measured as the resistance value of the sensor, which depends on the temperature.

- **Loss of excitation protection (Version 40Q)**

When a synchronous generator connected parallel to the network loses the excitation, or the field decreases below the permitted limit then the missing magnetizing reactive power is taken from the other generators and from the network. This state can be caused by the failure of the excitation system, the error of the voltage controller, or when the system is switched over from automatic excitation to manual control then the manual system is set to inappropriate state. The consequences are:

- The generator stator current increases to dangerous level,
- The reactive power is supplied by the other operating generators of the power station, and they get unwanted trip command, due to the increased current,
- The generator gets out of the synchronous state and
  - It operates after that as an asynchronous machine, causing power swing and additional heat generation,
  - Or the speed of the generator increases above the tolerable speed.

To prevent the dangers listed above, the generator without excitation should be tripped. This is the function of the loss of excitation protection.

- **Loss of excitation protection (Version 40Z)**

When the excitation is lost, then a relatively high inductive current flows into the generator. With the positive direction from the generator to the network, the calculated impedance based on this current and on the phase voltage is a negative reactive value. As the internal e.m.f. collapses, the locus of the impedance on the impedance plane travels to this negative reactive value. With an appropriate characteristic curve on the impedance plane, the loss of excitation state can be detected. The applied characteristic line is a closed offset circle, the radius and the centre of which is defined by parameter setting.

If the calculated impedance gets into the offset circle then the function generates a trip command.

The loss of excitation protection function provides two stages, where the parameters of the circles and additionally the delay times can be set independently.

- **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 overcurrent protection function for generator (46G)**

In case of asymmetrical faults on the connected network or at asymmetrical load states, thestator current of the generators is asymmetric. The negative sequence component of the stator current generates an inverse rotating magnetic field, and it causes eddy currents in the rotor. These phenomena can cause overheating and damages.

The fact fault clearing is the task of the fault protection. In case of continuous asymmetry however it is the negative sequence overcurrent protection function which prevents damages of the generator

- **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.

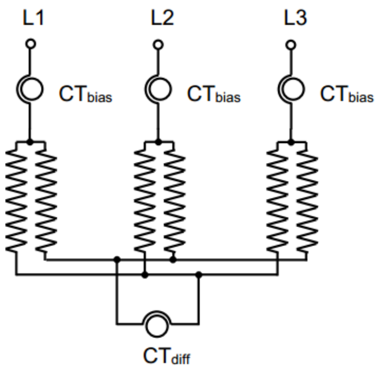
The function generates a trip commands without additional time delay if the detected values are above the current setting value.

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.

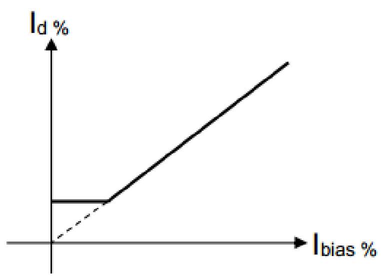
The residual instantaneous overcurrent protection function has a binary input signal, which serves the purpose of disabling the function. The conditions of disabling are defined by the user, applying the graphic equation editor.

- **Interturn fault protection function (50SP)**

In generators constructed for parallel windings, there is no current in the current transformer connected between the star points of the windings. The small current due to the natural asymmetry can be neglected.



A short circuit within a winding or between the turns of the parallel windings results high local fault current, but in the phase currents of the generator this current cannot be detected. This means that this kind of faults cannot be cleared by an overcurrent protection function. The differential current between the two star points however is a measurable value. The numerical base harmonic filter of the applied algorithm enables sensitive setting for current detection. Due to the relatively large false differential current in case of external fault, a biased characteristic is applied. The biasing current is the maximum of the measured phase currents.



The horizontal axis of the operating characteristic is drawn as the percent of the phase current transformer rated current, the scaling of the vertical axis is in percent of the crated value of the current transformer into the differential branch.

As the turn's ratio of the current transformer in the differential branch is much less than that of phase current transformers (one tenth or one over twenty), the decision can be performed in high precision.

If the generator has no parallel windings, this method cannot be applied. For these configurations, the application of the protection function based on voltage measurement is recommended.

- **Generator inadvertent energizing protection (50V/27AE)**

Inadvertent or accidental energizing of large generators while in still-stand can cause serious problems. This can be a consequence of faulty manual closing or flashover of the circuit breaker.

Under these conditions, the machine starts like an induction motor, taking large currents from the network. As a consequence, within a short time (some seconds) the generator can be damaged. The generated heat in the rotor is similar to the effect of negative sequence current component, but here the speed difference between the rotating field and the rotor is approximately the synchronous speed only.

The application of generator inadvertent energizing protection function prevents this error state. In this process the pre-fault state of the generator is characterized by zero voltage, after energizing however overcurrent can be detected. The generator inadvertent energizing protection function recognizes this event sequence.

The protection function is composed by an under-voltage function and an instantaneous overcurrent function.

If the voltage is below the setting level in all three phases then a timer, delayed on pick-up by a timer parameter, sets to true state. This means disconnected state of the generator, and the instantaneous overcurrent stage of the function is enabled. The pick-up delay is needed to prevent operation of the function in case of external fault. This time delay setting value should be longer than the maximum clearing time of any external fault. If the generator is energized inadvertently and during the drop-off time of the timer started by the undervoltage relay the overcurrent function detects current above the current setting value, then the function operates. The undervoltage stage drops after time-out of the drop-off time, disabling the function. In case of inadvertent energizing, the drop-off time delay defines the pulse duration of the generated trip command. When the timer drops off, the output of the function is blocked.

- **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.

- **Voltage dependent overcurrent protection (51V)**

When overcurrent protection function is applied and the current in normal operation can be high, related to the lowest fault current then the correct setting is not possible based on current values only. In this case however, if the voltage during fault is considerably below the lowest voltage during operation then the voltage can be applied to distinguish between faulty state and normal operating state. This is the application area of the voltage dependent overcurrent protection function.

The function has two modes of operation, depending on the parameter setting:

- Voltage restrained
- Voltage controlled

The overcurrent protection function realizes definite time characteristic based on three phase currents. The operation is restrained or controlled by three phase voltages. The function operates in three phases individually, but the generated general start signal and the general trip command is the OR relationship of the three decisions.

The function can be blocked by a user-defined signal or by the voltage transformer supervision function block, if the measured voltage is not available.

- **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.

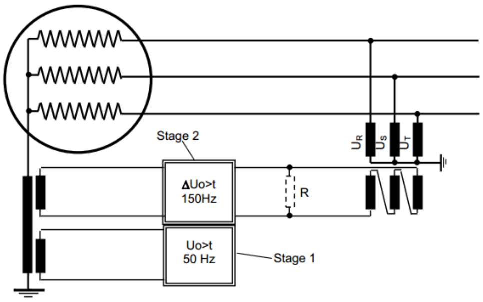
The residual overvoltage protection function has a binary input signal, which serves the purpose of disabling the function. The conditions of disabling are defined by the user, applying the graphic equation editor.

- **Third harmonic differential overvoltage protection (59TD/64TN)**

Partial stator earth-fault protection of generators is solved using TOV59N, 50 Hz zero sequence overvoltage function. This function is supplied by the neutral point voltage transformer or by the open delta connected voltage transformer at the connection side of the generator (See Figure 1–1).

The magnitude of the 50 Hz zero sequence voltage depends on the location of the statorearth-fault. As the earth-fault is getting closer to the neutral point, the 50 Hz zero sequence voltage decreases, and the protection function gets less and less sensitive. Accordingly, the setting value of the zero sequence voltage is advised to be set to a small value, to decrease the dead zone. The measured error voltages however act against this tendency: in case of earth faults at the connected high voltage network, a considerable zero sequence voltage is transmitted by the internal capacitances of the step-up transformer, and a third harmonic voltage distortion can also be detected. The fundamental harmonic component can be decreased using a resistor, connected to the open delta connected windings of the voltage transformers. The harmonic distortion can also be filtered using the Fourier method to get the fundamental harmonic component. With the application of these methods, about 85…90 % of the stator windings can beprotected.

Due to the applied harmonic filter, which detects the 50 Hz fundamental harmonic, the voltage setting value may be below the measured voltage by a voltmeter, because in this voltage the 150 Hz component dominates.



