NEO 3000
SYSTEM

FPC 400

USER MANUAL

Dec 2018

Feeder F1, F3, F4
Busbar B3
Motor M4
Transformer T4
Generator G4
Differential D7

Preface

Copyright

Purpose of this manual

The manual describes the functionality, as well as operation, installation and commissioning instructions for the FPC 400 types: F3, F4, B3, M4, T4 and G4.

Target audience

Protection engineers, mechatronic engineers, commissioning engineers, personnel concerned with setting, monitoring and service of protection equipment, industrial automatic and control facilities *and personnel of electrical facilities and power plants.*

Applicability

This manual is valid for all FPC 400 type multifunctional numerical relays.

Conformity

This product complies with the Low Voltage Directive 2014/35/EU and EMC Directive 2014/30/EU. This conformity has been proved by tests according to product standards IEC 60255-26 (for EMC directive) and IEC 60255-27 (for Low Voltage Directive).

Liability statement

Specialists and responsible persons of Iskra d.d. has checked the contents of this manual to ensure the description of both hardware and software are as accurate as possible. However, deviations from the description cannot be completely ruled out, so that no liability can be accepted for any errors or failures contained in the given manual. The content of this manual is reviewed regularly. Corrections will be included in following editions. Any suggested improvements are highly appreciated. We reserve the right to make technical improvements without notice.

Contact

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Safety symbols and messages

The warnings and notes contained in this manual serve for your own safety as well as safety of people and property around you. Please observe them!

The following indicators and standard definitions are used:

DANGER

Indicates an imminently hazardous situation which, if not avoided, will result in death, serious injury or property damage.

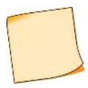
CAUTION

Indicates a potentially hazardous situation which, if not avoided, could result in minor or moderate injury of property damage.

WARNING

Indicates a potentially hazardous situation which, if not avoided, could result in death, serious injury or property damage.

NOTE



Indicates information about the device or respective part of instruction manual which is essential to highlight.

Explanation of device safety symbols

Depending on the device layout, the following labels and symbols can be used on device itself or in the corresponding technical documentation:

WARNING!
Risk of electrical shock!

CAUTION!
Refer to product technical documentation!

Protective and functional ground terminal.

Waste Electrical and Electronic Equipment (WEEE) Directive 2002/96/EC; the affixed product label indicates that you must not discard this electrical / electronic product in a domestic household waste.

Warning

Only qualified personnel can work on this device. Certain parts of the device inevitably have dangerous voltage. Thorough familiarity with all warnings and safety notices of this manual along with applicable safety regulations is required. Failure to observe these precautions can result in fatality, personal injury or extensive material damage. The successful and safe operation of this device is dependent on proper handling, installation, operation and maintenance by qualified personnel.

QUALIFIED PERSONNEL

For the purpose of this manual and product, a qualified person is the one who is familiar with the installation, construction and operation of the equipment and hazards involved. Following qualifications are needed:

- Knowledge to energize, de-energize, clear, ground and tag circuits and equipment in accordance with established safety practices.
- Knowledge of proper care and use of protective equipment in accordance with established safety practices.
- Proficiency in rendering first aid.

NOTE

This is a class A product. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

Content

1 Introduction

The chapter introduces FPC 400 device. Provided information can help you to pick device type which covers specific needs of your project.

1.1 Presentation

FPC 400 is a family of current and voltage numerical protection relays with easy to use interface meant for variety of solutions in industry and power distribution.

Its robust design enables it to be placed in demanding industrial environments.

Setting can be done completely through user friendly Human Machine Interface (HMI) unit. Visual experience is enhanced through PC based interface software MiQen featuring specially designed menus where electrical attributes of power system are graphically and numerically displayed in real time.

Transferring settings between different devices is easily done thanks to front panel USB port. Same settings are transferred from one device to another using USB stick which can also be used to save fault recordings, counters and software updates.

FPC 400 is a member of NEO3000 Substation system and can be integrated to any other new or existing substation or automation protection and control system.

Figure 1.1 FPC 400 protection relay.

Main features are:

- Robust design for industrial usage
- Fast and simple commissioning
- Fault and event recording
- Intuitive user interface
- Multiple communication capabilities
- Numerical and graphical MiQen software tool
- Easy data transfer using USB stick
- Low power consumption
- User defined keys (on medium housing)
- Local remote key (on medium housing)

1.2 Selection table

		F1	F3	F4	B3	M4	T4	G4	D7
Current protections									
Overcurrent DT/IDMT with Inrush restraint and Cold Load Pick-up	50/51	4	4	4		4	4	4	4
Directional overcurrent	67	✓	✓	✓		✓	✓	✓	✓
Earth fault overcurrent DT/IDMT with Inrush restraint and Cold Load Pick-up	50/51|N/G	4	4	4		4	4	4	4
Earth fault directional overcurrent, sensitive	67N/G/Ns	✓	✓	✓		✓	✓	✓	✓
Earth fault directional watt-metric/ VAr-metric	32NQ/32NP		✓	✓		✓	✓	✓	✓
Negative sequence/ unbalance overcurrent	46	1	2	2		2	2	2	2
Phase undercurrent	37		1	1		1			
Differential relay	87								2
Restricted earth-fault	64REF						2	2	2
Voltage protection									
Phase-to-phase under voltage	27	2	2	2	2	2	2	2	
Remanent undervoltage	27R					1		1	
Positive sequence undervoltage	27D			2	2	2	2	2	
Negative sequence overvoltage	47		1	1	1	1	1	1	
Phase-to-phase overvoltage	59		2	2	2	2	2	2	
Neutral voltage displacement/ Residual overvoltage	59N/G		2	2	2	2	2	2	2
Overfrequency	81H		2	2	2	2	2	2	
Underfrequency	81L		2	2	2	2	2	2	
Rate of change of frequency (df/ dt)	81R			1	1	1	1	1	
Power and machine protection									
3 phase thermal overload (feeders & cables)	49F		1	1			1		1
3 phase thermal overload (motors, generator)	49M/G/T					1	1	1	1
Overpower active	32P			1		2	1	2	
Underpower active	37P			1		2		2	
Overpower reactive	32Q					1		1	
Temperature monitoring (up to 8 sensors)*	38/49T					✓	✓	✓	✓
Locked rotor, excessive starting time	48/51LR/14					✓			
Starts per hour	66					✓			
Thermostat	26					2	2	2	2
Buchholz switch	63						2		
External trip			2	2	2	2	2	2	2
Automation and diagnostic									
Circuit breaker control and monitoring	94/69		✓	✓	✓	✓	✓	✓	✓
Circuit breaker failure	50BF		✓	✓	✓	✓	✓	✓	✓
Trip circuit supervision (TCS)	74		✓	✓	✓	✓	✓	✓	✓
Auto-reclosing	79		✓	✓					
Synchro Check	25			✓	✓	✓	✓	✓	
Lockout Relay	86/94		✓	✓	✓	✓	✓	✓	✓
Machine control, running hours						✓		✓	✓
Programmable logic			✓	✓	✓	✓	✓	✓	✓
Metering									
Phase current, RMS, THD, Harmonics, Residual c. $3I_0$		✓		✓	✓	✓	✓	✓	✓
Earth current sensitive		✓		✓	✓	✓	✓	✓	✓
Ph. & PPV voltages, RMS, THD, Harmonics		✓	✓	✓	✓	✓	✓	✓	
Frequency		✓	✓	✓	✓	✓	✓	✓	✓
Power		✓		✓	✓	✓	✓	✓	

Communication protocols	**Connector**

		F1	F3	F4	B3	M4	T4	G4	D7
IEC 61850 MMS Ethernet	Ethernet	Optional							
IEC 60870-5-101	Serial	Optional							
IEC 60870-5-103	Serial	✓	✓	✓	✓	✓	✓	✓	✓
IEC 60870-5-104	Ethernet	Optional							
DNP3	Eth., Serial	Optional							
Modbus RTU	Serial	✓	✓	✓	✓	✓	✓	✓	✓
Modbus TCP/IP	Ethernet	Optional							
mA Analog outputs	mA, V	Optional (3)							
External modules									
EX 408 (8x PT100, 2 or3 wires, powered from FPC)		Optional							

*Table 1: Selection table Opt. Optional, ✓ included, *Optional external temperature module EX 408.*

1.3 Device description

Design of FPC 400 is modular. Base unit consists of housing, human machine interface (HMI), analog measurement card (AMC) and six digital outputs (DO) with power supply (PS). Basic AMC provides current and voltage measurements. Optional cards extends the input/output and communication capabilities. Using a medium housing can further extent the number of additional digital outputs and inputs. Extension port is located on communication card.

Base unit with maximum configuration includes:

- Front panel with HMI and USB interface
- rear panel with 10 digital inputs
- 8 digital outputs
- 2 serial communication ports + extension port
- 3 analog outputs
- 8 analog inputs

Large unit with maximum configuration includes:

- Front panel with HMI and USB interface
- rear panel with 30 digital inputs
- 12 digital outputs
- 2 serial communication ports + extension port + Ethernet port
- 3 analog outputs
- 8 analog inputs

1.3.1 Connection configuration

Two connection configurations exist based on device type.

1.3.1.1 F3 Basic configuration

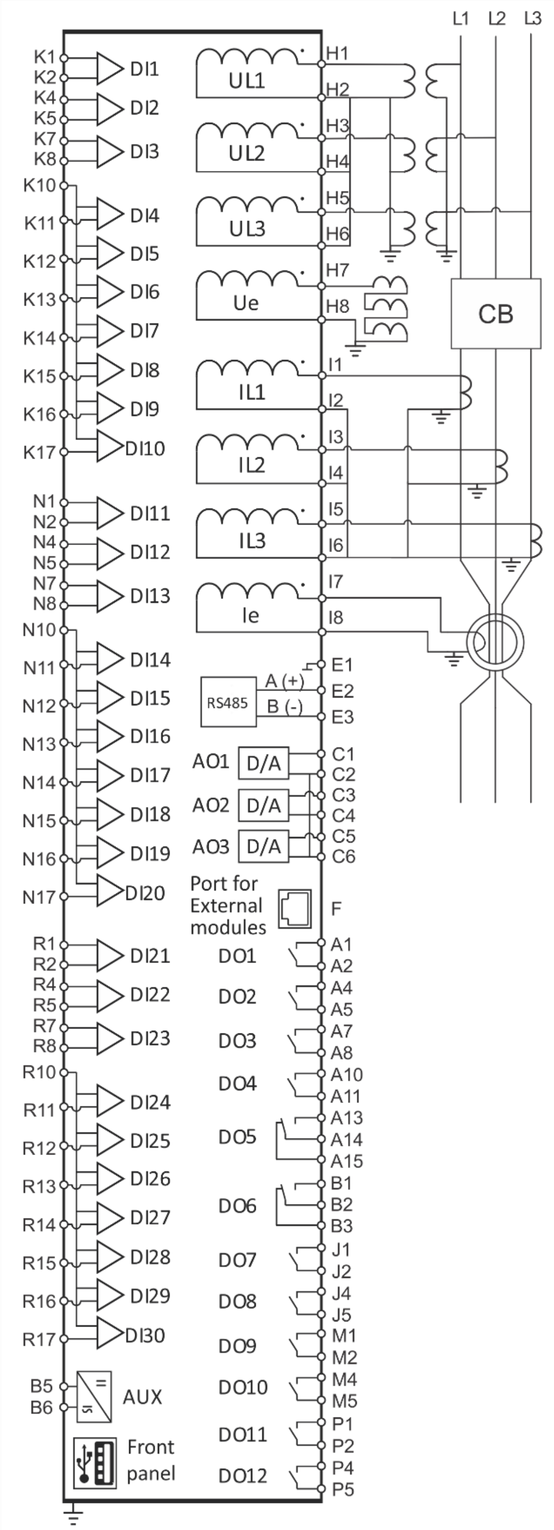


Figure 1.2 Basic feeder connection configuration.

1.3.1.2 B3 synchro check configuration

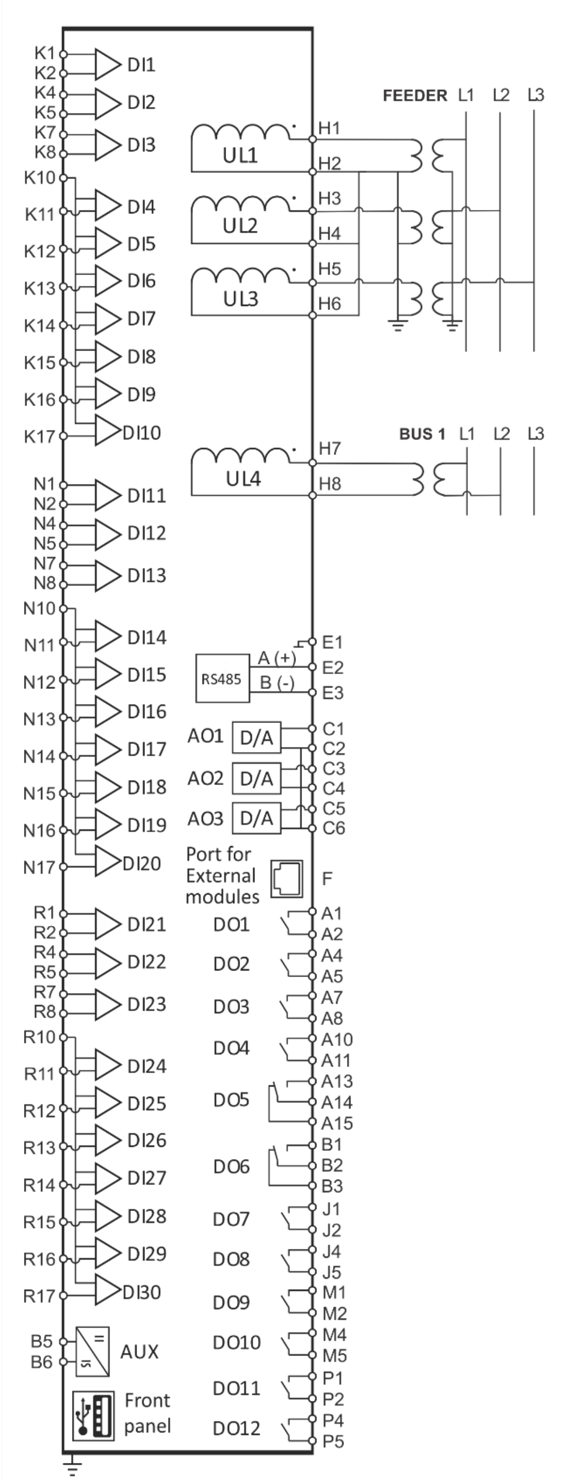


Figure 1.3 Basic two system synchro check [2.6.4] connection configuration.

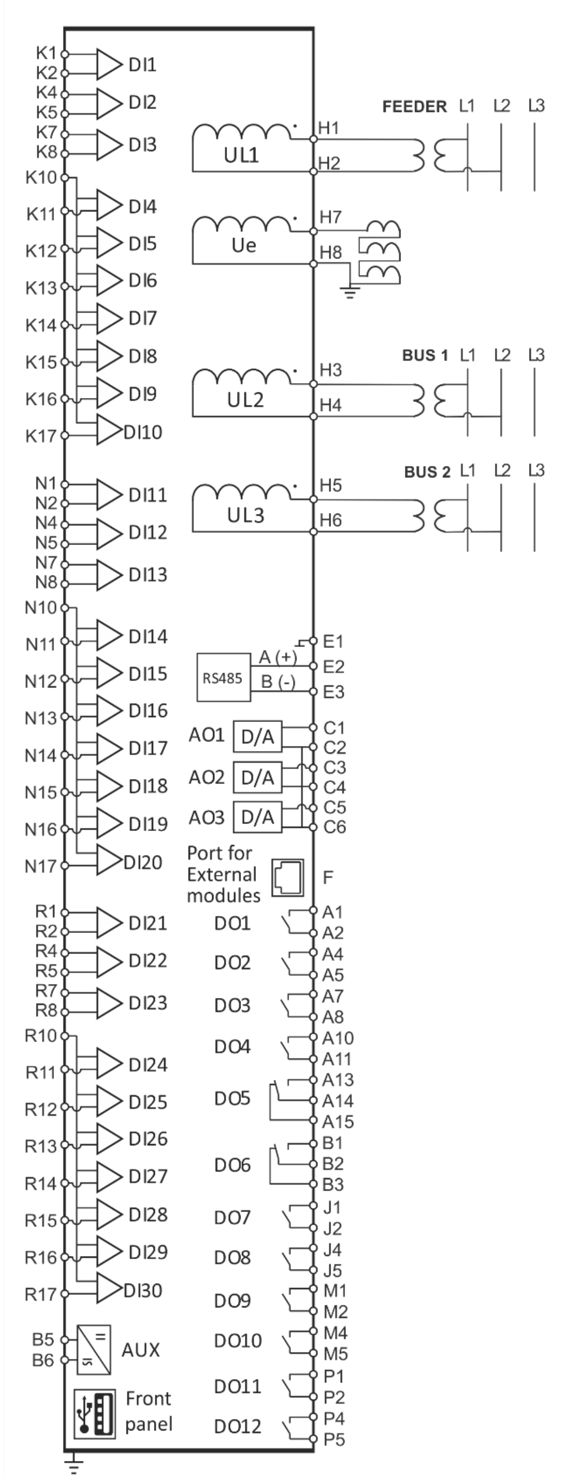


Figure 1.4 Basic three system synchro check [2.6.4] connection configuration.

1.3.1.3 M4 Motor configuration

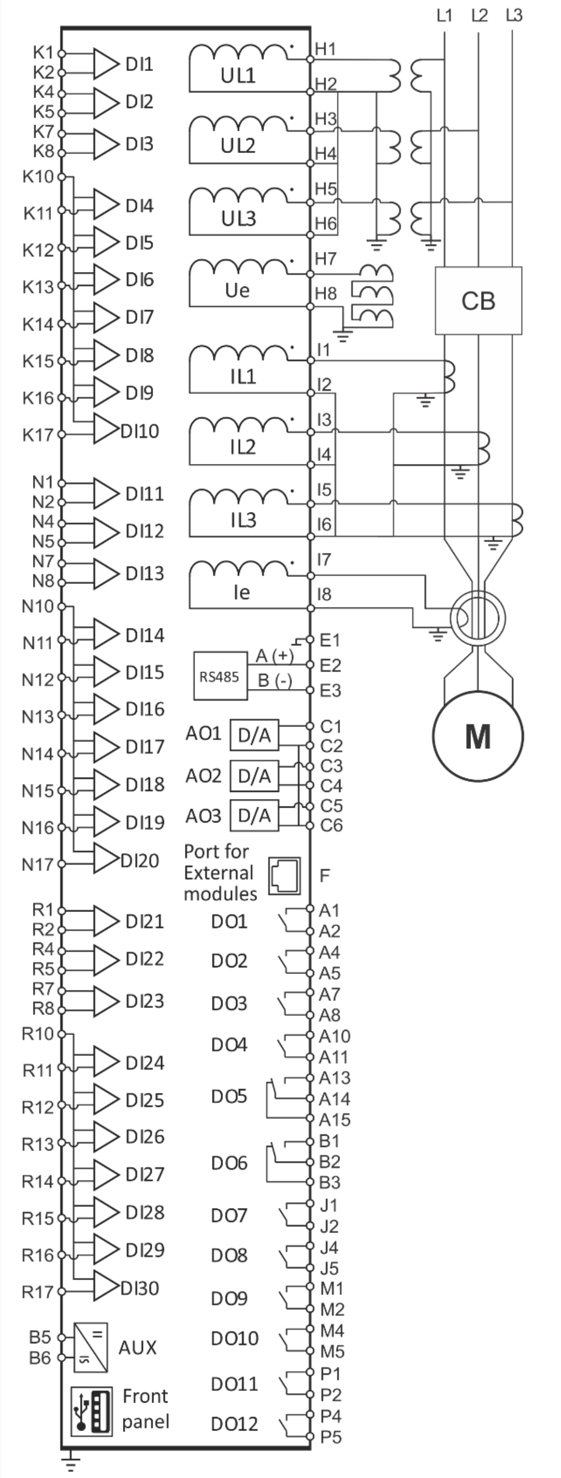


Figure 1.5 Basic motor connection configuration.

1.3.1.4 T4 transformer configuration

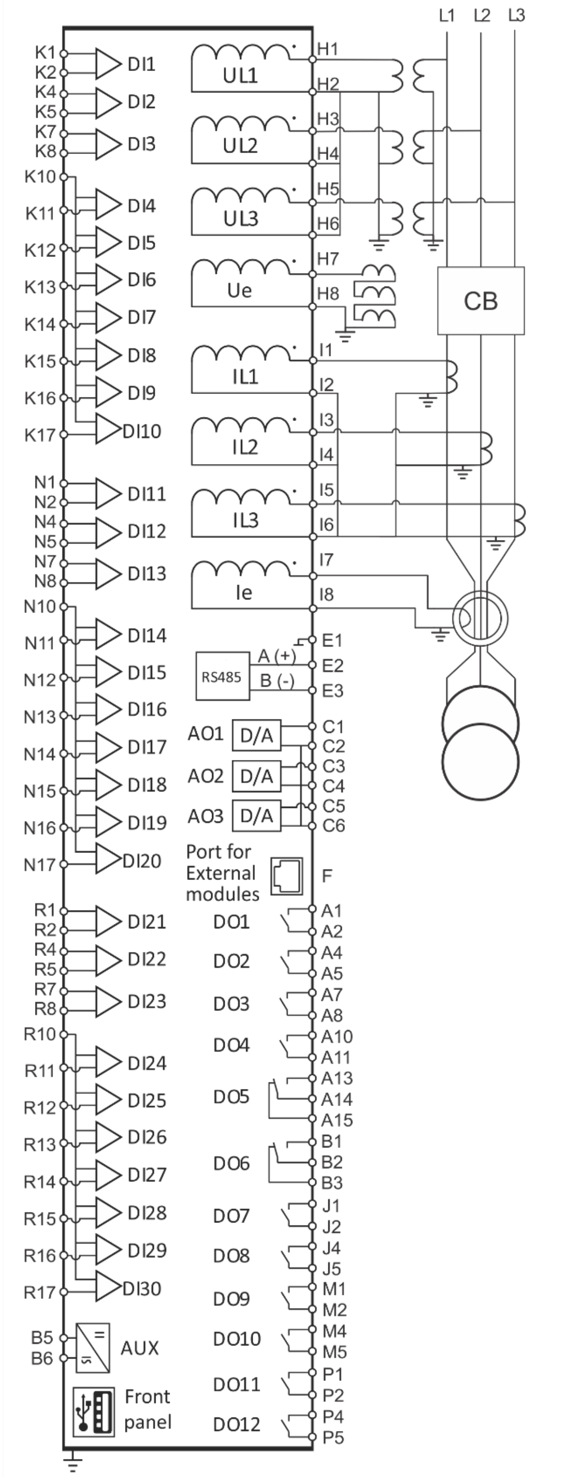


Figure 1.6 Basic transformer protection connection configuration.

2 Functionality

This chapter describes various functions of the FPC 400 device. It explains options of each function in maximum configuration and provides information on how to determine the setting values and, if required, corresponding formulas.

The following information also allows you to specify which of the available functions to use.

2.1 Protections in general

Within this chapter the general theory of protection functions is described. For clear understanding several time characteristics for different scenarios are presented.

2.1.1 Default values

Default values are presented as **bold**.

Example:

Parameter	Range
Pickup delay	0 … **5** … 1000 ms
Minimum value of pickup delay is 0 ms, maximum value is 1000 ms. Default value is set to **5** ms.	

Table 2 Example of default parameter setting.

2.1.2 Protection operation range

Fault is detected when monitored value exceeds the chosen threshold (**pickup value**). At that point the protection enters into protection operation range or fault area. To prevent unwanted switching a hysteresis characteristic is introduced. **Drop-out value** is set relative to **pickup value**.

When the monitored value enters the protection operating range the protections picks up. On the other hand when the value falls below the operating range the protection drops or resets.

Protection operation range is shown on Figure 2.1.

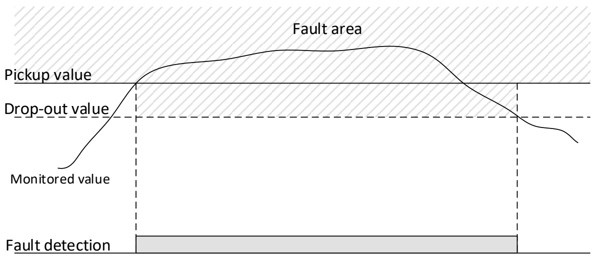


Figure 2.1 Protection operation range - fault area.

Example: Nominal current of protected element I_{n_obj} is set to 300 A, pickup value is set to 1,1 I_{n_obj} and Drop-out is 0,95 I_p. The protection will pick up when current exceeds 330 A. It will drop out when the current drops below 313,5 A.

Operational scenario is illustrated on Figure 2.2. **Drop-out delay** prevents the timer of protection function to reset in case the fault falls below the **pickup value** for a short period of time. It is usually used when very long time characteristics are used. In case the protection trips, drop out delay is not accounted for and other means of delaying trip signal are used.

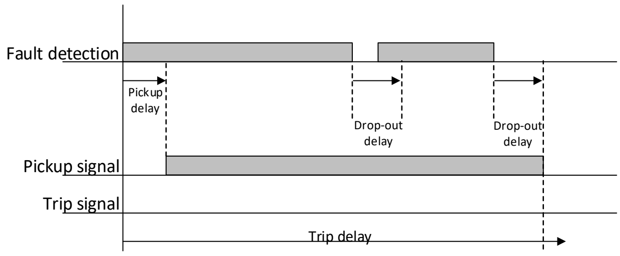


Figure 2.2: Pickup signal and Trip signal when fault duration is shorter than trip delay.

2.1.2.1 Pickup logic

The pickup signal indicates that monitored value exceeded the set value and indicates that a fault occurred (Figure 2.2). The **pickup delay** is intended for fault signalling stabilization to prevent the short-lived disturbances in the measuring part of the system from being reported as faults (Figure 2.4).

The pickup is set (Figure 2.3):

- When a fault is detected and
- Pickup delay confirmation time runs out and
- There is no blocking

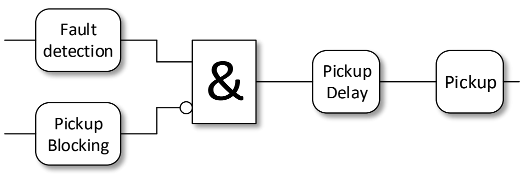


Figure 2.3 Pickup set logic.

Pickup drops when:

- Fault is not present anymore, the **drop-out delay** runs out and the Trip signal has not set yet or
- fault is not present anymore and Trip signal is already set or
- a blocking occurs.

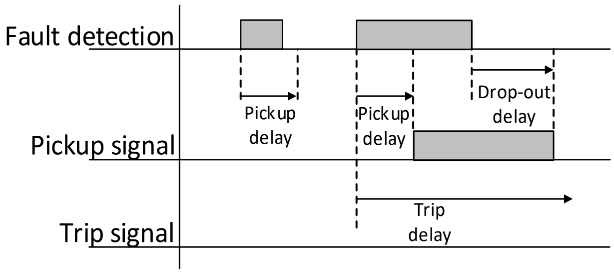


Figure 2.4 Fault confirmation.

2.1.2.2 Trip logic

The Trip signal is intended for opening of circuit breaker, which eliminates faulty element from power system. Majority of faults have transient character and disappear spontaneously. The duration of such faults is relatively short. In order to avoid unnecessary opening of circuit breaker the Trip signal can be delayed. Among others the delaying of Trip signal may be used to ensure selectivity along the power system network. The delay is set with Trip delay parameter. In case the protection is blocked the Trip signal will not set.

The Trip is set (Figure 2.5):

- When a fault is detected and
- when the pickup signal is stated and
- trip delay time runs out and
- no blocking is present.

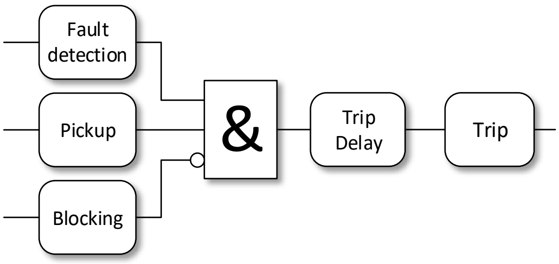


Figure 2.5 Trip set logic.

Trip signal drops:

- when the pickup drops or Blocking appears

When the protection trips there are some particular delays on detection and trip execution levels. Several milliseconds can pass during transfer of the signal to external output relay and forward to the circuit breaker switch of the circuit. The compensation of lost time is solved with default value.

2.1.2.3 Blocking

Function is blocked when any pickup Block input is set. It can be set through digital input port or it can be set internally in combination with different functions. When the protection is blocked the pickup signal drops and pickup blocked signal is stated. Consequently after the pickup signal drops the Trip delay timer resets. After the blocking is reset and if the fault is still present the protection function starts again. Protection operation with blocking signal turned on for a certain amount of time is shown on Figure 2.6.

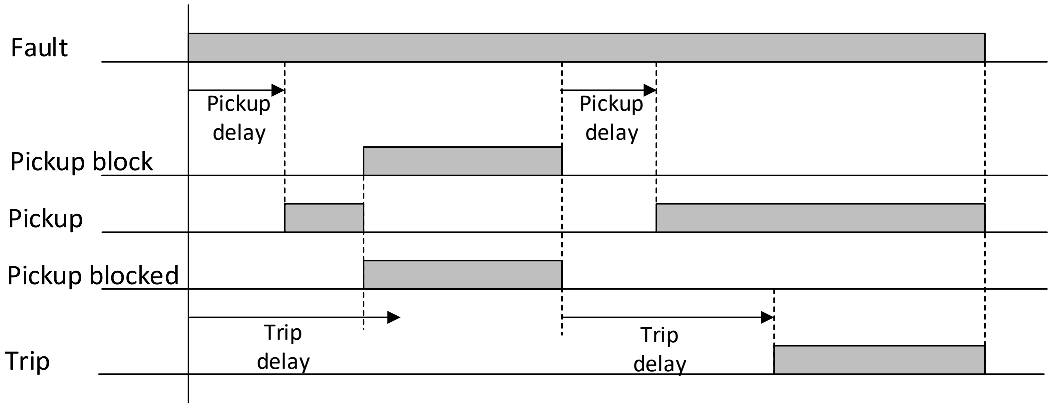


Figure 2.6 Protection operation with blocking signal turned on for a certain duration.

2.1.3 Inverse time characteristics

The main purpose of inverse time characteristics (IDMT – Inverse Definite Minimum Time) is to enable shorter time of protection trip when the fault current amplitude is greater. At a set fault value the protection must trip in time that can be read out from a characteristic. The operation time depends on the measured current value in accordance with standards IEC 60255-3 and IEEE C-37112. In rare cases are needed also user defined curves, determined by the user himself, like own standard curves.

The available area of inverse time characteristic is defined in a range between 1,1 I_p and 20 I_p, where I_p stands for **pickup value**. Amplitudes above 20 I_p have an equal trip delay as the amplitude at 20 I_p. Amplitudes from 1,1 I_p and lower have an equal trip delay as the amplitude at 1,1 I_p.

The Minimum operate time setting defines the minimum operating time for the IDMT curve, that is, the operation time is always at least the Minimum operate time setting, determined with parameter **Trip delay.** The calculation for the operation starts after **Pickup value** is reached.

The type of time characteristic can be chosen with the **mode** parameter. It is necessary to set the **Pickup value** and **IDMT coefficient** parameters. Values are used with all types of time characteristics. The IDMT coefficient factor defines the time delay level. Lower values indicate faster operation at equal fault values.

The fault current amplitude is not always constant and can change during fault duration. For his reason the algorithm dynamically integrates parts of time during the fault according to particular characteristic and when the sum reaches the switch off limit the protection trips.

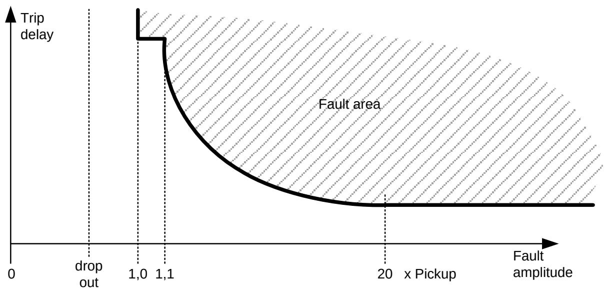


Figure 2.7 Time inverse characteristic.

Name of curve
IEC Normal inverse
IEC Very inverse
IEC Extremely inverse
IEC Long time inverse
IEEE Moderately inverse
IEEE Very inverse
IEEE Extremely inverse
RI curve
User defined curve 1 … 4

Table 3 Time inverse curve types.

2.1.3.1 Standard curves:

2.1.3.1.1 IEC characteristics

$$T = \frac{k \cdot \beta}{\left(\frac{I}{I_p}\right)^{\alpha} - 1}$$

Equation 1 Time to trip for IEC inverse characteristics.

Name of characteristic	α	β
Normal inverse	0,02	0,14
Very inverse	1	13.5
Extremely inverse	2	80
Long time inverse	1	120

Table 4: Coefficients of IEC characteristics.

2.1.3.1.2 RI curve

The RI-type simulates the behaviour of electromechanical relays.

$$T = \frac{k}{0{,}339 - 0{,}236 \cdot \left(\frac{I}{I_p}\right)^{-1}}$$

Equation 2 Time to trip for RI inverse characteristics.

2.1.3.1.3 IEEE characteristics

$$T = k \cdot \left[\frac{K}{\left(\frac{I}{I_p}\right)^{\alpha} - 1} + \beta \right]$$

Equation 3 Time to trip for IEEE inverse characteristics equation.

Name of characteristic	α	β	K
Moderately inverse	0,02	0,114	0,0515
Very inverse	2	0,491	19,61
Extremely inverse	2	0,1217	28,2

Table 5: Coefficients of IEEE characteristics.

T …	Protection trip time
k …	IDMT coefficient
α, β, K…	Coefficient values
I …	Fault current amplitude
I_p …	set limit of fault range, **pickup value**

2.1.3.2 User- defined curves

The user can define curves by entering parameters into the following standard formula:

$$T = k \cdot \left[\frac{K + K1}{\left(\frac{I}{I_p}\right)^{\alpha} - Q} + \beta \right] + K2$$

Equation 4: Time to trip for user defined characteristics equation.

T …	Protection trip time
k …	IDMT coefficient
α, β, $K, K1, K2, Q$…	User defined parameters
I …	Fault current amplitude
I_p …	Set limit of fault range, **pickup value**

User defined parameters $K, K1, K2, Q$, *Alpha, Beta* by himself. You will found that parameters if you follow the Main menu → Settings → User-defined curves.

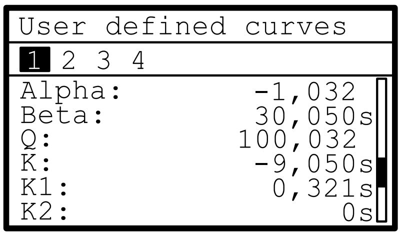


Figure 8: User defined curves like seen on HMI

2.1.3.2.1 Setting parameters

Parameter	Group	Range	Description
Alpha	X	-10,000 … **2,000** … 10,000	User-defined constant
Beta	X	-100,000 … **1,000** … 100,000	User-defined constant
Q	X	-10,000 … **1,000** … 10,000	User-defined constant
K	X	-500,000 … **10,000** … 500,000	User-defined constant
K1	X	-40,000 … **0,000** … 40,000	User-defined constant
K2	X	-1,000 … **0,000** … 1,000	User-defined constant

2.1.3.3 Graphs of inverse characteristics

Graphs below represent time to trip depending on current and user defined IDMT setting for each of the inverse time characteristics.

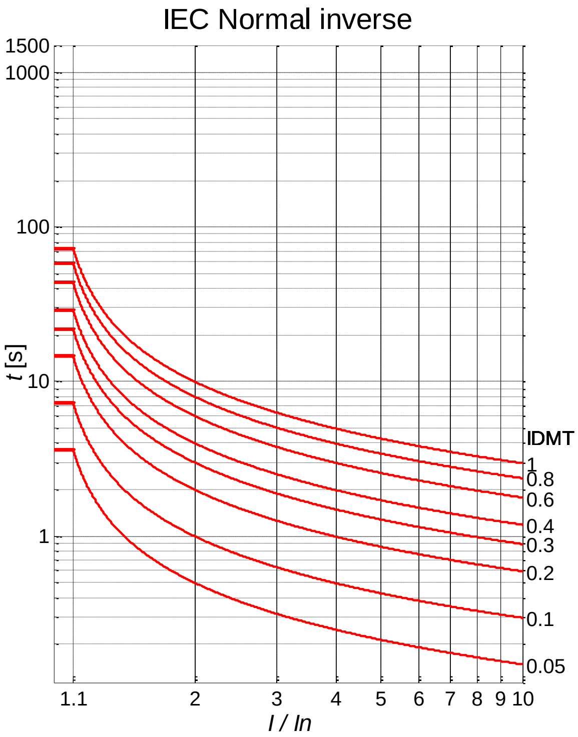


Figure 2.9 IEC Normal inverse characteristics.

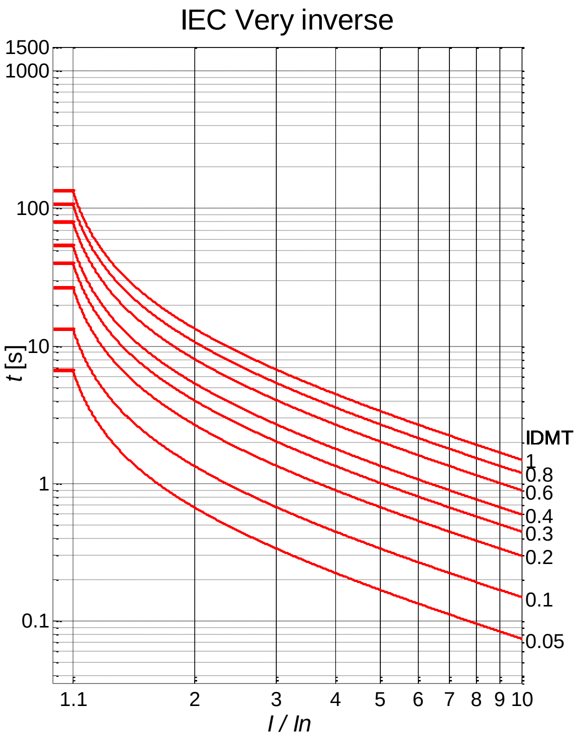


Figure 2.10 IEC Very inverse characteristics.

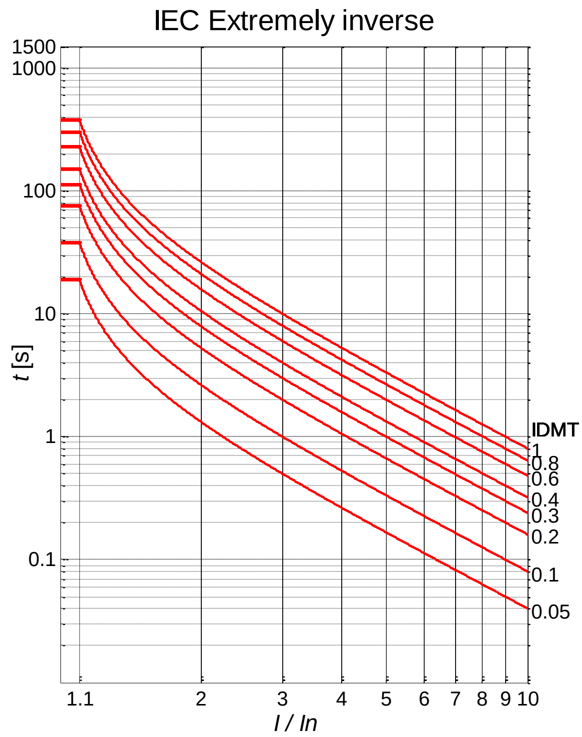


Figure 2.11IEC Extremely inverse characteristics.

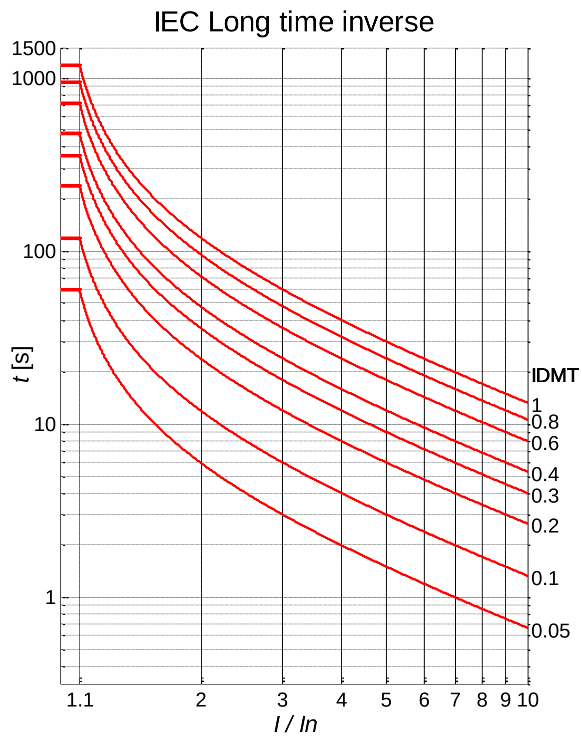


Figure 2.12 IEC Long time inverse characteristics.

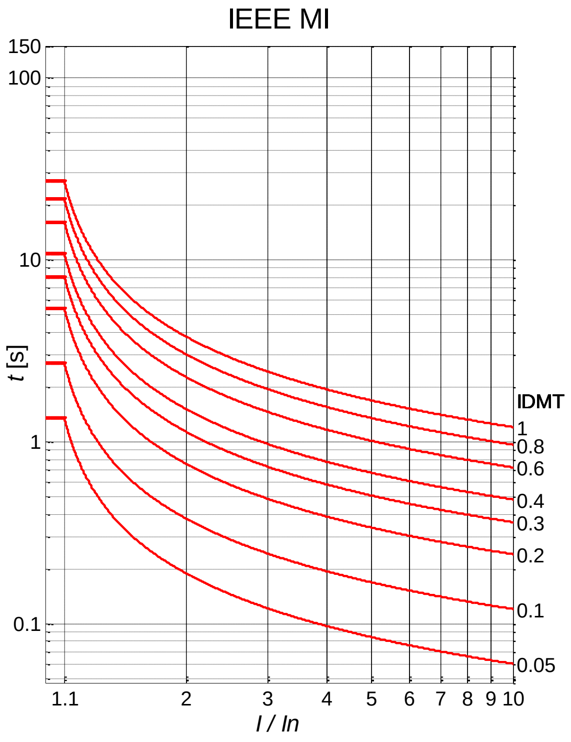


Figure 2.13 IEEE moderately inverse characteristics.