The EuroProt+ system applies a zero sequence overvoltage protection function (TOV59N) to perform the fundamental harmonic earth-fault protection. This function is described in a separate document.

- **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.

- **Voltage transformer supervision (VTS60)**

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. The user has to generate graphic equations for the application of the signal of this voltage transformer supervision function.

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 (3Uo) is above the preset voltage value AND the residual current (3Io) 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 (U2) is above the preset voltage value AND the negative sequence current component (I2) is below the preset current value.
- Special application: “VT failure” signal is generated if the residual voltage (3Uo) is above the preset voltage value AND the residual current (3Io) AND the negative sequence current component (I2) are below the preset current values.

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.

- **Third harmonic undervoltage protection (64/27TN)**

The definite time third harmonic undervoltage protection function can be applied to extend the stator earth fault protection system for a generator to 100% stator earth fault protection. Other protection functions, based on network frequency quantities, cannot detect the stator earthfaults near to the neutral point of the generator. This is due to the low value of the generated voltage in this range of the stator coil. These functions operate only if the earth-fault is relatively far from the neutral point.

The basic principle of extending the protected zone to the area near to the neutral point is the third harmonic voltage detection. It can be applied if a generator is connected to the unit transformer, the connection group of which isolates the generator form the network, regarding the zero sequence voltage and current.

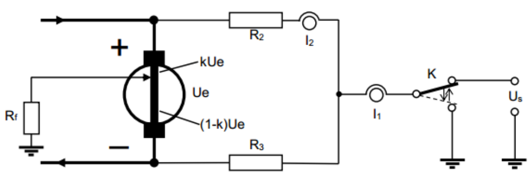
Along the stator windings of the phases, due to the construction of a generator, a third harmonic voltage component is generated, which is of zero sequence nature. This zero sequence third harmonic voltage is divided between the distributed capacitances of the system (generator and transformer earth capacitance, etc.). As a consequence, in normal, symmetric operation a certain amount of third harmonic voltage can be measured in the neutral of the generator.

In case of a single phase-to-ground fault near to the neutral point of the generator, this voltage decreases, and the third harmonic undervoltage protection function detects the earth fault.

- **Rotor earth fault function (64R)**

This Rotor earth fault protection function can be applied to provide protection against rotor earth faults in generators, where the excitation circuit is isolated from the rotor iron core. The method applies cyclic DC voltage and zero voltage (earthing) toggling for the measurement. Due to the measuring arrangement, the accuracy of the measured fault resistance is independent of the exciting voltage and also of the fault location (which part of the exciting voltage is inside themeasuring loop).

If both poles of the excitation winding are available then additionally to the fault resistance, also the fault location relative to the positive brush and also the exciting voltage can be calculated. The calculated exciting voltage can be applied to a rotor overload protection function in the form of overvoltage detection: Ue>t.



If only one of the poles of the excitation winding is available (e.g. in the case of excitation with rotating diodes) then the fault location and the exciting voltage cannot be calculated. The accuracy of the fault resistance calculation is however independent of these two factors. The applied algorithm is selected by parameter setting.

- **Three-phase directional overcurrent protection (67)**

The directional three-phase overcurrent protection function can be applied on solidly grounded, compensated or isolated networks, where the overcurrent protection must be supplemented with a directional decision.

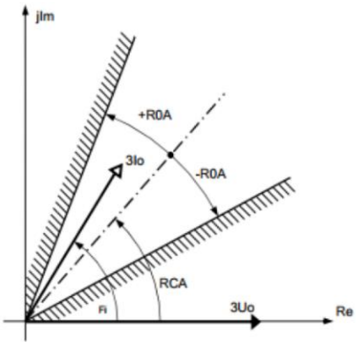
The direction can be selected as forward or backward. The overcurrent decision can be set also without considering the decision. The overcurrent decision can be based on current RMS values or on Fourier fundamental harmonic values. The time overcurrent characteristic can be definite time or several types of standard IEC or ANSI characteristics.

The function can be enabled or disabled by a parameter. The status signal of the VTS (voltage transformer supervision) function can also disable the directional operation.

- **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.

- **Inrush detection (68)**

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. 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 Disable. This signal is the result of logic equations graphically edited by the user. Using the inrush detection binary signals, other protection functions can be blocked during the transient period so as to avoid the unwanted trip.

- **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.).

- **Out of Step (Pole slipping) protection function (78)**

The pole slipping protection function can be applied mainly for synchronous generators. If a generator falls out of synchronism, then the voltage vector induced by the generator rotates slower or with a higher speed as compared to voltage vectors of the network. The result is that according to the frequency difference of the two vector systems, the cyclical voltage difference on the current carrying elements of the network are overloaded cyclically. To protect the stator coils from the harmful effects of the high currents and to protect the network elements, a disconnection is required.

The pole slipping protection function is designed for this purpose.

Main features

- A full-scheme system provides continuous measurement of impedances separately in three independent phase-to-phase measuring loops.
- Impedance calculation is conditional on the values of the positive sequence currents being above a defined value.
- A further condition of the operation is that the negative sequence current component is less than 1/6 of the value defined for the positive sequence component.
- The operate decision is based on quadrilateral characteristics on the impedance plane using four setting parameters.
- The number of vector revolutions can be set by a parameter.
- The duration of the trip signal is set by a parameter.
- Blocking/enabling binary input signal can influence the operation.

- **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.

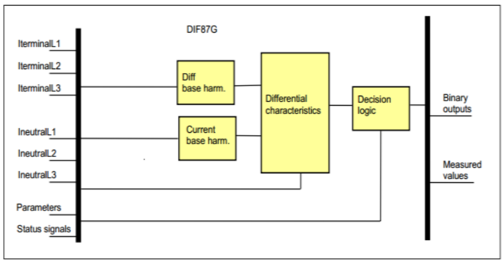
In lockout mode the output stays active until the function gets a reset signal on its reset input.

The trip requirements and the reset signal are programmed by the user, using the graphic equation editor.

- **Generator differential protection function (87G)**

The generator differential protection function provides main protection for generators or large motors. The application needs current transformers in all three phases both on the network side and on the neutral side.

The structure of the generator differential protection (DIF87G) algorithm in the picture below.



The inputs are:

- the sampled values of three phase currents measured at the network side,
- the sampled values of three phase currents measured at the neutral connection,
- parameters,
- status signal.

The outputs are

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

The software modules of the differential protection function:

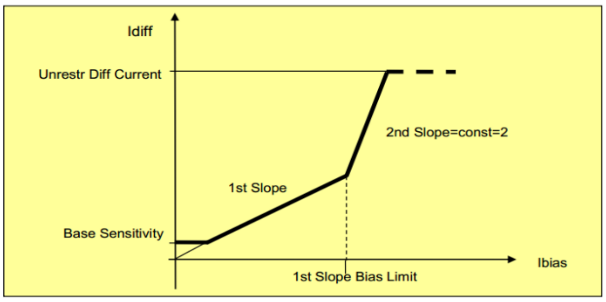
Diff base harm.: This module calculates the basic Fourier components of the three differential currents. These results are needed also for the high-speed differential current decision.

Current base harm.: This module calculates the basic Fourier components of the of the phase currents both for the network side and for the neutral side. The result of this calculation is needed for the differential characteristic evaluation.

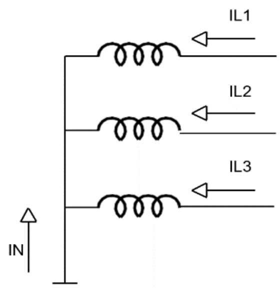
Differential: This module performs the necessary calculations for the evaluation of the “percentage differential characteristics”.

Decision logic: This module combines enabling parameter and blocking signal with the status signals of the differential decision to generate output trip signals and commands.

The generator differential protection characteristics:



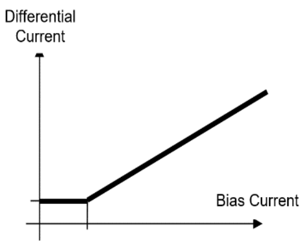
- **Restricted earth fault protection (87N)**



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). 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 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.

- **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.

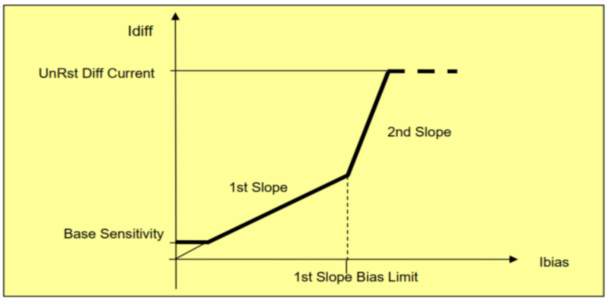
The differential current can be high during the transients of transformer energizing (inrush current) due to the current distortion caused by the transformer iron core asymmetrical saturation. In this case, the second harmonic content of the differential current is applied to disable the false operation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

MEASUREMENT FUNCTIONS

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

Measurement functions	E9-GEN	E10-GEN	E11-GEN	E12-GEN
Current (I1, I2, I3, I4, Iseq (I0, I1, I2))	X	X	X	X
Voltage (U1, U2, U3, U4, U12, U23, U31, Useq (U0, U1, U2)) and frequency	X	X	X	X
Power (P, Q, S, pf) and Energy (E+, E-, Eq+, Eq-)	X	X	X	X
Supervised trip contacts (TCS)	X	X	X	X

The measurement functions of the DTRV configuration

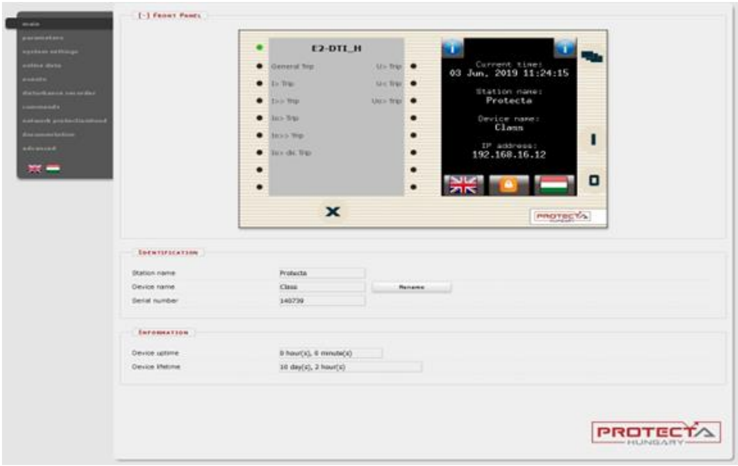
- **Monitoring functions**

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

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

HMI AND COMMUNICATION TASKS

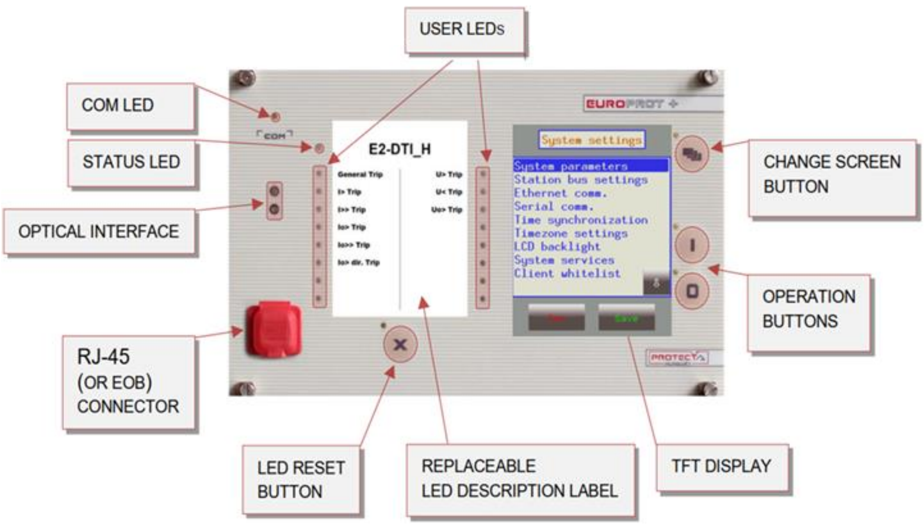
▪ **Embedded WEB-server:** Allows remote access via Ethernet port of device



- 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
Impedance protection with compounded circular characteristic (21)	
Operation	Off, NoCompound, FWCompound, BWCompound
Impedance Start Only	0, 1
IPh Base Sens	10-30% in 1% steps
IRes Base Sens	10-50% in 1% steps
IRes Bias	5-30% in 1% steps
PsImpAng	0-90deg in 1deg steps
OfsImpRch	-150-150ohm in 0.01ohm steps
PsImpRch	0.1-250ohm in 0.01ohm steps
Zone1 (Xo-X1)/3X1	0-5 in 0.01 steps
Zone1 (Ro-R1)/3R1	0-5 in 0.01 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
Synchro check (25)	
Voltage Select	L1-N, L2-N, L3-N, L1-L2, L2-L3, L3-L1
Voltage Select	Off, On, ByPass
SynSW Auto	Off, On
Energizing Auto	Off, DeadBus LiveLine, LiveBus DeadLine, Any energ case
Operation Man	Off, On, ByPass
SynSW Man	Off, On

Energizing Man	Off,DeadBus LiveLine, LiveBus DeadLine, Any energ case
U Live	60-110% in 1% steps
U Dead	10-60% in 1% steps
Udiff Syncheck auto	5-30% in 1% steps
Udiff SynSW auto	5-30% in 1% steps
MaxPhaseDiff auto	5-80º in 1º steps
Udiff SynCheck Man	5-30% in 1% steps
Udiff SynSW Man	5-30% in 1% steps
MaxPhaseDiff Man	5-80º in 1º steps
FrDiff SynCheck Auto	0.02-0.5Hz in 0.02Hz steps
FrDiff SynSW Auto	0.10-1.00Hz in 0.2Hz steps
FrDiff SynCheck Man	0.02-0.5Hz in 0.02Hz steps
FrDiff SynSW Man	0.10-1.00Hz in 0.2Hz steps
Breaker Time	0-500ms in 1ms steps
Close Pulse	10-60000ms in 1ms steps
Max Switch Time	100-60000ms in 1ms steps
Automatic generator synchronizer (25G)	
Operation	Off, On
U Matching	0, 1
F Matching	0, 1
U min	60-110% in 1% steps
TR1 Phase Shift	-180-180deg in 1deg steps
TR2 Phase Shift	-180-180deg in 1deg steps
dt/dU Factor	100-10000ms/% in 1ms/% steps
dt/df Factor	100-60000ms/Hz in 1ms/Hz steps
Udiff SWEna	2-20% in 1% steps
Udiff Max	5-30% in 1% steps
Timeout	10-600s in 1s steps
Stabilization Time	10-600s in 1s steps
TR1 AmplCorr	0.5-2 in 0.001 steps
TR2 AmplCorr	0.5-2 in 0.001 steps
FrDiff SWEna	0.1-1Hz in 0.01Hz steps
FrDiff Max	0.1-1Hz in 0.01Hz steps
Breaker Time	30-500ms in 1ms steps
Close Pulse	10-60000ms in 1ms steps
Ulmp Min	100-30000ms in 1ms steps
Ulmp Max	100-30000ms in 1ms steps
Flmp Min	100-30000ms in 1ms steps
Flmp Max	100-30000ms in 1ms steps
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
Directional overpower protection (32)	
Operation	Off, On
Direction Angle	-179-180deg in 1deg steps
Start Power	1-200% in 0.1% steps