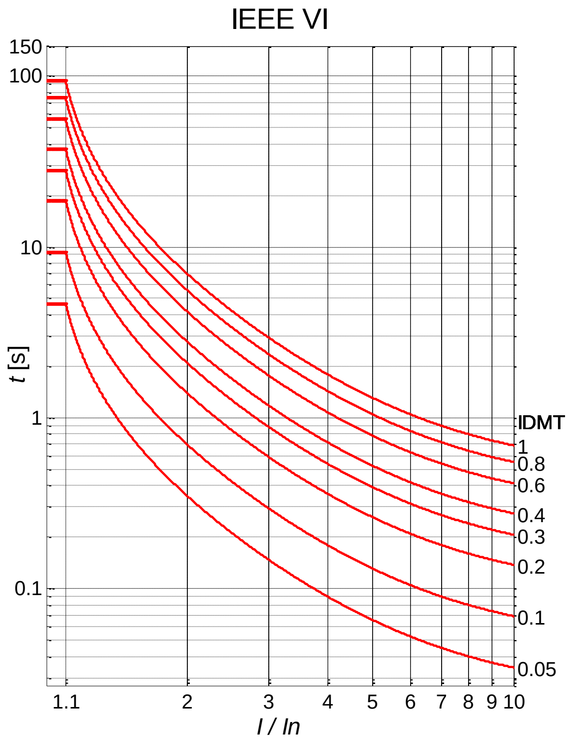


Figure 2.15 IEEE Very inverse characteristics.

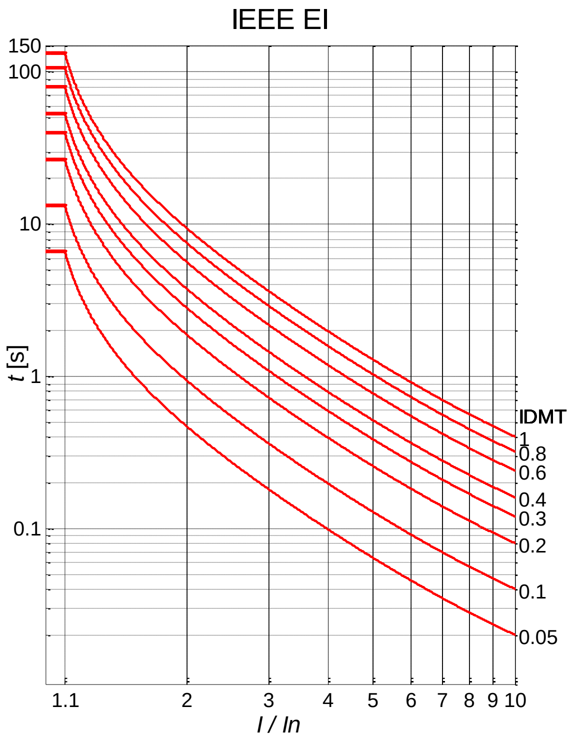


Figure 2.14 IEEE Extremely inverse characteristics.

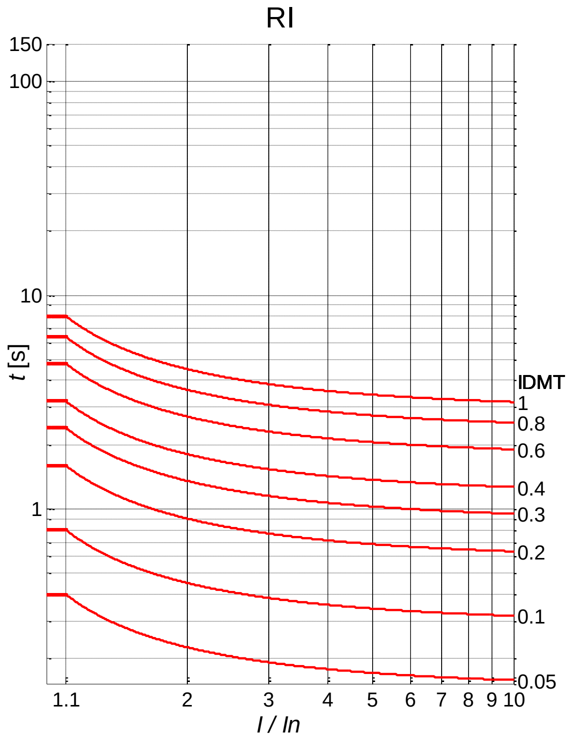


Figure 2.16 RI inverse time characteristics.

2.2 Current based protections

2.2.1 Overcurrent protection - ANSI code 50/51/67

Overcurrent protection is one of the basic functions of FPC 400 numerical relays. It protects the feeder or other elements of the power system from overcurrent when fault occurs. It comprises of various time-delayed characteristics. Protective function includes Inrush restraint [2.6.72.2.5] and Cold load pickup (CLP) protection.

2.2.1.1 Functionality

Overcurrent protection is used as non-directional time delayed overcurrent and short-circuit protection. It picks up when current in one, two or three phases exceeds the set threshold. The function can be enabled or disabled through corresponding menu. The trip time characteristics can be selected to be Instantaneous, definite time (DT) or inverse definite minimum time (IDMT). When instantaneous operation mode is selected the trip signal is stated as the DT characteristic. The settings of this function are applied to each of the three phases to produce pickup and trip signals per each phase.

Several overcurrent protection instances with different settings can run independently at the same time.

The selection of **pickup value**, **pickup delay** as well as **drop-out ratio** and **drop-out delay** helps the user to fine tune the protection according to the project specifications.

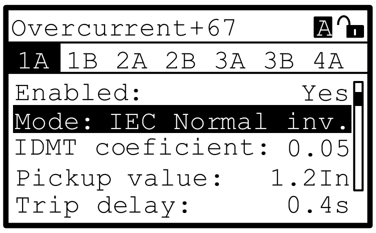


Figure 2.17 Overcurrent protection setting.

2.2.1.2 Measurements

The value of each phase current is acquired through separate input current transformer. The measured phase currents are compared with the set **pickup value**.

2.2.1.3 Delays

Function includes following delays explained in chapter [2.1]:

- Pickup delay
- Trip delay
- Inverse time trip delay
- Drop-out delay

2.2.1.4 Cold load pickup

A temporary increased starting current can appear when energizing feeders with loads that had a long zero voltage period (e.g. air-conditioning systems, heating installations, motors...). Its value can be up to several times higher than the nominal current. To avoid unwanted protection operation the pickup limit has to be raised temporarily. The function is set with parameter Enable. It triggers through the activation of corresponding digital input or when current raises above
5 % of I_{n_obj} in at least one phase after certain amount of time has passed.

The dynamic **pickup value** changeover is common to all overcurrent elements. With inverse characteristics, the CLP influences only the fault detection limit, whereas the time calculation of the selected inverse characteristic is not affected.

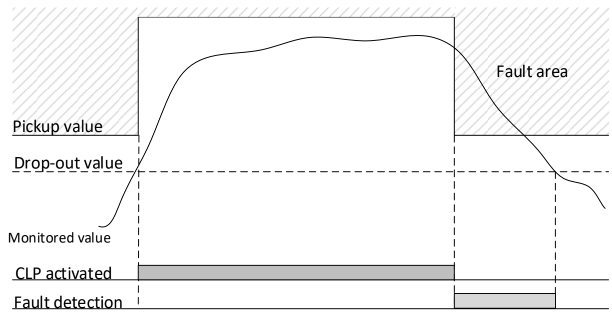


Figure 2.18 Operation with CLP activated for a shorter than fault time duration.

2.2.1.5 Directional condition - ANSI code 67

The direction condition can be taken into account for this protection function. The directional condition is verified for each phase separately. If the directional condition of separate phase is false, than pickup of this phase is blocked. If the fault current is inside the user defined area of operation the protection the tripping direction condition is true.

2.2.1.5.1 Determination of reference direction

Reference direction is determined for each phase voltage separately by using the perpendicular angle of the opposite phase to phase voltage. The calculation is active if referenced phase to phase voltage is greater than **RCA minimal voltage.** If voltage is lower than that value, the protection acts as non-directed overcurrent protection function.

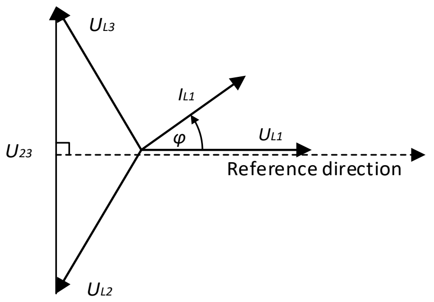


Figure 2.19 Example of reference direction and angle φ for L1.

2.2.1.5.2 Operation of direction condition

Direction of current is determined as an angle φ between reference direction and current direction of the same phase for each phase separately. Area of operation is separated on forward and reverse section. A forward direction area is presented in same direction as reference direction is pointing. Size of each area is narrowed by **RCA Correction angle** α on each side of perpendicular line to the direction line. The **RCA Direction angle** parameter determines the direction by which plains of forward and reverse section are oriented.

If the fault current is inside the user defined area of operation the protection the tripping direction condition is true. The hysteresis of correction angle is 3 °.

The area of operation is illustrated on the Figure 2.20.

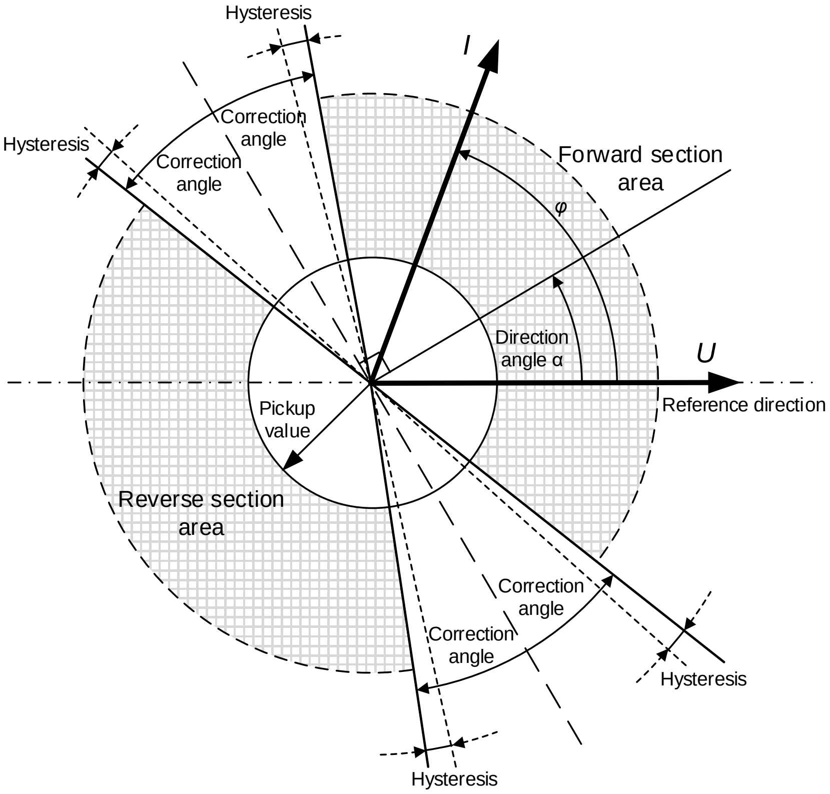


Figure 2.20 Diagram of directional condition function operation.

2.2.1.6 Setting parameters

Parameter	Group	Range	Description
Enabled		No **Yes**	Enabling protection function.
Operate mode	X	Instantaneous **Definite time** IEC Normal inverse IEC Very inverse IEC Extremely inverse IEC Long-time inverse IEEE Moderately inverse IEEE Very inverse IEEE Extremely inverse RI User-defined 1 User-defined 2 User-defined 3 User-defined 4	Protection operation mode: Instantaneous – minimal possible time of operation. Definite time – constant time of operation Inverse characteristics – selected IDMT characteristic
IDMT coefficient	X	**0,05** … 1,00	Coefficient of selected IDMT characteristic
Pickup value	X	0,05 … **1,00** … 40,00 I_{n_obj}	Limit of monitored current.
Trip delay	X	0,00 … **0,50** … 300,00 s	Delay of trip signal
Inrush restraint source	X	**None** Inrush-1 Inrush-2	Input source of Inrush restraint chapter [2.2.5] blocking function.
Enable direction condition		**No** Yes	Enables the protection function to take into account the directional condition of operation.
Directional mode	X	**Forward** Reverse	Determines the area of operation section for directional condition.
RCA direction angle	X	- 90 ° … **45 °** … 90 °	Reference condition angle of current to reference direction.
RCA correction angle		**0 °** … 90 °	Reduction of the area of operation by angle α on each side of perpendicular line to the direction line.
RCA minimal voltage		0,00 … **0,65** … 1,00 U_n	Minimum voltage amplitude used in reference direction calculation. Function acts as non-directed protection function, if this condition is not meet.
Pickup delay		0 … **5,00** … 1000 ms	Time stabilization of fault detection. As a filter of short disturbances on measuring circuits. Time before protection starts.
Drop-out delay		0,00 … **0,20** … 60,00 s	Time stabilization of pickup signal. Time when the monitored value is outside the operating range, but the protection does not stop yet.
Drop-out ratio		0,80 … **0,95** … 1,00 I_p	Drop-out value below which the protection drops.
Cold load pickup Enabled		**No** Yes	Enabling CLP function.
Cold load pickup Level		1,01 … **1,50** … 10,00 I_p	Pickup and drop-out value increase.
Cold load pickup Duration		0 … **60** … 3600 s	Pickup value increase duration time.
Pickup block		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.

Table 6: Overcurrent protection function parameters.

2.2.1.7 Counters

Name	Description
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.
Pickup L1	Consecutive number of pickup signals detected in phase L1
Pickup L2	Consecutive number of pickup signals detected in phase L2
Pickup L3	Consecutive number of pickup signals detected in phase L3
CLP	Consecutive number of cold load pickup

Table 7: Counters presented in overcurrent protection.

2.2.2 Earth fault overcurrent protection - ANSI code 50/51/67|N/G/Ns/Gs, 32|NQ/NP

Earth fault overcurrent protection is one of the basic functions of FPC 400 numerical relay. It comprises of various time-delayed characteristics. Protective function includes CLP and inhibition by Inrush restraint [2.6.72.2.5] function.

2.2.2.1 Functionality

Earth fault overcurrent function is used as non-directional earth fault protection. **Pickup value** of this function is normally set lower than **pickup value** of phase overcurrent protection. Protection picks up when the earth fault current exceeds the set threshold value. The function can be enabled or disabled through corresponding menu. Trip time characteristics can be selected to be Instantaneous, Definite time (DT) or Inverse definite minimum time (IDMT). When instantaneous operation mode is selected the trip signal is stated as the DT characteristic.

Several earth fault protection instances with different settings can run independently at the same time.

The selection of **pickup value**, **pickup delay** as well as **drop-out ratio** and **drop-out delay** helps the user to fine tune the protection according to the project specifications.

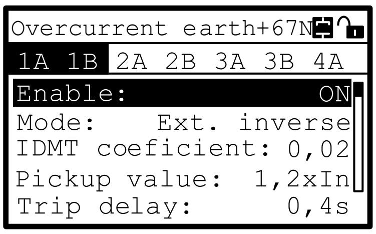


Figure 2.21 Earth fault overcurrent setting.

2.2.2.2 Measurements

Earth fault current is acquired directly through analog measurement or calculated.

Sensitive current input can be selected for direct earth fault measurement. When sensitive analog input I_e is not present earth current $3I_0$ is calculated using phase currents analog measurements.

2.2.2.3 Delays

Function includes following delays explained in chapter [2.1]:

- Pickup delay
- Trip delay
- Inverse time trip delay
- Drop-out delay

2.2.2.4 Cold load pickup

A temporary increased starting current can appear when energizing feeder loads that had a long zero voltage period (e.g. air-conditioning systems, heating installations, motors...). Its value can be up to several times higher than the nominal current. To avoid unwanted protection operation the pickup limit has to be raised temporarily. The function is set with parameter Enable. It triggers only when CB Close command is executed manually.

The dynamic **pickup value** changeover is common to all overcurrent elements. With inverse characteristics, the CLP influences only the fault detection limit, whereas the time calculation of the selected inverse characteristic is not affected.

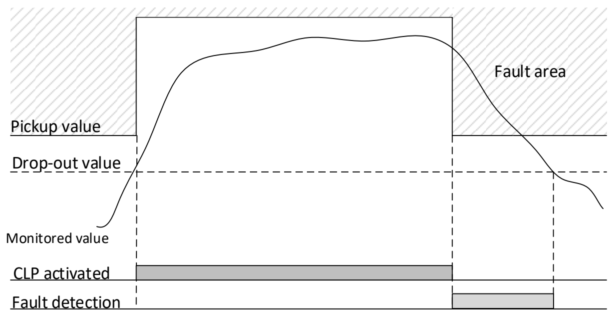


Figure 2.22 Operation with CLP activated for a shorter than fault time duration.

2.2.2.5 Directional condition - 67N/G/Ns, 32|NQ/NP

The direction condition can be taken into account for this protection function. If the condition of earth current direction is false, than pickup is blocked. If the fault current is inside the user defined area of operation the protection the tripping direction condition is true.

2.2.2.5.1 Determination of reference direction

Reference direction is the direction of earth voltage U_e. The calculation is active if the voltage is greater than **RCA minimal voltage.** If voltage is lower than that value, the protection acts as non-directed overcurrent earth protection function.

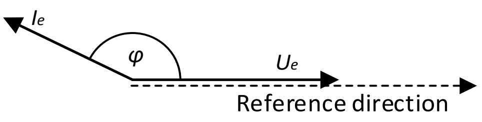


Figure 2.23 Example of reference direction, presented with angle φ.

2.2.2.5.2 Operation of direction condition

Direction of current is determined as an angle φ between reference direction and earth current I_e. Area of operation is separated on forward and reverse section. A forward direction area is presented in same direction as reference direction is pointing.

2.2.2.5.3 RCA direction condition

Using RCA direction condition the size of each area is limited with **RCA Correction angle** α on each side of perpendicular line to the direction line. The **RCA Direction angle** parameter determines the direction at which plains of forward and reverse section are oriented.

The hysteresis of correction angle is 3 °.

The area of operation is illustrated on the Figure 2.24

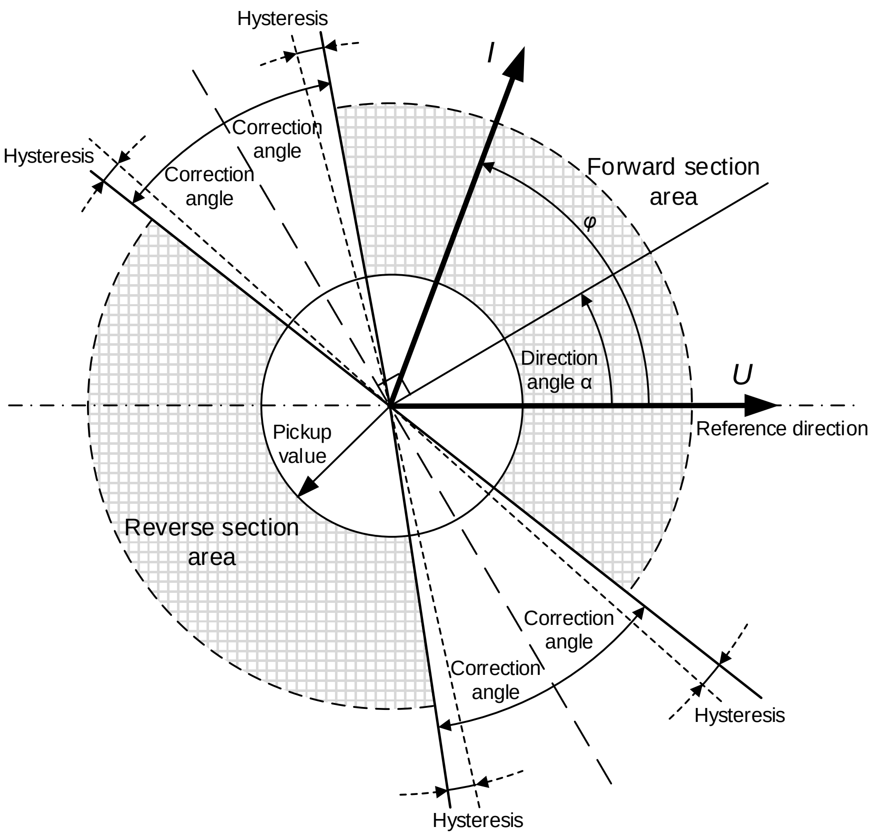


Figure 2.24 Diagram of RCA directional condition function operation.

2.2.2.5.4 Wattmetric direction condition - 32NQ

Wattmetric direction condition is using cosines component of earth current as tripping current. The area of operation starts with the parallel lines spanning a distance of a pickup value of the centre according to equation below. The lines are perpendicular to the line angled for **Direction angle** α.

$$I_{e\_W} = I_e \cdot \cos(\varphi - \alpha)$$

Equation 5 Calculation of earth current for wattmetric directional condition.

The area of operation is illustrated on the figure below:

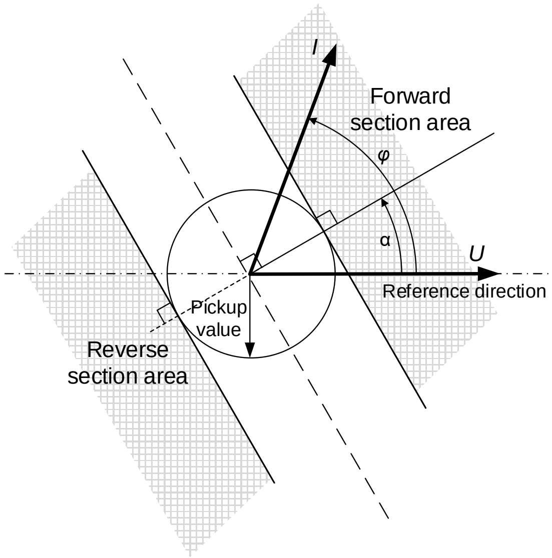


Figure 2.25 Diagram of wattmetric directional condition function operation.

2.2.2.5.5 Varmetric direction condition - 32NP

Varmetric direction condition is using sine component of earth current as tripping current. The area of operation starts with the parallel lines spanning a distance of a pickup value of the centre according to equation below. The lines are parallel to the **Direction angle** line. Forward section is positively perpendicular to the line angled for **Direction angle** α.

$$I_{e\_W} = I_e \cdot \sin(\alpha - \varphi)$$

Equation 6 Calculation of earth current for varmetric directional condition.

The area of operation is illustrated on the figure below:

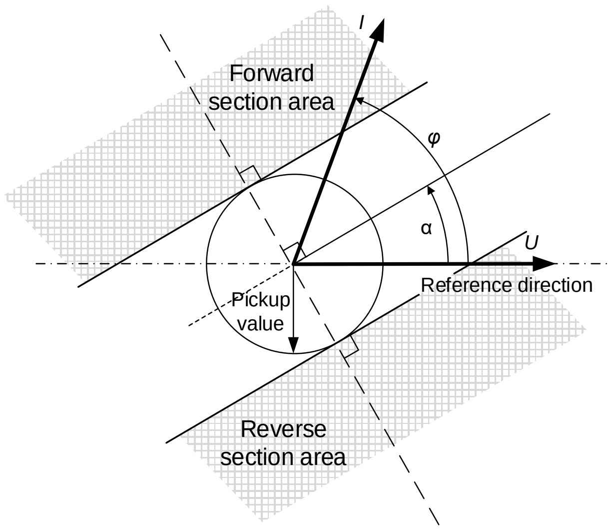


Figure 2.26 Diagram of varmetric directional condition function operation.

2.2.2.6 Setting parameters

Parameter	Group	Range	Description
Enabled		No **Yes**	Enabling protection function.
Operate mode	X	Instantaneous **Definite time** IEC Normal inverse IEC Very inverse IEC Extremely inverse IEC Long-time inverse IEEE Moderately inverse IEEE Very inverse IEEE Extremely inverse RI User-defined 1 User-defined 2 User-defined 3 User-defined 4	Protection operation mode: Instantaneous – minimal possible time of operation. Definite time – constant time of operation Inverse characteristics – selected IDMT characteristic
Pickup value	X	0,005 … **0,10** … 1,25 I_{n_e}	Limit of monitored current.
Trip delay	X	0,00 … **2,00** … 300,00 s	Delay of trip signal
IDMT coefficient	X	**0,05** … 1,00	Coefficient of selected IDMT characteristic
Inrush restraint source	X	**None** Inrush-1 Inrush-2	Input source of Inrush restraint chapter [2.2.5] blocking function.
Enable direction condition		**No** Yes	Enables the protection function to take into account the directional condition of operation.
Directional mode	X	Off **RCA** wattmetric varmetric	Direction function operation mode.
Direction	X	**Forward** Reverse	Determines the area of operation section for directional condition.
Direction angle	X	- 90 ° … **45 °** … 90 °	Reference condition angle of current to reference direction.
RCA correction angle		**0 °** … 90 °	Reduction of the area of operation by angle α on each side of perpendicular line to the direction line.
RCA minimal voltage		0,00 … **0,65** … 1,00 U_n	Minimum voltage amplitude used in reference direction calculation. Function acts as non-directed protection function, if this condition is not meet.
Pickup delay		0 … **5,00** … 1000 ms	Time stabilization of fault detection. As a filter of short disturbances on measuring circuits. Time before protection starts.
Drop-out delay		0,00 … **0,20** … 60,00 s	Time stabilization of pickup signal. Time when the monitored value is outside the operating range, but the protection does not stop yet.
Drop-out ratio		0,80 … **0,95** … 1,00 I_p	Drop-out value below which the protection drops.
Input current		**$3I_0$** I_e	Selector for protection to account for calculated residual current ($3I_0$) for 50N/51N function or measured residual current (I_e) for 50G/51G function.
Cold load pickup Enabled		**No** Yes	Enabling CLP function.
Cold load pickup Level		1,01 … **1,50** … 10,00 I_p	Pickup and drop-out value increase.
Cold load pickup Duration		0 … **60** … 3600 s	Pickup value increase duration time.
Pickup block		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.

Table 8: Earth fault overcurrent protection function parameters.

2.2.2.7 Counters

Name	Description
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.
CLP	Consecutive number of cold load pickup

Table 9: Counters presented in earth fault overcurrent protection.

2.2.3 Negative sequence/unbalance overcurrent protection - ANSI code 46

Uneven distribution of currents is caused by asymmetrical loads, single-phase or two-phase earth faults, line disconnections or irregular switching operations. Negative sequence/unbalance overcurrent protection function uses negative sequence current of symmetrical components in three phase system.

2.2.3.1 Functionality

Function is used for detecting unbalanced loads in the power system. Negative sequence value is defined by the asymmetry of power system. Asymmetrical faults selectivity is achieved by considering negative sequence value. If negative sequence current I_2 is greater than **pickup value** the protection trips.

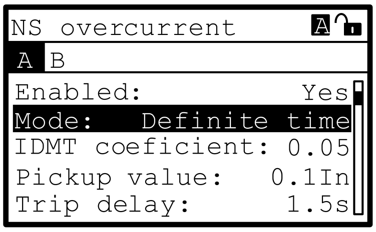


Figure 2.27 Example of parameter settings on HMI.

2.2.3.2 Current limitation

The correct function operation is ensured using parameters **minimum current** and **maximum current** value.

- If all measuring phase currents are below **maximum current** value, the protection is active.
- If at least one of the currents is above **minimum current** the protection is active.

2.2.3.3 Delays

Function includes following delays explained in chapter [2.1]:

- Pickup delay
- Trip delay
- Inverse time trip delay
- Drop-out delay

2.2.3.4 Setting parameters

Parameter	Group	Range	Description
Enabled		No **Yes**	Enabling protection function.
Operate mode	X	Instantaneous **Definite time** IEC Normal inverse IEC Very inverse IEC Extremely inverse IEC Long-time inverse IEEE Moderately inverse IEEE Very inverse IEEE Extremely inverse RI User-defined 1 User-defined 2 User-defined 3 User-defined 4	Protection operation mode: Instantaneous – minimal possible time of operation. Definite time – constant time of operation Inverse characteristics – selected IDMT characteristic
IDMT coefficient	X	**0,05** … 1,00	Coefficient of selected IDMT characteristic
Pickup value	X	0,01 … **0,10** … 3,00 I_{n_obj}	Limit of monitored current.
Trip delay	X	0,00 … **1,50** … 300,00 s	Delay of trip signal.
Pickup delay		0 … **5,00** … 1000 ms	Time stabilization of fault detection. As a filter of short disturbances on measuring circuits. Time before protection starts.
Drop-out delay		0,00 … **0,20** … 60,00 s	Time stabilization of pickup signal. Time when the monitored value is outside the operating range, but the protection does not stop yet.
Drop-out ratio		0,80 … **0,95** … 1,00 I_p	Drop-out value below which the protection drops.
Pickup block		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.
Minimal current		0,01 … **0,10** … 2,00 I_{n_obj}	Minimal current above which the protection operates. Protection is blocked if all phase currents are below the set value.
Maximum current		0,10 … **4,00** … 10,00 I_{n_obj}	Maximum current below which the protection still operates. Protection is blocked if any of the phase currents is above the set value.

Table 10: Negative/unbalance sequence protection function parameters.

2.2.3.5 Counters

Name	Description
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.

Table 11: Counters presented in negative sequence protection.

2.2.4 Restricted earth fault protection - ANSI code 64REF

Restricted Earth Fault function is one of advanced protection functions installed in FPC 400 protection relay. Protection detects earth faults in power transformers, shunt reactors, neutral earthing transformers/reactors, or rotating machines. Starpoint of protected element should be earthed. The starpoint CT and the phase CTs define the limits of absolutely selective protection. Restricted earth fault protection is not applicable to busbar, type B of FPC 400 protection relay.

2.2.4.1 Functionality

Function compares calculated residual phase current ($3I_0$) with measured neutral point current I_e.

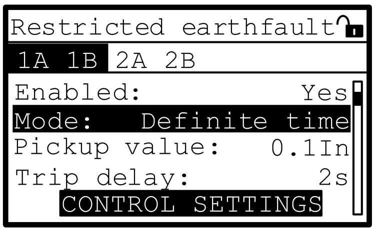


Figure 2.28 Example of parameter settings on HMI.

2.2.4.2 Delays

Function includes following delays explained in chapter [2.1]:

- Pickup delay
- Trip delay
- Drop-out delay

2.2.4.3 Connection scheme

Typical Connection scheme is shown on Figure 2.29.

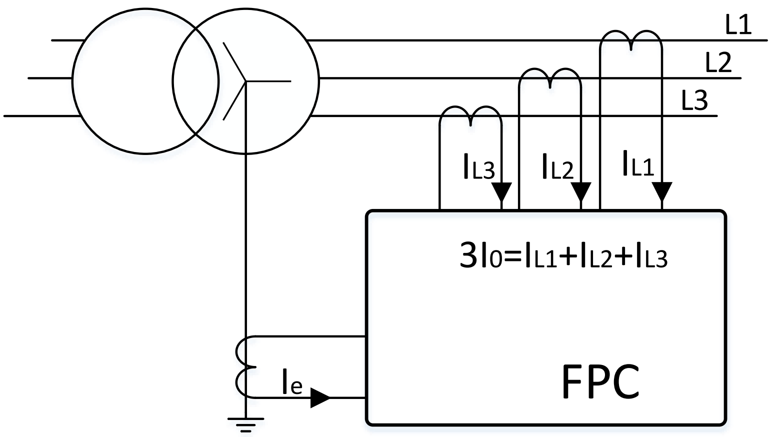


Figure 2.29 Connection scheme.

2.2.4.4 Setting parameters

Parameter	Group	Range	Description
Enabled		No **Yes**	Enabling protection function.
Operate mode	X	**Off** Definitive time	Enabling protection function separately for each group level.
Pickup value	X	0,005 … **0,10** … 2,00 I_{n_e}	Limit of monitored current.
Trip delay	X	0,00 … **2,00** … 300,00 s	Delay of trip signal.
Pickup delay		0 … **5,00** … 1000 ms	Time stabilization of fault detection. As a filter of short disturbances on measuring circuits. Time before protection starts.
Drop-out delay		0,00 … **0,20** … 60,00 s	Time stabilization of pickup signal. Time when the monitored value is outside the operating range, but the protection does not stop yet.
Drop-out ratio		0,80 … **0,95** … 1,00 I_p	Drop-out value below which the protection drops.
Pickup block		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.

Table 12: Restricted earth fault protection function parameters.

2.2.4.5 Counters

Name	Description
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.

Table 13: Counters presented in restricted earth fault protection.

2.2.5 Phase undercurrent protection - ANSI code 37

Phase to phase undercurrent is a function that protects the rotating machine or other elements of the power system from low current.

2.2.5.1 Functionality

Undercurrent protection is used as time delayed protection. It picks up when one of the phase currents drops below the selected threshold. The function can be enabled or disabled through corresponding menu.

The selection of **pickup value**, **pickup delay** as well as **drop-out ratio** and **drop-out delay** helps the user to fine tune the protection according to the project specifications.

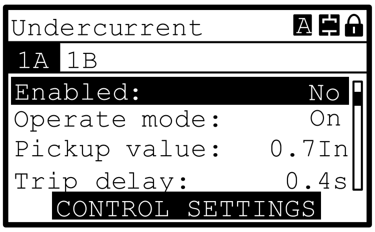


Figure 2.30 Phase undercurrent protection setting as seen on HMI.

2.2.5.2 Delays

Function includes following delays explained in chapter [2.1]:

- Pickup delay
- Trip delay
- Drop-out delay

2.2.5.3 Block settings

Pickup of any instance separately of protection can be individually blocked by:

- Any user defined signal [2.7].
- Defined **zero current level**.

If current supervision function is enabled the protection function is blocked if all phase currents drop below user defined **zero *I* level.**

2.2.5.4 Setting parameters

Parameter	Group	Range	Description
Enabled		No **Yes**	Enabling protection function.
Operate mode	X	Off **On**	Enabling protection function separately for each group level.
Pickup value	X	0,1 … **0,75** … 2,00 I_{n_obj}	Value at which fault conditions are considered.
Trip delay	X	0,00 … **1,50** … 300,00 s	Delay of trip signal
Pickup delay		10 … **20** … 1000 ms	Time stabilization of fault detection. As a filter of short disturbances on measuring circuits. Time before protection starts.
Drop-out delay		0,00 … **0,20** … 60,00 s	Time stabilization of pickup signal. Time when the monitored value is outside the operating range, but the protection does not stop yet.
Drop-out ratio		1,01 … **1,20** … 3,00 I_p	Drop-out value below which the protection drops.
Current Supervision Enabled		No **Yes**	Enabling Current Supervision.
Zero *I* level		0,04 … **0,10** … 1	Level of current below which operation of protection is blocked. Operation is blocked only in case of all three current amplitude Lx are below Zero *I* level.
Recovery time		0,00 … **60** … 100 ms	Time the protection is blocked after current reaching above **Zero *I* level**.
Pickup block		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.

Table 14: Phase undercurrent protection function parameters.

2.2.5.5 Counters

Name	Description
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.
Pickup L1	Consecutive number of pickup signals detected in phase L1
Pickup L2	Consecutive number of pickup signals detected in phase L2
Pickup L3	Consecutive number of pickup signals detected in phase L3

Table 15: Counters presented in phase undercurrent protection.

2.3 Voltage based protections

2.3.1 Phase to phase overvoltage protection - ANSI code 59

Phase to phase overvoltage protection is one of the basic functions of FPC 400 numerical relays. It protects the feeder or other elements of the power system from overvoltage. It comprises of time-delayed characteristics.

2.3.1.1 Functionality

Overvoltage protection is used as time delayed protection. It picks up when voltage in one, two or three phases exceeds the set threshold. The function can be enabled or disabled through corresponding menu. The settings of this function are applied to each of the three phases to produce pickup and per each phase and common trip signal.

Several overvoltage protection instances with different settings can run independently at the same time.

The selection of **pickup value**, **pickup delay** as well as **drop-out ratio** and **drop-out delay** helps the user to fine tune the protection according to the project specifications.

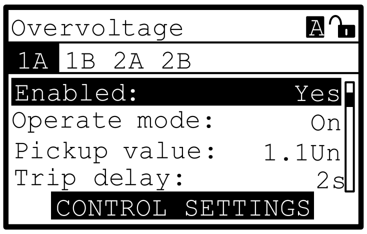


Figure 2.31 Overvoltage protection setting as seen on HMI.

2.3.1.2 Measurements

The value of each phase to phase voltages is calculated through measured phase voltages of measurement voltage transformers. The input voltage is compared to rated pickup voltage.

2.3.1.3 Delays

Function includes following delays explained in chapter [2.1]:

- Pickup delay
- Trip delay
- Drop-out delay

2.3.1.4 Block settings

Pickup of any instance separately of protection can be individually blocked by any user defined signal [2.6.7.].

2.3.1.5 Setting parameters

Parameter	Group	Range	Description
Enabled		No **Yes**	Enabling protection function.
Operate mode	X	Off **On**	Enabling protection function separately for each group level.
Pickup value	X	0,05 … **1,10** … 2,00 U_n	Value at which fault conditions are considered.
Trip delay	X	0,00 … **2,00** … 300,00 s	Delay of trip signal
Pickup delay		0 … **5** … 1000 ms	Time stabilization of fault detection. As a filter of short disturbances on measuring circuits. Time before protection starts.
Drop-out delay		0,00 … **0,20** … 60,00 s	Time stabilization of pickup signal. Time when the monitored value is outside the operating range, but the protection does not stop yet.
Drop-out ratio		0,80 … **0,95** … 0,99 U_p	Drop-out value below which the protection drops.
Pickup block		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.

Table 16: Overvoltage protection function parameters.

2.3.1.6 Counters

Name	Description
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.
Pickup L12	Consecutive number of pickup signals detected in phase L12.
Pickup L23	Consecutive number of pickup signals detected in phase L23.
Pickup L31	Consecutive number of pickup signals detected in phase L31.

Table 17: Counters presented in overvoltage protection.

2.3.2 Neutral voltage displacement - ANSI code 59N

Neutral voltage displacement protection is a function that detects residual overvoltage. It comprises of time-delayed characteristics.

2.3.2.1 Functionality

Neutral voltage displacement protection is used as time delayed protection. As voltage input this function can use measured U_e or calculated $3U_0$ source. It picks up when voltage from selected source exceed the selected threshold. The function can be enabled or disabled through corresponding menu.

Several voltage displacement protection instances with different settings can run independently at the same time.

The selection of **pickup value**, **pickup delay** as well as **drop-out ratio** and **drop-out delay** helps the user to fine tune the protection according to the project specifications.

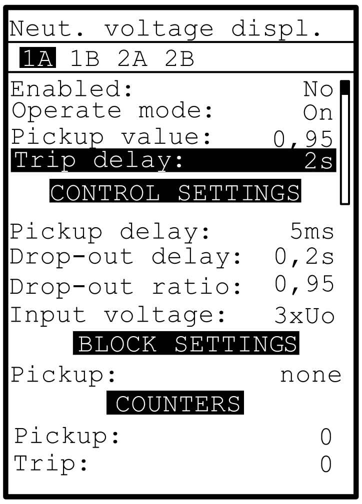


Figure 2.32 Neutral voltage displacement protection setting as seen on HMI.

2.3.2.2 Measurements

The value of earth voltage can be chosen between direct measurements U_e or calculated measurement using symmetrical components $3U_0$. Input value can be set in parameters settings for each instance of protection separately.

2.3.2.3 Delays

Function includes following delays explained in chapter [2.1]:

- Pickup delay
- Trip delay
- Drop-out delay

2.3.2.4 Block settings

Pickup of any instance separately of protection can be individually blocked by any user defined signal [2.6.7.].

2.3.2.5 Setting parameters

Parameter	Group	Range	Description
Enabled		No **Yes**	Enabling protection function.
Operate mode	X	Off **On**	Enabling protection function separately for each group level.
Pickup value	X	0,01 … **0,95** … 2,00 U_{e_n}	Value at which fault conditions are considered.
Trip delay	X	0,00 … **2,00** … 300,00 s	Delay of trip signal
Pickup delay		0 … **5** … 1000 ms	Time stabilization of fault detection. As a filter of short disturbances on measuring circuits. Time before protection starts.
Drop-out delay		0,00 … **0,20** … 60,00 s	Time stabilization of pickup signal. Time when the monitored value is outside the operating range, but the protection does not stop yet.
Drop-out ratio		0,80 … **0,95** … 1,00 U_p	Drop-out value below which the protection drops.
Input Voltage		U_e **$3U_0$**	Selector for input voltage to be used in protection.
Pickup block		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.

Table 18: Neutral voltage displacement protection function parameters.

2.3.2.6 Counters

Name	Description
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.

Table 19: Counters presented in neutral voltage displacement protection.

2.3.3 Negative sequence overvoltage protection - ANSI code 47

Uneven distribution of voltages can be a cause of a single-phase or two-phase earth faults. Negative sequence overvoltage protection function uses negative sequence voltage of symmetrical components in three phase system.

2.3.3.1 Functionality

Primary the protection is intended to detect distant one or two-phase faults and low current faults that do not trip current protections. If negative sequence voltage U_2 is greater than **pickup value** the protection trips.

The trip time can be selected to different operational characteristics:

- Instantaneous,
- definite time (DT)

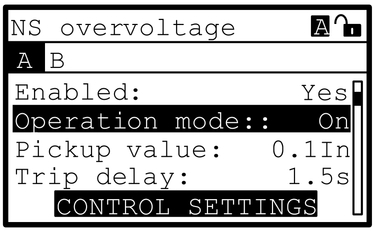


Figure 2.33 Example of parameter settings on HMI.

2.3.3.2 Delays

Function includes following delays explained in chapter [2.1]:

- Pickup delay
- Trip delay
- Drop-out delay

2.3.3.3 Setting parameters

Parameter	Group	Range	Description
Enabled		No **Yes**	Enabling protection function.
Operate mode	X	Off **On**	Enabling protection function separately for each group level.
Pickup value	X	0,01 … **0,10** … 3,00 U_n	Limit of monitored current.
Trip delay	X	0,00 … **1,50** … 300,00 s	Delay of trip signal.
Pickup delay		0 … **5,00** … 1000 ms	Time stabilization of fault detection. As a filter of short disturbances on measuring circuits. Time before protection starts.
Drop-out delay		0,00 … **0,20** … 60,00 s	Time stabilization of pickup signal. Time when the monitored value is outside the operating range, but the protection does not stop yet.
Drop-out ratio		0,80 … **0,95** … 1,00 U_p	Drop-out value below which the protection drops.
Pickup block		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.

Table 20: Negative sequence overvoltage protection function parameters.

2.3.3.4 Counters

Name	Description
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.

Table 21: Counters presented in negative sequence overvoltage protection function.

2.3.4 Phase to phase undervoltage protection - ANSI code 27

Phase to phase undervoltage is a function that protects the feeder or other elements of the power system from low voltage.

2.3.4.1 Functionality

Undervoltage protection is used as time delayed protection. It picks up when ph-ph voltage drops below the selected threshold. The function can be enabled or disabled through corresponding menu.

Several ph-ph undervoltage protection instances with different settings can run independently at the same time.

The selection of **pickup value**, **pickup delay** as well as **drop-out ratio** and **drop-out delay** helps the user to fine tune the protection according to the project specifications.

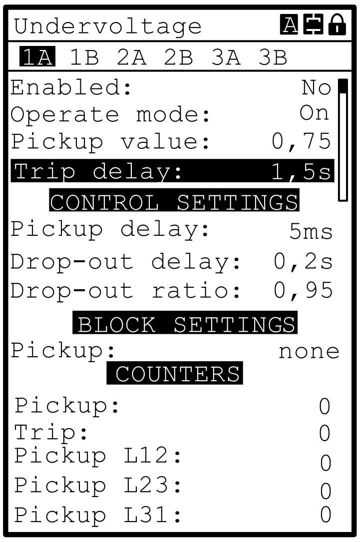


Figure 2.34 Ph-Ph undervoltage protection setting as seen on HMI.

2.3.4.2 Delays

Function includes following delays explained in chapter [2.1]:

- Pickup delay
- Trip delay
- Drop-out delay

2.3.4.3 Block settings

Pickup of any instance separately of protection can be individually blocked by:

- Any user defined signal [2.6.7].
- Enabling Fuse failure protection [2.6.5].

In addition the protection is blocked when voltage drops below 40 % of U_n. To ensure the correct function of the protection, the protection block is time delayed for a brief moment after any condition for blocking has expired. The individual protection trip exhibits pulse type if connected to trip relay [4.2.3.5.7, relay mapping section], to ensure correct CBFP [2.6.1.10] functionality.

2.3.4.4 Setting parameters

Parameter	Group	Range	Description
Enabled		No **Yes**	Enabling protection function.
Operate mode	X	Off **On**	Enabling protection function separately for each group level.
Pickup value	X	0,1 … **0,95** … 2,00 U_n	Value at which fault conditions are considered.
Trip delay	X	0,00 … **2,00** … 300,00 s	Delay of trip signal
Pickup delay		0,00 … **40,00** … 1000 ms	Time stabilization of fault detection. As a filter of short disturbances on measuring circuits. Time before protection starts.
Drop-out delay		0,00 … **0,20** … 60,00 s	Time stabilization of pickup signal. Time when the monitored value is outside the operating range, but the protection does not stop yet.
Drop-out ratio		1,01 … **1,05** … 3,00 U_p	Drop-out value below which the protection drops.
Pickup block		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.

Table 22: Undervoltage protection function parameters.

2.3.4.5 Counters

Name	Description
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.
Pickup L12	Consecutive number of pickup signals detected in phase L12.
Pickup L23	Consecutive number of pickup signals detected in phase L23.
Pickup L31	Consecutive number of pickup signals detected in phase L31.

Table 23: Counters presented in phase to phase undervoltage protection.

2.3.5 Positive sequence undervoltage protection - ANSI code 27D

Positive sequence undervoltage protection is a function that protects the feeder or other elements of the power system from wrong phase direction and low positive sequence of three phase system.

2.3.5.1 Functionality

Undervoltage protection is single analog input function, used as time delayed protection. It picks up when positive sequence voltage U_1 drops below the selected threshold. The function can be enabled or disabled through corresponding menu.

Several protection instances with different settings can run independently at the same time.

The selection of **pickup value**, **pickup delay** as well as **drop-out ratio** and **drop-out delay** helps the user to fine tune the protection according to the project specifications.

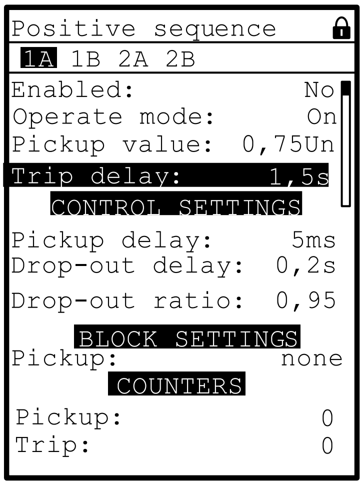


Figure 2.35 Positive sequence undervoltage protection setting as seen on HMI.

2.3.5.2 Delays

Function includes following delays explained in chapter [2.1]:

- Pickup delay
- Trip delay
- Drop-out delay

2.3.5.3 Block settings

Pickup of any instance separately of protection can be individually blocked by:

- Any user defined signal [2.6.7].
- Enabling Fuse failure protection [2.6.5].

In addition the protection is blocked when voltage drops below 40 % of U_n. To ensure the correct function of the protection, the protection block is time delayed for a brief moment after any condition for blocking has expired. The individual protection trip exhibits pulse type if connected to trip relay [4.2.3.5.7, relay mapping section], to ensure correct CBFP [2.6.1.10] functionality.

2.3.5.4 Setting parameters

Parameter	Group	Range	Description
Enabled		No **Yes**	Enabling protection function.
Operate mode	X	Off **On**	Enabling protection function separately for each group level.
Pickup value	X	0,1 … **0,95** … 2,00 U_n	Value at which fault conditions are considered.
Trip delay	X	0,00 … **2,00** … 300,00 s	Delay of trip signal
Pickup delay		0,00 … **5,00** … 1000 ms	Time stabilization of fault detection. As a filter of short disturbances on measuring circuits. Time before protection starts.
Drop-out delay		0,00 … **0,20** … 60,00 s	Time stabilization of pickup signal. Time when the monitored value is outside the operating range, but the protection does not stop yet.
Drop-out ratio		1,01 … **1,05** … 3,00 U_p	Drop-out value below which the protection drops.
Pickup block		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.

Table 24: Positive sequence undervoltage protection function parameters.

2.3.5.5 Counters

Name	Description
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.

Table 25: Counters presented in positive sequence under voltage protection.

2.3.6 Remanent undervoltage protection - ANSI code 27R

Remanent undervoltage protection is a function that prevents closing of the breaking element when voltage remaining by rotating machines is still present on the load power line.

2.3.6.1 Functionality

Remanent undervoltage protection is a single-phased function, used as time delayed protection. It picks up when ph-ph voltage U_{L12} drops below the selected threshold. The function can be enabled or disabled through corresponding menu.

The selection of **pickup value**, **pickup delay** as well as **drop-out ratio** and **drop-out delay** helps the user to fine tune the protection according to the project specifications.

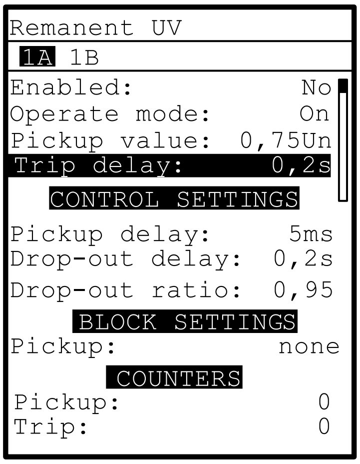


Figure 2.36 Remanent undervoltage protection setting as seen on HMI.

2.3.6.2 Delays

Function includes following delays explained in chapter [2.1]:

- Pickup delay
- Trip delay
- Drop-out delay

2.3.6.3 Block settings

Pickup of any instance separately of protection can be individually blocked by:

- Any user defined signal [2.6.7].
- Enabling Fuse failure protection [2.6.5].

Protection is blocked when voltage drops below 5 % of U_n. To ensure the correct function of the protection, the protection block is time delayed for a brief moment after any condition for blocking has expired. The individual protection trip exhibits pulse type if connected to trip relay [4.2.3.5.7, relay mapping section], to ensure correct CBFP [2.6.1.10] functionality.

2.3.6.4 Setting parameters

Parameter	Group	Range	Description
Enabled		No **Yes**	Enabling protection function.
Operate mode	X	Off **On**	Enabling protection function separately for each group level.
Pickup value	X	0,1 … **0,95** … 2,00 U_n	Value at which fault conditions are considered.
Trip delay	X	0,00 … **2,00** … 300,00 s	Delay of trip signal
Pickup delay		0,00 … **5,00** … 1000 ms	Time stabilization of fault detection. As a filter of short disturbances on measuring circuits. Time before protection starts.
Drop-out delay		0,00 … **0,20** … 60,00 s	Time stabilization of pickup signal. Time when the monitored value is outside the operating range, but the protection does not stop yet.
Drop-out ratio		1,01 … **1,05** … 3,00 U_p	Drop-out value below which the protection drops.
Pickup block		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.

Table 26: Remanent undervoltage protection function parameters.

2.3.6.5 Counters

Name	Description
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.

Table 27: Counters presented in remanent undervoltage protection.

2.4 Frequency based protections

2.4.1 Overfrequency protection - ANSI code 81H

Overfrequency protection is a function that protects the feeder or other elements of the power system from undesirable frequencies. It comprises of time-delayed characteristic and block on derivative of frequency with respect to time, which can be used to prevent operation of breaking element in certain frequency transient conditions.

2.4.1.1 Functionality

Overfrequency protection is a function, used as time delayed protection. It picks up when measured frequency exceeds the selected threshold. The function can be enabled or disabled through corresponding menu.

Several protection instances with different settings can run independently at the same time.

The selection of **pickup value**, **pickup delay** as well as **drop-out ratio** and **drop-out delay** helps the user to fine tune the protection according to the project specifications.

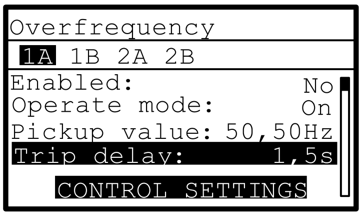


Figure 2.37 Overfrequency protection setting as seen on HMI.

2.4.1.2 Measurement

Frequency is determined based on healthy analog acquisition line measurement with priority of phase voltage measurements first, than phase current measurements. In addition the healthy line is considered as a line which value is nearest to U_n or I_n.

2.4.1.3 Delays

Function includes following delays explained in chapter [2.1]:

- Pickup delay
- Trip delay
- Drop-out delay

2.4.1.4 Block settings

Pickup of any instance separately of protection can be individually blocked by:

- Any user defined signal [2.6.7].
- derivative of frequency with respect to time
- minimal voltage level

2.4.1.5 Setting parameters

Parameter	Group	Range	Description
Enabled		No **Yes**	Enabling protection function.
Operate mode	X	Off **On**	Enabling protection function separately for each group level.
Pickup value	X	f_n + 0,01 … **0,50** … 10,00 Hz	Value at which fault conditions are considered.
Trip delay	X	0,00 … **60,00** … 300,00 s	Delay of trip signal
Pickup delay		0,00 … **5,00** … 1000 ms	Time stabilization of fault detection. As a filter of short disturbances on measuring circuits. Time before protection starts.
Drop-out delay		0,00 … **0,20** … 60,00 s	Time stabilization of pickup signal. Time when the monitored value is outside the operating range, but the protection does not stop yet.
Minimal voltage		0,00 … **0,65** … 1,00 U_n	Any of phase to phase voltage amplitudes, below which the protection block is considered.
Drop-out value		**0,01** … 1,00 Hz	Drop-out value below which the protection drops.
Pickup block		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.
Enable df/dt block		No **Yes**	Enabling derivative of frequency with respect to time protection block.
df/dt level		0,2 … **10,0** Hz/s	Value at which conditions for block are considered.
Block drop off delay		0 … **20** … 2000 ms	Time delay after block conditions have expired.

Table 28: Overfrequency protection function parameters.

2.4.1.6 Counters

Name	Description
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.

Table 29: Counters presented in overfrequency protection.

2.4.2 Underfrequency protection - ANSI code 81L

Underfrequency protection is a function that protects the feeder or other elements of the power system from undesirable frequencies. It comprises of time-delayed characteristic and block on derivative of frequency with respect to time, which can be used to prevent operation of breaking element in certain frequency transient conditions.

2.4.2.1 Functionality

Underfrequency protection is a function, used as time delayed protection. It picks up when measured frequency is lower than the selected threshold. The function can be enabled or disabled through corresponding menu.

Several protection instances with different settings can run independently at the same time.

The selection of **pickup value**, **pickup delay** as well as **drop-out ratio** and **drop-out delay** helps the user to fine tune the protection according to the project specifications.

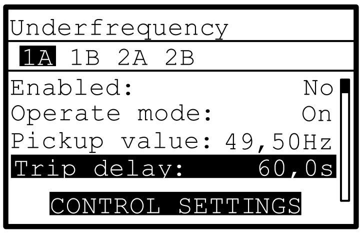


Figure 2.38 Underfrequency protection setting as seen on HMI.

2.4.2.2 Measurement

Frequency is determined based on healthy analog acquisition line measurement with priority of phase voltage measurements first, than phase current measurements. In addition the healthy line is considered as a line which value is nearest to U_n or I_n.

2.4.2.3 Delays

Function includes following delays explained in chapter [2.1]:

- Pickup delay
- Trip delay
- Drop-out delay

2.4.2.4 Block settings

Pickup of any instance separately of protection can be individually blocked by:

- Any user defined signal [2.6.7].
- derivative of frequency with respect to time
- minimal voltage level

2.4.2.5 Setting parameters

Parameter	Group	Range	Description
Enabled		No **Yes**	Enabling protection function.
Operate mode	X	Off **On**	Enabling protection function separately for each group level.
Pickup value	X	f_n - 10,0 … -**0,50** … - 0,01 Hz	Value at which fault conditions are considered.
Trip delay	X	0,00 … **60,00** … 300,00 s	Delay of trip signal
Pickup delay		0,00 … **5,00** … 1000 ms	Time stabilization of fault detection. As a filter of short disturbances on measuring circuits. Time before protection starts.
Drop-out delay		0,00 … **0,20** … 60,00 s	Time stabilization of pickup signal. Time when the monitored value is outside the operating range, but the protection does not stop yet.
Minimal voltage		0,00 … **0,65** … 1,00 U_n	Any of phase to phase voltage amplitudes, below which the protection block is considered.
Drop-out value		**0,01** … 1,00 Hz	Drop-out value below which the protection drops.
Pickup block		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.
Enable df/dt block		No **Yes**	Enabling derivative of frequency with respect to time protection block.
df/dt level		0,2 … **10,0** Hz/s	Value at which conditions for block are considered.
Block drop off delay		0 … **20** … 2000 ms	Time delay after block conditions have expired.

Table 30: Underfrequency protection function parameters.

2.4.2.6 Counters

Name	Description
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.

Table 31: Counters presented in underfrequency protection.

2.4.3 Rate of change of frequency protection - ANSI code 81R

Rate of change of frequency ROCOF protection is a function that indicated severity of the frequency transient. The result can be used as preventive load shedding. It comprises of time-delayed characteristic.

2.4.3.1 Functionality

ROCOF protection is a function, used as time delayed protection. It picks up when measured rate of change frequency exceeds the selected threshold. The frequency threshold can be set on negative, positive or both rates of change. The function operation can be enabled or disabled through corresponding menu.

The selection of **pickup value**, **pickup delay** as well as **drop-out ratio** and **drop-out delay** helps the user to fine tune the protection according to the project specifications.

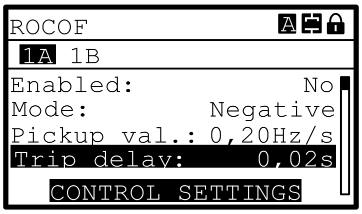


Figure 2.39 ROCOF protection setting as seen on HMI.

2.4.3.2 Measurement

Rate of change of frequency is determined based on frequency change over specific amount of time. The value is averaged to ensure proper function.

2.4.3.3 Delays

Function includes following delays explained in chapter [2.1]:

- Pickup delay
- Trip delay
- Drop-out delay

2.4.3.4 Block settings

Pickup of any instance separately of protection can be individually blocked by any user defined signal [2.6.7]. In addition ROCOF function is blocked if all phase voltages drops below **Minimal voltage**.

2.4.3.5 Setting parameters

Parameter	Group	Range	Description
Enabled		No **Yes**	Enabling protection function.
Mode	X	Off Positive **Negative** Both	Selection of different types of protection operation modes.
Pickup value	X	0,2 … **0,50** … 10,00 $\frac{Hz}{s}$	Value at which fault conditions are considered. The value is presented in absolute positive number.
Trip delay	X	0,10 … **0,20** … 300,00 s	Delay of trip signal
Pickup delay		**0,00** … 1000 ms	Time stabilization of fault detection. As a filter of short disturbances on measuring circuits. Time before protection starts.
Drop-out delay		0,00 … **0,20** … 60,00 s	Time stabilization of pickup signal. Time when the monitored value is outside the operating range, but the protection does not stop yet.
Drop-out ratio		0,80 … **0,95** … 1,00 Pickup	Drop-out ratio below which the protection drops.
Pickup block		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.
Minimal voltage		0,00 … **0,65** … 1,00 U_n	If all phase voltages of protected system are below value of this parameter the protection is blocked.

Table 32: ROCOF protection function parameters.

2.4.3.6 Counters

Name	Description
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.

Table 33: Counters presented in ROCOF protection.

2.5 Power and machine protections

2.5.1 Overpower active protection – ANSI code 32P

This function protect against generators or motors overloads and against reverse power. It supervises the direction of the power flow and reacts if power flow is opposite to the defined direction, t.i. when generators draw active power, because they are running like motors.

2.5.1.1 Functionality

Overpower active protection is a function, used as time delayed protection. This module is measuring power flow in the system and triggers Pickup in following cases:

- Active power P is over **Pickup value** = 0.05,
- P > **PQ ratio** 5.6% x Q

The function can be enabled or disabled through corresponding menu.

The selection of **pickup value**, **pickup delay** as well as **drop-out ratio** and **drop-out delay** helps the user to fine tune the protection according to the project specifications.

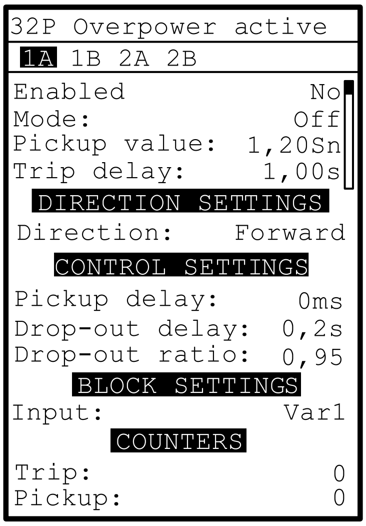


Figure 40: Overpower active settings as seen on HMI.

Direction condition determine direction of protection:

- Direction **forward** works on positive power
- Direction **reverse** works on negative power

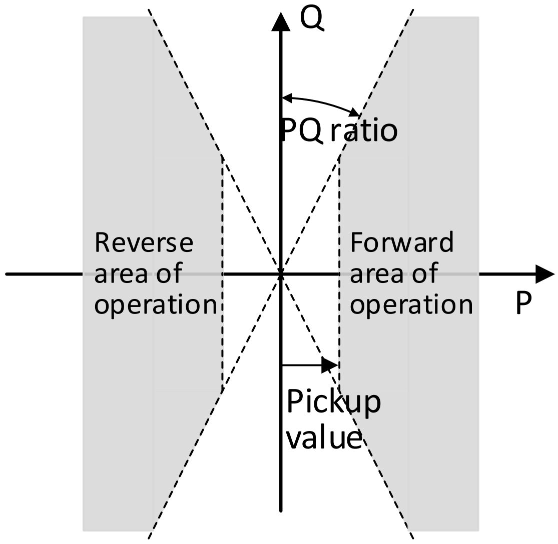


Figure 41: Zone of operation.

2.5.1.2 Delays

Function includes following delays explained in chapter [2.1]:

- Pickup delay
- Trip delay
- Drop-out delay

2.5.1.3 Block settings

Pickup of any instance separately of protection can be individually blocked by:

- Any user defined signal [2.6.7].

2.5.1.4 Setting parameters

Parameter	Group	Range	Description
Enabled		**No** Yes	Enabling protection function.
Operate mode	X	Off **Definite time**	Enabling protection function separately for each group level.
Pickup value	X	0,01 … -**1,10** … - 2,00 x Sn	Value at which fault conditions are considered.
Trip delay	X	0,00 … **0,50** … 300,00 s	Delay of trip signal
Direction		**Forward** … Reverse	Direction of active power.
Pickup delay		0,00 … **0** … 1000 ms	Time stabilization of fault detection. As a filter of short disturbances on measuring circuits. Time before protection starts.
Drop-out delay		0,00 … **0,20** … 60,00 s	Time stabilization of pickup signal. Time when the monitored value is outside the operating range, but the protection does not stop yet.
Drop-out ratio		0,80 … **0,95** … 0,99 Sp	Drop-out value below which the protection drops, relative on Pickup value.
Input (Block settings)		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.

Table 34: Overpower active protection function parameters.

2.5.1.5 Counters

Name	Description
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.

2.5.2 Overpower reactive protection – ANSI code 32Q

This function protect against excessive power consumption or generation of reactive power. It is also alternative for underexcitation protection of synchronous motors and generators and must prevent when synchronous generators, because of consuming more reactive power following field loss want to run like asynchronous generators. Otherwise that can lead in material damage.

2.5.2.1 Functionality

Overpower reactive protection is a function, used as time delayed protection. This module is measuring power flow in the system and triggers Pickup in following cases:

- Reactive power Q is over **Pickup value** = 0.05,
- Q > **PQ ratio** 5.6% x P

The function can be enabled or disabled through corresponding menu.

The selection of **pickup value**, **pickup delay** as well as **drop-out ratio** and **drop-out delay** helps the user to fine tune the protection according to the project specifications.

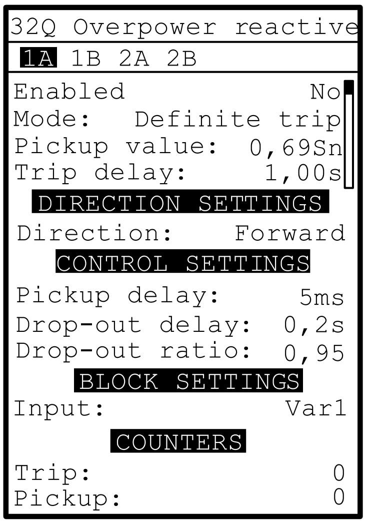


Figure 42: Overpower reactive settings as seen on HMI.

Direction condition determine direction of protection:

- Direction **forward** works on positive power
- Direction **reverse** works on negative power

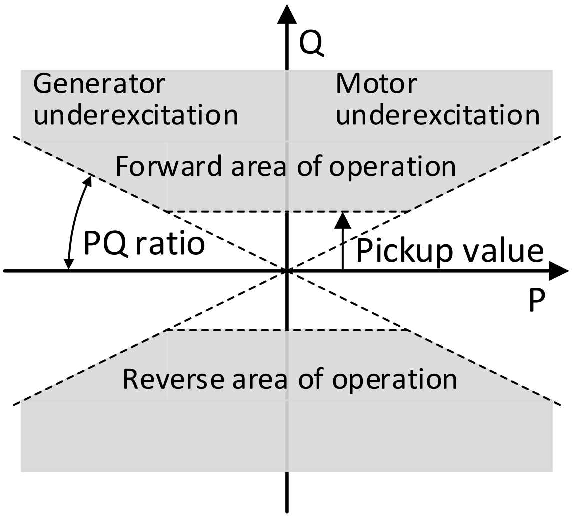


Figure 43: Operating zone.

2.5.2.2 Delays

Function includes following delays explained in chapter [2.1]:

- Pickup delay
- Trip delay
- Drop-out delay

2.5.2.3 Block settings

Pickup of any instance separately of protection can be individually blocked by:

- Any user defined signal [2.6.7]

Figure 44: Operating zone.

2.5.2.4 Setting parameters

Parameter	Group	Range	Description
Enabled		**No** Yes	Enabling protection function.
Operate mode	X	Off **Definite time**	Enabling protection function separately for each group level.
Pickup value	X	0,01 … -**0,70** … - 2,00 x Sn	Value at which fault conditions are considered.
Trip delay	X	0,00 … **0,50** … 300,00 s	Delay of trip signal
Direction		**Forward** … Reverse	Direction of active power.
Pickup delay		0,00 … **0** … 1000 ms	Time stabilization of fault detection. As a filter of short disturbances on measuring circuits. Time before protection starts.
Drop-out delay		0,00 … **0,20** … 60,00 s	Time stabilization of pickup signal. Time when the monitored value is outside the operating range, but the protection does not stop yet.
Drop-out ratio		0,80 … **0,95** … 0,99 Pp	Drop-out value below which the protection drops, relative on Pickup value.
Input (Block settings)		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.

Table 35: Overpower reactive protection function parameters.

2.5.2.5 Counters

Name	Description
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.

2.5.3 Underpower active protection – ANSI code 37P

This function protect against generators and motors overloads.

2.5.3.1 Functionality

Underpower active protection is a function, used as time delayed protection. This module is measuring active power in the system and triggers Pickup in following case:

- Active power P is under **Pickup value** = 0.05.

The function can be enabled or disabled through corresponding menu.

The selection of **pickup value**, **pickup delay** as well as **drop-out ratio** and **drop-out delay** helps the user to fine tune the protection according to the project specifications.

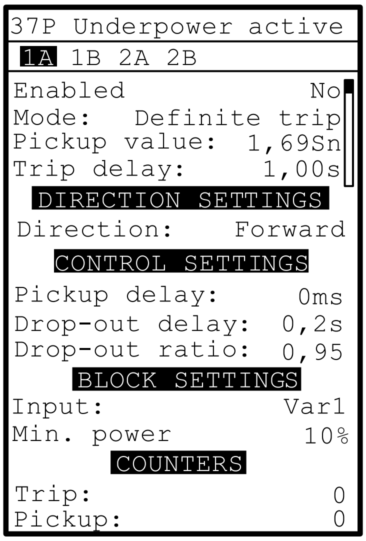


Figure 45: Underpower active settings as seen on HMI.

Direction condition determine direction of protection:

- Direction **forward** works on positive power
- Direction **reverse** works on negative power

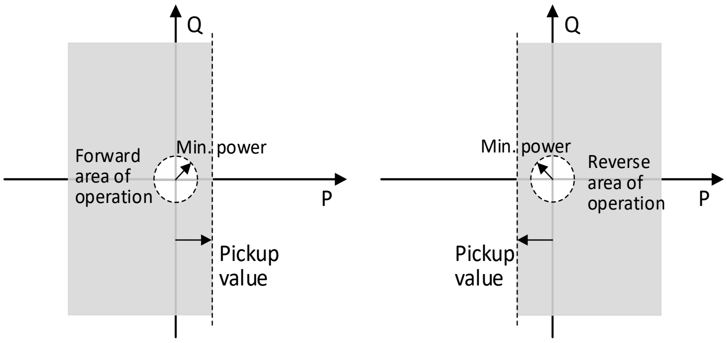


Figure 46: Operating zone.

2.5.3.2 Delays

Function includes following delays explained in chapter [2.1]:

- Pickup delay
- Trip delay
- Drop-out delay

2.5.3.3 Block settings

Pickup of any instance separately of protection can be individually blocked by:

- Any user defined signal [2.6.7]
- Minimal value of apparent power

2.5.3.4 Setting parameters

Parameter	Group	Range	Description
Enabled		**No** Yes	Enabling protection function.
Operate mode	X	Off **Definite time**	Enabling protection function separately for each group level.
Pickup value	X	0,01 … **-1,10** … - 2,00 x Sn	Value at which fault conditions are considered.
Trip delay	X	0,00 … **0,50** … 300,00 s	Delay of trip signal
Direction		**Forward** … Reverse	Direction of active power.
Pickup delay		0,00 … **0** … 1000 ms	Time stabilization of fault detection. As a filter of short disturbances on measuring circuits. Time before protection starts.
Drop-out delay		0,00 … **0,20** … 60,00 s	Time stabilization of pickup signal. Time when the monitored value is outside the operating range, but the protection does not stop yet.
Drop-out ratio		0,80 … **0,95** … 0,99 Sp	Drop-out value below which the protection drops, relative on Pickup value.
Input (Block settings)		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.
Min Power		0 … **10** …40 [%] x Sp	Value of apparent power below which the protection is blocked.

Table 36: Underpower active protection function parameters.

2.5.3.5 Counters

Name	Description
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.

2.5.4 Thermal overload protection – ANSI code 49T

This protection is designed to protect power lines, power cables and passive cooling transformers against thermal overload. The function estimates temperature of the object according to measured phase currents.

2.5.4.1 Functionality

The algorithm calculates the relative temperature of protected device based on current measurement. The temperature is calculated for each phase separately and only highest current is displayed. The monitored value for protection is the highest calculated temperature.

When the alarm or trip temperature value is reached, the appropriate alarm or trip temperature warning signal is stated. The **alarm** and **trip temperature** value parameter can be set in per cent of machine heating. In order to make the calculation of time to trip possible, the **heating time** constant must be set.

The **k-factor** of individual machine is similar to service factor and is maximal allowed permanent current of the object. **K-factor** is determined by materials used, construction properties and it is defined according to the environment where the protected device is used.

2.5.4.2 High temperature mode

Start on trip
High temperature signal starts with trip signal and ends when temperature drops below high temperature value.

Start on high temperature
Signal high temperature starts as the high temperature value is reached and ends when temperature drops below high temperature value.

The closing of circuit breaker is inhibited until the temperature fall below the set **High temperature** value.

2.5.4.2.1 Heating and cooling equation

$$\frac{d\Theta}{dt} + \frac{1}{\tau} \cdot \Theta = \frac{\Theta_I}{\tau}$$

Equation 5: Heating and cooling differential equation.

$$\Theta_I = \left(\frac{I}{I_n} \right)^2$$

Equation 6: Temperature which would be reached at specific current.

$$\Theta = \Theta_I + (\Theta_0 - \Theta_I) \cdot e^{-\frac{t}{\tau}}$$

Equation 7: temperature which would be reached at specific current I in specific time t, started from Θ_0 temperature.

I – Present machine current.
Θ_I – final temperature that would be reached in infinite amount of time, maintaining constant current.
Θ_0 – Initial temperature.
Θ – Current temperature.
τ – Heating and cooling time constant.
t – time

When the circuit breaker disconnects the line because of thermal protection, the trip signal resets, otherwise the CBFP protection of the circuit breaker Switch module would operate.

2.5.4.3 Setting parameters

Parameter	Group	Range	Description
Enabled		No **Yes**	Enabling protection function.
Operation Mode	X	Off **On**	Enabling protection function separately for each group level.
k-factor	X	0,1 … **1,10** … 4,0 In	Maximal permanent thermal current allowed relative to the nominal current.
Alarm temperature value	X	45,0 … **90,0** … 99,0 %	Alarm limit, Θ_{alm}
High temperature value	X	45,0 … **95,0** … 99,0 %	Signal intendent to inhibit closing of breaking device.
Heating time constant		1,0 … **100,0** … 1000,0 min	Heating and cooling time constant, τ
High temperature mode		**Start on trip** Start on high temperature	
Pickup block		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.

Table 37: Thermal overload function parameters.

2.5.4.4 Counters

Name	Description
Temperature L1	Calculated machine temperature in phase L1, 100% = 1.000 pieces.
Temperature L2	Calculated machine temperature in phase L2, 100% = 1.000 pieces.
Temperature L3	Calculated machine temperature in phase L3, 100% = 1.000 pieces.
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.
Temperature	Calculated machine temperature Θ, biggest phase, 100% = 1.000 pieces.

Table 38: Counters presented in thermal overload function.

2.5.5 Machine Thermal Overload Protection - ANSI code 49M

Machine thermal overload protection (MTOP) is designed to protect machines with different heating and cooling constant against thermal overload. The function estimates temperature of the object according to measured phase currents its characteristics and ambient temperature.

2.5.5.1 Functionality

The algorithm calculates the relative temperature of protected device based on current measurement. The temperature is calculated for each phase separately and only highest current is displayed. The monitored value for protection is the highest calculated temperature.

When the alarm or trip temperature value is reached, the appropriate alarm or trip temperature warning signal is stated. The **alarm** and **trip temperature** value parameter can be set in percentage of machine heating. In order to make the calculation of time to trip possible, the **heating** and **cooling time constant** parameters must be set. Information about the heating constant for particular machine can be found in device tables or acquired from the manufacturer of the protected equipment. For passive cooling machines, the **cooling constant** is equal to the **heating constant**.

The protection detects the overload, when the maximal allowed permanent thermal current I_{t_max}, which causes the start of overheating of protected element, is exceeded. The **service factor** has to be set. The constant is defined as **service factor** = I_{t_max} / I_{n_obj}, where the I_{t_max} is maximal thermal current and the I_{n_obj} is nominal current of the protected object.

The **service factor** is maximal allowed permanent current of the machine. It is determined by materials used, construction properties and it is defined according to the environment where the protected device is used. Usually it is available from property tables supplied by the manufacturer.

Trip signal is stated when current in any phase exceeds I_{t_max} and temperature exceeds set **trip temperature**.

Hot state indicates the level above which it is considered that machine is now at nominal operating temperature if set correctly.

When the circuit breaker disconnects the line because of thermal protection, the trip signal resets, otherwise the CBFP protection of the circuit breaker Switch module would operate.

CAUTION

The closing of circuit breaker is inhibited until the temperature fall below the set **High temperature** value.

Current over temperature values are written to Temperature Lx outputs separately for each phase. The value is written as a relative value, where 100 % represents that the maximal allowed over temperature is reached. By resetting values on outputs, their start values can be set by user interface. At the device start-up, this outputs are reset to zero, which represents no over temperature.

Equations below are used in protection algorithm.

2.5.5.1.1 Heating and cooling equation

$$\frac{d\Theta}{dt} + \frac{1}{\tau} \cdot \Theta = \frac{\Theta_I}{\tau}$$

Equation 8: Heating and cooling differential equation.

$$\Theta_I = \left(\frac{I}{I_n}\right)^2$$

Equation 9: Temperature which would be reached at specific current.

$$\Theta = \Theta_I + (\Theta_0 - \Theta_I) \cdot e^{-\frac{t}{\tau}}$$

Equation 10: temperature which would be reached at specific current I in specific time t, started from Θ_0 temperature.

I – Present machine current.
Θ_I – final temperature that would be reached in infinite amount of time, maintaining constant current.
Θ_0 – Initial temperature.
Θ – Current temperature.
τ – Heating or cooling time constant.
t - time

2.5.5.1.2 Hot state temperature detection of the machine

It is considered that the machine is in hot state when calculated temperature exceeds **Hot state level**.

$$\Theta_H = K_H \cdot (1 - HCR)$$

Equation 11 Hot state level equation.

K_H – **Hot state level**
Θ_H – Temperature level above which is considered hot state of the machine.
HCR – **Hot to cold ratio**

2.5.5.1.3 Start of overheated machine Inhibition

In certain cases when start of the machine would cause the temperature to exceed insulation class of the machine the high temperature signal is stated. The estimation is based on equation:

$$\Theta_{high} = \Theta_{start} + \left(\Theta_{trip} - \Theta_{start}\right) \cdot e^{+\frac{t_{start}}{\tau_{run}}}$$

Equation 12 High temperature equation.

t_{start} – correction factor.
I_{start} – positive sequence.
Θ_{start} – Thermal class of machine.
Θ_{high} – Thermal class of machine.
Θ_{trip} – Thermal class of machine.

2.5.5.1.4 Negative sequence component Influence

Additional negative sequence current can occur in rotating machines with coiled rotors. Difference in calculated heat can be taken into account by using the **Current unbalance factor**.

$$k_N = 1 + K \cdot \left(\frac{I_2}{I_1}\right)^2$$

Equation 13 Current unbalance current influence.

k_N – correction factor.
I_1 – positive sequence current.
I_2 – Negative sequence current.
K - **Current unbalance factor**.

Recommended parameter settings of **Current unbalance factor**:

$$K = 175 / I_{LRC}^2$$

Equation 14 Typical current unbalance factor.

$$K = 230 / I_{LRC}^2$$

Equation 15 Conservative current unbalance factor.

I_{LRC} – Locked rotor current of rotating machine.

2.5.5.1.5 Accounting for ambient temperature

The function can take into account the ambient temperature. Temperature can be obtained from external sensor or most common maximum operating temperature of machine 40 °C is used.

$$k_{amb} = \frac{\Theta_{\max} - \Theta_{amb\_\max}}{\Theta_{\max} - \Theta_{amb}}$$

Equation 16 Calculation of ambient temperature influence.

$$I_{eq}^2 = k_{amb} \cdot k_N \cdot I^2$$

Equation 17 Equivalent current calculation.

k_{amb} – Correction factor.
Θ_{max} – Thermal class of machine.
Θ_{amb_max} – Maximum ambient themperature.
Θ_{amb_max} – Current ambient themperature.
I_{eq} – Equivalent machine current.

2.5.5.1.6 Time to trip and time to drop out calculation equation

Time to trip and time to drop out calculation equation where there the longest time of separate phases is presented in time to drop out and shortest time is presented in time to trip.

$$t = \tau \cdot \ln\left(\frac{\Theta_I - \Theta_0}{\Theta_I - \Theta_2}\right)$$

Equation 18: Time to Trip.

Θ_2 – final temperature.
t – time in seconds.

2.5.5.2 Setting parameters

Parameter	Group	Range	Description
Enabled		No **Yes**	Enabling protection function.
Operate mode	X	Off **On**	Enabling protection function separately for each group level.
Alarm temperature value	X	10,0 … **80,0** … 200,0 %	Alarm limit, Θ_{alm}
Trip temperature value	X	**100,0** … 200,0 %	Critical temperature limit..
Running time constant		0,1 … **15,0** … 1000,0 min	Heating time constant τ.
Stopped time constant		0,1 … **30,0** … 1000,0 min	Cooling time constant τ.
Start-up time		0,1 … **10,0** … 1000,0 s	Full load start up time of the machine.
Start-up current		0,50 … **6,00** … 20,00 I_{n_obj}	Full load start up current of the machine.
Service factor		0,70 … **1,00** … 4,00 I_{n_obj}	Maximal permanent thermal current allowed relative to the nominal current.
Hot to cold time ratio		0,00 … **0,80** … 1,00	Allowed ratio between hot and cold start-up time.
Hot state level		0,00 … **50** … 100 %	Temperature above which is considered that machine is in hot state.
Current unbalance factor		0,00 … **4,50** … 9,00	Influence of negative sequence component to heating of machine.
Insulation max temperature		70 … **130** … 250 °C	Machine insulation class interpreted in maximal insulation temperature
Pickup block		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.
Ambient source		**None** Probe 8	Usage of external ambient source
Ambient constant		20 … **40** … 70	Constant of room temperature impact if Ambient source is set **None**
Maximal temperature		20 … **40** … 70	Maximal temperature for machine to work.

Table 39: Thermal overload function parameters.

2.5.5.3 Counters

Name	Description
Temperature L1	Calculated machine temperature in phase L1, 100% = 1.000 pieces.
Temperature L2	Calculated machine temperature in phase L2, 100% = 1.000 pieces.
Temperature L3	Calculated machine temperature in phase L3, 100% = 1.000 pieces.
Temperature	Calculated machine temperature Θ, biggest phase, 100% = 1.000 pieces.
Overload	Total consecutive number of Overload signals.
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.

Table 40: Counters presented in thermal overload function.

2.5.6 Temperature monitoring - ANSI code 38/49T

Temperature monitoring is associated with additional external module including up to 8 resistance temperature detectors (RTDs). Correct external module connection is required for protection to perform as specified.

2.5.6.1 Functionality

Temperature monitoring is a function, used as temperature dependent protection. Alarm signal is stated when measured temperature exceeds the selected alarm threshold. Trip signal of function is set when measured temperature exceeds the selected trip threshold. For each RTD there are separate function settings.

The function operation can be enabled or disabled individually for each RTD.

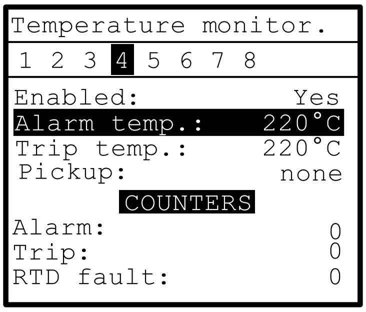


Figure 2.47 Temperature monitor setting as seen on HMI.

2.5.6.2 Measurement

Measurement is performed using specific algorithms to interpret measurement of probes resistance. RTDs are using 3-wire connection type to temperature sensors.

2.5.6.3 Delay

To ensure correct operation of function an individual measurement needs to exceed desired threshold of alarm or trip at least twice in a row.

2.5.6.4 Block of the protection

In addition the individual protection trip exhibits pulse type if connected to trip relay [4.2.3.5.7], relay mapping section], to ensure correct CBFP [2.6.1.10] functionality.

2.5.6.5 RTD fault

RTD fault signal is provided to ensure the correct operation of external module as well as its sensors. If the connection to one of the sensors is terminated or short-circuited, the RTD fault signal is activated. The signal remains active as long as the fault persists. The fault can only occur if a protection of a malfunction sensor is active.

In case a power or communication to sensor module is interrupted RTD fault signal is present for each of active temperature sensors.

2.5.6.6 Setting parameters

Parameter	Range	Description
Enabled	No **Yes**	Enabling protection function.
Alarm temperature	-35 … **220** °C	Temperature limit that triggers alarm signal
Trip temperature	-35 … **220** °C	Temperature limit that triggers trip signal
Pickup block	**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.

Table 41 Temperature monitoring parameters selection.

2.5.6.7 Counters

Name	Description
Alarm	Total consecutive number of alarm signals presented for each sensor separately.
Trip	Consecutive number of trip signals presented for each sensor separately.
RTD fault	Fault counter of any active probe.

Table 42: Counters presented in temperature monitoring function.

2.5.7 Locked rotor protection, excessive starting time - ANSI code 48/51LR/14

Failure of a rotating machine to accelerate when its stator is energized can be caused by several types of abnormal conditions, including mechanical failure of the machine or load bearings, low supply voltage, or an open circuit in one phase of a three-phase voltage supply. When a rotating machine stator winding is energized with the rotor stationary, the machine performs like a transformer with resistance-loaded secondary winding. Stator winding currents may typically range from three to seven or more times the rated full-load value, depending on the machine design and supply system impedance.

Although the rotating machine starting current does drop off near full speed, this effect is normally neglected, providing some safety margin from relay operation during rotor acceleration.

2.5.7.1 Functionality

Considering the current amplitude on start-up is at maximum most of the time, the algorithm takes into account that the start-up current is constant and is equal to maximum start-up current. Therefore the allowed start-up time is constant. This function distinguishes between different rotating machine conditions, regarding current and digital input states. Trip of the function is considered as soon as any stated condition is detected. When rotating machine reaches stopped state, all signals are set to zero and all timers are reset.

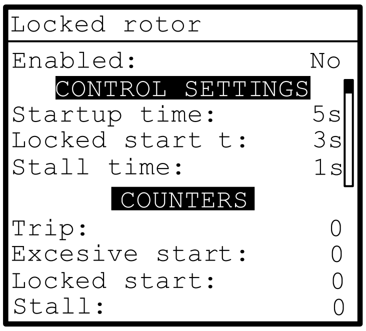


Figure 2.48 Locked rotor function parameters as seen on HMI.

Table 43 Locked rotor, excessive start time on HMI.

2.5.7.1.1 Excessive start – ANSI 48

Condition is considered if starting [2.6.6.3.2] signal is set for longer period than **Start-up time** of the machine, while rotation [2.5.7.3] signal is present.

2.5.7.1.2 Locked start – ANSI 51LR

Condition is considered if starting signal is set for longer period than **Locked start time** of the machine, while there is no rotation signal present.

2.5.7.1.3 Stall – ANSI 14

Condition is considered if stalling [2.6.6.3.6] signal is set for longer period than **Stall time** of the machine.

Rotation signal is usually connected to an external digital input, which is connected to a rotating machine rotation detector.

2.5.7.2 Setting parameters

Parameter	Range	Description
Enabled	No **Yes**	Enabling protection function.
Start-up time	0,5 … **5,0** … 300,0 s	Maximum machine start time with rotor rotation detection.
Locked start time	0,1 … **3,0** … 300,0 s	Maximum machine start time with blocked rotor detection.
Stall time	0,1 … **1,0** … 300,0 s	Maximum machine stall time during normal operation.