Time Delay	0-60000ms in 1ms steps
Directional residual wattmetric earth-fault protection (32N)	
Operation Min Res Voltage Min Res Current Operating Angle Characteristic Angle Cycle for Periodic Reporting Active Power Limit Time Delay Reset Time	Off, Forward, Backward 1-10% in 1% steps 1-50% in 1% steps 30-85deg in 1deg steps -180-180deg in 1deg steps 0-3600s in 5s steps 2.5-100% in 0.01% steps 0-60000ms in 1ms steps 0-60000ms in 1ms steps
Directional underpower protection (37)	
Operation Direction Angle Start Power Time Delay	Off, On -179-180deg in 1deg steps 1-200% in 0.1% steps 0-60000ms in 1ms steps
GGIORTD temperature measurement (38/49T)	
Resistor Type Min Value Max Value Low Alarm High Alarm	PT100, PT250, PT1000, Ni100, Ni120, Ni250, Ni1000, Ni120US, Cu10 -50ºC-150 ºC in 1 ºC steps -50ºC-150 ºC in 1 ºC steps -50ºC-150 ºC in 1 ºC steps -50ºC-150 ºC in 1 ºC steps
Loss of excitation protection (Version 40Q)	
Stage 1 Operation Stage 2 Operation Stage 1 Start Only Stage 2 Start Only Iph Base Sens Stage 1 X1 Stage 2 X1 Stage 1 X2 Stage 2 X2 Stage 1 Delay Stage 2 Delay	Off, On Off, On 0, 1 0, 1 10-30% in 1% steps 5-500% in 0.01% steps 5-500% in 0.01% steps 5-500% in 0.01% steps 5-500% in 0.01% steps 50-60000ms in 1ms steps 50-60000ms in 1ms steps
Loss of excitation protection (Version 40Z)	
Stage 1 Operation Stage 2 Operation Stage 1 Start Only Stage 2 Start Only Iph Base Sens Stage 1 Z Stage 1 X Offset Stage 1 R Offset Stage 2 Z Stage 2 X Offset Stage 2 R Offset	Off, On Off, On 0, 1 0, 1 10-30% in 1% steps 0.1-250ohm in 0.1ohm steps 0.1-250ohm in 0.1ohm steps 0.1-100ohm in 0.1ohm steps 0.1-250ohm in 0.1ohm steps 0.1-250ohm in 0.1ohm steps 0.1-100ohm in 0.1ohm steps

Stage 1 Delay Stage 2 Delay	0-60000ms in 1ms steps 0-60000ms in 1ms steps
Negative sequence overcurrent protection (46)	
Operation Start Current Time Multiplier Minimal time delay for the inverse char. Definite time delay Reset time delay for the inverse char	Off, DefiniteTime, IEC Inv,IEC VeryInv, IEC ExtInv,IEC LongInv, ANSI Inv, ANSI ModInv, ANSI VeryInv, ANSI ExtInv, ANSI LongInv, ANSI LongVeryInv, ANSI LongExtInv 5-3000% in 1% steps 0.05-999 in 0.01 steps 0-60000ms in 1ms steps 0-60000ms in 1ms steps 0-60000ms in 1ms steps
Negative sequence overcurrent protection for generators (46G)	
Mode Generator Rated Current K Cooling Time I2 Start Warning I2 Start Integration Warning Delay Trip Minimum Delay	Off, On 20-150% in 0.1% steps 1-500% in 0.1% steps 1-500% in 0.1% steps 2-50% in 0.1% steps 2-50% in 0.1% steps 60-30000ms in 1ms steps 60-30000ms in 1ms steps
Negative sequence overvoltage protection (47)	
Operation Start Voltage Time Delay	Off, On 2-40% in 1% steps 50-60000ms in 1ms steps
Thermal protection (49)	
Operation Alarm Temperature Trip Temperature Rated Temperature Base Temperature Unlock Temperature Ambient Temperature Startup Term Rated Load Current Time Constan	Off, Pulsed, Locked 60-200deg in 1deg steps 60-200deg in 1deg steps 60-200deg in 1deg steps 0-40deg in 1deg steps 20-200deg in 1deg steps 0-40deg in 1deg steps 0-60% in 1% steps 20-150% in 1% steps 1-999min in 1min step
Three-phase instantaneous overcurrent protection (50)	
Operation Start current	Off, Peak value, Fundamental value 5-3000% in 1% steps
Breaker failure protection (50BF)	
Operation Retrip Start Ph Current Start Res Current Retrip Time Delay Backup Time Delay Pulse Duration	Off, Current, Contact, Current/Contact Off, On 20-200% in 1% steps 10-200% in 1% steps 0-1000ms in 1ms steps 100-60000ms in 1ms steps 0-60000ms in 1ms steps

Residual instantaneous overcurrent protection (50N/50Ns)	
Operation Start Current	Off, Peak value, Fundamental value 5-3000% in 1% steps
Interturn fault protection (50SP)	
Operation Base Sensitivity Bias Time Delay	Off, On 10-800% in 1% steps 20-500% in 1% steps 0-60000ms in 1ms steps
Generator inadvertent energizing protection (50V/27AE)	
Operation Start Current Start Voltage Pickup Delay Dropout Delay	Off, Peak Value, Fundamental Value 20-3000% in 1% steps 30-130% in 1% steps 0-60000ms in 1ms steps 0-60000ms in 1ms 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 Time Multiplier Minimum time delay for the inverse char. Definite time delay for definite type char. Reset time delay for the IEC type inverse char.	5-3000% in 1% steps 0.05-999 in 0.01 steps 40-60000ms in 1ms steps 40-60000ms in 1ms steps 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 In = 200mA or 1A Time Multiplier Minimum time delay for the inverse char. Definite time delay for definite type char. Reset time delay for the inverse char.	 5-3000% in 1% steps 5-3000% in 1% steps 0.05-999 in 0.01 steps 40-60000ms in 1ms steps 40-60000ms in 1ms steps 60-60000ms in 1ms steps
Voltage dependent overcurrent protection (51V)	
Operation Restr. Mode Start Current U_lowlimit U_highlimit Ik_limit Time delay	Off, On Restrained, Controlled 20-3000% in 1% steps 20-60% in 1% steps 60-110% in 1% steps 20-60% in 1% steps 0-60000ms in 1ms steps
Definite time overvoltage protection (59)	
Operation	Off, On

Start Voltage Reset Ratio Time Delay	30-130% in 1% steps 1-10% in 1% steps 0-60000ms in 1ms steps
Residual overvoltage protection (59N)	
Operation Start Voltage Time Delay	Off, On 2-60% in 1% steps 0-60000ms in 1ms steps
Third harmonic differential overvoltage protection (59TD/64TN)	
Operation Mode Of Operation Phase Shift State A Phase Shift State B Warning Start Voltage Trip Start Voltage Multiplier State A Multiplier State B Un VT Correction Factor Ut/Utn VT Correction Factor Warning Delay Trip Delay	Off, Un-Ut, Un-Utn Normal, Balancing 1-1024 in 1 steps 1-1024 in 1 steps 10-500 in 1 steps (1 = 0.01%) 10-500 in 1 steps (1 = 0.01%) 0.1-10000 in 0.001 steps 0.1-10000 in 0.001 steps 0.1-10000 in 0.001 steps 0.1-10000 in 0.001 steps 0-60000ms in 1ms steps 0-60000ms in 1ms steps
Current unbalance protection (60)	
Operation Start Signal Only Start Current Diff Time Delay	Off, On False, True 10-90% in 1% steps 100-60000ms in 1ms steps
Voltage transformer supervision (60)	
Operation Min Operate Voltage Min Operate Current Start URes Start IRes Start UNeg Start INeg	Off, Zero sequence, Negative sequence, Special 10-100% in 1% steps 2-100% in 1% steps 5-50% in 1% steps 10-50% in 1% steps 5-50% in 1% steps 10-50% in 1% steps
Third harmonic undervoltage protection function (64/27TN)	
Operation UN3h Start Time Delay	Off, On 2-10% in 1% steps 1-3600s in 1s steps
Rotor earth fault function (64R)	
Operation Half-period length R2 R3 R Warning Start R Trip Start Ue Start Warning Delay	Off, ConnType1, ConnType2, Calibration 10-1000cycle in 1cycle steps 35000-80000ohm in 1ohm steps 35000-80000ohm in 1ohm steps 4000-40000ohm in 1ohm steps 4000-40000ohm in 1ohm steps 50-1300V in 1V steps 1000-64000ms in 1ms steps