Table 44: Locked rotor function parameters.

2.5.7.3 Associated digital inputs

Digital input	Description
Rotation	External indication about machine rotation.

Table 45 Digital inputs associated with the function.

2.5.7.4 Counters

Name	Description
Trip	Consecutive number of trip signals.
Excessive start	Consecutive number of excessive start signals.
Locked start	Consecutive number of locked start signals.
Stall	Consecutive number of stall signals.

Table 46: Counters presented in locked rotor protection.

2.5.8 Starts per hour - ANSI code 66

Protection Starts per hour is meant to prevent too frequent starts of the rotating machine in a given time window.

2.5.8.1 Functionality

Rotating machine manufacturers usually define allowed number of starts within given time period by one of two criteria:

- How many starts are allowed within one hour
- How many consecutive starts are allowed according to current thermal state of the machine

```
Starts per hour
Enabled:             No
Between starts:     60s
    ALLOWED STARTS
Enabled:             No
Allowed starts:       5
Starts period:    60min
```

Figure2.41:Starts per hour function parameters as seen on HMI.

This protection can be set up by either of those criteria, or even both of them. User can also define minimum delay between starts. When any of given criteria is reached the protection inhibits starting of the machine by blocking the circuit breaker closing command. Thermal state of the machine is determined by Thermal overload protection [2.5.4], which needs to be enabled for proper thermal detection of the machine.

Parameter	Range	Description
Enabled	No **Yes**	Enabling protection function.
Delay between starts	0 … **5** … 5400 s	Minimum required time between two machine starts.
Enable allowed starts	No **Yes**	Yes – Activated allowed starts functionality. No – Deactivated allowed starts functionality.
Allowed starts	1 … **10** … 60	Number of allowed machine starts inside Starts period.
Starts period	1 … **60** … 360 min	Machine starts period.
Enable consecutive starts	No **Yes**	Yes – Activated consecutive starts functionality. No – Deactivated Consecutive starts functionality.
Consecutive starts period	1 … **10** … 90 min	Consecutive starts period.
Allowed cold starts	1 … **2** … 5	Number of allowed consecutive cold starts.
Allowed hot starts	**1** … 5	Number of allowed consecutive hot starts.
Block settings 1	**None** Variable 1 Variable 2 Variable 3 …	Input of blocking Inhibit signal of engine start.

Table 47 Starts per hour function parameters.

2.5.8.2 Counters

Name	Description
Inhibit time	Time of Inhibit signal dropout in real time, in seconds.
Current starts	Current number of starts remaining, cold starts if the cold state is active and hot starts if hot state is currently present.
Consecutive cold starts	Current number of lapsed cold starts in certain short period of time.
Consecutive hot starts	Current number of lapsed hot starts in certain short period of time.
Inhibit counter	Consecutive number of inhibit signals.
Starts counter	Consecutive number of start signals.

Table 48: Counters presented in starts per hour function.

2.5.9 Buchholz relay protection – ANSI code 63

2.5.9.1 Description

Buchholz relay protection is external protection that mechanically controls oil level and oil flow in certain power transformers. Protection consists of two instances one dedicated to Leak and pressure switch and second to Float switch. Float switch indicates slow air build up in Buchholz cylinder, usually indicating minor discharge fault in transformer. While Leak and pressure switch detects forceful oil flow usually indicating major short-circuit related fault in transformer.

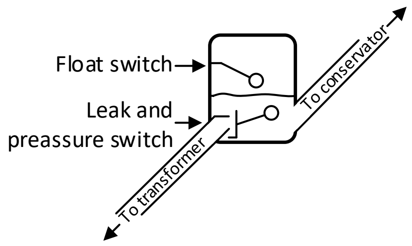


Figure 2.49 Schematic of Buchholz relay operation.

It is recommended that pressure switch immediately trips CB while float switch indicates fault that needs to be treated as soon as possible to prevent further damage to transformer.

2.5.9.1.1 Setting parameters

Parameter	Group	Range	Description
Enabled		No **Yes**	Enabling protection function.
Operate mode	X	Off **On**	Enabling protection function separately for each group level.
Trip delay	X	0,00 … **1,00** … 300,00 s	Delay of trip signal.
Pickup delay		0 … **5** … 1000 ms	Time stabilization of fault detection. As a filter of short disturbances on measuring circuits. Time before protection starts.
Drop-out delay		0,00 … **0,20** … 60,00 s	Time stabilization of pickup signal. Time when the monitored value is outside the operating range, but the protection does not stop yet.
Pickup block		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.

Table 49 Buchholz function parameters.

2.5.9.1.2 Associated digital inputs

Digital input	Description
Buchholz 1	External trigger of Buchholz relay 1 protection.
Buchholz 2	External trigger of Buchholz relay 2 protection.

Table 50 Digital inputs associated with the protection.

2.5.9.1.3 Counters

Name	Description
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.

Table 51: Counters presented in buchholz protection.

2.5.10 Thermal switch protection – ANSI code 26

2.5.10.1 Description

Thermal switch protection is an external protection device, mounted on the machine. Thermal switch usually consists of two binary signals, by which one is alarm temperature signal and another is trip temperature signal. Protection consists of two instances first dedicated to external trip signal and second to external alarm signal.

It is recommended that external trip temperature signal immediately trips CB while external alarm temperature signal acts as a warning that indicates overheating of the machine.

2.5.10.2 Setting parameters

Parameter	Group	Range	Description
Enabled		No **Yes**	Enabling protection function.
Operate mode	X	Off **On**	Enabling protection function separately for each group level.
Trip delay	X	0,00 … **1,00** … 300,00 s	Delay of trip signal.
Pickup delay		0 … **5** … 1000 ms	Time stabilization of fault detection. As a filter of short disturbances on measuring circuits. Time before protection starts.
Drop-out delay		0,00 … **0,20** … 60,00 s	Time stabilization of pickup signal. Time when the monitored value is outside the operating range, but the protection does not stop yet.
Pickup block		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.

Table 52 Thermal switch function parameters.

2.5.10.3 Associated digital inputs

Digital input	Description
Thermal switch 1	External trigger of Thermal switch 1 protection.
Thermal switch 2	External trigger of Thermal switch 2 protection.

Table 53 Digital inputs associated with the function.

2.5.10.4 Counters

Name	Description
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.

Table 54: Counters presented in thermal switch protection.

2.5.11 External trip – EXT-T

External trip function is one of the basics functions of the device. The function is triggered on external signal.

2.5.11.1 Functionality

By using External trip function it is possible to use a custom binary signal to trigger digital input. A function than set pickup and trip signal according to user defined settings. By using protection trip signal it is possible to trigger a trip of circuit breaker or to associate it to a desired output relay or LED of protective device.

2.5.11.2 Measurements

The function pickup is triggered by dedicated digital input signal.

2.5.11.3 Delays

Function includes following delays explained in chapter [2.1]:

- Pickup delay
- Trip delay
- Drop-out delay

2.5.11.4 Block settings

Pickup of any instance separately of protection can be individually blocked by any user defined signal [2.6.7.].

2.5.11.5 Setting parameters

Parameter	Group	Range	Description
Enabled		No **Yes**	Enabling protection function.
Operate mode	X	Off **On**	Enabling protection function separately for each group level.
Trip delay	X	0,00 … **1,00** … 300,00 s	Delay of trip signal.
Pickup delay		0 … **5** … 1000 ms	Time stabilization of fault detection. As a filter of short disturbances on measuring circuits. Time before protection starts.
Drop-out delay		0,00 … **0,20** … 60,00 s	Time stabilization of pickup signal. Time when the monitored value is outside the operating range, but the protection does not stop yet.
Pickup block		**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.

Table 55 External trip function parameters.

2.5.11.6 Associated digital inputs

Digital input	Description
External trigger 1	External trigger of External trip 1 protection.
External trigger 2	External trigger of External trip 2 protection.

Table 56 Selectable digital inputs of the function.

2.5.11.7 Counters

Name	Description
Pickup	Total consecutive number of pickup signals.
Trip	Consecutive number of trip signals.

2.6 Automation and diagnostic

FPC 400 can be used to control and monitor breaking devices.

2.6.1 Circuit breaker control and monitoring - ANSI 94/69 with integrated circuit breaker failure - ANSI 50BF and lockout relay – ANSI 86/94

2.6.1.1 Description

FPC 400 is used to control breaking devices equipped with different types of closing and tripping contacts. Therefore its output relays can be configured for non-latched, latched or pulse operation to match any type of breaking device.

2.6.1.2 Integrated circuit breaker

This function controls the breaking device. It works in conjunction with automatic re-closer and hierarchical interlocking with bypass ability. Detection of breaker failure when trip command is sent is included.

It performs the following functions:

Trip by

- protection configured to trip the circuit breaker
- remote control by communication (blocked if remote mode is off)
- external protection
- open command by HMI

Close by

- automatic re-closer
- remote control by communication (blocked if remote mode is off)
- closing command by HMI

Block by

- trip circuit supervision (TCS)
- SF6 fault
- interlocking

Different internal logic functions are used to prevent sending of open or close commands to circuit breaker. They are called interlocking. FPC 400 can check following interlocking (Table 57) prior to command execution. Block diagram is presented on Figure 2.50

Interlock	Cause of blocking
Command already in execution	Command already in progress
Trip present	Trip still present
System	Incorrect mode (Local/Remote)
Bay	Open or Close blocked or allowed by external input
Status	Circuit breaker in fault or unknown position
Maximal number of operations	Maximal number of mechanical operations of switchgear element exceeded
I^2t	Contact worn out

Table 57: Interlocking description.

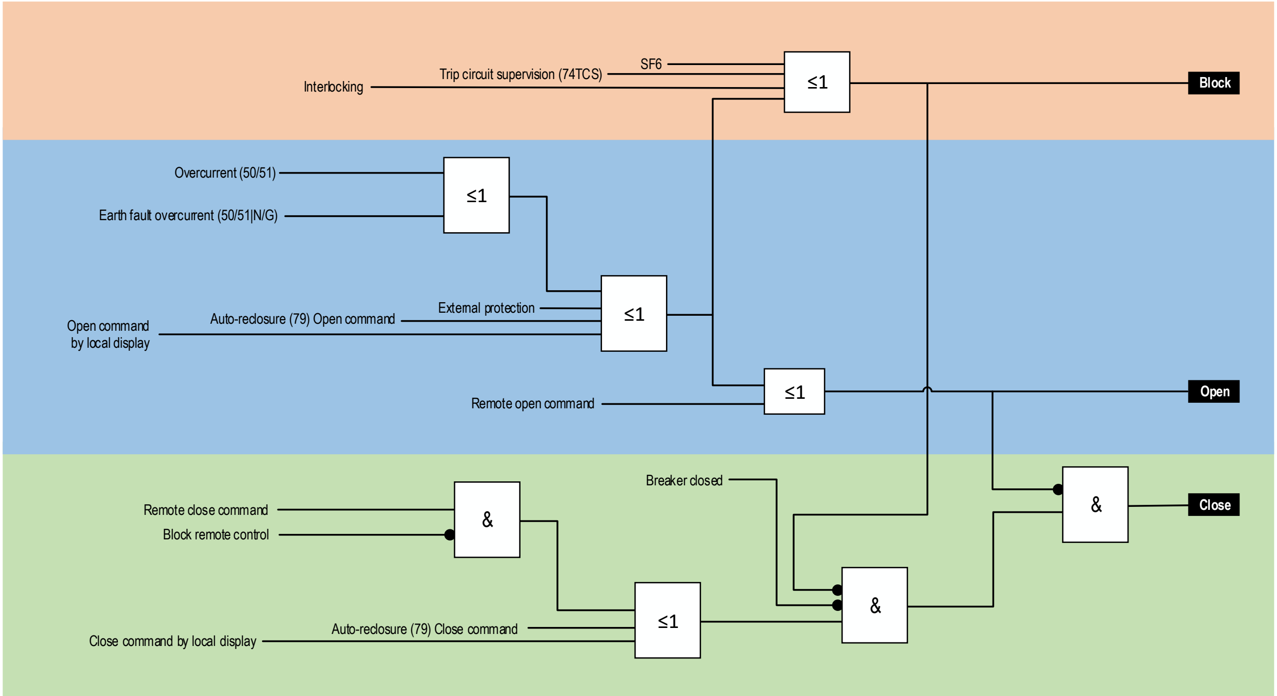


Figure 2.50 Blocking diagram.

2.6.1.3 Control settings

2.6.1.3.1 Command timeout

Time used for a device to wait for switchgear element to change state. If this time is exceeded and no return information was given, an error *Command failed* popup window will be displayed on HMI in addition an information can be accessed using the available communication protocol.

2.6.1.3.2 Operation time

Time measured from moment when device relay contacts initiate switchgear open command till moment when switchgear element primary contacts open. This information is vital calculation of cumulative breaking current of primary contacts [2.6.1.7]. The information is usually available in circuit breaker technical data.

2.6.1.4 Command objects

Command objects defines weather DI source of commands is considered as local command or remote command.

2.6.1.5 Interlocking system

Interlocking system serves as a switch allowing remote or local commands to be issued. Local commands are always allowed while remote command can be allowed by using parameter via HMI, MiQen software, Modbus table and DI.

2.6.1.6 Max trip open (MTO)

Max trip open is a cumulative counter of CB trips. Alarm and Block signal can be set after a certain number of trip signals dedicated to open CB has passed. If number present exceeds a Block set limit a circuit breaker MTO interlock will engage.

2.6.1.7 Cumulative breaking current I^2t

Function indicates the cumulative breaking current in square kilo amperes. Total sum number information of each phase is provided in appropriate diagnostic section [4.2.3.1.3]. Alarm and block signal can be set for certain amount of cumulative breaking current. If number present exceeds a **Block set** limit a circuit breaker I^2t interlock will engage.

Current calculation is performed every time a command open is executed or trip signal dedicated to open a CB is initiated. The current readout is performed at exact time of CB contact separation by taking into account a user definable parameter **CB operation time**.

2.6.1.7.1 Readout

Measurements are accessed via:

- HMI diagnostic [4.2.3.1.3],
- MiQen software,
- Communication link.

The value can be reset in counters section of CB.

2.6.1.8 Bay

Interlocking bay is intended to allow or block operation of CB by using DI signals. Bay restrictions influence manual and remote commands excluding trip signals registered for tripping CB.

2.6.1.8.1 Associated digital inputs

Digital input	Description
Open allow	Allowing executing of CB open command.
Open block	Inhibition of CB open command.
Close allow	Allowing executing of CB close command.
Close block	Inhibition of CB close command.

Table 58 Associated digital input signals.

2.6.1.9 Status

Interlocking status inhibit executing of the command if the CB is already in the same position as the command demands.

To use this function properly, it is necessary that CB position is known to the device.

2.6.1.10 Circuit breaker failure (CBFP)

This function is designed to detect when a breaker does not open when a trip is sent. User defined **delay** timer is started every time trip command is sent to trip relay [4.2.3.5.7, relay mapping section]. In case a fault condition is not cleared in that time, the CBFP open command is initiated.

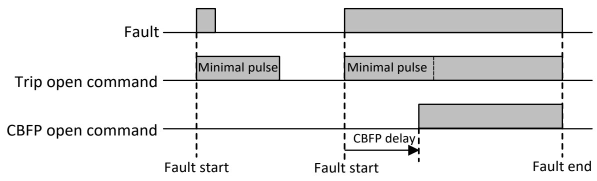


Figure 2.51 Example of CBFP operation.

2.6.1.11 CB Ready

CB ready is intended to indicate the ready status of circuit breaker. Multiple DI signals can be assigned to indicate ready status. This function does not prevent manual command operation to CB but it serves as the interlocking for AR function [2.6.4].

2.6.1.12 Lockout Relay ANSI 86/94

Lockout relay function if activated prevents closing a CB by any operation after it was tripped by a protection. If AR function [2.6.4] is active, the lockout will engage after a **definite trip block** signal is present.

Lockout can be reset only manually by using reset lockout function on HMI, located in Reset/clear menu [4.2.3.6].

2.6.1.13 Example of operation

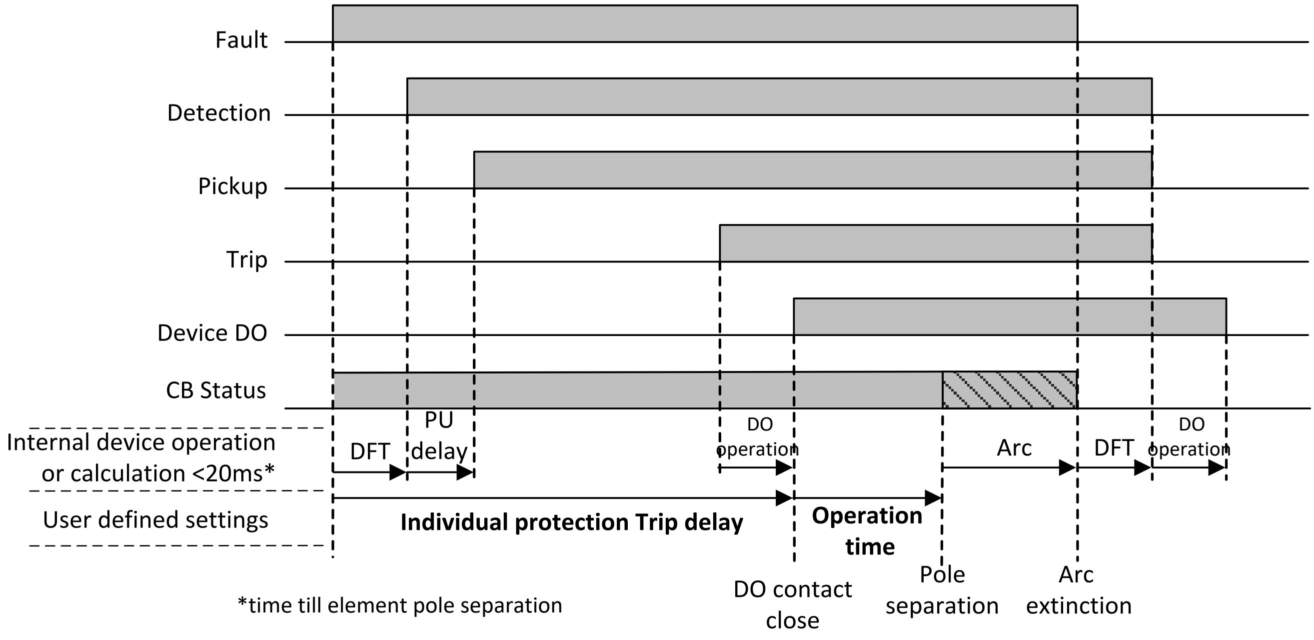


Figure 2.52 Circuit breaker operation.

2.6.1.14 Parameter table

Parameter	Range	Description
Control settings		
Command timeout	0,00 … **0,02** … 1000,00 s	Maximal time of command execution.
CB operation time	0 … **100** … 2000 ms	Time after open or trip command, till CB pole separation.
Command object DI		
Source	**Local** Remote	Defines the Di command local or remote attribute
Interlocking system		
Remote enabled	No **Yes**	Disable or enable remote or local operation of CB.
Interlocking MTO		
Enabled	No **Yes**	Enabling functionality of CB control.
Alarm set	1 … **1000** … 100.000	Consecutive number of trips which triggers an MTO alarm signal.
Block set	1 … **1010** … 100.000	Consecutive number of trips which triggers an MTO block signal.
Interlocking I^2t		
Enabled	**No** Yes	Enabling functionality of CB control.
Alarm set	1 … **24000** … 100.000	Consecutive number of trips which triggers an I^2t alarm signal.
Block set	1 … **30000** … 100.000	Consecutive number of trips which triggers an I^2t block signal.
Nominal breaking current of CB (HMI: CB I_n *break*)	0,00 … **0,60** … 50,00 kA	Defined nominal breaking current of CB breaker.
Maximal breaking current of CB (HMI: CB I_{max} break)	0,00 … **30,00** … 150,00 kA	Defined maximal breaking current of CB breaker.
Number of operations at nominal breaking current (HMI: Opr. At I_n)	1 … **30.000** … 100.000	Defined maximal number of operations of CB at nominal breaking current.
Number of operations at maximal breaking current (HMI: Opr. At I_{max})	1 … **50** … 100.000	Defined maximal number of operations of CB at maximal breaking current.
Interlocking Bay		
Enabled	**No** Yes	Enabling functionality of CB control.
CBFP		
Enabled	**No** Yes	Enabling functionality of CB control.
Delay	0,00 … **0,2** … 100,00 s	CBFP signal delay. Starts after any trip is present dedicated to open CB.
Ready		
Enabled	**No** Yes	Enabling functionality of CB control.
Ready value	0 **1**	State of binary value for which is considered CB is ready
Lockout		
Enabled	**No** Yes	Enabling functionality of CB control.

Table 59 Parameters of CB control function.

2.6.1.15 Counters

Name	Description
MTO	Consecutive number of MTO signals.
$I^2t\ L_1$	Total number of breaking current of CB in phase L_1
$I^2t\ L_2$	Total number of breaking current of CB in phase L_1
$I^2t\ L_3$	Total number of breaking current of CB in phase L_1
CBFP	Consecutive number of CBFP signals.

Table 60 Counters presented CB control.

2.6.2 Trip circuit supervision - ANSI 74 - TCS

Trip circuit supervision function (TCS) is designed for surveillance of breaker control circuits.

2.6.2.1 Functionality

Function is executed autonomously by the device. Two digital galvanic isolated inputs are used. The result of Trip circuit supervision function is a signal that can be used to activate digital output. The signal can also be accessed using the communication protocol. The function itself has different operating modes each using its own connection scheme and alarm status trigger.

Mode	
Mode 1	Uses CB status for TCS function.
Mode 2	Uses CB status plus one additional digital input.
Mode 3	TCS using external resistor.
Mode 4	TCS without using external resistor.

Table 61: Basic description of TCS module functionalities.

2.6.2.2 Mode 1

Mode 1 is considered basic TCS operation. TCS state is valid if exactly one of the Input TCS 1 or TCS 2 has value 1. Invalid states are 00 and 11. For each of invalid states a delay is set. After corresponding delay elapses the *TCS wrong position* signal is stated.

CB closed	CB open	Alarm
0	0	After the Delay00 time elapses.
0	1	Off.
1	0	Off.
1	1	After the Delay00 time elapses.

Table 62: TCS function response according to inputs using Mode 1 setting.

The benefit of using two digital inputs is that only two digital inputs are used to indicate status of circuit breaker and monitor the trip circuit. There is also no need of external resistor to be used. It has to be taken in to account that, when circuit breaker is in open position trip circuit supervision does not monitor line from trip contact to circuit breaker compartment. Scheme can be found on Figure 2.53

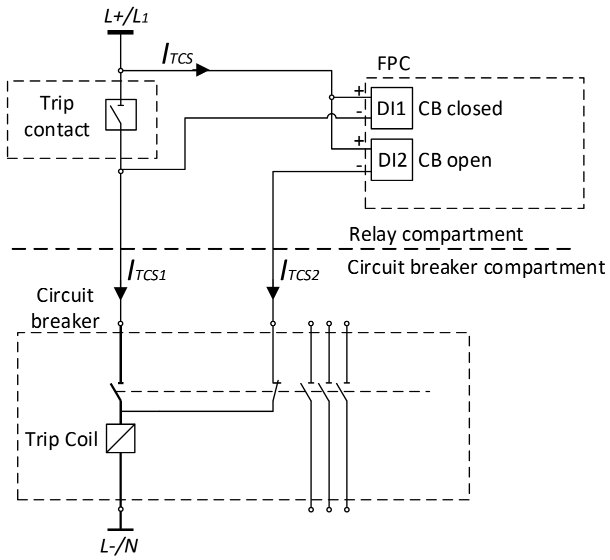


Figure 2.53 Trip circuit supervision with two digital inputs and function of monitoring circuit breaker position.

2.6.2.3 Mode 2

In order to supervise section between trip contact compartment and circuit breaker compartment when CB is in open position, a control diagram used in Mode 2 (Figure 2.54) can be used by adding two additional wires to circuit breaker compartment.

It should be noted that by using this scheme, both of trip circuit supervision digital inputs are connected in serial. The case occurs when circuit breaker is in open position and none of trip contacts is active. This situation will result in a valid position when both of the contacts are active.

CB open	TCS 1	Alarm
0	0	After the Delay00 time elapses.
0	1	Off.
1	0	Off.
1	1	Off.

Table 63: TCS function response according to inputs using Mode 2 setting.

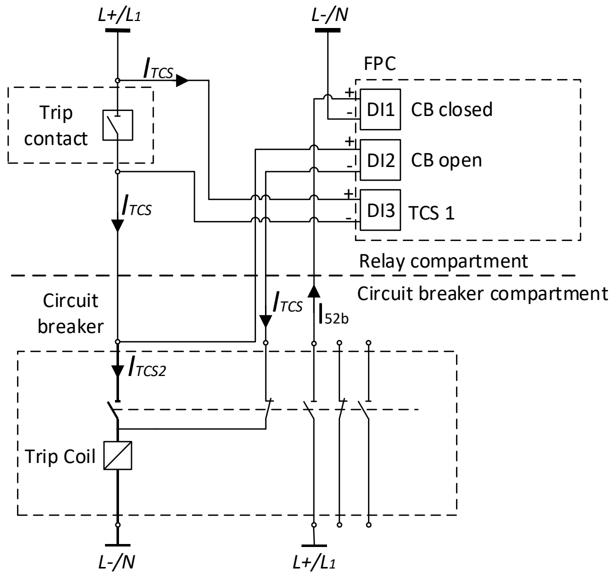


Figure 2.54 Trip circuit supervision with two digital inputs tailored for full line control of trip circuit in both positions of circuit breaker. The diagram also implies aditional digital input to be used as circuit breaker closed position.

Please note that a trip line inside the trip contact compartment (example can be seen on Figure 2.54) cannot be supervised using any of the schemes mentioned in this section.

2.6.2.4 Mode 3

Mode 3 is a single TCS input mode. The benefit of using one digital input is that no additional wiring from the device to the circuit breaker compartment is needed. It should be noted that by using this scheme an additional external resistor is needed. By using the resistor a trip circuit is supervised in closed and opened position of CB.

TCS 1	Alarm
0	After the Delay00 time elapses
1	Off

Table 64: TCS function response according to inputs using Mode 3 setting.

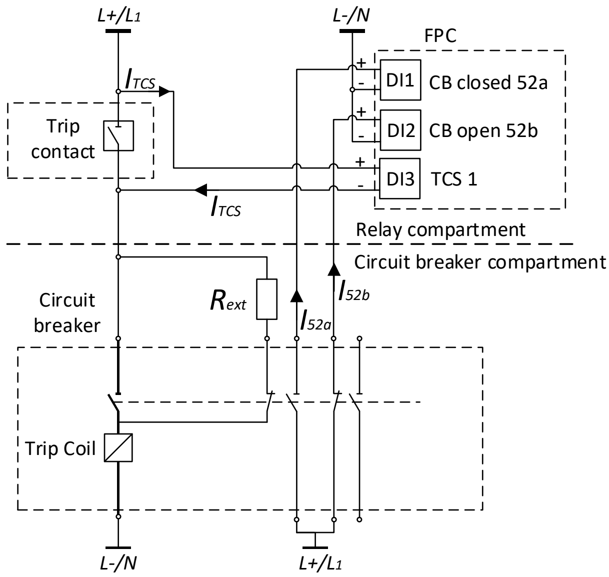


Figure 2.55 Trip circuit supervision using only one digital input and external resistor. The diagram also implies connection of circuit breaker status.

2.6.2.4.1 External resistor estimation

Estimated external resistor R_{ext} value is determined in the table below.

Type	$L+/L_1$ [V]	R_{ext} [kΩ]	P [W]
DC	24	1	≥3
DC	48	27	
DC	60	39	
DC	110	82	
DC	125	100	
DC	220	200	
AC	230	200	

Figure 2.56 External resistor values depending on voltage level.

2.6.2.5 Mode 4

Mode 4 is a single TCS input mode without using external resistor. A trip circuit is supervised only by circuit breaker being in closed position. The scheme of such case can be seen on Figure 2.57.

CB position	TCS 1	Alarm
Opened	0	Off.
Opened	1	Off.
Closed	0	After the Delay00 time elapses.
Closed	1	Off.
Unknown	0	After the Delay00 time elapses.
Unknown	1	Off.

Table 65: TCS function response according to inputs using Mode 4 setting.

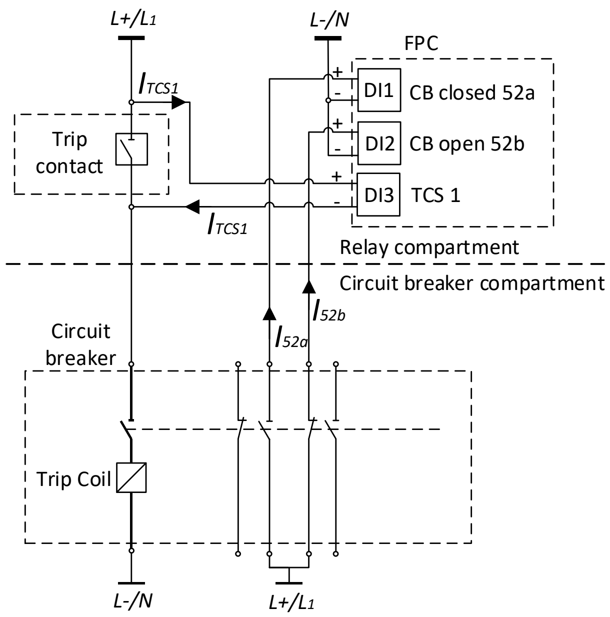


Figure 2.57 Trip circuit supervision using only one digital input without external resistor. The diagram also implies connection of circuit breaker status.

2.6.2.6 Setting parameters

Parameter	Range	Description
Enabled	No **Yes**	Enabling supervision function.
Delay00	0 … **1000** … 60000 ms	Delay of 00 state alarm.
Delay11	0 … **1000** … 10000 ms	Delay of 11 state alarm, inhibited if Allow position 11 is enabled.
Mode	**1. Mode 1** **I1OP+TC, I2CL+TC** 2. Mode 2 I1OP, I2CL+TC, I3TC 3. Mode 3 I1OP, I2CL, I3TC+ER 4. Mode 4 I1OP, I2CL, I3TC	Activation of TCS blocking when CB is in closed position.

Table 66: TCS function parameters.

2.6.2.7 Counters

Name	Description
TCS alarm	Total consecutive number of TCS alarm signals.

Table 67: Counter presented in TCS.

2.6.3 CT supervision function – ANSI 60

CT supervision function is designed to prevent nuisance tripping of relay in case of broken secondary current measuring circuits.

2.6.3.1 Functionality

Function is executed autonomously by the device. All three phase currents of a three phase system must be connected to the device [2.10.1] for this function to be operational. The function only operates on exactly one faulty secondary current.

2.6.3.1.1 Operation

In case of an exactly one faulty secondary current measuring circuit the function estimates that the remaining two currents measurements remains the part of a three phase system. If such case is detected the function triggers the *CT failure pickup* signal, and after a user defined **Delay** a *CT failure* signal.

The function is able to block certain current protection functions if parameter **Function** is set to block.

Blocked protection functions:

- 37 Undercurrent [2.2.5].
- 46 Negative sequence overcurrent [2.2.3].
- 50N/51N/67N Earth fault if using sum3I0 for direction or input measurement [2.2.2].
- 64REF Restricted earth fault [2.2.4].

2.6.3.2 Faulty measuring circuit detection

The function distinguish between open and closed line value for each of the phase currents the values can be adjusted using factor **Sensitivity**:

$$k = \frac{\boldsymbol{Sensitivity}}{100}$$

$$\begin{aligned} open\ line &= 0{,}02 \cdot k \cdot Un \\ closed\ line &= 0{,}10 \cdot k \cdot Un \end{aligned}$$

If exactly one line is below the open line value and two other phase currents are above the closed line value, while maintaining the angle φ within **Angle φ tolerance** + 120˚ value, than the function triggers *CT faulty pickup* signal. The Figure 2.58 visually represents the operation of the function.

The function condition is released when all three of the phases are 20 % above **Closed line** value.

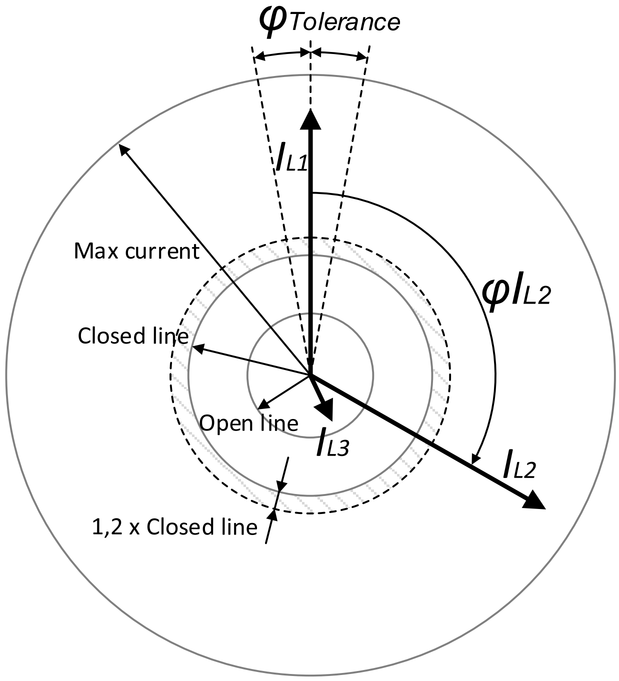


Figure 2.58 Diagram of function operation. Faulty I_{L3} measuring circuit is presented.

2.6.3.3 Blocking of the function

CT supervision function is immediately blocked if any of the relevant measured currents exceed **Max current** value or at least two of the phase currents drops below **Open line** value. In addition *CT faulty pickup* can be blocked by any user defined signal [2.6.7].

The blocking of function is reset when all three of the phases are 20 % above **Closed line** value.

2.6.3.4 Setting parameters

Parameter	Range	Description
Enabled	No **Yes**	Enabling supervision function.
Function	None **Block**	None – Do not block the protections. Block – Block the functions dependent on full three phase system also described in 2.6.3.1.1 Operation.
Delay	0 … **0,15** … 300 s	Time delay of the function operation after *CT faulty pickup* is triggered.
Sensitivity	50 … **100** … 300 %	Factor which increases or decreases open and closed line values.
Angle φ tolerance	5 … **10** … 30 °	Angle tolerance to the angle between two healthy phase currents.
Pickup block	**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.

Table 68: CT supervision function parameters.

2.6.3.5 Counters

Name	Description
CT faulty pickup	Total consecutive number of *CT faulty pickup* signals.
CT faulty	Total consecutive number of *CT faulty* signals.

Table 69: Counter presented in CT supervision.

2.6.4 Auto-reclosing function - ANSI 79 - AR

Approximately 85 % of all faults occurring at overhead lines have temporary short circuit character. After protection operation they usually disappear. Line is switched back into operation the moment when fault is not present anymore and any delay runs out. Reclosing is executed with auto-reclosing function. If the fault is still present after reclosing the protection function will operate again. Based on setting the process of reclosing can repeat several times.

2.6.4.1 Functionality

The auto-reclosing function (AR) can be used with any circuit breaker suitable for auto reclosing. Four programmable AR shots are provided. Combined with dead time duration user can form a scenario which will be executed in case of fault occurrence.

Auto reclose function is set in standby mode when it is enabled and no blocking or trip signals are present. The function monitors trip signals. When any of them is triggered the function operates according to defined scenario.

In case when the last auto-reclosing shot is still unsuccessful a final trip order is given and AR function is blocked until circuit breaker close command is initiated.

Reclosing is considered successful when no trip signal appears after reclosing during the **Reclaim time** (Figure 2.59). In case of dynamic blocking, scenario is reset after one second delay. In case of fault appearing before reclaim time has passed AR function will continue with next cycle if any left.

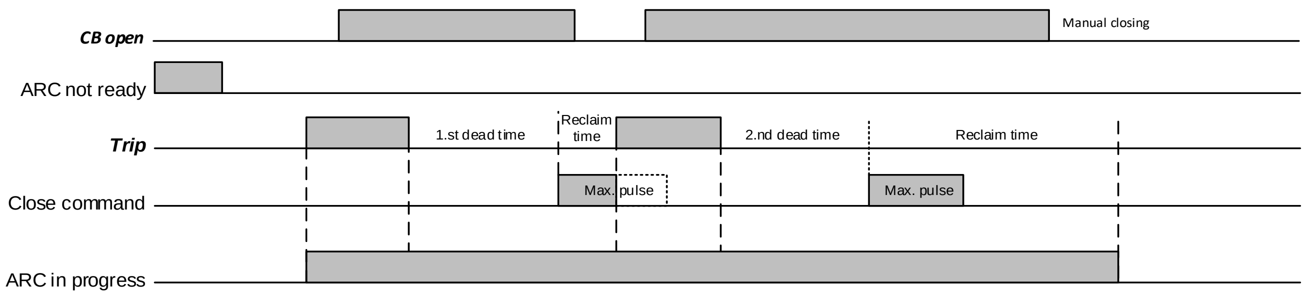


Figure 2.59 Automatic reclosing successful in second attempt.

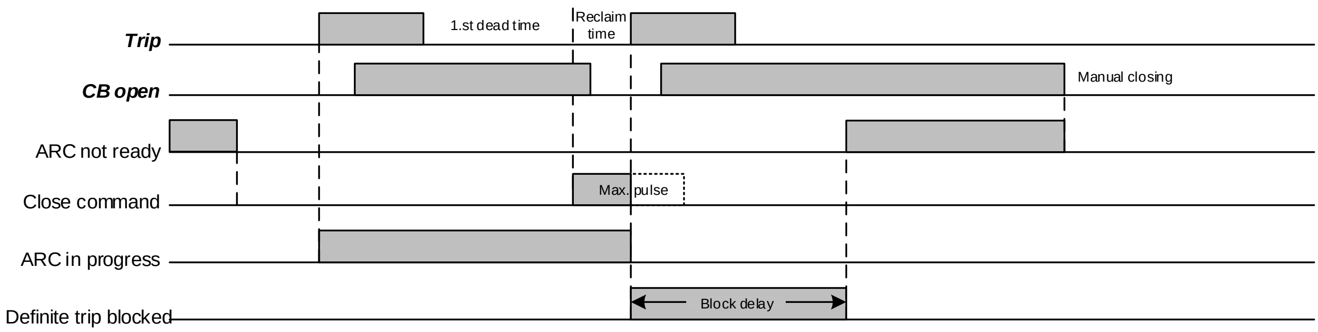


Figure 2.60 Unsuccessful automatic reclosing, dynamic block.

2.6.4.2 Blocking

Two blocking types are included in AR function. Auto-reclosing function is deactivated when any blocking is set (Figure 2.60).

2.6.4.2.1 Static blocking

Following conditions block AR function during standby mode:

- External digital input **AR static block** is active
- Circuit breaker not in closed position
- Switchgear-related fault

2.6.4.2.2 Dynamic blocking

Following conditions block AR when function is in progress:

- Manual close or open command is issued
- First time switching the breaker on for the duration of Manual close block time to avoid operating in switch-on-fault condition.
- Switchgear-related fault
- External digital input **AR dynamic block** is active

2.6.4.3 Setting parameters

Parameter	Range	Description
Enabled	No **Yes**	Enabling function.
Reclaim time	0,5 … **3,0** … 300,0 s	Time after the last AR closing without a new Trip. Reclosing is successful when time elapses.
Maximal dead time	**0,00** … 60 s	
Number of cycles	0 … **1** … 5	Number of active AR cycles.
1st dead time	**0,00** … 300,00 s	Dead time of the 1st cycle.
2nd dead time	**0,00** … 300,00 s	Dead time of the 2nd cycle.
3rd dead time	**0,00** … 300,00 s	Dead time of the 3rd cycle.
4th dead time	**0,00** … 300,00 s	Dead time of the 4th cycle.
5th dead time	**0,00** … 300,00 s	Dead time of the 5th cycle.
50/51-1	**No** Yes	Tripping of this protection will trigger AR cycle
50/51-2	**No** Yes	Tripping of this protection will trigger AR cycle
50/51-3	**No** Yes	Tripping of this protection will trigger AR cycle
50/51-4	**No** Yes	Tripping of this protection will trigger AR cycle
50N/51N-1	**No** Yes	Tripping of this protection will trigger AR cycle
50N/51N-2	**No** Yes	Tripping of this protection will trigger AR cycle
50N/51N-3	**No** Yes	Tripping of this protection will trigger AR cycle
50N/51N-4	**No** Yes	Tripping of this protection will trigger AR cycle
Manual Close	No **Yes**	Tripping of this protection will trigger AR cycle
Manual close block time	0,20 … **1,00** … 300,00 s	Time after CB is manually closed when the AR is in the block state.
Input	**None** Variable 1 Variable 2 Variable 3 …	

Table 70: Auto-reclosing function parameters.

2.6.4.4 Predefined values

Constant	Value	Description
Max trip time	1 s	Maximum duration when trip signal can be present. Dynamic block is set if trip signal duration exceeds Max trip time.
Block delay	1 s	Blocking time after dynamic blocking conditions occur. Standby conditions are checked when Block delay time elapses.
Maximum close pulse time	0,3 s	Maximum duration of Close command output pulse.

Table 71: Auto-reclosing function predefined values.

2.6.4.5 Counters

Name	Description
1st cycle	Consecutive number of active first cycles of the function.
2nd cycle	Consecutive number of active second cycles of the function.
3rd cycle	Consecutive number of active third cycles of the function.
4th cycle	Consecutive number of active fourth cycles of the function.
5th cycle	Consecutive number of active fifth cycles of the function.
Definite trip	Consecutive number of definite trip signals.

Table 72 Counters presented auto-reclosing function.

2.6.5 Synchro check - ANSI 25 - SC

Purpose of Synchro check function is coupling two separated power systems together. The function is designed to couple power systems when they are synchronized, to minimalize transient response. Voltage level, frequency and angle between both systems are being checked prior to the close command execution.

2.6.5.1 Functionality

If SC is enabled any close command will be checked according to user defined interlocking criteria to meet the desired conditions. In case that conditions checking matches the criteria the relay initiate SC procedure. Detailed description is written in the section [2.6.5.4].

2.6.5.2 Connection type

For its operation a synchro check, a connection type needs to be selected accordingly. The description about connection type can be found in the section [2.10.1.1]. Close command is always initiated over a circuit breaker.

Examples of a connection diagram using synchro check function:

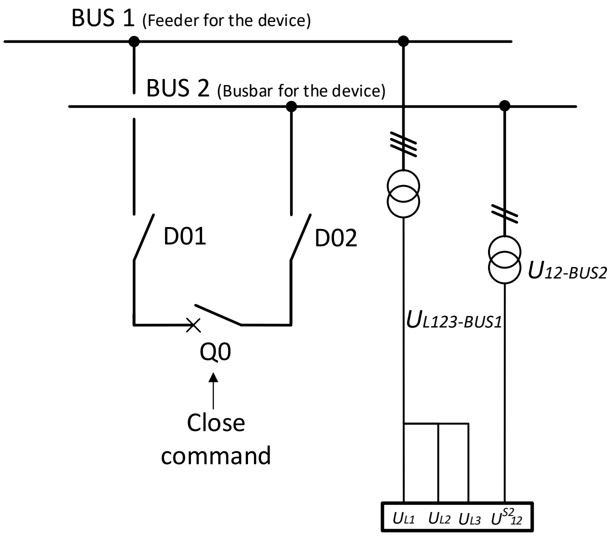


Figure 2.61 Single pole schematics, intended for coupling two live busbars.

Note that in case of Figure 2.61 connection a BUS 1 is considered to be named feeder and a BUS 2 to be named a first busbar for the device.

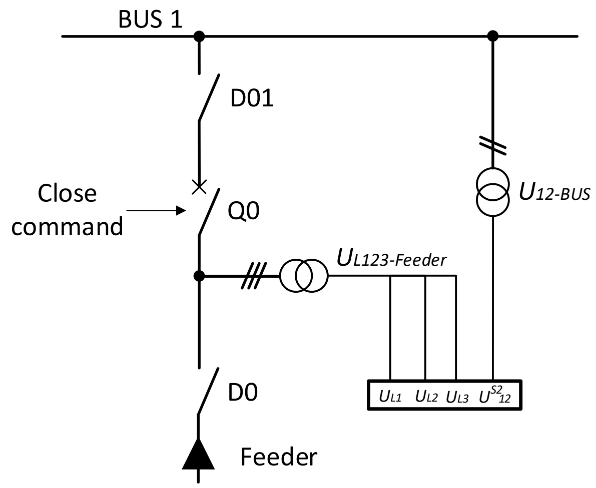


Figure 2.62 Single pole shematics intended for coupling live feeder with live busbar.

On the presented examples above the elements on the figures represents:
Q0 = Breaker element
D0 = Disconnector element
D01 = Active bus 1 disconnector
D02 = Active bus 2 disconnector

The function supports checking conditions for two disconnectors in case a double busbar system as seen on Figure 2.62 is used.

2.6.5.3 Synchronous state measuring

The device constantly compares the following values between the protected line voltages and coupling system phase to phase voltage:

- Delta voltage
- Delta frequency
- Delta phase

2.6.5.4 Initiating a closing procedure

Each close command is checked according to user defined interlocking criteria [2.6.5.6]. The device response is directly related on cases written below.

2.6.5.4.1 Valid measurements

For busbar or protected line to achieve valid measurement status certain conditions must be met:

- Voltage above user defined **Live level U>**
- Or voltage level below user defined **Dead level U<.**

If above conditions are not met, **unsuccessful execution** signal is presented in case a close command is initiated.

2.6.5.4.2 Valid status of disconnector

In case:

- Feeder disconnector status not defined as closed or open.
- Bus1 disconnector status not defined as closed or open.

If any of above conditions are not met, **unsuccessful execution** signal is presented in case a close command is initiated.

2.6.5.4.3 Open disconnector

In case a status of Feeder disconnector or Bus1 disconnector is open a close command is allowed.

2.6.5.4.4 Dead voltage case

Voltage level of feeder or busbar is considered dead below **Dead level U<.** If Feeder or Busbar voltage level is considered dead and user defined parameter allows it [2.6.5.6], a close command is allowed.

If Dead level conditions are not met, **unsuccessful execution** signal is presented in case a close command is initiated.

Parameter	Description
Feeder< Bus<	Dead feeder dead busbar level voltage.
Feeder> Bus<	Live feeder, dead busbar level voltage.
Feeder< bus>	Dead feeder, live busbar level voltage.

Table 73 User defined true-false inhibition conditions for manual closing and AR.

2.6.5.4.5 Live voltage synchronous execution

A synchronous closing procedure is executed if:

- Voltage levels of feeder and busbar are above **Live level U>.**
- Statuses of feeder and bus1 disconnectors are closed.
- Measured Voltages are below **Max delta voltage sync.**
- Measured angle is below **Max delta angle**
- Measured frequencies are below **Max delta frequency sync**.

All conditions check only once. And if they meet criteria, close command is initiated. If criteria are not met **unsuccessful execution** signal is presented.

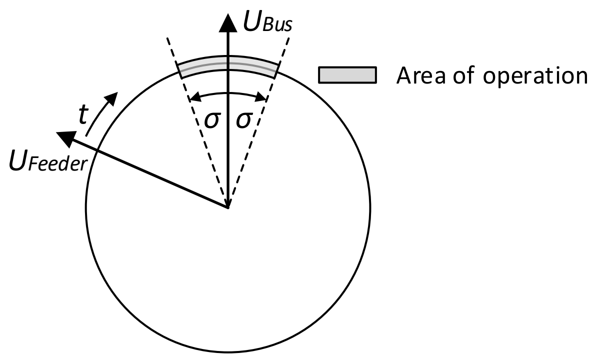


Figure 2.63 Synchronous execution time diagram.

U_{Bus} – Phasor of busbar voltage.
U_{Feeder} – Phasor of feeder voltage.
σ – **Max delta angle.**
t – time.

2.6.5.4.6 Live voltage asynchronous execution

An asynchronous closing procedure is executed if:

- It is enabled.
- voltage levels of feeder and busbar are above **Live level U>.**
- Statuses of feeder and bus1 disconnectors are closed.
- Measured voltages are above **Max delta voltage async**.
- Measured frequencies are above **Max delta frequency sync.**
- Measured frequencies are below **Max delta frequency async**.

When asynchronous operation is initiated it waits for a **Max duration** time for all conditions to meet synchronous mode conditions criteria. During this time an output indicator **In progress** is active. When conditions are met the close command is initiated.

In asynchronous execution the area of operation is displaced for angle δ_{async}:

$$\delta_{async} = \delta_{Bus} - 360 \cdot \Delta f \cdot t_{CB}$$

Equation 19 Calculation of displacement angle.

δ_{Bus} – Angle of feeder voltage Phasor.
δ_{async} – Displacement angle for area of operation.
t_{CB} – **CB close time**.

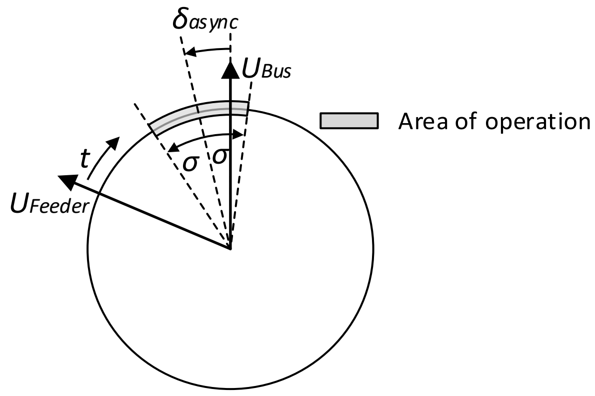


Figure 2.64 Asynchronous execution time diagram.

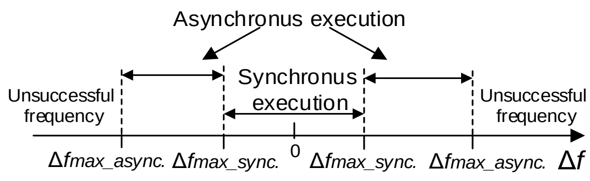


Figure 2.65 Synchronous and asynchronous execution in dependence of the frequency difference.

Δf – Frequency difference between two systems.
Δf_{max_sync} – **Max delta frequency sync.**
Δf_{max_async} – **Max delta frequency async.**

2.6.5.5 Signals associated with synchro check

2.6.5.5.1 Digital input signals

DI parameter	Description
Closed 52a	Breaking element status closed.
Open 52b	Breaking element status open.
Feeder closed 52a	First disconnector element status closed.
Feeder open 52b	First disconnector element status open.
Bus1 closed 52a	Second disconnector element status closed.
Bus1 open 52b	Second disconnector element status open.
Feeder invalid	Initiates not valid status for feeder.
Bus1 invalid	Initiates not valid status for first busbar.

Table 74 Digital inputs associates with synchro check function.

2.6.5.5.2 Output signals

DO parameter	Description
In progress	Close command is in progress
Close output	Close command signal
Not allowed	Command not allowed
Unsuccessful execution	Command execution failed.
Active bus1	First busbar conditions meets certain criteria [**Error! Reference source not ound.**]
Feeder live	Feeder voltage above **Live level U>**
Bus1 live	Busbar 1 voltage above **Live level U>**

Table 75 Output signals associated with synchro check function.

2.6.5.6 Predefined values

Constant	Value	Description
Live level U>	0,03 … **0,8** … 1,00 U_n	Live level voltage condition.
Dead level U<	0,03 … **0,05** … 1,00 U_n	Dead level voltage condition.
Max delta angle	3 ° … **10 °** … 80 °	Maximum angle difference closing conditions.
Max delta voltage sync.	3 … **5** … 100 %	Maximum voltage difference closing conditions.
Max delta frequency sync.	0,01 … **0,1** … 2,00 Hz	Maximum frequency difference closing conditions.
Asynchronous mode	On **Off**	Enable asynchronous procedure execution.
Max delta voltage async.	3 … **5** … 100 %	Maximum voltage difference closing conditions for asynchronous execution.
Max delta frequency async.	0,01 … **0,1** … 2,00 Hz	Maximum frequency difference closing conditions for asynchronous execution.
CB close time	0,00 … **0,3** … 3,00 s	Circuit breaker closing time.
Max duration	0,01 … **0,3** … 1200,0 s	Maximum duration of closing procedure for synchro check.
Sync. Close enabled manually	**True** False	Enables manual synchronous execution.
Async. Close enabled manually	True **False**	Enables manual asynchronous execution.
Feeder < Bus < enabled manually	**True** False	Enables manual command execution when feeder and bus have voltage level below **Dead level U<.**
Feeder > Bus < enabled manually	**True** False	Enables manual command execution when feeder is live and bus have voltage below **Dead level U<.**
Feeder < Bus > enabled manually	**True** False	Enables manual command execution when feeder have voltage below **Dead level U<** and bus is live.
Sync. Close enabled AR	**True** False	Enables AR synchronous execution.
Async. Close enabled AR	True **False**	Enables AR asynchronous execution.
Feeder < Bus < enabled AR	**True** False	Enables AR command execution when feeder and bus have voltage level below **Dead level U<.**
Feeder > Bus < enabled AR	**True** False	Enables AR command execution when feeder is live and bus have voltage below **Dead level U<.**
Feeder < Bus > enabled AR	**True** False	Enables AR command execution when feeder have voltage below **Dead level U<** and bus is live.
Bus 2 enabled	True **False**	Enable second busbar.
Pickup block	**None** Variable 1 Variable 2 Variable 3 …	Source of blocking signal.

Table 76: Auto-reclosing function predefined values.

2.6.6 Machine control

2.6.6.1 Description

Machine control is a control function which includes basic parameters of rotating machine used for calculation of rotation status and operating time of machine.

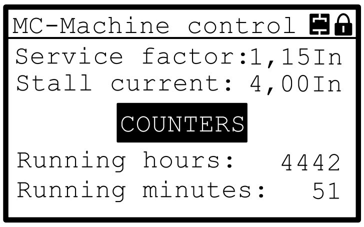


Figure 2.66 Wiring scheme of voltage measurement transformers.

2.6.6.2 Operation

Machine control constantly calculates rotation status of machine. The function distinguish between six different states of rotating machine:

- Stopped
- Starting
- Normal operation
- Overload
- Re-acceleration
- Stalling

Functions as Starts per hour [2.5.8] and Locked rotor [2.5.7] than uses information about rotation status to ensure correct function operation.

2.6.6.3 Status detection

2.6.6.3.1 Stopped

Rotational machine is considered stopped when all of the currents are below 5 % of I_{n_obj} for at least brief amount of time.

2.6.6.3.2 Starting

State can be active if previous state was stopped and at least one of the phase currents exceeds **Service factor** level of I_{n_obj}.

2.6.6.3.3 Normal operation

State is active if all of the currents are below **Service factor** and above 5 % of I_{n_obj}.

2.6.6.3.4 Overload

Overload state is considered if previous state was normal operation and one of phase currents exceeds **Service factor** level of I_{n_obj}.

2.6.6.3.5 Re - acceleration

Re-acceleration is considered if previous state was Normal operation or Overload and one of phase currents exceeds **Service factor** level of I_{n_obj}, while re-acceleration digital input is active.

2.6.6.3.6 Stalling

Stall state is considered if previous state was Overload and one of phase currents exceeds **Stall current** level of I_{n_obj}.

2.6.6.4 Accessibility

Current status of rotating machine can be accessed using LEDs, Digital relay outputs, communication, pc software MiQen and it can also be accessed via diagnostic on HMI:

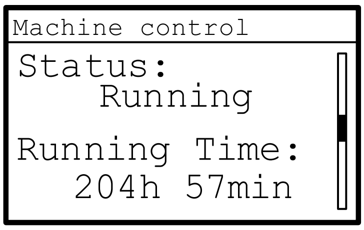


Figure 2.67 Diagnostic screen of rotating machine.

2.6.6.5 Setting parameters

Parameter	Range	Description
Service factor	0,50 … **1,15** … 4,00 I_{n_obj}	Service factor of rotating machine.
Stall current	0,50 … **4,00** … 10,00 I_{n_obj}	Current limit above which stall of the rotating machine is considered.

Table 77 Machine control function parameters.

2.6.6.6 Counters

Name	Description
Running hours	Number of running hours of a rotating machine.
Running minutes	Number of running minutes of one hour of a rotating machine.

Table 78 Counters presented in machine control function.

2.6.7 Inrush restraint

Inrush restraint function is a blocking function. The function can block overcurrent or earth fault overcurrent protection from operating for pre-defined period of time.

2.6.7.1 Functionality

Transformer inrush current includes high 2nd harmonic component. The Inrush restraint function is based on evaluation of 2nd harmonic component present in the inrush current. Inrush current detection is set for each monitored current separately as defined in Table 79. When transformer is energized high amount of 2nd harmonic component is present. In order to prevent unwanted tripping Inrush restraint function can be used. Another example is in combination with 50N/51N protection function. When large object (e.g. Transformer) is energized large amount of transients are present. Because of that a large zero sequence can be calculated which can trigger unwanted tripping of 50N/51N protection function. To once again prevent unwanted tripping Inrush restraint should be used.

In order for inrush restraint to inhibit desired protection its output should be assigned in parameter Inrush restraint source which is present in all types of overcurrent protection [2.2.1, 2.2.2].

2.6.7.2 Monitoring

Monitored currents are different for each protection function.

Protection function	Monitored currents
Overcurrent protection	Phase currents

Table 79: Monitored currents.

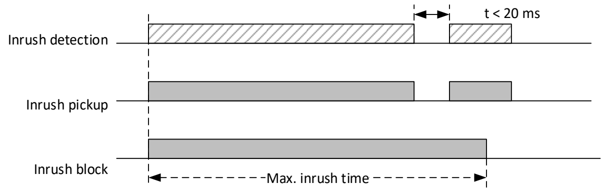


Figure 2.68 Inrush Restrain characteristic.

2.6.7.3 Setting parameters

Parameter	Range	Description
Enabled	No **Yes**	Enabling of function.
Inrush pickup	1 … **15** … 70 %	Higher 2nd harmonic current limit in comparison to fundamental current, above which the detection of inrush current is enabled.
Dropout delay	0 … **0,20** … 10 s	
Max time	0 … 5,00 … 60 s	
Max current	0,30 … **7,50** … 30,00 I_{n_obj}	Maximum value of fundamental current above which the protection is disabled.

Table 80: Inrush restraint function parameters.

2.6.7.4 Predefined values

Constant	Value	Description
Inrush drop-out delay	0,20 s	Time stabilization of pickup signal. Predefined time when the monitored harmonic component value is outside the operating range, but the protection does not stop yet.
Max inrush time	5,00 s	Predefined time when inrush restraint function is disabled.

Table 81: Inrush restraint predefined values.

2.6.7.5 Counters

Name	Description
Inrush counter	Total consecutive number of detected inrush signals.

Table 82: counter presented in inrush restraint function.

2.7 User programmable logic

User programmable logic enables various options of operating of specified functions in the device, selected by the user. The main purpose of logic is determining of necessary conditions for closing / opening of circuit breaker and operation of protection.

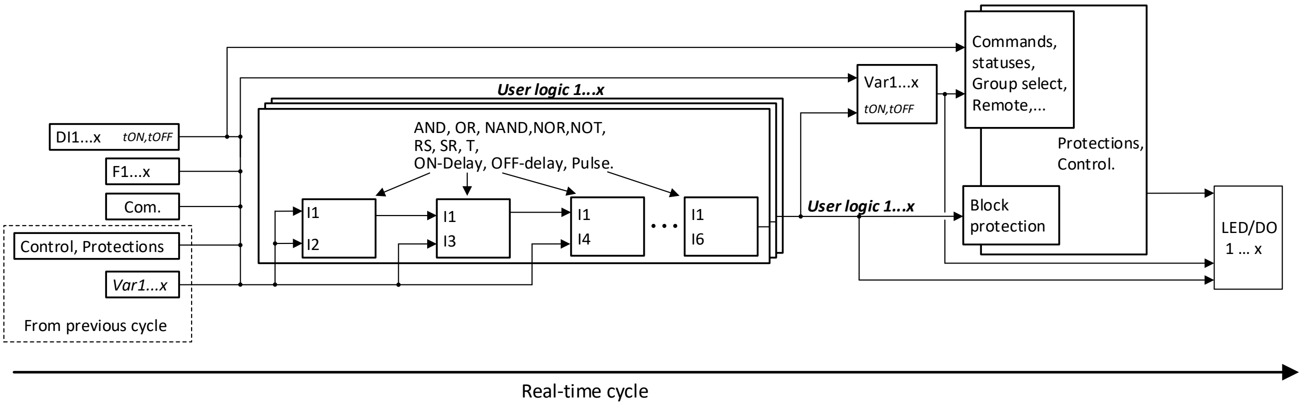


Figure 69: User defined signals in real-time cycle.

2.7.1 Description

All logic signals are binary. Description of operation in real-time diagram is given in picture above [Figure 75].

Maximum number of inputs any of the variable takes into account is 10.

2.7.2 Functions

2.7.2.1 Logic gates

- AND
- NAND
- OR
- NOR
- XOR
- XNOR
- NOT

2.7.2.2 Bistable elements

- RS-FF

If S (Set) is pulsed high while R (Reset) is held low, then the Q output is forced high, and stays high when S returns to low; similarly, if R is pulsed high while S is held low, then the Q output is forced low, and stays low when R returns to low.

In case of set state of both inputs pulsed high, the Output is forced low.

- SR-FF

If S (Set) is pulsed high while R (Reset) is held low, then the Q output is forced high, and stays high when S returns to low; similarly, if R is pulsed high while S is held low, then the Q output is forced low, and stays low when R returns to low.

In case of set state of both inputs pulsed high, the Output is forced high.

- T-FF – Toggle

If the T input is high, the T flip-flop changes state ("toggles") whenever the clock input is strobed. If the T input is low, the flip-flop holds the previous value.

2.7.2.3 Timers

The main function of a timer is to keep an output on for a specific length of time. The three different types of timers that are used are an OFF-delay, an ON-delay and Pause:

- ON delay

An ON-delay timer is activated by input and counts up to a programmed value before cutting off. It is cleared when the enabling input is turned off.

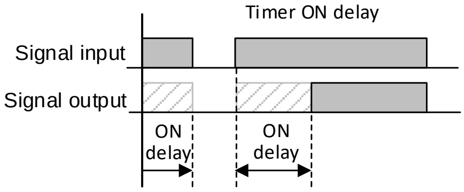


Figure 70: On delay characteristic.

- OFF delay

An OFF-delay timer activates immediately when turned on, counts down from a programmed time before cutting off. It is cleared when the enabling input is off.

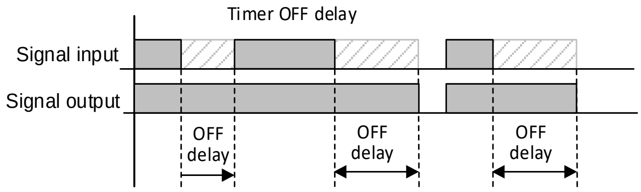


Figure 71: OFF delay characteristic.

- Pulse

A Pulse timer is used to generate a pulse of specific duration. Its output is ON when the timer is running and OFF at all other times.

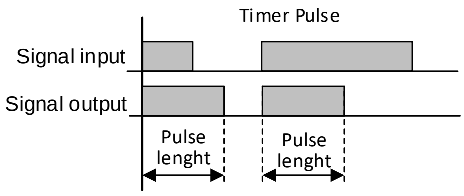


Figure 72: Pulse characteristic.

2.7.3 Input modules

2.7.3.1 Protection and Control

Protection and control modules have all the outputs available for operating with logic.

2.7.3.2 Function keys

Function keys are determined as external binary output. Every signal of function keys could be connected on selected variable as one of the inputs.

2.7.3.3 Module of common signals

Common to	Description
Every protection	
Active group	Currently active group.
Any Trip	All protections with trip signal.
Protection blocked	Anyone of the protections blocked.
Current protection	
Current Trip	50/51/67 Overcurrent 50N/51N/67N Earth fault
Pickup L1	50/51/67 Overcurrent
Pickup L2	50/51/67 Overcurrent
Pickup L3	50/51/67 Overcurrent
Cold load active	50/51/67 Overcurrent 50N/51N/67N Earth fault 87 Differential
Thermal protection	
Temperature Trip	38/49T Temperature sensor 1 – 16 49F 49M
Temperature Alarm	38/49T Temperature sensor 1 – 16 49F 49M
RTD fault	38/49T Temperature sensor 1 – 16

Table 83: Common signals.

2.7.4 Output modules

Output modules are connecting output and input signals inside device.

Modules, which give out output signals:

- Digital inputs
- Virtual inputs
- Function keys
- Outputs of protection and control modules
- Outputs variables
- Communication

Modules, which take in input signals:

- Control modules
- External protection
- Protection blocks
- Communication
- Input of variables

List of input commands
None
Closed 52a
Open 52b
Open command
Close command
CB ready
Group select
TCS2
Cold load pickup activate
External trigger 1
External trigger 2
Remote enabled
Disturbance Record
Alarm reset
Bypass interlocking
Block protection
Open allow
Open block
Close allow
Close block
AR block
Backlight
Thermal switch 1
Thermal switch 2
Buchholz 1
Buchholz 2
Rotation
Feeder invalid
Feeder closed 52a
Feeder open 52b
Bus 1 invalid
Bus 1 closed
Bus 1 open

Table 84: List of input commands in device.

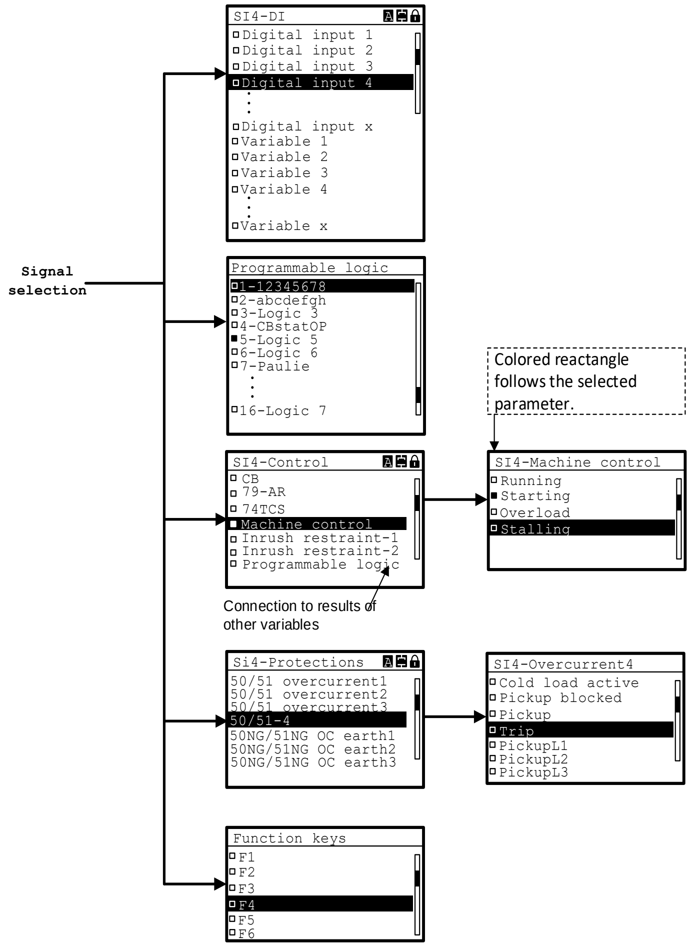


Figure 73: Signal selection on as seen on HMI.

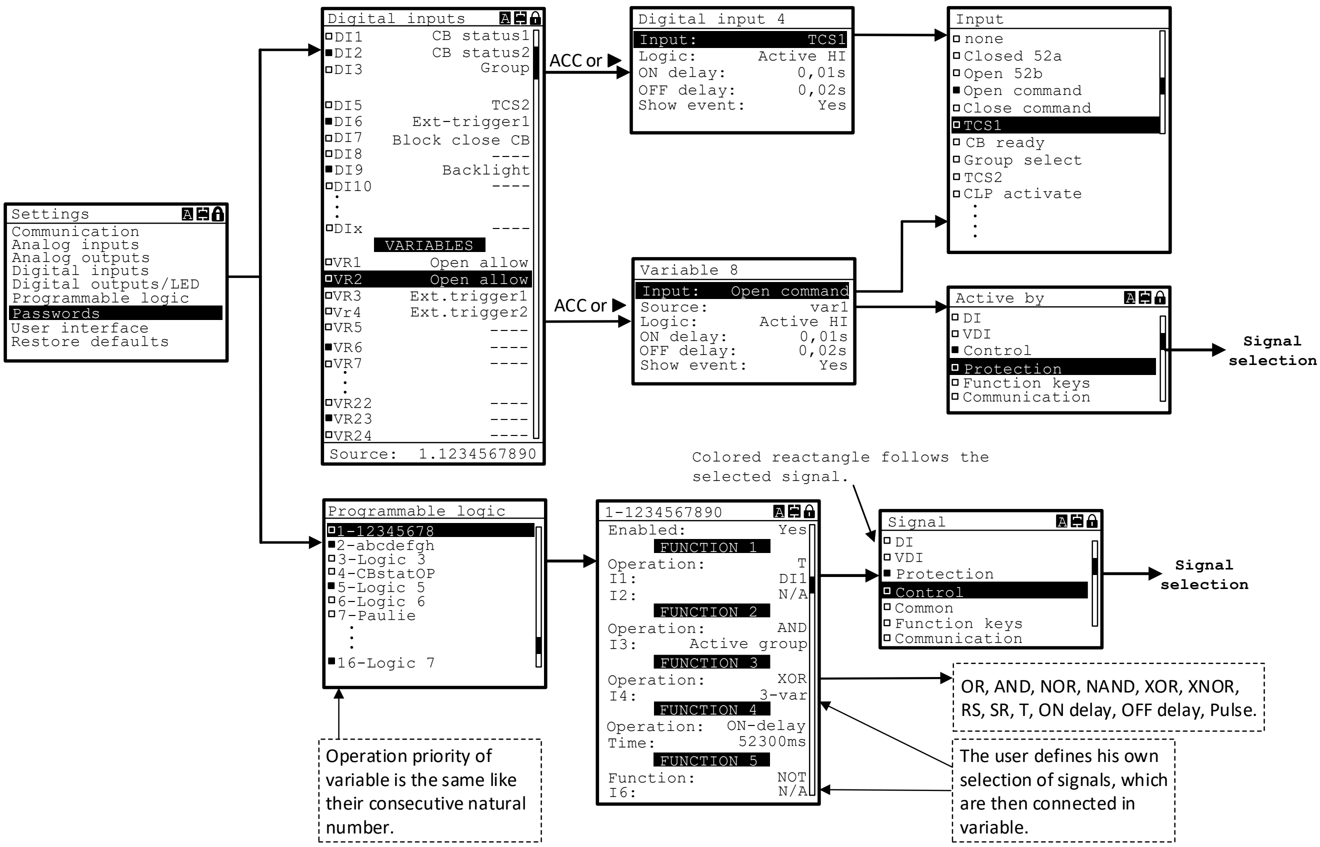


Figure 74: Settings of programmable logic as seen on HMI.

2.7.4.1 Setting parameters

Parameter	Range	Description
Enabled	Yes **No**	Enabling function.
Title		Name of the function given by its user. Available letters of English alphabet A-Z and signs: <space>, ., +, -, >, <, %, ?, of maximum 10 signs length.
Function 1		
Operation	**None** OR NOR AND NAND XOR XNOR NOT RS F/F SR F/F Toggle	Operation of function.
Input / Set / Reset	Signal selection	Name of the input is determined accordance to selected operation of function 1. Usually it is **Input**, except for operation of **SR F/F** or **RS F/F**. Could be connected with any binary signal.
Input / N/A	Signal selection	Name of the input is determined accordance to selected operation od function 1. Usually it is Input, except for operation of **NOT** or **Toggle**. Could be connected with any binary signal.
Function 2 … 5		
Operation	**None** OR NOR AND NAND XOR XNOR NOT RS F/F SR F/F Toggle	Operation of function.
Input	Signal selection	Input is always connected with output of previous function.
Input / N/A	Signal selection	Name of the input is determined accordance to selected operation od function 2 … 5. Usually it is **Input**, except for operation of **NOT** or **Toggle**. Could be connected with any binary signal.

Table 85 User programmable logic function parameters.

2.8 Counters

2.8.1 Description

The counters are predicted for counting of binary settings of signal. The counter counts up when the corresponding binary input **Count up** is pulsed on. The final number is displayed in output **Value**. Pulsing on the binary input **Reset**, resets the counter on **Reset value**.

The counter is limited by a 32-bit unspecified number. When the maximum value is reached, the count stops.

If **Value** is greater or equal to **Alarm value**, **Alarm** output is set.

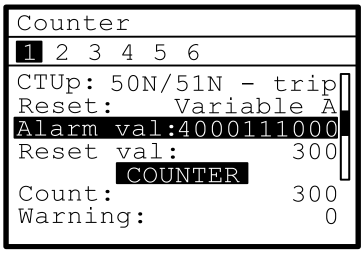


Figure 75: The menu of Counter as seen on HMI.

The view of the current states of the counters you found in the main menu → Information → Diagnostic.

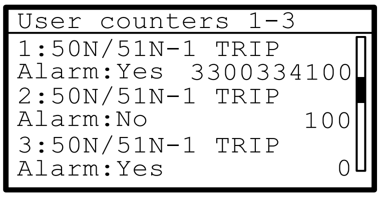


Figure 76: Diagnostic menu as seen on HMI

2.8.1.1 Setting parameters

Parameter	Range	Description
Source	Digital input	Input signal, which is counted. Connection is set from collection of signal selection.
Reset	Digital input	Simplification of Value on Reset value. The connection is set from collection of signal selection.
Alarm value	0 … **2000** …x	Border value of counter, above which follows alarm state.
Reset value	0 … **0** …x	Value of counter after reset input is set.

2.9 Disturbance recording

2.9.1 Description

Disturbance recording function is used to record analog and binary values intended for post fault analysis. Disturbance records are saved in non-volatile device memory and can be read and analysed using USB memory stick. The device can hold up to 127 disturbance records, with user definable **sample rate** and **pretrigger** record time. In the device records are sorted by date of trigger occurred.

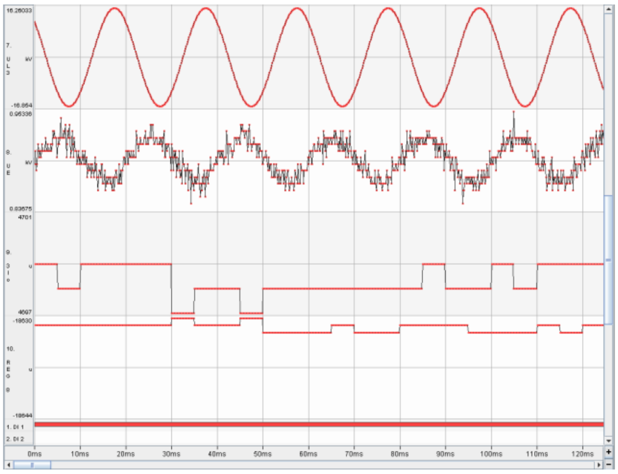


Figure 2.77 Disturbance recording saved as COMTRADE format and visualized with fault analysis software.

2.9.2 USB stick

The records can be transferred to USB stick separately or altogether. They can be transferred from device as standard COMTRADE file and reviewed in third party software. For purpose of transparency of the stored data a separate folder named by serial number is created on USB stick by the device. In the created folder records are named by the following mask: year, month, day, hour, minute, second, millisecond and name of the trigger.

2.9.3 Trigger

Trigger purpose is to activate record of disturbance record. It can be set through corresponding menu and includes, defined by user: Any trip signals, any pickup signals and all individual digital outputs and inputs respectively.

2.9.4 Recorded data

There are four separate channels reserved for analog values, dedicated to record AI measurement values. Based on a device type a current or voltage values are stored. In addition the binary signals of functions, protections, digital outputs and digital inputs in the device are also recorded. Additionally to achieve better transparency of the disturbance data only enabled functions and protection functions are recorded.

All recorded digital input and output signals are presented in positive logic regardless of individual binary signal logic setting.

2.9.5 Clearing disturbance records

Disturbance records can be manually cleared using Reset/Clear menu [4.2.3.6].

2.9.6 Setting parameters

Parameter	Range	Description
Control parameters		
Sample rate	400 Hz 800 Hz **1600 Hz** 3200 Hz	Data recording sample rate. The setting effects on duration of the record.
Duration (depends on **sample rate** setting)	5120 ms 2560 ms **1280** ms 640 ms	Record duration calculated based on selected sample rate. **Duration** is informative and not user definable parameter.
Pretrigger	0 … **25** … 100 %	Time in percent of total duration of the record, that presents the fault recorded before actual trigger.
Triggers		
Pickup	Yes **No**	Enabling trigger on appearance of any trip signal.
Trip	Yes **No**	Enabling trigger on appearance of any pickup signal.
DO 1 … 8	Yes **No**	Enabling trigger on signal dedicated to activate user defined DO respectively.
DI 1 … 10	Yes **No**	Enabling trigger on activated DI signal respectively.

Table 86 Disturbance recording function parameters.

2.10 Measurements

Measurement values can be accessed by reading it via communication [3.1.7.6] or by accessing them using dedicated PC based software [4.3.2.4] or by using local HMI [4.2.3.2].

2.10.1 Connection type

Connection type defines a manner of which analog input values are connected to device. By selection of this settings the device adjusts the calculation of certain values according to available measurements. Supported current connection is three phase connection. Voltage connection type is described in section below [2.10.1.1].

Connection type	Description
Mode 1 U_{L1}, U_{L2}, U_{L3}, U_e	Three phase voltage connection type with earth voltage.
Mode 2 U_{L1}, U_{L2}, U_{L3}, U^{S2}_{L1}	Three phase voltage connection type with other system phase voltage.
Mode 3 U_{L1}, U_{L2}, U_{L3}, U^{S2}_{12}	Three phase voltage connection type with other system phase to phase voltage.

Table 87 Voltage connection types.

2.10.1.1 Voltage connection type

For a purpose of using the device function synchro check [2.6.5], a connection type needs to be selected accordingly.

2.10.1.1.1 Mode 1 - U_{L1}, U_{L2}, U_{L3}, U_e.

Three phase connection type with earth voltage (U_{L1}, U_{L2}, U_{L3}, U_e). Most common connection type, using three phase voltages and one earth voltage.

2.10.1.1.2 Mode 2 - U_{L1}, U_{L2}, U_{L3}, U^{B2}_{L1}.

Using this connection type enables using a function Synchro check [2.6.5]. Connection type is dedicated to monitor another three phase system while maintaining the ability for the device to retain most of the information of the protected three phase system. The monitored value is phase voltage of the second system U^{S2}_{12}.

2.10.1.1.3 Mode 3 - U_{L1}, U_{L2}, U_{L3}, U^{B2}_{12}.

Using this connection type enables using a function Synchro check [2.6.5]. Connection type is dedicated to monitor another three phase system while maintaining the ability for the device to retain most of the information of the protected three phase system. The monitored value is phase to phase voltage of the second system U^{S2}_{12}.

CAUTION

By using connections Mode 1 or Mode 2 the device does not measure earth voltage U_e. Therefore function 59N [2.3.2] is disabled while using this mode. 50N/51N/67N

2.10.2 Presented measured values

Device is able to measure currents, voltages and power. AMC consist of eight analog measured values. Device measures and calculates all presented values and displays them. Measurements are presented in:

- RMS,
- average RMS in user defined interval **cycle time**,
- peak of average RMS,
- RMS in bar maximum 150 % of I_n,
- separate harmonics up to 9th harmonic,
- harmonics presented in percent of RMS value in bars separately,
- phase unbalance,
- frequency

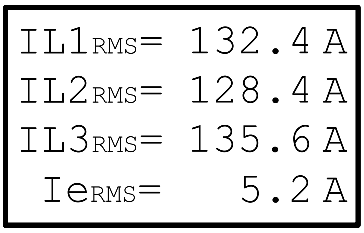


Figure 2.78Example of current measurement screen as seen on HMI.

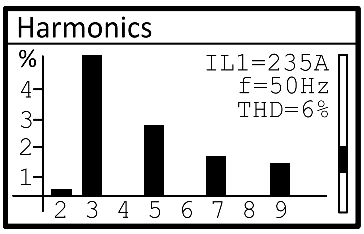


Figure 2.79 Example of harmonics overview as seen on HMI.

2.10.2.1 Scaling of presented measurements

Presented measurements of current, voltage and power are scaled according to user defined parameters defined in protected object data. The values are scaled to a closest presentable unit prefix of parameters **Nominal current of the object** and **VT primary**. The unit prefix for power is dictated by true power estimation using formula below:

Equation 20 Estimation for unit prefix.

$$P = U \cdot I \cdot \sqrt{3}$$

True power, apparent power and reactive power are all presented in same unit prefix.

2.10.3 Nominal values

Nominal values U_n and I_n are calculated based on user defined settings in section [4.2.3.5.4].

2.10.3.1 Nominal current value

Rated nominal current of the object I_{n_obj} (outgoing feeder, motor, etc.) the value of the presents 1 p.u. on the device.

Example:
Calculation of motor phase currents based on nominal primary current of the motor I_{n_obj}:

CT = 400 A/1 A $\quad$ *I_{n_obj} = 350 A*

Device measure current I_S = 0.7 A

$$I_{PU} = \frac{I_S \cdot CT_{PRI}}{I_{n\_obj} \cdot CT_{SEC}} \qquad I_{PU} = 0.8\ p.u.$$

That would mean that motor phase currents I_{n_obj} are currently at 80 % of its nominal value.

Analog value	Description
I_{n_obj}	Nominal device current

2.10.3.2 Nominal voltage value

Nominal voltage value is equal to the secondary voltage of voltage transformer [4.2.3.5.4, **Error! Reference ource not found.**].

Analog value	Description
U_n	Nominal device voltage

Table 88 Nominal values of the device.

2.10.4 Current measurement

The value of each of phase currents and earth current is acquired through dedicated input current transformer.

Analog value	Description
I_{L1}	Phase current
I_{L2}	Phase current
I_{L3}	Phase current

Table 89 Measured current values.

2.10.5 Voltage measurement

The value of each of phase to phase voltages is calculated through measured phase voltages of measurement voltage transformers.

Analog value	Description
U_{L1}	Phase voltage
U_{L2}	Phase voltage
U_{L3}	Phase voltage
U_{12}	Phase to phase voltage
U_{23}	Phase to phase voltage
U_{31}	Phase to phase voltage

Table 90 Measured voltages values.

2.10.6 Frequency measurement

Frequency is determined based on healthy analog acquisition line measurement with priority of phase voltage measurements first, than phase current measurements. In addition the healthy line is considered as a line which value is nearest to U_n or I_n. Device frequency determines FFT window length to be used in exact device measurement of analog values.

Analog value	Description
f	Device base frequency

Table 91 Frequency value.

2.10.7 Power

The device also displays active reactive and apparent power for all phases simultaneously.

Power is calculated using equations below:

$$P_{Lx} = U_{Lx} \cdot I_{Lx} \cdot \cos \varphi_{Lx}$$

$$Q_{Lx} = -U_{Lx} \cdot I_{Lx} \cdot \sin\varphi_{Lx}$$

Equation 21 Calculation of active and reactive power per phase.

Depending on the chosen connection type [4.2.3.5.4, Connection type] a total power of the protected object is calculated.

When all three phases of current and voltage are available, power is calculated:

$$P = P_{L1} + P_{L2} + P_{L3}$$

$$Q = P_{L1} + P_{L2} + P_{L3}$$

$$S = P + jQ$$

Equation 22Calculation of active, reactive and apparent power of the protected object.

2.10.8 Symmetrical components

By using three symmetrical systems any three-phase non-symmetrical system can be presented. These systems are named positive negative and zero sequence systems:

- Positive sequence indicates rotating magnetic field in native direction. In fully symmetrical three phase system only positive sequence is present while negative and zero sequence have zero value.
- Negative sequence value indicates presence of rotating magnetic field in opposite direction than native direction of three phase system.
- Zero sequence is present if three-phase system is not balanced

Analog value	Description
I_1	Positive sequence
I_2	Negative sequence
I_0	Zero sequence
$3I_0$	three times zero sequence
U_1	Positive sequence
U_2	Negative sequence
U_0	Zero sequence
$3U_0$	three times zero sequence

Table 92 Symmetrical components values.

2.10.9 Temperature

Measurement is performed by using appropriate external module [5.6.1]. Specific algorithms are used to interpret measurement of probes resistance. RTDs are using 3-wire connection type. The measured temperatures are updated each second.

Following RTD type is supported:

RTD type
Pt100

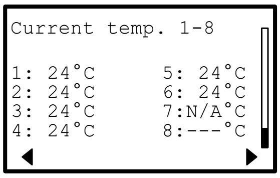
Table 93 Type of supported RTD.

2.10.9.1 Minimum and maximum measured values

Each probe has a lower and upper limit, indicating malfunction of probe if the measured temperature exceeds this limits. If any limit is exceeded an *RTD fault* [2.5.6.5] signal activates and in addition a dedicated sign is presented on HMI. Also average, maximal, and minimal temperature can be accessed for each individual probe.

Temperature limit	Temperature
Upper	250 °C
Lower	-50 °C

Table 94 Maximum and minimum limits of temperature measurement.



7:N/A°C
Detection of open probe contacts
8:---°C
Detection of short circuit probe contacts

Figure 2.80 Temperature measurement as presented on HMI. If any temperature limit is exceeded a dedicated sign is presented.

2.11Self-diagnostic

Several self-monitoring functions run continuously to check the operation of hardware and software while device is in service. Device status is represented by internal watchdog that can be connected to Ready Relay output via Relay mapping menu. Digital output 6 can be set to operate as ready relay as it is designed to operate as such. FPC 400 distinguish between two major types of internal faults:

- Hardware internal faults
- Software internal faults

2.11.1 System status register

System status register is a 16 bit memory register dedicated to correspond with specific internal fault type. It is possible to access this register by Modbus RTU. Internal fault is detected if value of stored bit is equal to 1.