Trip Delay Ue Delay	1000-64000ms in 1ms steps 1000-64000ms in 1ms steps
Three-phase directional overcurrent protection (67)	
Direction	NonDir, Forward, Backward
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
Operating Angle	30-80º in 1º steps
Characteristic Angle	40-90º in 1º steps
Start Current	5-3000% in 1% steps
Time Multiplier	0.05-999 in 0.01 steps
Minimum time delay for the inverse char.	30-60000ms in 1ms steps
Definite time delay	30-60000ms in 1ms steps
Reset time	60-60000ms 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
Inrush detection (68)	
Operation	Off, On
2nd Harm Ratio	5-50% in 1% steps
Basic sensitivity of the function	20-100% in 1% steps
Pole slipping protection (78)	
Operation	Off, On
Max. Cycle Number	1-10 cycle in 1 cycle steps
I1 Low Limit	50-200% in 1% steps
R Forward	0.1-150ohm in 0.01ohm steps
X Forward	0.1-150ohm in 0.01ohm steps
R Backward	0.1-150ohm in 0.01ohm steps
X Backward	0.1-150ohm in 0.01ohm steps
Dead Time	1000-60000ms in 1ms steps
Trip Pulse	50-60000ms in 1ms steps
Overfrequency protection (81O) **Undefrequency protection (81U)**	
Operation	Off, On

Start signal only Start frequency Time Delay Voltage limit	False, True 40-70Hz in 0.01Hz steps 0-60000ms in 1ms steps 0.3-1.0 Un
Rate of change of frequency protection (81R)	
Operation Start signal only Start df/dt Time Delay	Off, On False, True -5.00-5.00Hz/s in 0.01Hz/s steps 0-60000ms in 1ms steps
Lockout trip logic (86/94)	
Operation Min pulse duration	Off, On, Lockout 50-60000ms in 1ms steps
Rectricted earth fault protection (87N)	
Operation Directional check Io Primary Match Neutral Match Base Sensitivity Slope Base Sens Bias Limit	Off, On False, True 20-500% in 1% steps 100-1000% in 1% steps 10-50% in 1% steps 50-100% in 1% steps 100-200% in 1% steps
Differential protection (87T)	
Operation Pri-Sec VGroup Pri-Ter VGroup* Zero Seq Elimination TR Primary Comp TR Secondary Comp TR Tertiary Comp 2nd Harm Ratio 5th Harm Ratio Base Sensitivity 1st Slope 1st Slope Bias Limit UnRst Diff Current	Off, On Dy1, Dy5, Dy7, Dy11, Dd0, Dd6, Dz0, Dz2, Dz4, Dz6, Dz8, Dz10, Yy0, Yy6, Yd1, Yd5, Yd7, Yd11, Yz1, Yz5, Yz7, Yz11 Dy1, Dy5, Dy7, Dy11, Dd0, Dd6, Dz0, Dz2, Dz4, Dz6, Dz8, Dz10, Yy0, Yy6, Yd1, Yd5, Yd7, Yd11, Yz1, Yz5, Yz7, Yz11 False, True 20-500% in 1% step 20-500% in 1% step 20-200% in 1% step 5-50% in 1% step 5-50% in 1% step 10-50% in 1% step 10-50% in 1% step 200-2000% in 1% step 800-2500% in 1% step
Disturbance recorder	
Operation Resolution Prefault PostFault Max Recording Time	Off, On 1/1.2 kHz; 2/2.4kHz 100-1000ms in 1ms steps 100-10000ms in 1ms steps 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
RTD Inputs	
Measurement method	2, 3 or 4 wire configuration
Sensor type	Pt100/Ni100, Ni120/Ni120US, Pt250/Ni250, Pt1000/Ni1000, Cu10, Service-Ohm(60 Ω … 1.6 kΩ)
Measurement ranges	-50^{0}C ÷ +150^{0}C
Accuracy	± 0.5 % ± 1 digit
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 Continuous carry Thermal withstand voltage Breaking capacity Making capacity Operating time	24VDC/48VDC/110VDC/220VDC 8A 72VDC (Rated voltage: 24VDC or 48VDC) 150VDC (Rated voltage: 110VDC) 242VDC (Rated voltage: 220VDC) 4A (L/R=40ms) 30A for 0.5s With pre-trip 0.5 ms, without pre-trip typically 10 ms
Generator protection module	
Rated voltage Input voltage range Output voltage range Measurement range	110V/220V 88-264VDC; 80-250VAC 100VDC ± 2% ± 20mA
Auxiliary boxes for rotor earth fault protection	
Maximum input voltage Series resistance on sides Filter capacitor	200V / 300V / 400V/ 500V /600V /1200V 10kΩ /15kΩ /20kΩ /25kΩ /35kΩ /30 kΩ 4x10 μF /2x1 μF
Mechanical Design	
Installation Case Protection class	Flush mounting 42 or 84 HP (height:3U) IP41 from front side, IP2x from rear side IP54 Rated mounting kit
Key & LED	
Device keys Capacitive touch key LEDS Number of configurable LED Device status LED	Capacitive touch keys 4 pcs yellow, 3 mm circular LEDs indicating touch key actions 16 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 100Base-FX Serial Interface	IP56 rated with RJ-45 connector 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 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
Impedance protection with compounded circular characteristic (21)	
Rated current In Rated Voltage Un Current effective range Voltage effective range Impedance effective range In=1A In=5A Zone static accuracy 48Hz-52Hz 49.5Hz-50.5Hz Zone angular accuracy Operate time Minimum operate time Reset time Reset ratio	1/5A, parameter setting 100/200V, parameter setting 20 – 2000% of In, accuracy: ±1% of In 3-110 % of Un, accuracy: ±1% of Un 0.1 – 200 Ohm, accuracy: : ±5% 0.1 – 40 Ohm, accuracy: : ±5% ±7% ±2% ±3º Typically 55 ms, accuracy: ±3 ms <60 ms if nominal < 100 ms if 48-52 Hz 30 – 55 ms 1.1
Overexcitation protection (24)	
U/f pick up accuracy U/f drop off ratio DT and custom char. time delay accuracy IEEE char. time delay accuracy	<1% 0.95 < 1% < 5%
Synchrocheck (25)	
Rated Voltage Un Voltage effective range Frequency Phase angle accuracy Operate time Reset time Reset ratio	100/200V, parameter setting 10-110 % of Un, accuracy: ±1% of Un 47.5 – 52.5 Hz, accuracy: ±10 mHz ±3 ° Setting value, accuracy: ±3 ms <50 ms 0.95 Un
Automatic generator synchronizer (25G)	
Rated Voltage Un Voltage effective range Frequency Phase angle accuracy Operate time accuracy	100/200V, parameter setting 10-110 % of Un, accuracy: ±1% of Un 47.5 – 52.5 Hz, accuracy: ±10 mHz ±3º ±3 ms
Definite time undervoltage protection (27)	
Pick-up starting accuracy Reset time U> → Un U> → 0 Operate time accuracy	< ± 0,5 % 50 ms 40 ms < ± 20 ms

Minimum operate time	50 ms
Directional over-power protection (32)	
P,Q measurement	Effective range: I>5% In, accuracy: <3%
Directional residual wattmetric earth-fault protection (32N)	
Operating accuracy	< ±2 %
Operate time accuracy	±5% or ±15 ms, whichever is greater
Accuracy in minimum time range	±35 ms
Reset ratio	0,95
Reset time accuracy	±35 ms
Transient overreach	<2 %
Pickup time	25 – 30 ms
Angular accuracy	
3Io ≤ 0.1 In	< ±10°
0.1 In < 3Io ≤ 0.4 In	< ±5°
0.4 In < 3Io	< ±2°
Angular reset ratio	
Forward and backward	10°
All other selection	5°
Directional under-power protection (37)	
P,Q measurement	Effective range: I>5% In, accuracy: <3%
GGIORTD temperature measurement (38/49T)	
Relative accuracy	2, 3 or 4 wire configuration
Sensor type	± 0.5% ± 1 digit
	Pt100/Ni100, Ni120/Ni120US, Pt250/Ni250, Pt1000/Ni1000,
Measurement range	Cu10, Service-Ohm (60 Ω … 1.6 kΩ)
	2 Ω … 200 Ω, 10 Ω … 1000 Ω, - 50 °C – +150 °C
Loss of excitation protection (Version 40Q)	
Operating characteristic	Negative reactance circle
Reset ratio	0,95
Accuracy of the characteristic	<2%)
Accuracy of the time delay	±5% or ±15 ms, Whichever is greater
Loss of excitation protection (Version 40Z)	
Rated current In	1/5A, parameter setting
Rated Voltage Un	100/200V, parameter setting
Current effective range	35 – 2000% of In, accuracy: ±1% of In
Voltage effective range	3 - 110 % of Un, accuracy: ±1% of Un
Impedance effective range	
In=1A	0.1 – 200 Ohm, accuracy: : ±5%
In=5A	0.1 – 40 Ohm, accuracy: : ±5%
Zone static accuracy	
48Hz-52Hz	±5%
49.5Hz-50.5Hz	±5%
Zone angular accuracy	±3°
Operate time	Typically 50 ms, accuracy: ±3 ms
Minimum operate time	<60 ms

Reset time Reset ratio	30 – 60 ms 1.1
Negative sequence overcurrent protection (46)	
Operating accuracy Operate time accuracy Reset ratio Reset time Dependent time char. Definite time char. Reset accuracy time Transient overreach Pickup time * Overshot time Dependent time char. Definite time char. Influence of time varying value of the input current (IEC 60255-151) accuracy	<2% (when 20 ≤ G_S ≤ 1000) ±5% or ±15 ms, whichever is greater 0.95 Dependent time char. Approx 60 ms < 2% or ±35 ms, whichever is greater < 2 % < 40 ms 25 ms 45 ms < 4 %
Negative sequence overcurrent protection for generators (46G)	
Operating characteristic Reset ratio Inverse characteristic Definite time Accuracy of the characteristic Operate time accuracy of the inverse characteristic Operate time accuracy of the definite time characteristic	Integrating/Linear 0.9 0.95 < 2 % ±5% ±5% or ±15 ms, whichever is greater
Negative sequence overvoltage protection (47)	
Pick-up starting accuracy Blocking voltage accuracy Reset time U> → Un U> → 0 Operate time accuracy Drop-off ratio accuracy Minimum operate time	< ± 0,5 % < ± 1,5 % 60 ms 50 ms < ± 20 ms ± 0,5 % 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 Reset ratio Operate time at 2*I_S Reset time Transient overreach	Instantaneous, accuracy < 6 % 0.85 <15 ms <40 ms 90%
Using Fourier basic harmonic calculation	

Operating characteristic Reset ratio Operate time at $2*I_S$ Reset time Transient overreach	Instantaneous, accuracy < 2 % 0.85 <25 ms <60 ms 15%
Breaker failure protection (50BF)	
Pick-up starting accuracy Operating time accuracy Retrip time Reset ratio Current reset time	<2 % ±5% or ±15 ms, whichever is greater approx. 15 ms 0.9 16-25ms
Residual instantaneous overcurrent protection (50N/50Ns)	
Using peak value calculation	
Operating characteristic (I>0.1 In) Reset ratio Operate time at $2*I_S$ Reset time * Transient overreach	Instantaneous, accuracy <6% 0.85 < 15 ms < 35 ms 85 %
Using Fourier basic harmonic calculation	
Operating characteristic (I>0.1 In) Reset ratio Operate time at $2*I_S$ Reset time * Transient overreach	Instantaneous, accuracy <6% 0.85 < 25 ms < 60 ms 15 %
Interturn fault protection (50SP)	
Characteristic Drop-off ratio Time delay accuracy Drop-off time	Definite time delay, accuracy: <2% 0.95 ±5% or ±15 ms, whichever is greater 16 – 31 ms
Generator inadvertent energizing protection (50V/27AE)	
Operating characteristic Drop-off ratio of overcurrent Drop-off ratio of undervoltage Accuracy of voltage measurement Accuracy of peak current measurement Accuracy of current fundamental harmonic component measurement Accuracy of definite time delay	Undervoltage/overcurrent 0.85 1.05 2% 6% 2% ±5% or ±15 ms, whichever is greater
Three-phase time overcurrent protection (51)	
Operating accuracy Operate time accuracy Reset ratio Reset time Dependent time char. Definite time char. Reset time accuracy	<2% (when $20 \le G_S \le 1000$) ±5% or ±15 ms, whichever is greater 0.95 Dependent time char. Approx 60 ms < 2% or ±35 ms, whichever is greater

Transient overreach Pickup time * Overshot time Dependent time char. Definite time char. Influence of time varying value of the input current (IEC 60255-151)	< 2 % < 40 ms 30 ms 50 ms < 4 %
Residual time overcurrent protection (51N/51Ns)	
Operating accuracy Operate time accuracy Reset ratio Reset time Dependent time char. Definite time char. Reset accuracy time Transient overreach Pickup time * Overshot time Dependent time char. Definite time char. Influence of time varying value of the input current (IEC 60255-151) accuracy	<3% (when 20 ≤ G_S ≤ 1000) ±5% or ±15 ms, whichever is greater 0.95 Dependent time char. Approx 60 ms < 2% or ±35 ms, whichever is greater < 2 % ≤ 40 ms 30 ms 50 ms < 4 %
Voltage dependent overcurrent protection (51V)	
Operating accuracy Operate time accuracy Reset ratio Reset time Dependent time char. Definite time char. Reset time accuracy Transient overreach Pickup time * Overshot time Dependent time char. Definite time char. Influence of time varying value of the input current (IEC 60255-151)	<2% (when 20 ≤ G_S ≤ 1000) ±5% or ±15 ms, whichever is greater 0.95 Dependent time char. Approx 60 ms < 2% or ±35 ms, whichever is greater < 2 % < 40 ms 30 ms 50 ms < 4 %
Definite time overvoltage protection (59)	
Pick-up starting accuracy Reset time U> → Un U> → 0 Operate time accuracy Minimum operate time	< ± 0,5 % 60 ms 50 ms < ± 20 ms 50 ms
Residual overvoltage protection (59N)	
Pick-up starting accuracy 2 – 8 % 8 – 60 % Reset time	 < ± 2 % < ± 1.5 %

U> → Un	60 ms
U> → 0	50 ms
Operate time	50 ms
Operate time accurracy	< ± 20 ms
Third harmonic differential overvoltage protection (59TD/64TN)	
Drop-off ratio	0.9
Characteristic accuracy	<2%
Time delay accuracy	±5% or ±15 ms, whichever is greater
Current unbalance protection (60)	
Pick-up starting accuracy at In	Pick-up starting accuracy at In
Reset ratio	0.95
Operate time	70 ms
Voltage transformer supervision (60)	
Pick-up voltage accuracy	<1%
Operate time	<20 ms
Reset ratio	0.95
Third harmonic undervoltage protection (64/27TN)	
Pick-up starting accuracy	< ±0.5 %
Blocking voltage	< ±1.5 %
Reset time	50ms
Operate time accuracy	< ± 20ms
Minimum operate time	50ms
Rotor earth fault function (64R)	
Resistance range	0 – 1000000 Ω, accuracy: ±10% ± (R2+R3)/400 Ω
Setting resistance range	4000 – 40000 Ω, accuracy: ±5% ± (R2+R3)/400 Ω
k (fault location relative to the positive brush)	0 – 100 %, accuracy: ±5%
Excitation voltage	0 – 1300 V, accuracy: ±5%
Setting excitation voltage range	50 – 1300 V, accuracy: ±5%
Operating time	(2-3) * half measuring period, accuracy: ±10 ms
Reset time	(2-3) * half measuring period, accuracy: ±10 ms
Reset ratio for R<	1.1
Reset ratio for Ue>	0.9
Timer (started at fault detection)	±5 ms
Three-phase directional overcurrent protection (67)	
Operating accuracy	< 2 %
Operating accuracy	If Time multiplier is >0.1: ±5% or ±15 ms, whichever is greater
Accuracy in minimum time range	±35 ms
Reset ratio	0.95
Reset time	Approx 100 ms
Transient overreach	2 %
Pickup time	<100 ms
Memory storage time span	
50Hz	70 ms
60Hz	60 ms
Angular accuracy	<3º
Residual directional overcurrent protection (67N/67Ns)	