2.11.2 Operating states

Three operating states are used to increase reliability of protection relay self-diagnosis. According to internal fault type, the device will start to function in designated operating state.

Operating state	Description	Output signal	Protection functions
Normal state	FPC 400 is fully operational	- Ready LED ON - Ready relay ON	- All functions are operating
Error state	Fault is detected. If internal fault is eliminated in 5 s time, device returns to Normal state.	- Blinking Ready LED - Continuous sound beeping - System status register = 1 - HMI is displaying internal fault	- Protection functions are blocked. - Output relays are blocked.
Confirmed error state	Fault is detected and manually confirmed.	- Blinking Ready LED - System status register = 1	- Protection functions are blocked. - Output relays are blocked

Table 95 Operating states of the device.

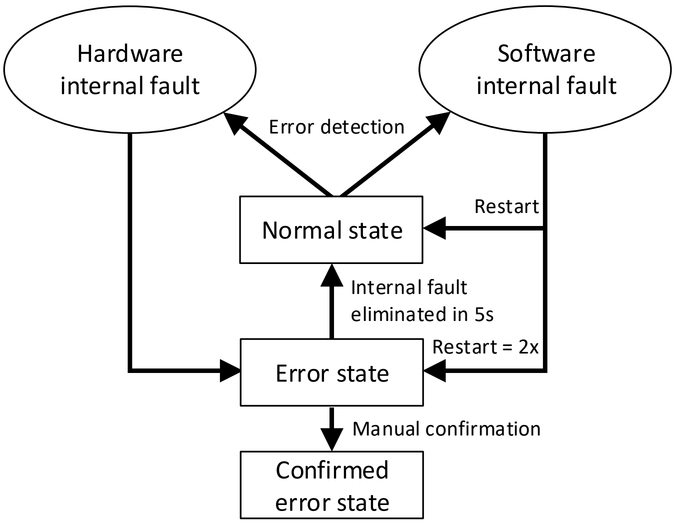


Figure 2.81 Diagram of FPC 400 self-diagnostic error detection

2.11.3 Internal faults description

Description of specific faults can be found in the table below.

Hardware internal faults	Display massage	System status register bit
External RTC not responding	EXT clock error	125.0
Internal RTC not responding	INT clock error	125.1
EEPROM for settings not responding	Memory 1 error	125.2
EEPROM on AI card not responding	AI card error 2	125.3
MRAM not responding	Memory 2 error	125.4
eMMC not responding	Memory 3 error	125.5
CPU powered from USB port, main power disconnected	Main power off	125.6
ADC on AI card not responding	AI card error 1	125.7
PS-DO card not responding	DO card error	125.8
DIO card not responding	DIO card 1 error	125.9
CPU on AO card not responding	AO card error	125.12
Software internal faults		
RT module not responding	RT error	125.13
NRT module not responding	NRT error	125.14

Table 96 Internal faults description.

3 Communication

FPC 400 can be connected to supervision communication network based on following communication protocols:

- Modbus RTU
- IEC60870-5-103

3.1 Modbus RTU

3.1.1 General description

Modbus communication protocol uses request-reply logic to obtain information from dedicated devices. The device that executes request is always a master and device that listens to request is always a slave. Modbus protocol allows several slave devices to be connected to a single master device. Individual devices are addressed by a specific code unique to each slave device connected to communication network. FPC 400 is always a slave station and it allows to be connected to any other device with Modbus master communication channel.

3.1.2 Modbus PDU (protocol data unit)

Every Modbus character frame send or received consists two fields which assign function code being used and data being transferred. The total number of data bits to be transferred in one package is dependent of the transfer function to be used. If there was no error during transmission of data function codes in request and reply are identical. There are two types of data that can be transmitted, bits (also called Coils) and 16 bit words (also called Registers). Words used to transfer data are always represented in big-endian format.

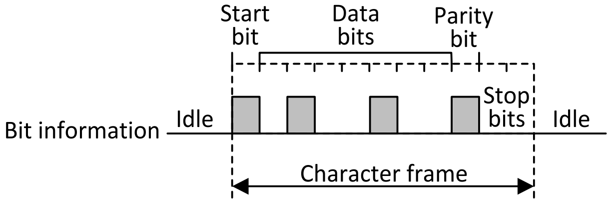


Figure 3.1 Modbus RTU character frame

Modbus PDU format	**2 - 5**
Function code (8 bits)	Data (0 to n bytes)

Table 97 Modbus PDU format.

3.1.3 Modbus function supported

Modbus protocol uses standard set of functions. Functions are divided by the ability to read or write one or multiple data bits.

3.1.3.1 Read functions:

- Function 2: reading of n input bits
- Function 3: reading of n output or internal bits
- Function 4: reading of n input words

3.1.3.2 Write functions:

- Function 5: writing of 1 bit
- Function 6: writing of 1 word

Function 16: writing of n words

3.1.4 Time synchronization

Time synchronization zone is dedicated to set exact time to the device. To write time massage function 16 containing 4 words should be used. Reading device time massages can be done separately word by word, or by using a multiple words function 3 can be used to access whole timestamp instead. It is possible that internal clock could drift over time. To ensure that device internal time is set correctly, time synchronization should be carried out over regular intervals of 10 to 60

s. If device receives no time synchronization massage for 300 s the event *Time not sync* is triggered.

Internal clock is written according to IEC 60870-5-4, Binary Time 2a standard and consists of 8 characters structure:

Word	Most significant byte	Least significant byte
1	0	Year: 0 … 99
2	Month: 1 … 12	Day: 1 … 31
3	Hour: 1 … 23	Minute: 0 … 59
4	Millisecond: 0 … 59999	

Table 98 Communication telegram structure of time synchronization.

3.1.5 Events

The clock synchronization sending telegram interval should be more than 30 sec apart.

3.1.5.1 Time tagging of events

For purpose of transparency of the data processed by FPC 400, the device uses time tagging function to timestamp specific events that occurred during its operation. Therefore chronological order of events can be maintained accurately. Internal time is used when device time tags the event.

All the events that are recorded in device are available over Modbus communication with two internal storage queues of total 100 stored events.

3.1.5.2 Structure

The device presents up to four events at the same time for each buffer and one control word. Structure of data in the table looks as follows:

Control word + Event 1 + Event 2 + Event 3 + Event 4

The function of control word is to ensure correct reception of all data, even in case of trouble and loss of data at communication. To ensure this, it includes number of transactions and number of events. On device boot, number of transactions is 0.

Events are recorded in 8 word structure. Each event consists of the following information:

- Address where the data is stored
- Exact time of the event
- Value of the event

Word	**Control word structure**	
	Most significant byte	Least significant byte
1	Number of transaction: 0 … 255	Number of events: 0 … 4
Word	**Single event structure**	
	Most significant byte	Least significant byte
1	Type of event: 08	Type of event: 00
2	Address: 1 … 65535	
3	00	00
4	00	Value: 0 … 3
5	0	Year: 0 … 99
6	Month: 1 … 12	Day: 1 … 31
7	Hour: 1 … 23	Minute: 0 … 59
8	Millisecond: 0 … 59999	

Table 99 Event reading communication telegram structure.

3.1.5.3 Reading of events

Monitoring system periodically reads the control word and checks whether there are new events available. Only reading of control word is allowed or reading of the whole 33 word block. For all other requests, the device returns an error (Wrong data).

On the arrival of new events in the buffer, the device writes the values of events into the structure in the analogue table and increases the number of transactions in the control word by 1 and sets the number of written events (maximum 4).

Monitoring system reads the values of the events, checks for any reception errors and validity of the data. If events are present, device stops to write new events in the buffer and waits for confirmation for those that were sent last.

Monitoring system confirms correct reception to device with writing into control word the same transaction number and number of events is reset to 0.

Upon confirmation of successful reception from the monitoring system, the device erases the transferred events from buffer, in analog table all words for the events are set to 0, writes new events and sets a new control word, as previously described. Deletion of events is only allowed if a request to read the entire block of events has previously been issued. Namely, the monitoring system can't confirm events, if it did not read them previously.

When device sends all events and clears its buffer, it does not change the control word anymore even after the monitoring system reads the control word.

3.1.5.4 Remote deletion of events

Monitoring system has the ability to delete all events in the device, in the buffer and in the analogue table, by writing control word which has the number of events set to FF. In this case, the number of transactions is reset to 0.

3.1.5.5 Reading 32 bit float measurements

Float measurements are coded using Mid-little endian (CDAB) mode. It is advised to use this conversion type to acquire true measurements.

3.1.6 Parameters

The following parameters needs to be set for the communication to be established properly

Parameter	Range	Description
Protocol	**Modbus RTU** IEC103	Selection of active communication protocol.
Device address	0 … **33** … 247	Number by each slave device is uniquely addressed.
Baud rate	1200 2400 4800 9600 **19200** 38400 57600 115200	Defines the number of binary information to be transmitted per second.
Parity	**None** Odd Even	Adds an error checking bit that follows the data bits in the character frame.
Stop bits	1 2	Number of stop bits after each character frame.
Data bits	**8** 9	Number of data bits in each character frame.

Table 100 Parameters of Modbus RTU communication protocol.

3.1.7 Address table

3.1.7.1 Time synchronization

Type	Format	Address (Hexadecimal)	Access	Function code
Time synchronization		**10 - 13**	**R / W**	
Year	UINT16	10	R / W	3,4,16
Month + Day	UINT16	11	R / W	3,4,16
Hour + Minute	UINT16	12	R / W	3,4,16
Milliseconds	UINT16	13	R / W	3,4,16

Table 101 Modbus communication table.

3.1.7.2 Event recorder

Type	Format	Address (Hexadecimal)	Access	Function code
Events 1		**40 – 6F**	**R / W**	
Exchange word	UINT16	40	R / W	4
Event 1	UINT16	41	R	4
Event 2	UINT16	49	R	4
Event 3	UINT16	51	R	4
Event 4	UINT16	59	R	4
Events 2		**70 – A0**	**R / W**	
Exchange word	UINT16	70	R / W	4
Event 1	UINT16	71	R	4
Event 2	UINT16	79	R	4
Event 3	UINT16	81	R	4
Event 4	UINT16	89	R	4

Table 102 Modbus communication table.

3.1.7.3 Statuses

3.1.7.3.1 Trip signals

Type	Format	Address (Hexadecimal)	Access	Function code	Event ID
Trip signals		**FA**	**R**	**3, 4**	
Protection OC1 [50/51 - 1]	BOOL	FA.0	R	1, 2	0
Protection OC2 [50/51 - 2]	BOOL	FA.1	R	1, 2	1
Protection OC3 [50/51 - 3]	BOOL	FA.2	R	1, 2	2
Protection OC4 [50/51 - 4]	BOOL	FA.3	R	1, 2	3
Protection OCE 1 [50NG/51NG - 1]	BOOL	FA.4	R	1, 2	4
Protection OCE 2 [50NG/51NG - 2]	BOOL	FA.5	R	1, 2	5
Protection OCE 3 [50NG/51NG - 3]	BOOL	FA.6	R	1, 2	6
Protection OCE 4 [50NG/51NG - 4]	BOOL	FA.7	R	1, 2	7
Protection REF 1 [64REF - 1]	BOOL	FA.8	R	1, 2	8
Protection REF 2 [64REF - 2]	BOOL	FA.9	R	1, 2	9
Protection NS [46]	BOOL	FA.A	R	1, 2	10
Protection UC [37]	BOOL	FA.B	R	1, 2	12
Reserved	BOOL	FA.C	R	1, 2	
Reserved	BOOL	FA.D	R	1, 2	
Reserved	BOOL	FA.E	R	1, 2	
Reserved	BOOL	FA.F	R	1, 2	
Trip signals		**FB**	**R**	**3, 4**	
Protection UV 1 [27 - 1]	BOOL	FB.0	R	1, 2	13
Protection UV 2 [27 - 2]	BOOL	FB.1	R	1, 2	14
Protection RUV [27R]	BOOL	FB.2	R	1, 2	15
Protection PSUV 1 [27D - 1]	BOOL	FB.3	R	1, 2	16
Protection PSUV 2 [27D - 2]	BOOL	FB.4	R	1, 2	17
Protection OV 1 [59 - 1]	BOOL	FB.5	R	1, 2	18
Protection OV 2 [59 - 2]	BOOL	FB.6	R	1, 2	19
Protection NVD 1 [59NG - 1]	BOOL	FB.7	R	1, 2	20
Protection NVD 2 [59NG - 2]	BOOL	FB.8	R	1, 2	21
Reserved	BOOL	FB.9	R	1, 2	22
Reserved	BOOL	FB.A	R	1, 2	23
Negative sequence [47]	BOOL	FB.B	R	1, 2	24
Reserved	BOOL	FB.C	R	1, 2	
Reserved	BOOL	FB.D	R	1, 2	
Reserved	BOOL	FB.E	R	1, 2	
Reserved	BOOL	FB.F	R	1, 2	
Trip signals		**FC**	**R**	**3, 4**	
Protection OF 1 [81H - 1]	BOOL	FC.0	R	1, 2	25
Protection OF 2 [81H - 2]	BOOL	FC.1	R	1, 2	26
Protection UF 1 [81L - 1]	BOOL	FC.2	R	1, 2	27
Protection UF 2 [81L - 2]	BOOL	FC.3	R	1, 2	28
Reserved	BOOL	FC.4	R	1, 2	29
Reserved	BOOL	FC.5	R	1, 2	30
Protection ROCOF [81R]	BOOL	FC.6	R	1, 2	31
Protection TO [49F]	BOOL	FC.7	R	1, 2	32
Protection MTO [49M/T]	BOOL	FC.8	R	1, 2	33
Reserved	BOOL	FC.9	R	1, 2	
Reserved	BOOL	FC.A	R	1, 2	
Reserved	BOOL	FC.B	R	1, 2	
Reserved	BOOL	FC.C	R	1, 2	
Reserved	BOOL	FC.D	R	1, 2	
Reserved	BOOL	FC.E	R	1, 2	
Reserved	BOOL	FC.F	R	1, 2	

Table 103 Modbus communication table.

Type	Format	Address (Hexadecimal)	Access	Function code	Event ID
Trip signals		**FD**	**R**	**3, 4**	
Protection LR [48/51LR/14]	BOOL	FD.0	R	1, 2	34
Protection SPH [66]	BOOL	FD.1	R	1, 2	35
Thermostat switch 1 [26 -1]	BOOL	FD.2	R	1, 2	36
Thermostat switch 2 [26 -2]	BOOL	FD.3	R	1, 2	37
Buchholz 1 [63 – 1]	BOOL	FD.4	R	1, 2	38
Buchholz 1 [63 – 2]	BOOL	FD.5	R	1, 2	39
Reserved	BOOL	FD.6	R	1, 2	40
Reserved	BOOL	FD.7	R	1, 2	41
Reserved	BOOL	FD.8	R	1, 2	42
Reserved	BOOL	FD.9	R	1, 2	43
Reserved	BOOL	FD.A	R	1, 2	44
Reserved	BOOL	FD.B	R	1, 2	45
Reserved	BOOL	FD.C	R	1, 2	46
Reserved	BOOL	FD.D	R	1, 2	47
Reserved	BOOL	FD.E	R	1, 2	48
Reserved	BOOL	FD.F	R	1, 2	
Trip signals		**FE**	**R**		
External trip 1	BOOL	FE.0	R	1, 2	49
External trip 2	BOOL	FE.1	R	1, 2	50

Table 104 Modbus communication table.

3.1.7.3.2 Device and breaker status

Type	Format	Address (Hexadecimal)	Access	Function code	Event ID
Device and breaker status signals		**FE**	**R**		
Settings group	BOOL	FE.2	R	1, 2	
Breaker device open status	BOOL	FE.3	R	1, 2	
Breaker device close status	BOOL	FE.4	R	1, 2	
Breaker device status alarm	BOOL	FE.5	R	1, 2	
Open enabled	BOOL	FE.6	R	1, 2	
Close enabled	BOOL	FE.7	R	1, 2	
RTD Fault	BOOL	FE.8	R	1, 2	
ARC not ready	BOOL	FE.9	R	1, 2	
ARC in progress	BOOL	FE.A	R	1, 2	
ARC definite trip	BOOL	FE.B	R	1, 2	
System local	BOOL	FE.A	R	1, 2	
System remote	BOOL	FE.B	R	1, 2	
Reserved	BOOL	FE.E	R	1, 2	
Reserved	BOOL	FE.F	R	1, 2	
Breaker status signals		**FF**	**R**	**3, 4**	
CB max break alarm	BOOL	FF.0	R	1, 2	
CB max break block	BOOL	FF.1	R	1, 2	
CB max trip alarm	BOOL	FF.2	R	1, 2	
CB max trip block	BOOL	FF.3	R	1, 2	
CB max trip OC alarm	BOOL	FF.4	R	1, 2	
CB max trip OC block	BOOL	FF.5	R	1, 2	
CB command allowed	BOOL	FF.6	R	1, 2	
CB command blocked	BOOL	FF.7	R	1, 2	
CB command failed	BOOL	FF.8	R	1, 2	
CB command successful	BOOL	FF.9	R	1, 2	
Reserved	BOOL	FF.A	R	1, 2	
Reserved	BOOL	FF.B	R	1, 2	
Reserved	BOOL	FF.C	R	1, 2	
Reserved	BOOL	FF.D	R	1, 2	
Reserved	BOOL	FF.E	R	1, 2	
Reserved	BOOL	FF.F	R	1, 2	

Table 105 Modbus communication table.

3.1.7.3.3 Temperature signals

Type	Format	Address (Hexadecimal)	Access	Function code	Event ID
Alarm signals		**100**	**R**	**3, 4**	
Protection TMO 1 [38/49T - 1]	BOOL	100.0	R	1, 2	51
Protection TMO 2 [38/49T - 2]	BOOL	100.1	R	1, 2	52
Protection TMO 3 [38/49T - 3]	BOOL	100.2	R	1, 2	53
Protection TMO 4 [38/49T - 4]	BOOL	100.3	R	1, 2	54
Protection TMO 5 [38/49T - 5]	BOOL	100.4	R	1, 2	55
Protection TMO 6 [38/49T - 6]	BOOL	100.5	R	1, 2	56
Protection TMO 7 [38/49T - 7]	BOOL	100.6	R	1, 2	57
Protection TMO 8 [38/49T - 8]	BOOL	100.7	R	1, 2	58
Reserved	BOOL	100.8	R	1, 2	59
Reserved	BOOL	100.9	R	1, 2	60
Reserved	BOOL	100.A	R	1, 2	61
Reserved	BOOL	100.B	R	1, 2	62
Reserved	BOOL	100.C	R	1, 2	63
Reserved	BOOL	100.D	R	1, 2	64
Reserved	BOOL	100.E	R	1, 2	65
Reserved	BOOL	100.F	R	1, 2	66
Trip signals		**101**	**R**	**3, 4**	
Protection TMO 1 [38/49T - 1]	BOOL	101.0	R	1, 2	67
Protection TMO 2 [38/49T - 2]	BOOL	101.1	R	1, 2	68
Protection TMO 3 [38/49T - 3]	BOOL	101.2	R	1, 2	69
Protection TMO 4 [38/49T - 4]	BOOL	101.3	R	1, 2	70
Protection TMO 5 [38/49T - 5]	BOOL	101.4	R	1, 2	71
Protection TMO 6 [38/49T - 6]	BOOL	101.5	R	1, 2	72
Protection TMO 7 [38/49T - 7]	BOOL	101.6	R	1, 2	73
Protection TMO 8 [38/49T - 8]	BOOL	101.7	R	1, 2	74
Reserved	BOOL	101.8	R	1, 2	75
Reserved	BOOL	101.9	R	1, 2	76
Reserved	BOOL	101.A	R	1, 2	77
Reserved	BOOL	101.B	R	1, 2	78
Reserved	BOOL	101.C	R	1, 2	79
Reserved	BOOL	101.D	R	1, 2	80
Reserved	BOOL	101.E	R	1, 2	81
Reserved	BOOL	101.F	R	1, 2	82

Table 106 Modbus communication table.

3.1.7.3.4 Digital inputs and outputs

Type	Format	Address (Hexadecimal)	Access	Function code	Event ID
Digital inputs		**102**	**R**	**3, 4**	
Digital input 1	BOOL	102.0	R	1, 2	
Digital input 2	BOOL	102.1	R	1, 2	
Digital input 3	BOOL	102.2	R	1, 2	
Digital input 4	BOOL	102.3	R	1, 2	
Digital input 5	BOOL	102.4	R	1, 2	
Digital input 6	BOOL	102.5	R	1, 2	
Digital input 7	BOOL	102.6	R	1, 2	
Digital input 8	BOOL	102.7	R	1, 2	
Digital input 9	BOOL	102.8	R	1, 2	
Digital input 10	BOOL	102.9	R	1, 2	
Digital input 11	BOOL	102.A	R	1, 2	
Digital input 12	BOOL	102.B	R	1, 2	
Digital input 13	BOOL	102.C	R	1, 2	
Digital input 14	BOOL	102.D	R	1, 2	
Digital input 15	BOOL	102.E	R	1, 2	
Digital input 16	BOOL	102.F	R	1, 2	
Digital inputs		**103**	**R**	**3, 4**	
Digital input 17	BOOL	103.0	R	1, 2	
Digital input 18	BOOL	103.1	R	1, 2	
Digital input 19	BOOL	103.2	R	1, 2	
Digital input 20	BOOL	103.3	R	1, 2	
Digital input 21	BOOL	103.4	R	1, 2	
Digital input 22	BOOL	103.5	R	1, 2	
Digital input 23	BOOL	103.6	R	1, 2	
Digital input 24	BOOL	103.7	R	1, 2	
Digital input 25	BOOL	103.8	R	1, 2	
Digital input 26	BOOL	103.9	R	1, 2	
Digital input 27	BOOL	103.A	R	1, 2	
Digital input 28	BOOL	103.B	R	1, 2	
Digital input 29	BOOL	103.C	R	1, 2	
Digital input 30	BOOL	103.D	R	1, 2	
Reserved	BOOL	103.E	R	1, 2	
Reserved	BOOL	103.F	R	1, 2	
Digital outputs		**104**	**R**	**3, 4**	
Digital output 1	BOOL	104.0	R	1, 2	
Digital output 2	BOOL	104.1	R	1, 2	
Digital output 3	BOOL	104.2	R	1, 2	
Digital output 4	BOOL	104.3	R	1, 2	
Digital output 5	BOOL	104.4	R	1, 2	
Digital output 6	BOOL	104.5	R	1, 2	
Digital output 7	BOOL	104.6	R	1, 2	
Digital output 8	BOOL	104.7	R	1, 2	
Digital output 9	BOOL	104.8	R	1, 2	
Digital output 10	BOOL	104.9	R	1, 2	
Digital output 11	BOOL	104.A	R	1, 2	
Digital output 12	BOOL	104.B	R	1, 2	
Reserved	BOOL	104.C	R	1, 2	
Reserved	BOOL	104.D	R	1, 2	
Reserved	BOOL	104.E	R	1, 2	
Reserved	BOOL	104.F	R	1, 2	

Table 107 Modbus communication table.

3.1.7.3.5 System status

Type	Format	Address (Hexadecimal)	Access	Function code	Event ID
System status		**105**	**R**	**3, 4**	
Device error	BOOL	105.0	R	1, 2	
Device ready	BOOL	105.1	R	1, 2	
Time synchronized	BOOL	105.2	R	1, 2	
Reserved	BOOL	105.3	R	1, 2	
Reserved	BOOL	105.4	R	1, 2	
Reserved	BOOL	105.5	R	1, 2	
Reserved	BOOL	105.6	R	1, 2	
Reserved	BOOL	105.7	R	1, 2	
Reserved	BOOL	105.8	R	1, 2	
Reserved	BOOL	105.9	R	1, 2	
Reserved	BOOL	105.A	R	1, 2	
Reserved	BOOL	105.B	R	1, 2	
Reserved	BOOL	105.C	R	1, 2	
Reserved	BOOL	105.D	R	1, 2	
Reserved	BOOL	105.E	R	1, 2	
Reserved	BOOL	105.F	R	1, 2	
System status		**106**	**R**	**3, 4**	
EXT clock error	BOOL	106.0	R	1, 2	
INT clock error	BOOL	106.1	R	1, 2	
Eeprom 1 error	BOOL	106.2	R	1, 2	
Eeprom 1 error	BOOL	106.3	R	1, 2	
Mram error	BOOL	106.4	R	1, 2	
Emmc error	BOOL	106.5	R	1, 2	
12V error	BOOL	106.6	R	1, 2	
Adc error	BOOL	106.7	R	1, 2	
PS and DO card error	BOOL	106.8	R	1, 2	
DIO card 1 error	BOOL	106.9	R	1, 2	
DIO card 2 error	BOOL	106.A	R	1, 2	
DIO card 3 error	BOOL	106.B	R	1, 2	
AO card error	BOOL	106.C	R	1, 2	
RT environment error	BOOL	106.D	R	1, 2	
NRT environment error	BOOL	106.E	R	1, 2	
Reserved	BOOL	106.F	R	1, 2	

Table 108 Modbus communication table.

3.1.7.4 Remote command and control

Type	Format	Address (Hexadecimal)	Access	Function code	Event ID
Remote control		**118**	**W**	**6**	
CB Open command	BOOL	118.0	W	5	
CB Close command	BOOL	118.1	W	5	
Settings group A	BOOL	118.2	W	5	
Settings group B	BOOL	118.3	W	5	
Local mode	BOOL	118.4	W	5	
Remote mode	BOOL	118.5	W	5	
Confirm alarms	BOOL	118.6	W	5	
Reset protection counters	BOOL	118.7	W	5	
Reset operation counters	BOOL	118.8	W	5	
Disturbance record trigger	BOOL	118.9	W	5	
Reserved	BOOL	118.A		-	
Reserved	BOOL	118.B		-	
Reserved	BOOL	118.C		-	
Reserved	BOOL	118.D		-	
Reserved	BOOL	118.E		-	
Reserved	BOOL	118.F		-	

Table 109 Modbus communication table.

3.1.7.5 Counters

Counter status – Current protections	Address (Hexadecimal)	Access
Protection OC1 [50/51 - 1]	**1194**	**R**
Trip	1194	R
Pickup	1195	R
Pickup L_1	1196	R
Pickup L_2	1197	R
Pickup L_3	1198	R
CLP	1199	R
Protection OC1 [50/51 - 2]	**119A**	**R**
Trip	119A	R
Pickup	119B	R
Pickup L_1	119C	R
Pickup L_2	119D	R
Pickup L_3	119E	R
CLP	119F	R
Protection OC1 [50/51 - 3]	**11A0**	**R**
Trip	11A0	R
Pickup	11A1	R
Pickup L_1	11A2	R
Pickup L_2	11A3	R
Pickup L_3	11A4	R
CLP	11A5	R
Protection OC1 [50/51 - 4]	**11A6**	**R**
Trip	11A6	R
Pickup	11A7	R
Pickup L_1	11A8	R
Pickup L_2	11A9	R
Pickup L_3	11AA	R
CLP	11AB	R
Protection OCE 1 [50NG/51NG - 1]	**11AC**	**R**
Trip	11AC	R
Pickup	11AD	R
CLP	11AE	R
Protection OCE 1 [50NG/51NG - 2]	**11AF**	**R**
Trip	11AF	R
Pickup	11B0	R
CLP	11B1	R
Protection OCE 1 [50NG/51NG - 3]	**11B2**	**R**
Trip	11B2	R
Pickup	11B3	R
CLP	11B4	R
Protection OCE 1 [50NG/51NG - 4]	**11B5**	**R**
Trip	11B5	R
Pickup	11B6	R
CLP	11B7	R

Table 110 Modbus communication table.

Counter status – Current protections	Address (Hexadecimal)	Access
Protection REF 1 [64REF - 1]	**11B8**	**R**
Trip	11B8	R
Pickup	11B9	R
Protection REF 2 [64REF - 2]	**11BA**	**R**
Trip	11BA	R
Pickup	11BB	R
Protection NSOC [46]	**11BC**	**R**
Trip	11BC	R
Pickup	11BD	R
Protection UC [37]	**11BE**	**R**
Trip	11BE	R
Pickup	11BF	R
Pickup L_1	11C0	R
Pickup L_2	11C1	R
Pickup L_3	11C2	R

Table 111 Modbus communication table.

Counter status – Voltage protections	Address (Hexadecimal)	Access
Protection UV 1 [27 - 1]	**11C3**	**R**
Trip	11C3	R
Pickup	11C4	R
Pickup L_1	11C5	R
Pickup L_2	11C6	R
Pickup L_3	11C7	R
Protection UV 2 [27 - 2]	**11C2**	**R**
Trip	11C8	R
Pickup	11C9	R
Pickup L_1	11CA	R
Pickup L_2	11CB	R
Pickup L_3	11CC	R
Protection RUV [27R]	**11CD**	**R**
Trip	11CD	R
Pickup	11CE	R
Protection PSUV 1 [27D - 1]	**11CF**	**R**
Trip	11CF	R
Pickup	11D0	R
Protection PSUV 2 [27D - 2]	**11D1**	**R**
Trip	11D1	R
Pickup	11D2	R
Protection OV 1 [59 - 1]	**11D3**	**R**
Trip	11D3	R
Pickup	11D4	R
Pickup L_{12}	11D5	R
Pickup L_{23}	11D6	R
Pickup L_{31}	11D7	R
Protection OV 2 [59 - 2]	**11D8**	**R**
Trip	11D8	R
Pickup	11D9	R
Pickup L_{12}	11DA	R
Pickup L_{23}	11DB	R
Pickup L_{31}	11DC	R
Protection OVE 1 [59NG - 1]	**11DD**	**R**
Trip	11DD	R
Pickup	11DE	R
Protection OVE 2 [59NG - 2]	**11DF**	**R**
Trip	11DF	R
Pickup	11E0	R
Reserved	11E1	R
Reserved	11E2	R
Reserved	11E3	R
Reserved	11E4	R

Table 112 Modbus communication table.

Counter status – Frequency protections	Address (Hexadecimal)	Access
Protection OF 1 [81H - 1]	**11E5**	**R**
Trip	11E5	R
Pickup	11E6	R
Protection OF 2 [81H - 1]	**11E7**	**R**
Trip	11E7	R
Pickup	11E8	R
Protection UF 1 [81L - 1]	**11E9**	**R**
Trip	11E9	R
Pickup	11EA	R
Protection UF 2 [81L - 2]	**11EB**	**R**
Trip	11EB	R
Pickup	11EC	R
Protection UF 3 [81L - 3]	**11ED**	**R**
Trip	11ED	R
Pickup	11EE	R
Protection UF 4 [81L - 4]	**11EF**	**R**
Trip	11EF	R
Pickup	11F0	R
Protection ROCOF [81R]	**11F1**	**R**
Trip	11F1	R
Pickup	11F2	R

Table 113 Modbus communication table.

Counter status – Other	Address (Hexadecimal)	Access
Machine control MC	**11F3**	**R**
Running hours	11F3	R
Running minutes	11F4	R
Protection TO [49T]	**11F5**	**R**
Trip	11F5	R
Pickup	11F6	R
Protection MTO [49M]	**11F7**	**R**
Trip	11F7	R
Pickup	11F8	R
Protection SPH [66]	**11F9**	**R**
Current starts	11F9	R
Current consecutive cold starts	11FA	R
Current consecutive hot starts	11FB	R
Inhibit counter	11FC	R
Starts counter	11FD	R
Protection LR [48/51LR/14]	**11FE**	**R**
Trip	11FE	R
Excessive start	11FF	R
Locked rotor	1200	R
Stall	1201	R
Protection Thermostat 1	**1202**	**R**
Trip	1202	R
Pickup	1203	R
Protection Thermostat 2	**1204**	**R**
Trip	1204	R
Pickup	1205	R
Protection Buchholz 1	**1206**	**R**
Trip	1206	R
Pickup	1207	R
Protection Buchholz 2	**1208**	**R**
Trip	1208	R
Pickup	1209	R
Protection EXT 1	**120A**	**R**
Trip	120A	R
Pickup	120B	R
Protection EXT 2	**120C**	**R**
Trip	120C	R
Pickup	120D	R
Inrush restraint 1	**120E**	**R**
Block	120E	R
Inrush restraint 2	**120F**	**R**
Block	120F	R

Table 114 Modbus communication table.

Counter status – Other	Address (Hexadecimal)	Access
Protection TMO 1 [38/49T - 1]	**1210**	**R**
Trip	1210	R
Pickup	1211	R
Protection TMO 2 [38/49T - 2]	**1212**	**R**
Trip	1212	R
Pickup	1213	R
Protection TMO 3 [38/49T - 3]	**1214**	**R**
Trip	1214	R
Pickup	1215	R
Protection TMO 4 [38/49T - 4]	**1216**	**R**
Trip	1216	R
Pickup	1217	R
Protection TMO 5 [38/49T - 5]	**1218**	**R**
Trip	1218	R
Pickup	1219	R
Protection TMO 6 [38/49T - 6]	**121A**	**R**
Trip	121A	R
Pickup	121B	R
Protection TMO 7 [38/49T - 7]	**121C**	**R**
Trip	121C	R
Pickup	121D	R
Protection TMO 8 [38/49T - 8]	**121E**	**R**
Trip	121E	R
Pickup	121F	R
TCS	**1220**	**R**
Alarm	1220	R
CB [94/69]	**1221**	**R**
$I^2t - L_1$	1221	R
$I^2t - L_2$	1222	R
$I^2t - L_3$	1223	R
Open	1224	R
Close	1225	R
Trip	1226	R
Trip OC	1227	R
CBFP	1228	R
LCR	**1229**	**R**
Active	1229	R
AR [79]	**122A**	**R**
1st cycle	122A	R
2nd cycle	122B	R
3rd cycle	122C	R
4th cycle	122D	R
5th cycle	122E	R

Table 115 Modbus communication table.

3.1.7.6 Measurements 16 bit

3.1.7.6.1 Current

Type	Format	Address (Hexadecimal)	Access	Function code	Unit
Current		**1010 – 102B**	**R**		
Phase current I_{L1}	UINT16	1010	R	3, 4	0,1 A
Phase current I_{L2}	UINT16	1011	R	3, 4	0,1 A
Phase current I_{L3}	UINT16	1012	R	3, 4	0,1 A
Earth current I_e	UINT16	1013	R	3, 4	0,1 A
Average phase current I_{L1}	UINT16	1014	R	3, 4	0,1 A
Average phase current I_{L2}	UINT16	1015	R	3, 4	0,1 A
Average phase current I_{L3}	UINT16	1016	R	3, 4	0,1 A
Average earth current I_e	UINT16	1017	R	3, 4	0,1 A
Phase current I_{L1}	UINT16	1018	R	3, 4	1 A
Phase current I_{L2}	UINT16	1019	R	3, 4	1 A
Phase current I_{L3}	UINT16	101A	R	3, 4	1 A
Earth current I_e	UINT16	101B	R	3, 4	1 A
Average phase current I_{L1}	UINT16	101C	R	3, 4	1 A
Average phase current I_{L2}	UINT16	101D	R	3, 4	1 A
Average phase current I_{L3}	UINT16	101E	R	3, 4	1 A
Average earth current I_e	UINT16	101F	R	3, 4	1 A
Max phase current I_{L1}	UINT16	1020	R	3, 4	1 A
Max phase current I_{L2}	UINT16	1021	R	3, 4	1 A
Max phase current I_{L3}	UINT16	1022	R	3, 4	1 A
Max earth current I_e	UINT16	1023	R	3, 4	1 A
Positive sequence current I_1	UINT16	1024	R	3, 4	0,1 A
Negative sequence current I_2	UINT16	1025	R	3, 4	0,1 A
Zero sequence current I_0	UINT16	1026	R	3, 4	0,1 A
3xZero sequence current $3xI_0$	UINT16	1027	R	3, 4	0,1 A
THD current I_{L1}	UINT16	1028	R	3, 4	0,1 %
THD current I_{L2}	UINT16	1029	R	3, 4	0,1 %
THD current I_{L3}	UINT16	102A	R	3, 4	0,1 %
THD current I_e	UINT16	102B	R	3, 4	0,1 %

Table 116 Modbus communication table.

3.1.7.6.2 Voltage

Type	Format	Address (Hexadecimal)	Access	Function code	Unit
Voltage		**102C – 104D**	**R**		
Phase to phase voltage U_{12}	UINT16	102C	R	3, 4	1 V
Phase to phase voltage U_{23}	UINT16	102D	R	3, 4	1 V
Phase to phase voltage U_{31}	UINT16	102E	R	3, 4	1 V
Phase voltage U_{L1}	UINT16	102F	R	3, 4	1 V
Phase voltage U_{L2}	UINT16	1030	R	3, 4	1 V
Phase voltage U_{L3}	UINT16	1031	R	3, 4	1 V
Earth voltage U_e	UINT16	1032	R	3, 4	1 V
Average phase voltage U_{L1}	UINT16	1033	R	3, 4	1 V
Average phase voltage U_{L2}	UINT16	1034	R	3, 4	1 V
Average phase voltage U_{L3}	UINT16	1035	R	3, 4	1 V
Average earth voltage U_e	UINT16	1036	R	3, 4	1 V
Phase to phase voltage U_{12}	UINT16	1037	R	3, 4	10 V
Phase to phase voltage U_{23}	UINT16	1038	R	3, 4	10 V
Phase to phase voltage U_{31}	UINT16	1039	R	3, 4	10 V
Phase voltage U_{L1}	UINT16	103A	R	3, 4	10 V
Phase voltage U_{L2}	UINT16	103B	R	3, 4	10 V
Phase voltage U_{L3}	UINT16	103C	R	3, 4	10 V
Earth voltage U_e	UINT16	103D	R	3, 4	10 V
Average phase voltage U_{L1}	UINT16	103E	R	3, 4	10 V
Average phase voltage U_{L2}	UINT16	103F	R	3, 4	10 V
Average phase voltage U_{L3}	UINT16	1040	R	3, 4	10 V
Average earth voltage U_e	UINT16	1041	R	3, 4	10 V
Max phase voltage U_{L1}	UINT16	1042	R	3, 4	10 V
Max phase voltage U_{L2}	UINT16	1043	R	3, 4	10 V
Max phase voltage U_{L3}	UINT16	1044	R	3, 4	10 V
Max earth voltage U_e	UINT16	1045	R	3, 4	10 V
Positive sequence voltage U_1	UINT16	1046	R	3, 4	1 V
Negative sequence voltage U_2	UINT16	1047	R	3, 4	1 V
Zero sequence voltage U_0	UINT16	1048	R	3, 4	1 V
3xZero sequence voltage $3xU_0$	UINT16	1049	R	3, 4	1 V
THD U_{L1}	UINT16	104A	R	3, 4	0,1 %
THD U_{L2}	UINT16	104B	R	3, 4	0,1 %
THD U_{L3}	UINT16	104C	R	3, 4	0,1 %
THD U_e	UINT16	104D	R	3, 4	0,1 %

Table 117 Modbus communication table.

3.1.7.6.3 Frequency

Type	Format	Address (Hexadecimal)	Access	Function code	Unit
Frequency		**104E**	**R**		
System frequency f	UINT16	104E	R	3, 4	0,001 Hz
Max system frequency f_{max}	UINT16	104F	R	3, 4	0,001 Hz
Min system frequency f_{min}	UINT16	1050	R	3, 4	0,001 Hz
Reserved	-	1051	-	-	-
Reserved	-	1052	-	-	-

Table 118 Modbus communication table.

3.1.7.6.4 Temperature

Type	Format	Address (Hexadecimal)	Access	Function code	Unit
Temperature		**1053**	**R**		
Sensor 1	INT16	1053	R	3, 4	0,1 °C
Sensor 2	INT16	1054	R	3, 4	0,1 °C
Sensor 3	INT16	1055	R	3, 4	0,1 °C
Sensor 4	INT16	1056	R	3, 4	0,1 °C
Sensor 5	INT16	1057	R	3, 4	0,1 °C
Sensor 6	INT16	1058	R	3, 4	0,1 °C
Sensor 7	INT16	1059	R	3, 4	0,1 °C
Sensor 8	INT16	105A	R	3, 4	0,1 °C
Sensor 9	INT16	105B	R	3, 4	0,1 °C
Sensor 10	INT16	105C	R	3, 4	0,1 °C
Sensor 11	INT16	105D	R	3, 4	0,1 °C
Sensor 12	INT16	105E	R	3, 4	0,1 °C
Sensor 13	INT16	105F	R	3, 4	0,1 °C
Sensor 14	INT16	1060	R	3, 4	0,1 °C
Sensor 15	INT16	1061	R	3, 4	0,1 °C
Sensor 16	INT16	1062	R	3, 4	0,1 °C

Table 119 Modbus communication table.

3.1.7.6.5 Other analog values

Temperature		**1063**	**R**		
Tripping current phase 1	UINT16	1063	R	3, 4	1 A
Tripping current phase 2	UINT16	1064	R	3, 4	1 A
Tripping current phase 3	UINT16	1065	R	3, 4	1 A

Table 120 Modbus communication table.

3.1.7.7 Measurements 32 bit

3.1.7.7.1 Current

Type	Format	Starting address (Hexadecimal)	Access	Function code	Unit
Current		**1068 – 108F**	**R**		
Phase current I_{L1}	FLOAT32	1068	R	3, 4	[A]
Phase current I_{L2}	FLOAT32	106A	R	3, 4	[A]
Phase current I_{L3}	FLOAT32	106C	R	3, 4	[A]
Earth current I_e	FLOAT32	106E	R	3, 4	[A]
Average phase current I_{L1}	FLOAT32	1070	R	3, 4	[A]
Average phase current I_{L2}	FLOAT32	1072	R	3, 4	[A]
Average phase current I_{L3}	FLOAT32	1074	R	3, 4	[A]
Average earth current I_e	FLOAT32	1076	R	3, 4	[A]
Max phase current I_{L1}	FLOAT32	1078	R	3, 4	[A]
Max phase current I_{L2}	FLOAT32	107A	R	3, 4	[A]
Max phase current I_{L3}	FLOAT32	107C	R	3, 4	[A]
Max earth current I_e	FLOAT32	107E	R	3, 4	[A]
Positive sequence current I_1	FLOAT32	1080	R	3, 4	[A]
Negative sequence current I_2	FLOAT32	1082	R	3, 4	[A]
Zero sequence current I_0	FLOAT32	1084	R	3, 4	[A]
3xZero sequence current $3xI_0$	FLOAT32	1086	R	3, 4	[A]
THD current I_{L1}	FLOAT32	1088	R	3, 4	[%]
THD current I_{L2}	FLOAT32	108A	R	3, 4	[%]
THD current I_{L3}	FLOAT32	108C	R	3, 4	[%]
THD current I_e	FLOAT32	108E	R	3, 4	[%]

Table 121 Modbus communication table.