Operating accuracy Operating accuracy Accuracy in minimum time range Reset ratio Reset time Reset time accuracy Transient overreach Pickup time Angular accuracy Io ≤ 0.1 In Io ≤ 0.1 In Io ≤ 0.1 In Angular reset ratio Forward and backward All other selection	< ±2 % ±5% or ±15 ms, whichever is greater 0.95 ±35 ms 0.95 Approx 50 ms ±35 ms < 2 % ±35 ms <3º <±10º <±5º <±2º 10º 5º
Inrush detection (68)	
Range Current accuracy	20 – 2000% of In ±1% of In
Pole slipping protection (78)	
Rated current In Rated Voltage Un Current effective range Voltage effective range Impedance effective range In=1A In=5A Zone static accuracy 48Hz-52Hz 49.5Hz-50.5Hz Operate time Minimum operate time Reset time	1/5A, parameter setting 100/200V, parameter setting 20 – 2000% of In, accuracy: ±1% of In 2-110 % of Un, accuracy: ±1% of Un 0.1 – 200 Ohm, accuracy: : ±5% 0.1 – 40 Ohm, accuracy: : ±5% ±5% ±5% Typically 25 ms, accuracy: ±3 ms <20 ms 16 – 25 ms
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
Generator differential protection (87G)	
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
Transformer differential protection (87T)	

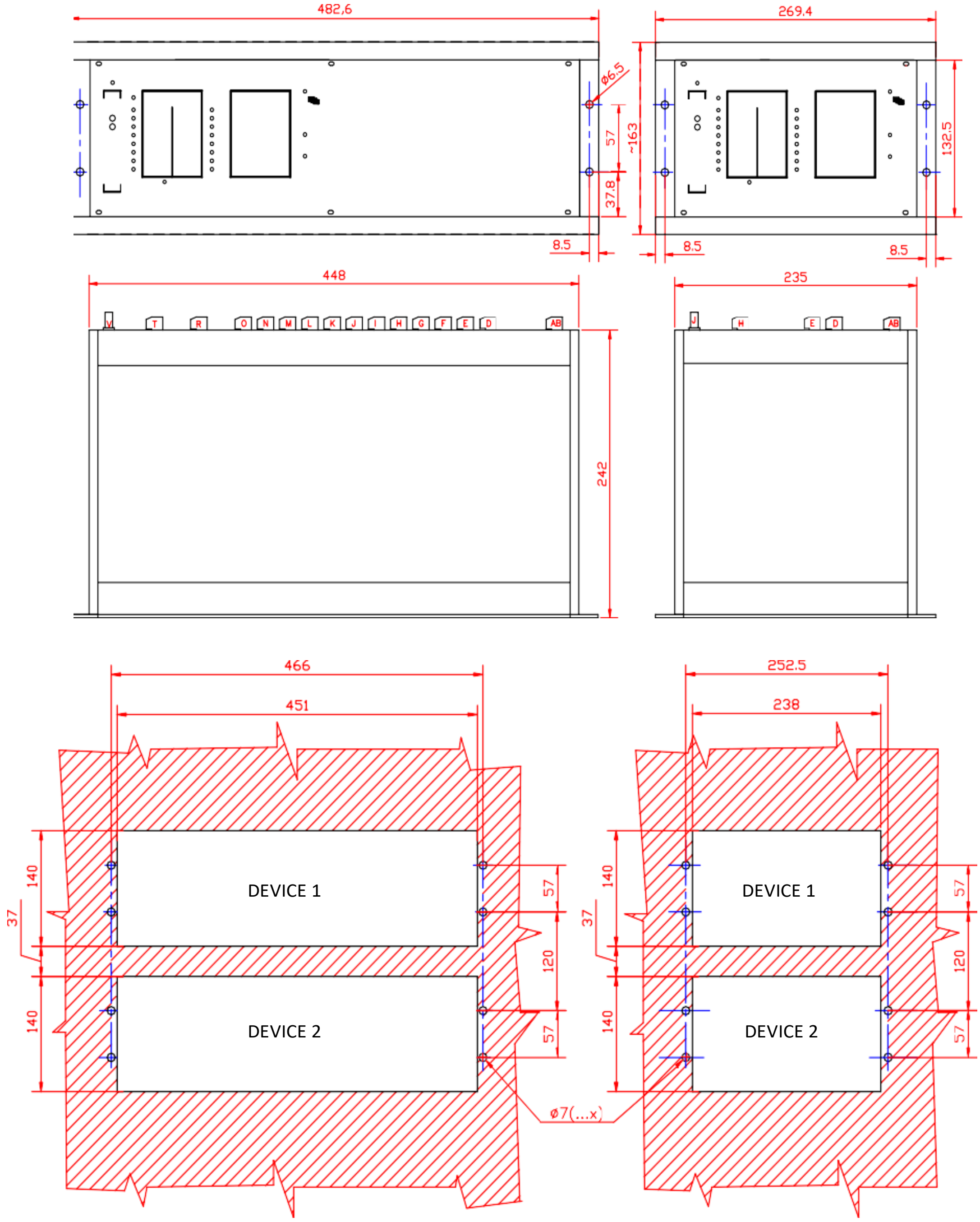
Operating characteristic Reset ratio Characteristic accuracy Operate time, unrestrained Reset time, unrestrained Operate time, restrained Reset time, restrained	2 breakpoints 0.95 <2% Typically 20 ms Typically 25 ms Typically 30 ms Typically 25 ms
MEASUREMENT FUNCTION	
Current	
With CT+/5151; CT+/5153 (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