3.1.7.7.2 Voltage

Type	Format	Address (Hexadecimal)	Access	Function code	Unit
Voltage		**1090 – 10BD**	**R**		
Phase to phase voltage U_{12}	FLOAT32	1090	R	3, 4	[V]
Phase to phase voltage U_{23}	FLOAT32	1092	R	3, 4	[V]
Phase to phase voltage U_{31}	FLOAT32	1094	R	3, 4	[V]
Phase voltage U_{L1}	FLOAT32	1096	R	3, 4	[V]
Phase voltage U_{L2}	FLOAT32	1098	R	3, 4	[V]
Phase voltage U_{L3}	FLOAT32	109A	R	3, 4	[V]
Earth voltage U_e	FLOAT32	109C	R	3, 4	[V]
Average phase voltage U_{L1}	FLOAT32	109E	R	3, 4	[V]
Average phase voltage U_{L2}	FLOAT32	10A0	R	3, 4	[V]
Average phase voltage U_{L3}	FLOAT32	10A2	R	3, 4	[V]
Average earth voltage U_e	FLOAT32	10A4	R	3, 4	[V]
Max phase voltage U_{L1}	FLOAT32	10A6	R	3, 4	[V]
Max phase voltage U_{L2}	FLOAT32	10A8	R	3, 4	[V]
Max phase voltage U_{L3}	FLOAT32	10AA	R	3, 4	[V]
Max earth voltage U_e	FLOAT32	10AC	R	3, 4	[V]
Positive sequence voltage U_1	FLOAT32	10AE	R	3, 4	[V]
Negative sequence voltage U_2	FLOAT32	10B0	R	3, 4	[V]
Zero sequence voltage U_0	FLOAT32	10B2	R	3, 4	[V]
3xZero sequence voltage $3xU_0$	FLOAT32	10B4	R	3, 4	[V]
THD U_{L1}	FLOAT32	10B6	R	3, 4	[%]
THD U_{L2}	FLOAT32	10B8	R	3, 4	[%]
THD U_{L3}	FLOAT32	10BA	R	3, 4	[%]
THD U_e	FLOAT32	10BC	R	3, 4	[%]

Table 122 Modbus communication table.

3.1.7.7.3 Frequency

Type	Format	Address (Hexadecimal)	Access	Function code	Unit
Frequency		**10BE – 10C8**	**R**		
System frequency f	FLOAT32	10BE	R	3, 4	[Hz]
Max system frequency f_{max}	FLOAT32	10C0	R	3, 4	[Hz]
Min system frequency f_{min}	FLOAT32	10C2	R	3, 4	[Hz]
Reserved	-	10C4	-	-	-
Reserved	-	10C6	-	-	-

Table 123 Modbus communication table.

3.1.7.7.4 Power

Type	Format	Address (Hexadecimal)	Access	Function code	Unit
Power		**10C8 – 10F3**	**R**		
Active power P_{rms}	FLOAT32	10C8	R	3, 4	[W]
Reactive power Q_{rms}	FLOAT32	10CA	R	3, 4	[var]
Apparent power S_{rms}	FLOAT32	10CC	R	3, 4	[VA]
Power factor Cos φ	FLOAT32	10CE	R	3, 4	-
Average active power P_{rms}	FLOAT32	10D0	R	3, 4	[W]
Average reactive power Q_{rms}	FLOAT32	10D2	R	3, 4	[var]
Average apparent power S_{rms}	FLOAT32	10D4	R	3, 4	[VA]
Max active power P_{rms}	FLOAT32	10D6	R	3, 4	[W]
Max reactive power Q_{rms}	FLOAT32	10D8	R	3, 4	[var]
Max apparent power S_{rms}	FLOAT32	10DA	R	3, 4	[VA]
Active power P_{L1}	FLOAT32	10DC	R	3, 4	[W]
Active power P_{L2}	FLOAT32	10DE	R	3, 4	[W]
Active power P_{L3}	FLOAT32	10E0	R	3, 4	[W]
Reactive power Q_{L1}	FLOAT32	10E2	R	3, 4	[var]
Reactive power Q_{L2}	FLOAT32	10E4	R	3, 4	[var]
Reactive power Q_{L3}	FLOAT32	10E6	R	3, 4	[var]
Apparent power S_{L1}	FLOAT32	10E8	R	3, 4	[VA]
Apparent power S_{L2}	FLOAT32	10EA	R	3, 4	[VA]
Apparent power S_{L3}	FLOAT32	10EC	R	3, 4	[VA]
Power factor Cos $φ_1$	FLOAT32	10EE	R	3, 4	-
Power factor Cos $φ_2$	FLOAT32	10F0	R	3, 4	-
Power factor Cos $φ_3$	FLOAT32	10F2	R	3, 4	-

Table 124 Modbus communication table.

3.1.7.7.5 Other analog values

Type	Format	Address (Hexadecimal)	Access	Function code	Unit
Power		**1106 – 1067**	**R**		
Tripping current I_{trip_L1}	UINT32	1106	R	3, 4	[A]
Tripping current I_{trip_L2}	UINT32	1108	R	3, 4	[A]
Tripping current I_{trip_L3}	UINT32	110A	R	3, 4	[A]

Table 125 Modbus communication table.

3.1.7.8 Remote registers

Type	Format	Address (Hexadecimal)	Access	Function code	Unit
Power		**2710 – 2712**	**W**		
Analog set-point 1	UINT16	2710	W	6, 16	-
Analog set-point 2	UINT16	2711	W	6, 16	-
Analog set-point 3	UINT16	2712	W	6, 16	-

Table 126 Modbus communication table.

3.2 Protocol IEC60870-5-103

Standard IEC60870-5-103 defines communication between protection equipment and dedicated supervisor devices. The standard in full form can be obtained from the International Electrotechnical Commission (IEC).

3.2.1 General description

The IEC60870-5-103 protocol is a Slave – Master based communication protocol. An information can be exchanged between master and one or multiple slave devices. A supervisor or other device is used as master and the device is always used as a slave station. Multiple slave stations can be connected to the supervisor device. Each slave station is identified by unique address.

The following application functions can be accessed or executed using this protocol:

- Time synchronization
- Confirmation of alarms
- Reading the metering information
- Reading the device status and switchgear diagnostic information
- Transmission of remote controls

3.2.2 Acronyms and Terms

Acronym or term	Description
ASDU	Application Service data unit.
BIDI	Event on bidirectional transition.
CADD	Common address of ASDU.
COT	Cause of Transmission of ASDU.
FUN	The number of the function to which data belongs.
GI	A General Interrogation marker.
INF	The information number of the basic data.
TYPE	Type identification of ASDU.
Normalize Factor	Rate factor, valid just for measurements.
Rated Value	Reference unit, valid for metering information.

Table 127 Description of acronyms and terms.

If a BIDI is selected the event is generated on both on event occurrence and event disappearance. Else event is generated only on its occurrence.

3.2.3 Protocol data transfer

The standard defines two methods of exchanging information. First, which is supported, by using predefined ASDU (Application Service Data Units) data structures and predefined transmission of standardized information. Second, non-supported, uses generic services which defines the transmission of any type of information. The protocol is using two types of exchanging information based on its source divided to control direction and monitoring direction.

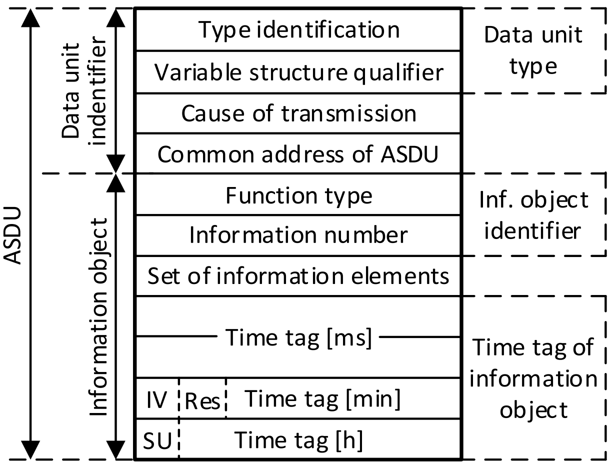


Table 128 ASDU structure, as presented in the standard IEC60870-5-103.

3.2.3.1 Monitor direction

Defines direction of transmission from the protection equipment to the control system. Primarily it is used to send cyclic and event information transmission requests of master to the slave device/s.

- Class 1 data pooling is usually used for event type of transmission.
- Class 2 data pooling is usually used for Cyclic sending of data. Typically for metering information.

COT	Label	Description
1	Spontaneous	Date-tagged event information.
2	Cyclic	Cyclic produced Metering information.
3	Reset (FCB)	Response to the reset the frame count bit.
4	Reset (CU)	Response to the reset communication unit.
5	Start/restart	Response to the command to initialise a communication.
8	Time synchronization	Response to the time synchronization command.
9	General interrogation	Response according to GI request.
10	End of General interrogation	Termination massage of the general interrogation cycle.
12	Remote operation	A change of status resulted by a master command.
20	Positive acknowledgement	Positive response of the generic write command.
21	Negative acknowledgement	Negative Response of the generic write command.

Table 129 Supported COT numbers in monitor direction.

3.2.3.2 Control direction

Defines direction of transmission from the control system to the protection equipment. Typically for:

- sending control commands
- time synchronization commands
- Executing of start/reset communication commands.

COT	Label	Description
8	Time synchronization	Time synchronization command.
9	General interrogation	Initialization of a general interrogation cycle.
20	General command	Response to the reset the frame count bit.

Table 130 Supported COT numbers in control direction.

3.2.3.3 The device initialization

Whenever the device has started, a Start/restart procedure is required to initialise a communication. The device communications can be reset using either the Reset CU or Reset FCB command. The Command Reset CU will also clear any unsent massages while Reset FCB will only initialise the communication.

3.2.3.4 Time synchronization

The device date and time can be synchronized using the standardized synchronization command. The command can be send to individual with confirm request or to all devices with no reply request (address 255). The device also accounts time synchronization correction according to this standard.

3.2.3.5 General interrogation

General interrogation represents group of data, general information about the status of the device. If GI is requested the device will respond with the data as marked in Table 132. This data is also transmitted spontaneously (COT 1).

3.2.4 Supported standard options and functions

This section is direct copy of a standard IEC 60870-5-103 © IEC:1997, 159-171. To represent what options from the standard are included in communication service.

8 Interoperability

8.1 Physical layer

8.1.1 Electrical interface

☒ EIA RS-485

☒ Number of loads ...32... for one protection equipment.

8.1.2 Electrical interface

☒ Glass fibre

☐ Plastic fibre

☐ F-SMA type connector

☐ BFOC/2,5 type connector

8.1.3 Transmission speed

☒ 9600 bit/s

☒ 19200 bit/s

(Plus additional settings)

8.2 Link layer

There are no choices for the link layer.

8.3 Application layer

8.3.1 Transmission mode for application data

Mode 1 (least significant octet first), as defined in 4.10 of IEC870-5-4. Is used exclusively in this companion standard

8.3.2 Common address of ASDU

☐ One common address of ASDU (identical with station address)

☐ More than one common address of ASDU

8.3.3 Selection of standard information numbers in monitor direction

8.3.3.1 System functions in monitor direction

	INF	**Semantics**
☒	<0>	End of general interrogation
☒	<0>	Time synchronization
☒	<2>	Reset FCB
☒	<3>	Reset CU
☒	<4>	Start/restart
☐	<5>	Power on

8.3.3.2 Status indication in monitor direction

	INF	Semantics
☒	<16>	Auto-recloser active
☐	<17>	Teleprotection active
☐	<18>	Protection active
☒	<19>	LED reset
☐	<20>	Monitor direction blocked
☐	<21>	Test mode
☐	<22>	Local parameter setting
☒	<23>	Characteristic 1
☒	<24>	Characteristic 2
☐	<25>	Characteristic 3
☐	<26>	Characteristic 4
☐	<27>	Auxiliary input 1
☐	<28>	Auxiliary input 2
☐	<29>	Auxiliary input 3
☐	<30>	Auxiliary input 4

8.3.3.3 Supervision indications in monitor direction

	INF	Semantics
☒	<32>	Measurand supervision I
☒	<33>	Measurand supervision V
☐	<35>	Phase sequence supervision
☒	<36>	Trip circuit supervision
☐	<37>	I>> back-up operation
☐	<38>	VT fuse failure
☐	<39>	Teleprotection disturbed
☐	<46>	Group warning
☐	<47>	Group alarm

8.3.3.4 Earth fault indications in monitor direction

	INF	Semantics
☐	<48>	Earth fault L_1
☐	<49>	Earth fault L_2
☐	<50>	Earth fault L_3
☐	<51>	Earth fault forward, i.e. line
☐	<52>	Earth fault reverse, i.e. busbar

8.3.3.5 Fault indications in monitor direction

	INF	Semantics
☐	<64>	Start/pick-up L_1
☐	<65>	Start/pick-up L_2
☐	<66>	Start/pick-up L_3
☐	<67>	Start/pick-up N
☒	<68>	General trip
☐	<69>	Trip L_1
☐	<70>	Trip L_2
☐	<71>	Trip L_3
☐	<72>	Trip I>> (back-up operation)
☐	<73>	Fault location X in ohms
☐	<74>	Fault forward/line
☐	<75>	Fault reverse/busbar
☐	<76>	Teleprotection signal transmitted
☐	<77>	Teleprotection signal received
☐	<78>	Zone 1
☐	<79>	Zone 2
☐	<80>	Zone 3
☐	<81>	Zone 4
☐	<82>	Zone 5
☐	<83>	Zone 6
☐	<84>	General start/pick-up
☒	<85>	Breaker failure
☐	<86>	Trip measuring system L_1
☐	<87>	Trip measuring system L_2
☐	<88>	Trip measuring system L_3
☐	<89>	Trip measuring system E
☒	<90>	Trip I>
☒	<91>	Trip I>>
☒	<92>	Trip IN>
☒	<93>	Trip IN>>

8.3.3.6 Auto-reclosure indications in monitor direction

	INF	Semantics
☒	<128>	CB 'on' by AR
☐	<129>	CB 'on' by long-time AR
☐	<130>	AR blocked

8.3.3.7 Measurands in monitor direction

	INF	Semantics
☒	<144>	Measurand I
☒	<145>	Measurand I, V
☐	<146>	Measurand I, V, P, Q
☐	<147>	Measurand I_N, V_{EN}
☒	<148>	Measurands $I_{L1,2,3}$, $V_{L1,2,3}$, P, Q, f

8.3.3.8 Generic functions in monitor direction

	INF	Semantics
☐	<240>	Read headings of all defined groups
☐	<241>	Read values of attributes of all entries of one group
☐	<243>	Read directory of a single entry
☐	<244>	Read value or attribute of a single entry
☐	<245>	End of general interrogation of generic data
☐	<249>	Write entry with confirmation
☐	<250>	Write entry with execution
☐	<251>	Write entry aborted

8.3.4 Selection of standard information numbers in control direction

8.3.4.1 System functions in control direction

	INF	Semantics
☒	<0>	Initiation of general interrogation
☒	<0>	Time synchronization

8.3.4.2 General commands in control direction

	INF	Semantics
☐	<16>	Auto-recloser on/off
☐	<17>	Teleprotection on/off
☐	<18>	Protection on/off
☒	<19>	LED reset
☒	<23>	Activate characteristic 1
☒	<24>	Activate characteristic 2
☐	<25>	Activate characteristic 3
☐	<26>	Activate characteristic 4

8.3.4.3 Generic functions in control direction

	INF	Semantics
☐	<240>	Read headings of all defined groups
☐	<241>	Read values of attributes of all entries of one group
☐	<243>	Read directory of a single entry
☐	<244>	Read value or attribute of a single entry
☐	<245>	General interrogation of generic data
☐	<248>	Write entry
☐	<249>	Write entry with confirmation
☐	<250>	Write entry with execution
☐	<251>	Write entry abort

8.3.5 Basic application functions

☐ Test mode

☐ Blocking of monitor direction

☐ Disturbance data

☐ Generic services

☐ Private data

8.3.1 Miscellaneous

Measurands are transmitted with ASDU 3 as well with ASDU 9. As defined in 7,2,6,8, the maximum MVAL can either be 1,2 or 2,4 times the rated value. No different rating shall be used in ASDU 3 and ASDU 9, i.e. for each measurand there is only one choice.

Measurand	**Max. MVAL = rated value times**		
	1,2	**or**	**2,4**
Current L_1	☒		☐
Current L_2	☒		☐
Current L_3	☒		☐
Voltage L_{1-E}	☒		☐
Voltage L_{2-E}	☒		☐
Voltage L_{3-E}	☒		☐
Active power P	☒		☐
Reactive power Q	☒		☐
Frequency f	☒		☐
Voltage L_1 - L_2	☒		☐

3.2.5 Parameters

The following parameters needs to be set for the communication to be established properly

Parameter	**Range**	**Description**
Protocol	**ModbusRTU** IEC103	Selection of active communication protocol.
Device address	0 … **33** … 254	Number by each slave device is uniquely addressed.
Baud rate	1200 2400 4800 9600 **19200** 38400 57600 115200	Defines the number of binary information to be transmitted per second.
Parity	**Even**	Adds an error checking bit that follows the data bits in the character frame.
Stop bits	**1**	Number of stop bits after each character frame.
Data bits	**8**	Number of data bits in each character frame.

Table 131 Parameters of Modbus RTU communication protocol.

3.2.6 Data table – Monitor direction

ASDU	FUN	INF	COT	GI	IEC 60870-5-103 semantic	FPC 400 semantic
System functions						
8	255	0	10		End of general interrogation	
6	255	0	8		Time synchronization	
5	255	2	3		Reset frame count bit (FCB)	
5	255	3	4		Reset communication unit (CU)	
5	255	4	5		Start/restart	
Over-current protection (IEC 60870-5-103 standard function)						
1	160	16	1,9	X	Auto-recloser active	79 - AR in progress
1	160	19	1,12,20,21		LED reset	
1	160	23	1,9,12,20,21	X	Characteristic 1	Set group A
1	160	24	1,9,12,20,21	X	Characteristic 1	Set group B
1	160	32	1,9	X	Measurand supervision I	ADC error
1	160	33	1,9	X	Measurand supervision V	ADC error
1	160	36	1,9	X	Trip circuit supervision	74TCS wrong position
2	160	68	1		General trip	Common trip
2	160	85	1		Breaker failure	CBFP open command
2	160	90	1		Trip I>	Protection OC1 [50/51 - 1]
2	160	91	1		Trip I>	Protection OC2 [50/51 - 2]
2	160	92	1		Trip IN>	Protection OCE 1 [50NG/51NG-1]
2	160	93	1		Trip IN>	Protection OCE 2 [50NG/51NG-2]
1	160	128	1		CB 'on' by Auto-recloser	79 – AR CB close
FPC400 supervisor						
1	20	1	1,9	X		Device ready
1	20	2	1,9	X		Device error
1	20	3	1,9	X		PS - DO card error
1	20	4	1,9	X		DIO card 1 error
1	20	5	1,9	X		DIO card 2 error
1	20	6	1,9	X		DIO card 3 error
1	20	7	1,9	X		RT environment error
Switchgear and network						
1	21	1	1,9	X		CB status
1	21	3	1,9	X		CB local mode
1	21	4	1,9	X		CB remote mode
1	21	5	1,9	X		79 – AR not ready
1	21	6	1,9	X		79 – AR definite trip
Current protections						
2	100	1	1			Protection OC3 [50/51 - 3]
2	100	2	1			Protection OC4 [50/51 - 4]
2	100	3	1			Protection OCE 3 [50NG/51NG-3]
2	100	4	1			Protection OCE 4 [50NG/51NG-4]
2	100	5	1			Protection REF1 [64REF - 1]
2	100	6	1			Protection REF2 [64REF - 2]
2	100	7	1			Protection NS [46]
2	100	8	1			Protection NS [46]
2	100	9	1			Protection UC [37]
2	100	10	1			Protection UC [37]

Table 132 Data table of the standard protocol IEC60870-5-103, monitor direction.

ASDU	FUN	INF	COT	GI	IEC 60870-5-103 semantic	FPC 400 semantic
					Voltage protections	
2	102	1	1			Protection UV 1 [27 - 1]
2	102	2	1			Protection UV 2 [27 - 2]
2	102	3	1			Protection RUV [27R]
2	102	4	1			Protection PSUV 1 [27D - 1]
2	102	5	1			Protection PSUV 2 [27D - 2]
2	102	6	1			Protection OV 1 [59 - 1]
2	102	7	1			Protection OV 2 [59 - 2]
2	102	8	1			Protection NVD 1 [59NG - 1]
2	102	9	1			Protection NVD 2 [59NG - 2]
2	102	10	1			Protection NVD 1 [59NG - 3]
2	102	11	1			Protection NVD 2 [59NG - 4]
					Frequency protections	
2	103	1	1			Protection OF 1 [81H - 1]
2	103	2	1			Protection OF 2 [81H - 2]
2	103	3	1			Protection UF 1 [81L - 1]
2	103	4	1			Protection UF 2 [81L - 2]
2	103	5	1			Protection UF 3 [81L - 3]
2	103	6	1			Protection UF 4 [81L - 4]
2	103	7	1			Protection ROCOF [81R]
					Motor/generator protections	
2	104	1	1			Protection TO [49T]
2	104	2	1			Protection MTO [49M]
2	104	3	1			Protection LR [48/51LR/14]
2	104	4	1			Protection SPH [66]
					Miscellaneous protections	
2	105	1	1			Protection EXT 1
2	105	2	1			Protection EXT 2
2	105	3	1			Thermostat 1
2	105	4	1			Thermostat 2
2	105	5	1			Buchholz 1
2	105	6	1			Buchholz 2
					Thermal protections	
2	106	1	1			Protection TMO 1 [38/49T - 1]
2	106	2	1			Protection TMO 2 [38/49T - 2]
2	106	3	1			Protection TMO 3 [38/49T - 3]
2	106	4	1			Protection TMO 4 [38/49T - 4]
2	106	5	1			Protection TMO 5 [38/49T - 5]
2	106	6	1			Protection TMO 6 [38/49T - 6]
2	106	7	1			Protection TMO 7 [38/49T - 7]
2	106	8	1			Protection TMO 8 [38/49T - 8]
2	106	9	1			Protection TMO 9 [38/49T - 9]
2	106	10	1			Protection TMO 10 [38/49T - 10]
2	106	11	1			Protection TMO 11 [38/49T - 11]
2	106	12	1			Protection TMO 12 [38/49T - 12]
2	106	13	1			Protection TMO 13 [38/49T - 13]
2	106	14	1			Protection TMO 14 [38/49T - 14]
2	106	15	1			Protection TMO 15 [38/49T - 15]
2	106	16	1			Protection TMO 16 [38/49T - 16]

Table 133 Data table of the standard protocol IEC60870-5-103, monitor direction.

ASDU	FUN	INF	COT	GI	IEC 60870-5-103 semantic	FPC 400 semantic
					Standard measurements	
9	160	148	2		MEA1: Phase current I1	MEA1: Phase current I_{L1}
					MEA2: Phase current I2	MEA2: Phase current I_{L2}
					MEA3: Phase current I3	MEA3: Phase current I_{L3}
					MEA4: Phase voltage U1	MEA4: Phase voltage U_{L1}
					MEA5: Phase voltage U2	MEA5: Phase voltage U_{L2}
					MEA6: Phase voltage U3	MEA6: Phase voltage U_{L3}
					MEA7: Active power P	MEA7: Active power P
					MEA8: Reactive power Q	MEA8: Reactive power Q
					MEA9: Frequency f	MEA9: System frequency f
					Custom measurements	
9	11	1	2			MEA1: Earth current I_e
						MEA2: Phase to phase voltage U_{12}
						MEA3: Phase to phase voltage U_{23}
						MEA4: Phase to phase voltage U_{31}
						MEA5: Earth voltage U_e
						MEA6: Positive sequence current I_1
						MEA7: Negative sequence current I_2
						MEA8: Zero sequence current I_0
						MEA9: 3xZero sequence current $3xI_0$
						MEA10: Positive sequence voltage U_1
						MEA11: Negative sequence voltage U_2
						MEA12: Zero sequence voltage U_0
						MEA13: 3xZero sequence voltage $3xU_0$
					Temperature measurements	
9	10	1	2			MEA1: Temperature sensor 1
						MEA2: Temperature sensor 2
						MEA3: Temperature sensor 3
						MEA4: Temperature sensor 4
						MEA5: Temperature sensor 5
						MEA6: Temperature sensor 6
						MEA7: Temperature sensor 7
						MEA8: Temperature sensor 8
						MEA9: Temperature sensor 9
						MEA10: Temperature sensor 10
						MEA11: Temperature sensor 11
						MEA12: Temperature sensor 12
						MEA13: Temperature sensor 13
						MEA14: Temperature sensor 14
						MEA15: Temperature sensor 15
						MEA16: Temperature sensor 16

Table 134 Data table of the standard protocol IEC60870-5-103, monitor direction.

3.2.7 Data table – Control direction

ASDU	FUN	INF	COT	GI	IEC 60870-5-103 semantic	FPC 400 semantic
					System functions	
7	255	0	9		Initiation of general interrogation	Initiation of general interrogation
6	255	0	8		Time synchronization	Time synchronization
					General commands	
20	160	23	20		Active characteristic 1	Switching to setting group A (ON)
20	160	24	20		Active characteristic 2	Switching to setting group B (ON)
					Switchgear and network commands	
20	21	1	20			CB open/close
20	21	3	20			CB set local time
20	21	4	20			CB set remote mode
20	21	5	20			Confirm alarms
20	21	6	20			Reset protection counters
20	21	7	20			Reset operation counters

Table 135 Data table of the standard protocol IEC60870-5-103, control direction.

3.3 Protocol IEC 60870-5-104

IEC 60870-5-104 enables communication between control station and substation via a standard TCP/IP network.

3.3.1 General description

The IEC60870-5-104 protocol is a Slave – Master based communication protocol. An information can be exchanged between master and one or multiple slave devices. A supervisor or other device is used as master and the device is always used as a slave station. Multiple slave stations can be connected to the supervisor device. Each slave station is identified by unique address.

The following application functions can be accessed or executed using this protocol:

- Time synchronization
- Reading the measurement information
- Reading digital input states and switchgear position information
- Protection tripping and other events with time
- Transmission of remote controls

3.3.2 Acronyms and Terms

Acronym or term	Description
K	Maximum difference receive sequence number to send state variable.
W	Latest acknowledge after receiving W I-format APDUs
T0	Time out of connection establishment.
T1	Time out of send or test APDUs.
T2	Time out for acknowledges in case of no data messages T2 < T1.
T3	Time out for sending test frames in case of a long idle state.
ASDU	Application service data unit.
CAA	Common address of ASDU.
IOA	Information object address.
TID	Type identification.
AM	Analogue measurement.

Table 136 Description of acronyms and terms.

3.3.3 Protocol data transfer

The ASDU contains two main sections: the data unit identifier (with the fixed length of six bytes), and the data itself, made up of one or more information objects. The data unit identifier defines the specific type of data, provides addressing to identify the specific identity of the data, and includes additional information as cause of transmission. Each ASDU can transmit maximum 127 objects.

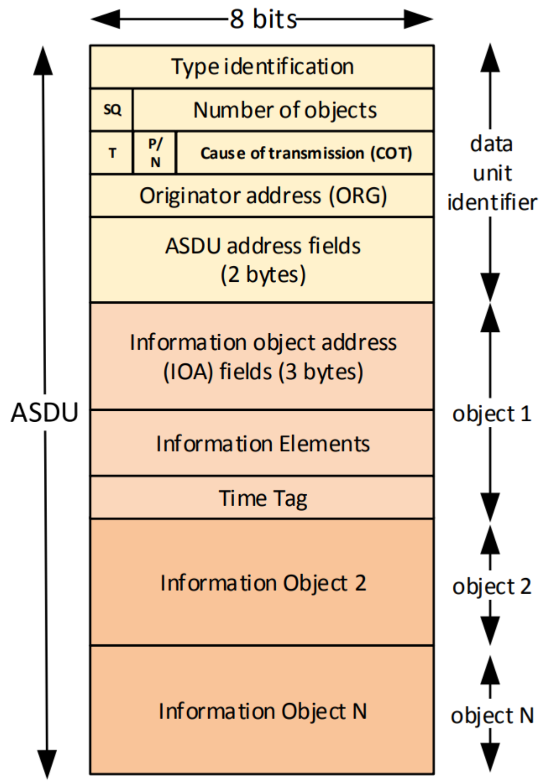


Table 137 ASDU format, as presented in the standard IEC60870-5-104.

3.3.3.1 Monitor direction

Defines direction of transmission from the protection equipment to the control system. Primarily it is used to send cyclic and event information transmission requests of master to the slave device/s. Following causes of transmission are supported:

COT	Label	Description
1	Per/cyc	Periodic, cyclic
3	Spont	Spontaneous
4	Init	Initialized
5	Req	Request or requested
20	Inrogen	Interrogated by general interrogation
21	Inro1	Interrogated by group 1 interrogation
22	Inro2	Interrogated by group 2 interrogation
23	Inro3	Interrogated by group 3 interrogation
24	Inro4	Interrogated by group 4 interrogation
25	Inro5	Interrogated by group 5 interrogation
26	Inro6	Interrogated by group 6 interrogation
27	Inro7	Interrogated by group 7 interrogation

Table 138 Supported COT numbers in monitor direction.

3.3.3.2 Control direction

Defines direction of transmission from the control system to the protection equipment. Typically for:

- sending control commands
- time synchronization commands
- Executing of start/reset communication commands.

COT	Label	Description
6	Act	Activation
7	Actcon	Activation confirmation
8	Deact	Deactivation
9	Deactcon	Deactivation confirmation
10	Actterm	Activation termination
11	Retrem	Return information caused by a remote command
12	Retloc	Return information caused by a local command

Table 139 Supported COT numbers in control direction. Time synchronization

The device date and time can be synchronized using the standardized synchronization command.

3.3.3.3 Initialisation

The initialisation of the controlling station starts e.g. with power off/on. Any data requested right before the initialisation cannot be received by the controlling station because it is no longer available.
The link of the controlling station then establishes connection with the link of the controlled station by transmitting a "Request status of link" that is answered by a "Status of link" response from the controlled station.
The controlling station then transmits a "Reset of remote link" that is answered by an "ACK", which confirms the start condition of the link layer of the controlled station.
After the initialisation the controlling station is updated by issuing a general interrogation command to the controlled station. If appropriate, the time of the two stations is then synchronised by a clock synchronisation command.

3.3.3.4 General interrogation

The general interrogation application function is used to update the controlling station after the internal station initialisation procedure or when the controlling station detects a loss of information.
The general interrogation function of the controlling station requests the controlled station to transmit the actual values of all its process variables. The interrogation procedure completes when the controlling station receives an End of Interrogation message.

3.3.4 Supported standard options and functions

3.3.4.1 Supported ASDUs

TID	Description	Label	FPC mapping
	Digital status information		
None	No selection	/	/
1	Single point information	M_SP_NA_1	Source signal
2	Single point information with time tag	M_SP_TA_1	Source signal
3	Double point information	M_DP_NA_1	Double-point source signal
4	Double point information with time tag	M_DP_TA_1	Double-point source signal
30	Single point information with time tag CP56Time2a	M_SP_TB_1	Source signal
31	Double point information with time tag CP56Time2a	M_DP_TB_1	Double-point source signal
	Measurements		
9	Measured value, normalized value	M_ME_NA_1	Analogue source signal
10	Measured value, normalized value with time tag	M_ME_TA_1	Analogue source signal
11	Measured value, scaled value	M_ME_NB_1	Analogue source signal
12	Measured value, scaled value with time tag	M_ME_TB_1	Analogue source signal
13	Measured value, short floating point value	M_ME_NC_1	Analogue source signal
14	Measured value, short floating point value with time tag	M_ME_TC_1	Analogue source signal
21	Measured value, normalized value without quality descriptor	M_ME_ND_1	Analogue source signal
34	Measured value, normalized value with time tag CP56Time2a	M_ME_TD_1	Analogue source signal
35	Measured value, scaled value with time tag CP56Time2a	M_ME_TE_1	Analogue source signal
36	Measured value, short floating point with time tag CP56Time2a	M_ME_TF_1	Analogue source signal
	Commands		
45	Single command	C_SC_NA_1	Command
46	Double command	C_DC_NA_1	Command
58	Single command with time tag CP56Time2a	C_SC_TA_1	Command
59	Double command with time tag CP56Time2a	C_DC_TA_1	Command

Table 140 Supported ASDUs.

3.3.4.2 Interrogation and periodic

It is possible to group information objects into interrogation groups. Seven separate groups are supported. For every object user can choose between four different cyclical periods. Information objects can be included or excluded from general interrogation procedure.

3.3.5 FPC Mapping

Describes signal types used for FPC mapping

3.3.5.1 Source signals

See chapter **Error! Reference source not found.** Output odules for set of available signals.

3.3.5.2 Double-point source signals

Label	Description
Q0	Circuit breaker
Q1	Bus disconnector 1
Q2	Bus disconnector 2
Q8	Earthing switch
Q9	Line disconnector

Table 141 Possible double point source signals.

3.3.5.3 Analog source signals

Group	Type	Measurement
S1 … S4		
UL IL	Phase 1 Phase 2 Phase 3	Amplitude Amplitude max Angle Amplitude cycle average Amplitude cycle max H1, H2, … , H10 RMS THD Frequency
ULL	P2P 12 P2P 23 P2P 31	Amplitude Amplitude max Angle
Ue Ie	/	Amplitude Amplitude max Angle Amplitude cycle average Amplitude cycle max H1, H2, … , H10 RMS THD Frequency
U Symmetrical components I Symmetrical components	/	Amplitude zero Amplitude positive Amplitude negative Amplitude 3xzero Angle zero Angle positive Angle negative Angle zero reverse
System	/	Frequency Frequency min Frequency max

Table 142 Analog source signals.

3.3.5.4 Commands

Command	Description
Q0 Open / Close	Circuit breaker double bit commands.
Q0 Open	Circuit breaker single bit open command.
Q0 Close	Circuit breaker single bit close command.
Q1 Open / Close	Bus disconnector 1 double bit commands.
Q1 Open	Bus disconnector 1 single bit open command.
Q1 Close	Bus disconnector 1 single bit close command.
Q2 Open / Close	Bus disconnector 2 double bit commands.
Q2 Open	Bus disconnector 2 single bit open command.
Q2 Close	Bus disconnector 2 single bit close command.
Q8 Open / Close	Grounding switch double bit commands.
Q8 Open	Grounding switch single bit open command.
Q8 Close	Grounding switch single bit close command.
Q9 Open / Close	Line disconnector double bit commands.
Q9 Open	Line disconnector single bit open command.
Q9 Close	Line disconnector single bit close command.
Group A/B	Change group double bit commands.
Group A	Change group to A single bit command.
Group B	Change group to B single bit command.
Local/remote	System interlock double bit commands.
Local	System interlock local single bit command.
Remote	System interlock remote single bit command.
Reset LEDs	Reset active latched LEDs.
Reset DOs	Reset active latched DOs.
Reset 86 lockout	Reset active lockout.
Reset protection counters	Set all protection counters to 0.
Reset CB counters	Set all CB control counters to 0.
Reset all counters	Set all counters to 0.
Reset max values	Reset all maximum values displayed on HMI.
Clear disturbance recorder	Clear all disturbance records.
Tigger disturbance recorder	Trigger a disturbance record.

Table 143 List of communication commands.

3.3.6 Parameters

Parameter	Range	Description
Control		
Protocol	**IEC-104**	Name of selected communication protocol.
Device address	1 … **33** … 247	Device Link address.
Network		
DHCP	**No**, Yes	Enables dynamic host configuration protocol operation.
IP	**0.0.0.0** … 255.255.255.255	Device IP address.
Mask	**0.0.0.0** … 255.255.255.255	Network mask configuration.
Gateway	**0.0.0.0** … 255.255.255.255	Network gateway configuration.
NTP 1	**0.0.0.0** … 255.255.255.255	IP address of NTP server 1.
NTP 2	**0.0.0.0** … 255.255.255.255	IP address of NTP server 2.
IEC60870-104 Link		
Port	0 … **2404** … 65535	TCP port used for communication.
Max clients	0 … **4**	Setting 0 is dedicated for unlimited number of clients.
Mode	**Balanced**, Unbalanced	Operation mode.
K	0 … **12** … 255	Maximum difference receive sequence number to send state variable.
W	0 … **8** … 255	Latest acknowledge after receiving.
T0	0 … **10** … 100 s	Time out of connection establishment.
T1	0 … **15** … 100 s	Time out of send or test APDUs.
T2	0 … **10** … 100 s	Time out for acknowledges in case of no data messages T2 < T1.
T3	0 … **20** … 100 s	Time out for sending test frames in case of a long idle state.
Driver		
CAA length	1, **2**	Common address of ASDU length.
IOA length	1, 2, **3**	Information object address length.
CAA	**1** … 65534	Common address of ASDU.
Time format	**CP24Time2a**, CP56Time2a	Time format length.
Cyclical Period 1	0 … **10** … 65534 s	Duration of the 1st period.
Cyclical Period 2	0 … **10** … 65534 s	Duration of the 2nd period.
Cyclical Period 3	0 … **10** … 65534 s	Duration of the 3rd period.
Cyclical Period 4	0 … **10** … 65534 s	Duration of the 4th period.
Information object 1 … 50		
IOA	**0** … 16777215	
Type	**None**, … , 59	See 3.3.4.1, TID, type identification of Informational object.
	FPC mapping - depending on **Type** (See 0)	
Dead-band	**0** … 1000 ‰	Information object address.
Event edge	**None**, Up, Down, Any	See 3.3.4.1, TID, type identification of Informational object.
	Interrogation	
General	**No**, Yes	Included or excluded from General interrogation procedure.
Group 1	**No**, Yes	Included or excluded from Group 1 of General interrogation.
Group 2	**No**, Yes	Included or excluded from Group 2 of General interrogation.
Group 3	**No**, Yes	Included or excluded from Group 3 of General interrogation.
Group 4	**No**, Yes	Included or excluded from Group 4 of General interrogation.
Group 5	**No**, Yes	Included or excluded from Group 5 of General interrogation.
Group 6	**No**, Yes	Included or excluded from Group 6 of General interrogation.
Group 7	**No**, Yes	Included or excluded from Group 7 of General interrogation.
	Periodic	
Period 1	**No**, Yes	Uses Cyclical Period 1 duration setting.
Period 2	**No**, Yes	Uses Cyclical Period 2 duration setting.
Period 3	**No**, Yes	Uses Cyclical Period 3 duration setting.
Period 4	**No**, Yes	Uses Cyclical Period 4 duration setting.

Table 144 Parameters selection for IEC60870-5-104.

4 Settings

This chapter is intended for qualified and experienced personnel. Knowledge of commissioning protection and control systems, with management power systems and with relevant safety rules and guidelines is required.

4.1 Introduction

Setting can be done using graphical interface MiQen Setting Studio software via Laptop or PC connected to device or using HMI.

Parameters presented in section below have equal name adjusted for HMI written beside real parameter in form of:
Setting [*HMI name*]

4.2 Human machine interface (HMI)

4.2.1 User interface

Figure below represents the front panel of the device as HMI. Figure also shows positions of all associated elements used to set, control and monitor the FPC device.

4.2.1.1 Small housing

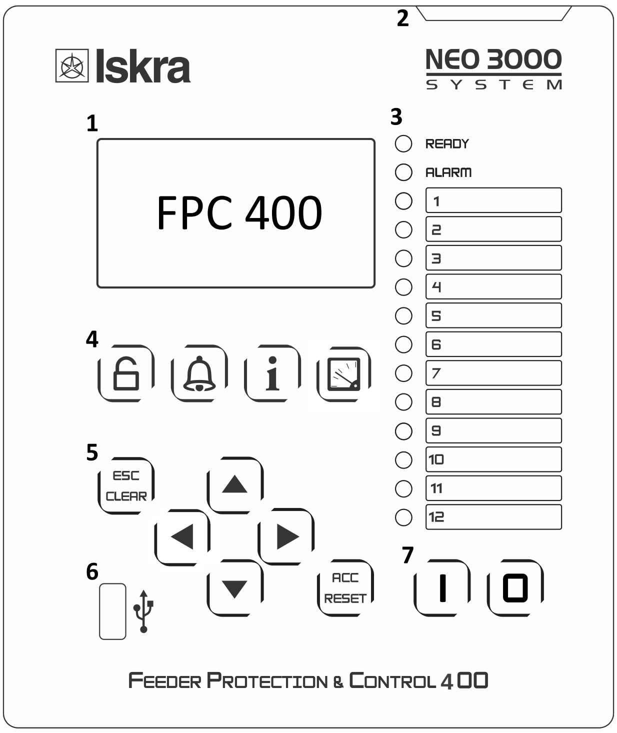


Figure 4.1 Front panel of the device.

Front panel consists of:

1. LCD
2. LED Name tag slot
3. LED indicators
4. Quick keys
5. Navigational panel
6. USB port
7. Command keys

4.2.1.2 Medium housing

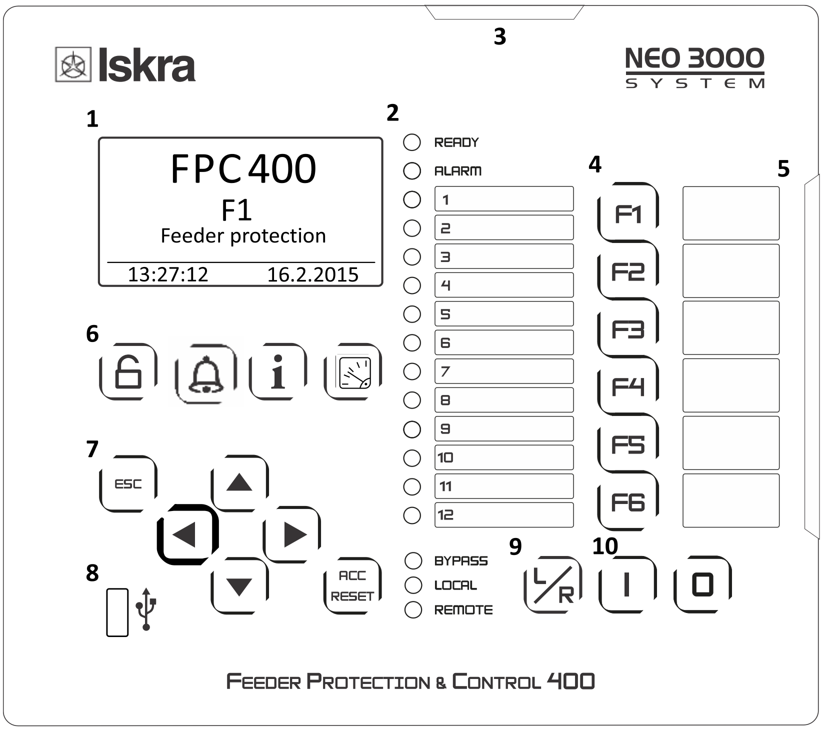


Figure 4.2 Front panel of the device.

Front panel consists of:

1. LCD
2. LED indicators
3. LED name tag
4. Function keys
5. Function keys name tag slot
6. Quick keys
7. Navigational panel
8. USB port
9. Local remote key with indicator LEDs
10. Command keys

4.2.1.3 LCD

The device is provided with a monochromatic backlighted 128x64 pixel display installed. Character length are in accordance with using different fonts and languages. Pressing any key while backlight is turned off will switch it on and will not take any other action. The backlight turn off automatically after user adjustable time (1 min to 60 min). It is also possible to activate backlight using one of the digital inputs.

4.2.1.4 LED indicators

LED indicators consists of 3 different types of LEDs:

- **READY LED** (Green) shows status and power of the FPC.
- **ALARM LED** (Red) indicates tripping circuit.
- **Programmable LEDs** (Red) can be controlled using matrix by HMI or designated software MiQen.