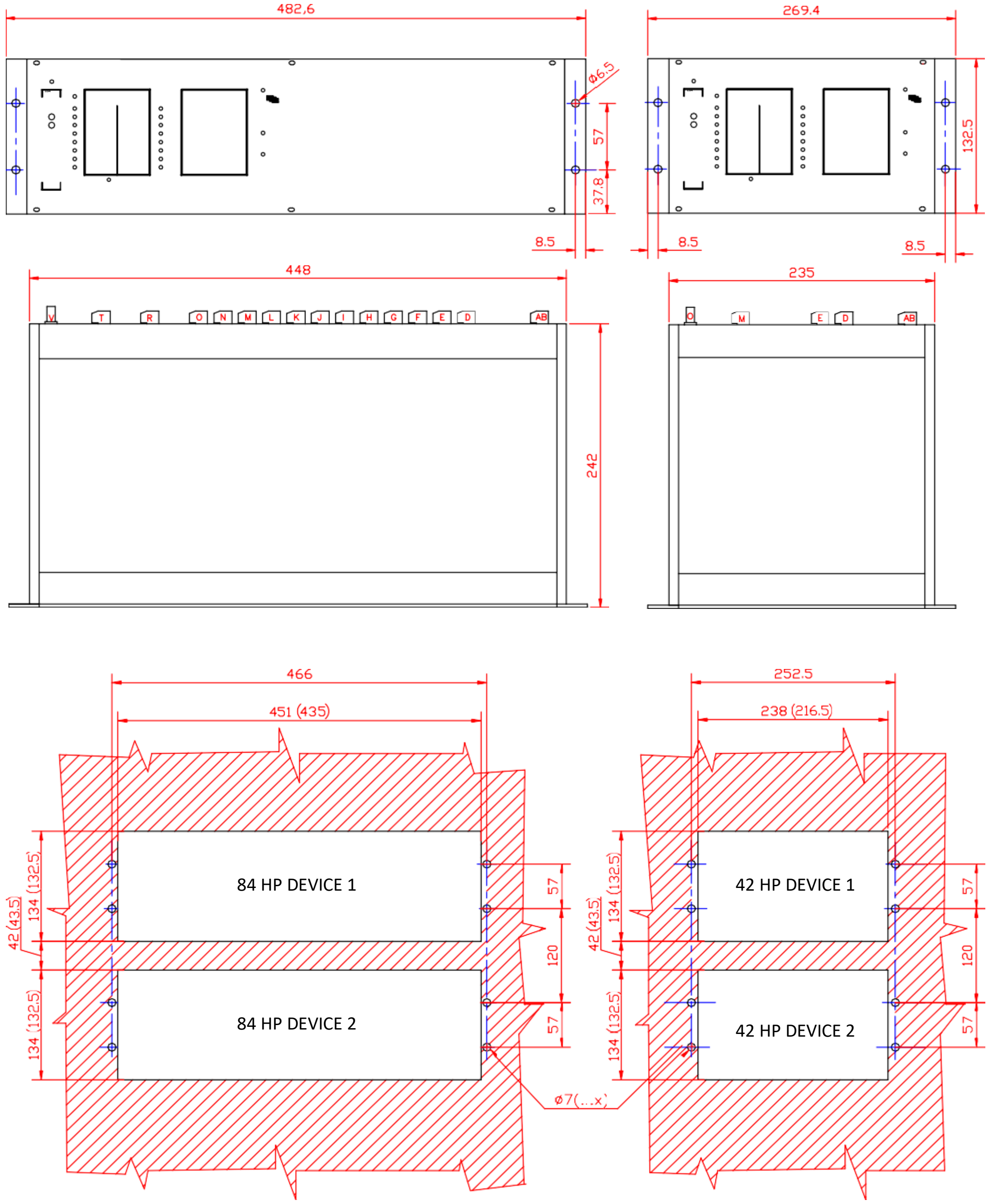
- **Flush mounting**



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**

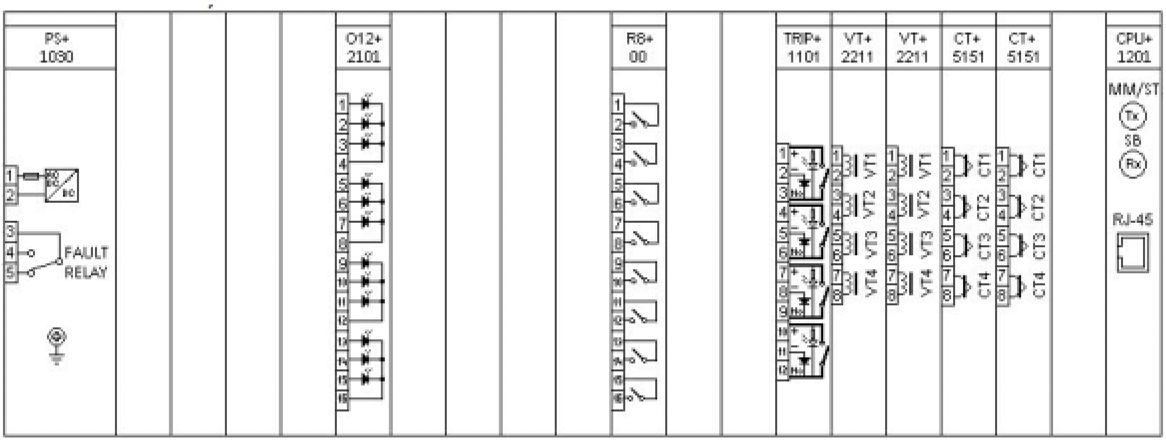
The standard number of inputs and outputs of each variant are listed in the table below.

Hardware configuration	E9-GEN	E10-GEN	E11-GEN	E12-GEN
Current inputs (4th channel can be sensitive)	8	8	8	12
Voltage inputs	8	8	8	8
Binary inputs	12	12	12	12
Binary outputs	8	8	8	8
Fast trip outputs	4	4	4	4
Temperature monitoring (RTDs)	Op.	Op.	Op.	Op.
Rotor earth fault protection	Op.	Op.	Op.	Op.

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

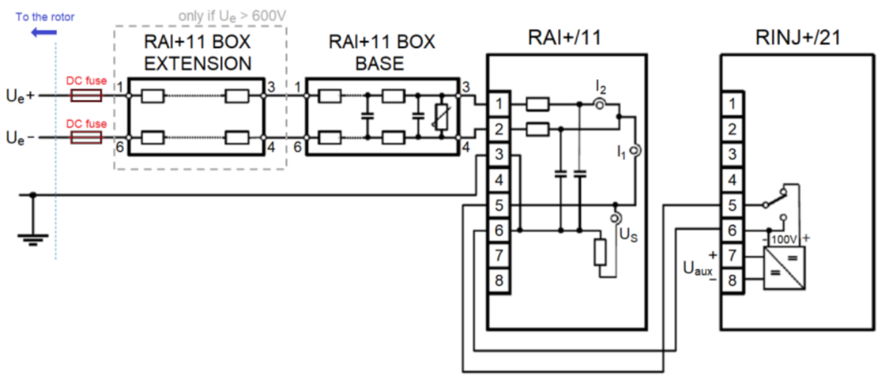
Hardware configuration	E9-GEN	E10-GEN	E11-GEN	E12-GEN
Binary inputs (Max)	112	112	112	112
Binary outputs (Max)	60	60	60	60
Fast trip outputs (Max)	12	12	12	12

- **Module arrangement**

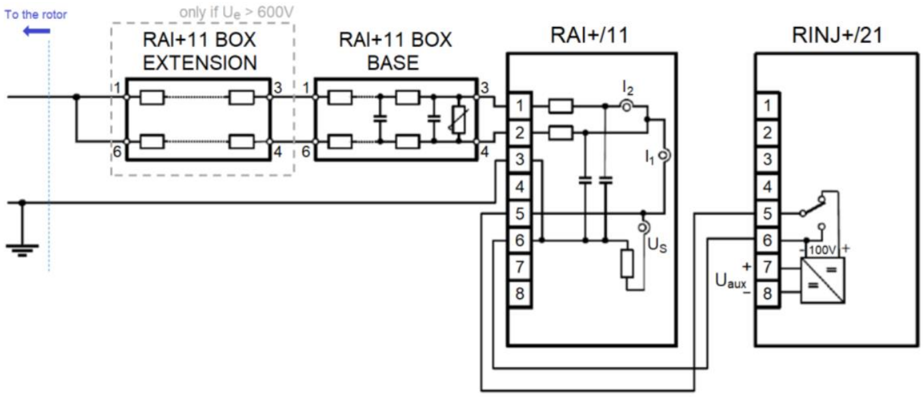


Basic module arrangement of the DTRV E9-Gen configuration (84TE, rear view)

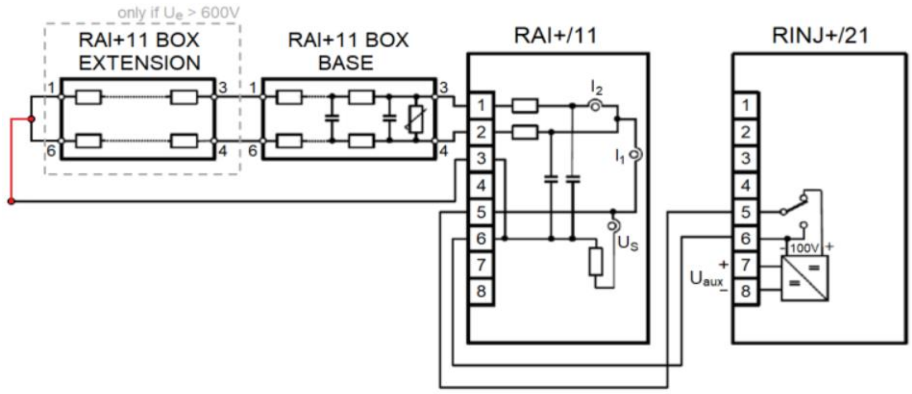
- **Wiring of the rotor earth fault protection modules for ungrounded (isolated) rotors**



Wiring for ConnType1 mode (connecting to two points)

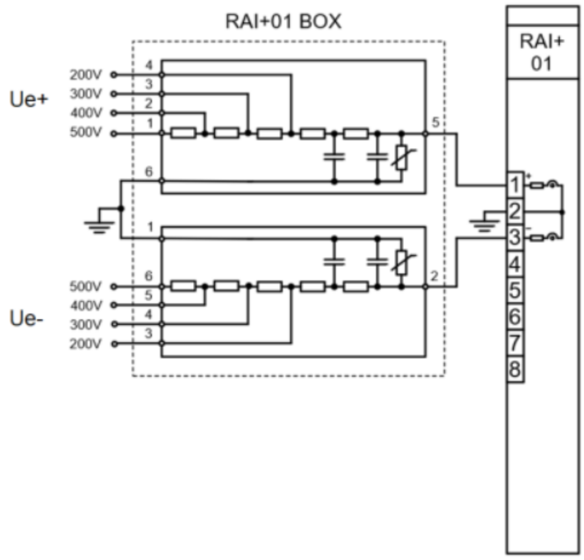


Wiring for ConnType2 (single point connection) mode



Wiring for Calibration mode

- **Wiring of the rotor earth fault protection modules for middle-grounded rotors**



CONTACT

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

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