Programmable LEDs can be set on latched, latched-blinking and non-latched option. The LEDs can be used to indicate information about alarm, acknowledgement or operation. For indication purpose it is possible to insert a sheet of paper into a designated space next to LEDs.

4.2.1.5 USB communication port

FPC is provided with type A USB communication port, which can be either used directly with USB storage device or by using designated Male-A type to Male-A type USB cable to connect device to PC. Additionally the connector is protected by an external rubber cover.

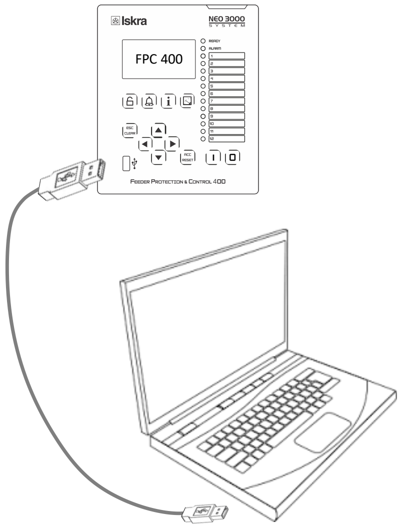


Figure 4.3: Connection using USB cable

4.2.1.6 HMI keypad

Using only control buttons it is possible to navigate, view and set all the functions of FPC only by using control buttons on local HMI. With shortcuts it is possible to access all of the important menus as they would be accessed using control keys.

4.2.1.6.1 Navigation keys

Move to submenu

Move on upper menu level

Up on the presenting menu, also increment numerical value

Down on the presenting menu, also decrement numerical value.

4.2.1.6.2 Control keys

Accept, confirm key and also reset function in measurements menu. (ACC)

Return to main menu, cancel current operation. (ESC)

4.2.1.6.3 Quick keys

By using quick keys it is possible to easily access alarms, events, measurements and lock or unlock device.

Measurement key

All of the measurement screens can be accessed sequentially by pressing measurement quick key. It is also possible to navigate measurement screens with▲,▼ navigational keys.

Diagnostic

All of the diagnostic screens can be accessed sequentially by pressing diagnostic information quick key.
The menu contain all of the basic data about device and data regarding breaking device.

Alarms and events key

Press ''alarms and events'' key to display alarms menu of the device, pressing it for the second time will display events menu. The third press will display a system log events.

To view all the alarms and events it is possible to press▲ ,▼ navigational keys to access all of the alarms, 100 events and 40 system log events stored in the corresponding menu.

Lock key

Press the ''lock key'' to lock/unlock device if password protection is enabled. Action is based on whether the device is locked or unlocked.

When device is locked pressing a lock key will open Enter password menu.

When device is unlocked pressing a lock key will lock device and a popup will open with massage *Device is now locked*.

Manual CB close command key

The command key is intended to manually execute close command to control CB. As the action is confirmed a closing signal is initiated.

Manual CB open key

The command key is intended to manually execute open command to control CB. As the action is confirmed a closing signal is initiated.

Function key (1…6)

Function key act as user defined shortcut to access certain menu or executing certain predefined actions.

Please note that password level 1 is required to successfully execute any of commands.

4.2.2 Menu overview

4.2.2.1 Basic menu tree

HMI menu is presented in a way that is possible to view measurements, operating events, set and change all of the parameters necessary for normal operation. Menu has treelike shape with maximum of 4 different levels. Full menu shape can be found on figure below.

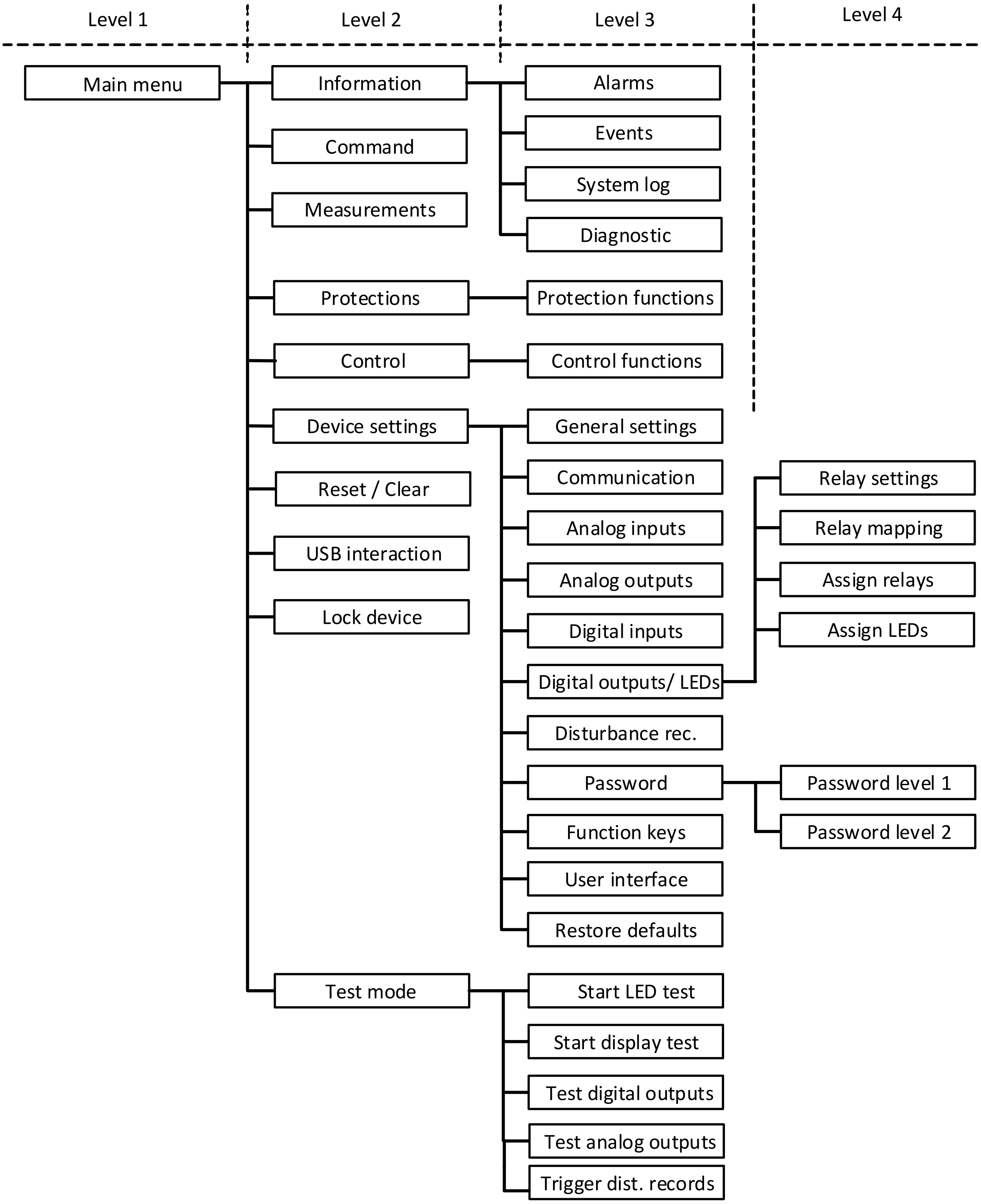


Figure 4.4 Overlook of the tree menu of the device

4.2.2.2 Navigating the menu

By using navigation keys (▲, ▼, ►, ◄) it is possible to access all of the menus. To return to main menu from any submenu press ESC key for longer period of time. Figure below represents steps to access submenu containing communications settings.

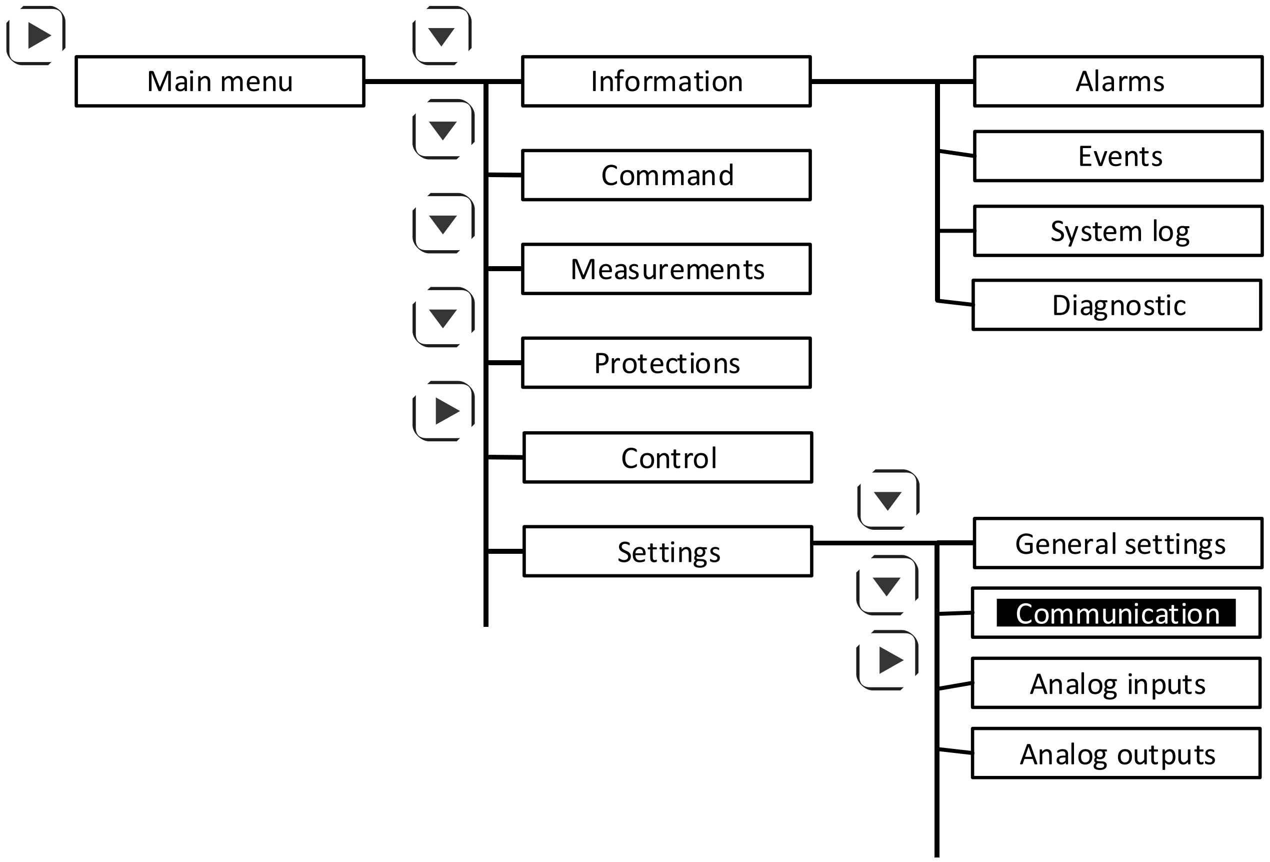


Figure 4.5 Example of basic navigation through the tree menu

4.2.2.3 Basic LCD view

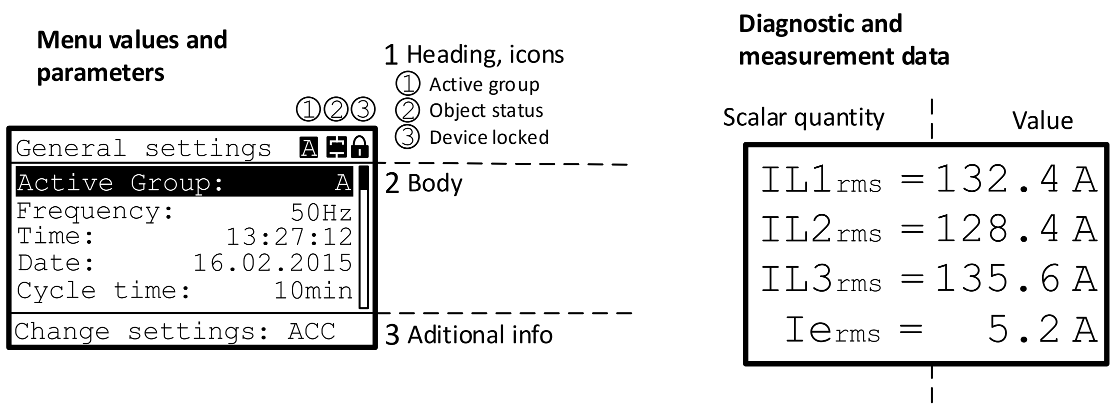


Figure 4.6 General description about two types of menu.

In general there are two types of HMI menu, one is suited to present diagnostic or measurement data and other to display parameter and menu values:

1. Menu values and parameters HMI view consist of main parts, heading, icons, body and additional information in lower part used in dedicated menus.
2. Diagnostic and measurement data HMI view consists of Scalar quantity and it is presenting value with appropriate unit.

4.2.2.4 Changing and confirming parameter

All parameters can always be found on last level of the tree-menu. Each parameter can be accessed by pressing the ACC key. Action will activate new dedicated screen with information about the parameter. Parameter can be incremented or decremented with designated▲,▼ navigation keys.

Desired choice can be selected by pressing ACC key. Before applying it is possible to change any number of parameters within one module of settings (For example: 50/51 Overcurrent protection all instances is one module and digital inputs is another module). By leaving the module settings can be saved and applied. If there is a change in parameter settings a multiple choice popup will appear, with the following choices:

- **Yes**: Save and apply parameters, in some cases a HW reset is needed to reassure safety.
- **No**: Revert all changed parameters to previous state.
- **Cancel**: Return to previous menu without taking any action.

Example chart of changing numerical value can be seen on Figure 4.7.

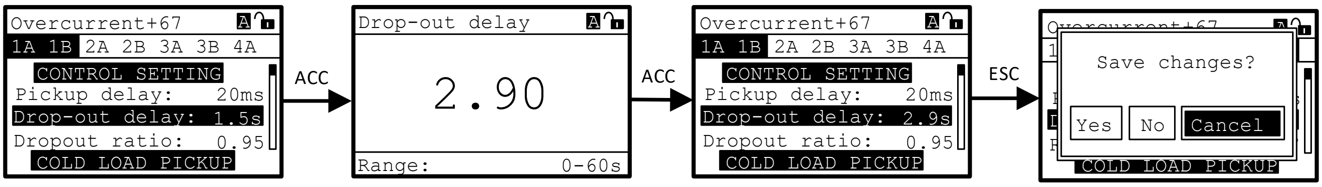


Figure 4.7 Changing numerical value

4.2.3 Submenus overview

4.2.3.1 Information menu

Information submenu contains current status, alarms, events and other data about device and switchgear. In general Info menu consists of: alarms, events, system log and diagnostic.

All present values of alarms and last 20 events are permanently stored in non-volatile memory in case of power loss.

4.2.3.1.1 Alarms

All non-confirmed alarms can be viewed in alarms section. Non-volatile memory is used to store alarms. General information and timestamp can be viewed about the alarm that occurred. If the same alarm has been activated again before it was cleared, only last information of the alarm will be presented. Information about previous alarms can be viewed in events section. Alarm can be cleared by pressing ACC control key.

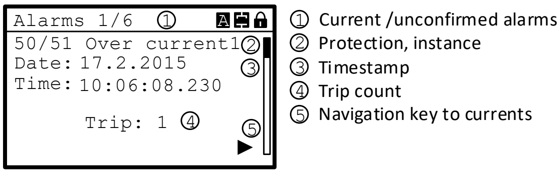


Figure 4.8 Overview of alarms.

Pressing right arrow navigation key (▶) shows corresponding values at the time when alarm occurred.

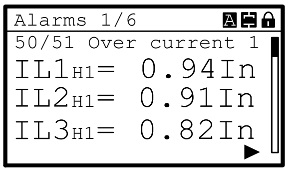


Figure 4.9 Currents overview of captured alarm.

Recording of alarm is triggered when trip signal occurs by a protection. In addition a popup screen is generated informing user about new alarm present, presenting basic alarm information.

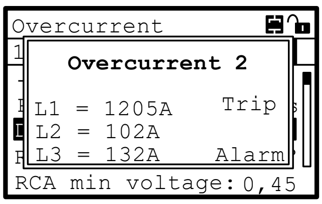


Figure 4.10 Example of popup that is displayed in case of alarm being triggered.

4.2.3.1.2 Events

The device is able to show last 100 events. Last 20 events are stored permanently in non-volatile FIFO memory in case of power loss.

Event record trigger:

- Pickup
- Trip
- Changing state of CB
- Changing device settings
- Device power on or power off
- Custom digital input

Each event is equipped with timestamp and event trigger.

4.2.3.1.3 Diagnostic

In diagnostic section all the data about device, switchgear and as well as temperatures and temperature calculation of the protection is presented. The seen on figure below. The corresponding menus may differ according to version of software used.

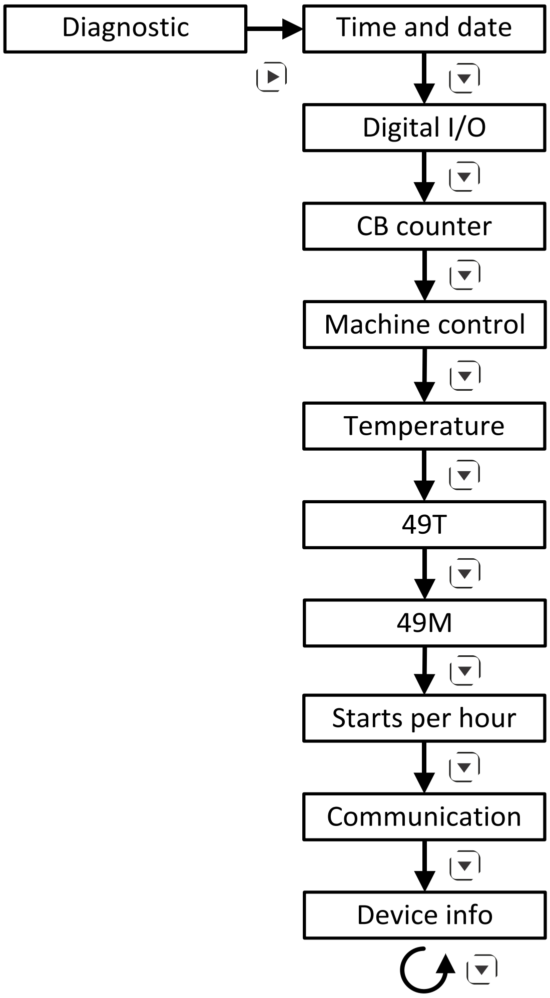


Figure 4.11 Section of diagnostic menu overview

4.2.3.2 Measurements

All data measured from analog inputs is presented in measurements menu. The corresponding menus may differ according to version of software used. Example of the device with current measurement is found in schematic below.

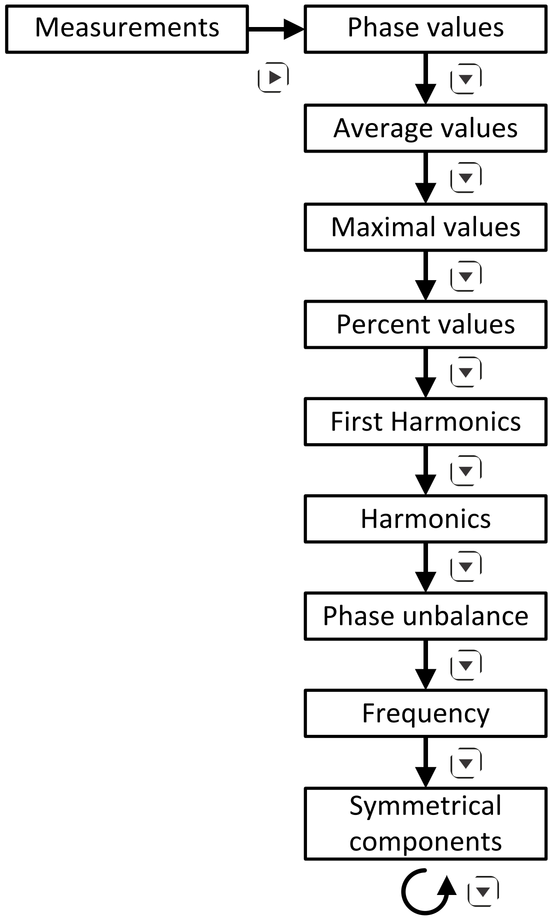


Figure 4.12 Section of measurements menu overview.

4.2.3.2.1 Average values

Indication for average value of user defined window of data is in minutes. Window length can be set in General settings menu screen as parameter Cycle time. On defined amount of cycle time a magnitude of measured value is calculated based on samples taken every second. Bar of **cycle time** is shown for a brief period every time the screen is shown.

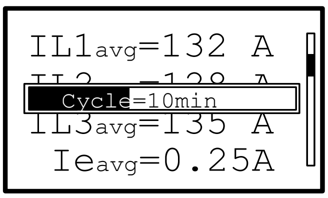


Figure 4.13 Example of displaying of average values.

4.2.3.3 Protection settings

Options to set protections of the device are located in this section of tree-menu. On first page an overview showing active protection functions is presented.

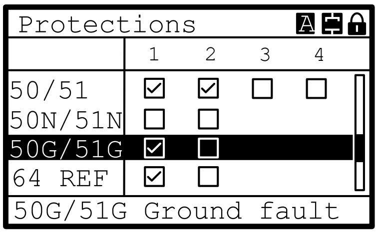


Figure 4.14 Example of active protections overview screen.

Parameters can be set for each instance and group of protection respectively. To move between different instance and group press◄, ► navigational keys. Each protection has sets of different parameters that can be divided in to two major groups:

4.2.3.3.1 Fundamental parameters:

Change of this parameter type will affect specific group and instance of individual protection

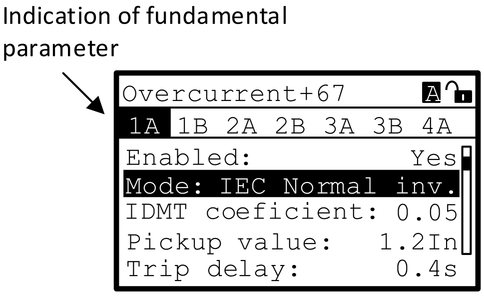


Figure 4.15 Parameter setting of individual instance and group of single protection.

4.2.3.3.2 Common parameters:

Change of this parameter will affect all groups in specific instance of individual protection.

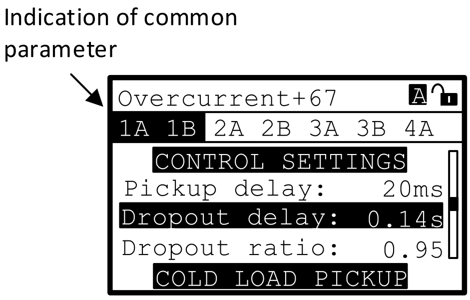


Figure 4.16 Common parameter setting of individual instance of single protection.

Only parameters of one protection (50/51, 50N/51N, 46) can be set before saving and applying changes. For changing a parameter see chapter [2].

Each protection is disabled by default.

4.2.3.4 Command menu

Command to open or close circuit breaker can be send manually through by using dedicated quick keys or by accessing via command menu. Note that password level 1 is needed to perform commands.

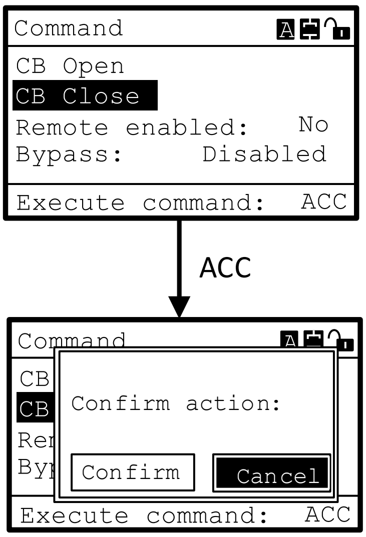


Figure 4.17 Procedure of executing commands.

4.2.3.5 Device setting

Options to set and control device are located in this section of tree menu.

4.2.3.5.1 General settings

General settings define basic settings for device to be operational.

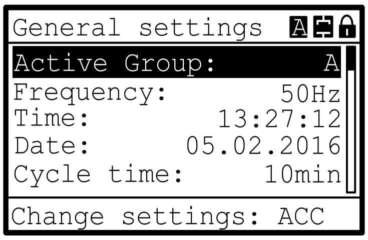


Figure 4.18 Example of general settings menu.

Active group
Active group defines the running group of protection settings.

Frequency
Frequency parameter defines nominal frequency used in national power system.

Time
This parameter is used to set and show current device time.

Date
This parameter is used to set and show current device date.

Cycle time
Cycle time defines refresh rate of average values used in measurements.

Parameter	Range
Active group	**A** B Input select
Frequency	**50 Hz** 60 Hz
Time	hh:mm:ss
Date	dd.mm.LL
Cycle time	**1** ... 60 min

Table 145 General settings parameters.

4.2.3.5.2 CB control

This section defines how the device will operate with CB all the details about operation can be found in section [2.6.1].

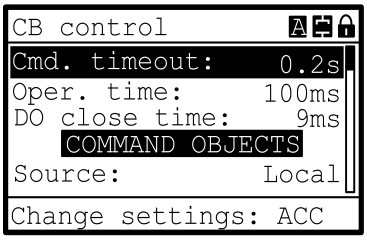


Figure 4.19 Example of circuit breaker control menu.

Command timeout [*Cmd. timeout*]
Time of command execution can be set in this section. Detailed description can be found in section [2.6.1.3.1].

Operation time [*Oper. time*]
Time defining switchgear primary contact separation. Detailed description can be found in section [2.6.1.3.2].

Command objects
Include parameter **Source** that defines weather commands over DI are considered as local or remote commands.

Interlocking
Table lists abbreviation for interlocking is presented in Table 57. Detailed description of interlocking start at section [2.6.1.3].

Circuit breaker failure [*CBFP*]
Circuit breaker failure function can be enabled and set under CBFP header in CB control menu. Detailed description can be found in section [2.6.1.10].

Ready
Ready value of switchgear element can be defined in this section. Detailed description can be found in section [2.6.1.11].

CAUTION

Ready value does not count as interlock for executing commands.

Lockout relay

Enabling of Lockout relay functionality is done under corresponding header of CB control menu. Detailed description can be found in section [2.6.1.12].

Counters

Appropriate counters are presented at the end of CB control menu, list can be found in section [2.6.1.15].

4.2.3.5.3 Communication

Communication submenu consists of all communication settings. Menu is adjusted for specific ordered communication protocol.

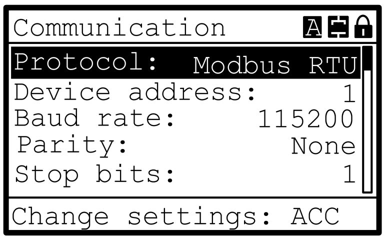


Figure 4.20 Example of communication menu.

Protocol

Protocol presents device communication software installed. All parameters below are referred to specific communication protocol. More advanced information can be found in chapter [3].

4.2.3.5.4 Analog inputs

Analog inputs are used for selecting a manner of connection for current and voltages and settings needed for fundamental measurement of currents and voltages used in protecting switchgear. Analog inputs use currents and voltages from current and voltage instrument transformers installed in switchgear. The following parameters of submenu may differ for different device types.

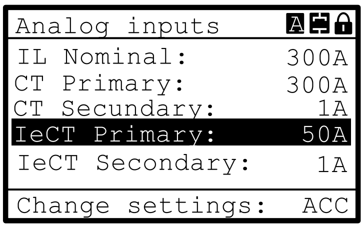


Figure 4.21 Example of analog inputs menu.

Connection type voltages

Connection type is a selector to identify a manner of which voltage analog input values are connected to device. Additional information can be found on section [2.10.1].

Rated nominal current of the object [*In Object*]

The parameter defines rated nominal current (1 p.u.) of protected object I_{n_obj}. Additional information about nominal current calculation can be found in section [2.10.3.1]

CT Primary

Rated primary current of installed current transformer I_{pri}.

CT Secondary

Parameter for rated secondary current of installed current transformer I_n. This parameter is multiple choice option between 1 A and 5 A.

IeCT Primary

Rated primary current of installed earth current transformer I_{e_pri}.

IeCT Secondary

Parameter for rated secondary current of installed earth current transformer I_{e_n}. This parameter is multiple choice option between 1 A and 5 A.

UeVT Primary

Rated primary phase voltage of installed earth voltage transformer U_{e_pri}.

UeVT Secondary

Rated secondary phase voltage of installed earth voltage transformer U_{e_n}.

Phase sequence

Parameter of rotation change for all phase inputs.

I_L polarity

Parameter of polarity of all phase inputs.

I_e polarity

Parameter of polarity of earth current

Parameter	Range
Connection type voltages	*U_{L1}, U_{L2}, U_{L3}, U_e* *U_{L1}, U_{L2}, U_{L3}, U^{S2}_{12}*
In Object	1 … **300** … 60000 A
CT primary	1 … **300** … 60000 A
CT secondary	**1 A** 5 A
IeCT primary	0,1 … **150** … 60000,0 A
IeCT secondary	**1 A** 5 A
VT primary	0,06 … **20** … 440 kV
VT secondary	60 … **100** … 500 V
UeVT primary	0,06 … **11,54** … 440 kV
UeVT secondary	60 … **100** … 500 V
Phase sequence	**ABC** ACB
I_L polarity	**Normal** Reverse
I_e polarity	**Normal** Reverse

Table 146 Parameters of Analog inputs settings.

4.2.3.5.5 Analog outputs DC

Analog output presents information about fundamental measurement and calculations of the device in form of output current. The output current ranges maximally from 0 mA to 20 mA. Output current peak to peak value is user defined. On the device it is possible to use 3 separate analog outputs.

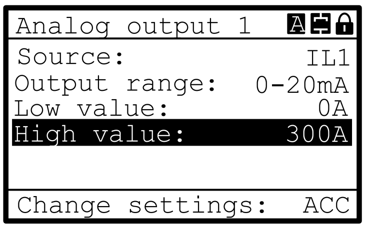


Figure 4.22 Example of analog outputs menu.

Source

Parameter defines fundamental measurement or calculation which magnitude is used as analog output magnitude.

Output range

Analog output can be set inside following ranges:

- 0-10 mA
- 4-10 mA
- 0-20 mA
- 4-20 mA

Low value

Defines the point of fundamental measurement or calculation at which output current is minimal.

High value

High value defines the point of fundamental measurement or calculation at which output current is at its maximum.

Parameter	Range
Source	*None,* *I_{L1}, I_{L2}, I_{L3}, I_e, I_1, I_2, I_0, $3xI_0$,* *U_{L1}, U_{L2}, U_{L3}, U_e, U_{12}, U_{23}, U_{31},* *f, P, Q, S, PF.* *I'_{L1}, I'_{L2}, I'_{L3}, I'_e,I'_1, I'_2, I'_0, $3xI'_0$,* *U'_{L1}, U'_e, U'_{12}*
Output range	***0 - 10 mA*** *4 - 10 mA* *0 - 20 mA* *4 - 20 mA*
Low value	**0** … 60000 A (Currents) **0** … 660 kV (Voltages) 0 … **45** … 72 Hz (Frequency) **0.001** … 100 MW, Mvar, MVA (Power) **-1** … 1 (Power factor)
High value	0 … **60000 A** (Currents) 0 … **660 kV** (Voltages) 0 … **55** … 72 Hz (Frequency) 0.001 … **100 MW**, Mvar, MVA (Power) -1 … **1** (Power factor)

Table 147 Parameters of Analog outputs settings.

4.2.3.5.6 Digital inputs

For control purposes there are, depending on hardware, number of available digital inputs. Function, control logic positive or negative and delay for each DI can be configured according to application.

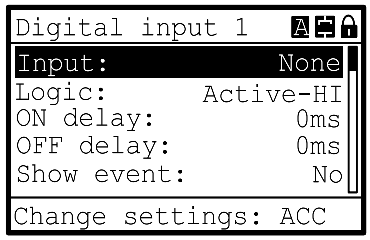


Figure 4.23 Example of parameter settings of single digital input menu.

Input

Defines specific input signal to be matched to predefined internal signal.

DI parameter
None
Closed 52a
Open 52b
Open command
Close command
CB ready
Group select
TCS 1
TCS 2
CLP activate
Ext-trigger 1
Ext-trigger 2
Remote enabled
Disturbance recording
Alarm reset
Bypass interlock
Block protection
Open allow
Open block
Close allow
Close block
AR block
Backlight
Thermal switch 1
Thermal switch 2
Buchholz 1
Buchholz 2
Re-acceleration
Rotation
Bus1 closed 52a
Bus1 open 52b
Feeder invalid
Bus1 invalid

Table 148 Selection of DI parameter.

Logic
Digital input logic defines state for specific input to be active.

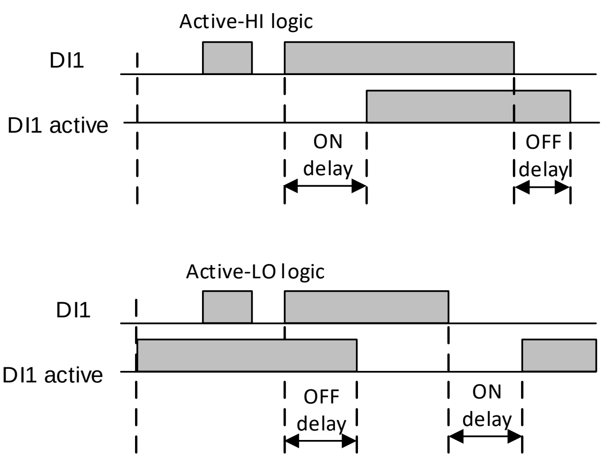


Figure 4.24 Active HI and LO logic of digital input.

ON delay
Signal duration needed for input to change state to active.

OFF delay
Signal duration needed for input to change state to inactive.

Show event
Display change of specific input in events respectively.

Parameter	Range
Input	*Selection on Table 148*
Logic	**Active – HI** Active – LO
ON delay	**0** … 60000 ms
OFF delay	**0** … 60000 ms
Show event	**No** Yes

Table 149 Parameters of individual Digital input setting.

4.2.3.5.7 Digital outputs

For means of communication, operation and display functions, software of relay operates using three types of internal signals:

- Trip
- Pickup
- Command/control

Control matrix can be used to assign internal signals of individual elements (etc. individual protections) to interact with output relays or LED indicators. The Figure 4.25 represents selection of Digital outputs menu.

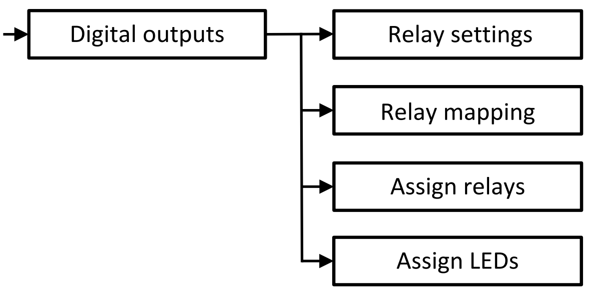


Figure 4.25 Section of assignment menu.

Relay settings
Relay basic options can be found in *Relay settings* submenu. According to general purpose for each individual output relay a basic options can be set.

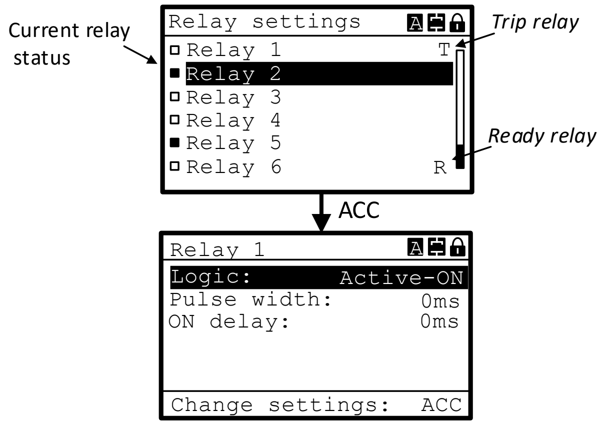


Figure 4.26 Settings of individual output relay

<u>Logic</u>

Digital output logic defines state of specific output relay at non-active position.

<u>Pulse width</u>

States time which defines output relay to be active after certain signal become apparent.

Only for trip relay a trip signal has priority over *pulse width setting.*

<u>ON delay</u>

Time delay after which output relay becomes active

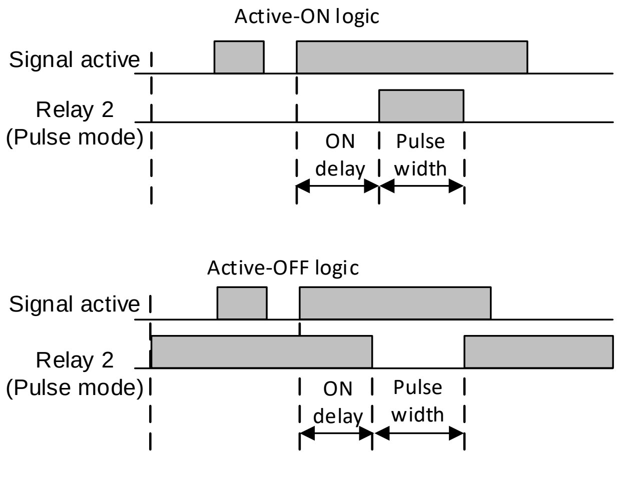


Figure 4.27 Output relay logic.

Parameter	**Range**
Logic	*Active – ON* *Active – OFF*
Pulse width	10 … **100** … 1000 ms
ON delay	**0** … 5000 ms

Table 150 Relay settings parameters.

Relay mapping

Trip relay, Close relay 1, Close relay 2 and Ready relay are mapped in Relay mapping menu. Also open commands are executed on trip relay.

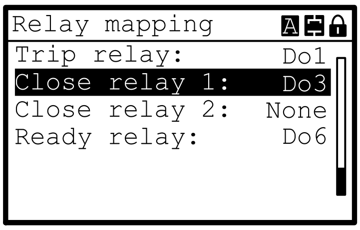


Figure 4.28 Assigning different types to specific output relays.

Ready relay can be mapped only to DO6. In case if it is mapped to ready relay the setting **logic: Active-OFF** is not taken into account.

Set relay on signal

Setting matrix is shown on Figure 4.29. For each element custom relay indicator can be set to:

- ■ Latched
- □ Non-latched
- ⎍ Pulse

Trip relay can only be chosen or not. It does not possess custom indicator because it is controlled by separate module.

If Close relays and Ready relay are chosen then those relays cannot be used for anything else.

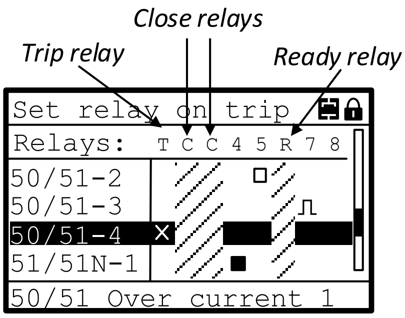


Figure 4.29 Setting matrix

Set LED on signal

Triggering of individual LED is defined under Set LED on signal menu. Each output LED can be set on:

- Trip
- Pickup
- Command
- Variable
- Temperature

List of commands is the same as listed above in Set relay on signal

For each element a custom LED indicator can be set to:

- ■ Latched
- □ Non-latched
- ◪ Latched blinking

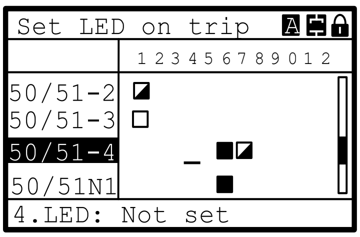


Figure 4.30 Assigning matrix for LEDs.

Different types of LED operation can be assigned on specific LED for different individual signals (e.g. Non-latched for pickup, latched blinking for trip signal.).

Set relay / LED on signal table

Triggering of individual relay/LED is set under Set relay/LED on signal menu. Each relay can be set on:

- Trip
- Pickup
- Command
- Variable
- Temperature

HMI name	Description
CB open	Circuit breaker open
CB cls.	Circuit breaker close
CB rdy.	Circuit breaker ready
CB blk.	Circuit breaker Command blocked
AR prg.	Auto-reclosing in progress
AR nrd.	Auto-reclosing not ready
74-TCS	74TCS Trip circuit supervision wrong position
50BF	CBFP open
CLP act	CLP active
Inrush1	Inrush restraint 1
Inrush2	Inrush restraint 2
86LR	Lockout relay
Prt blk	Protection blocked
MTO alm	Maximum trip open alarm
MTO blk	Maximum trip open block
I2t alm	I2t alarm
I2t blk	I2t alarm
Running	Machine control status running
Start	Machine control status starting
Overld.	Machine control status overload
Stall	Machine control status Stalling
Hot St.	49M – Hot state
High T	49M – High temperature
Inh st.	66 – Inhibit start
Exc st.	48 – Excessive start
Lck st.	51 – Locked start
LRstall	14 – Stall
High T	49T – High temperature
Alarm T	49T – Alarm temperature
Remote	CB remote enabled
AR def.	Auto-reclosing definite trip
RTD fl.	RTD fault
Opn. en	Open command enabled
Cls. en	Close command enabled

Table 151 Relay and LED signals and its HMI names.

4.2.3.5.8 Disturbance recording

In this section a disturbance recording function can be set. Description can be found in [2.9] section.

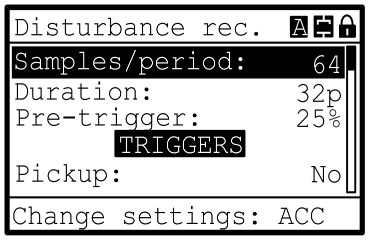


Figure 4.31 Disturbance recording settings.

4.2.3.5.9 Passwords

In password settings menu it is possible to disable or enable password protection for protector mode (password level 1) and parameter setting mode (password level 2).

To change specific password press *Enable* in dedicated password level. This applies even if the password is already active.

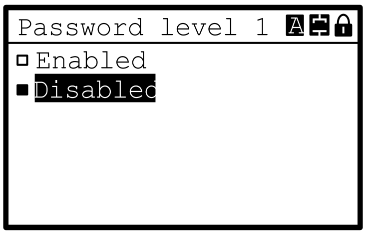


Figure 4.32 Enabling password

4.2.3.5.10 User interface

Various parameters important to local display unit experience are set under User interface menu.

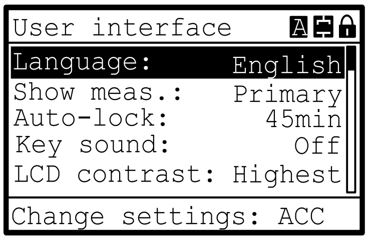


Figure 4.33 User interface settings.

Language

Different language of local display unit are set.

Show measurements
Measurements can be set to be displayed as:

- Primary values
- Secondary values
- Per-unit

Auto-lock
Device is set to enter locked state after defined amount of time. Same action apply if **Lock key** is pressed or device locked via corresponding menu. Time range after device automatically enters locked state is from 1 to 60 minutes.

Key sound
Key sound can be turned on or off. When set to enable each push on any key triggers a short beeping sound.

Alarm sound
Alarm sound can be turned on or off. When set to enable with any alarm fault detection will trigger beeping sound until alarm is cleared manually or remotely.

LCD contrast
Display contrast can be adjusted to suit different temperature environments.

Parameter	Range
Language	**English** Slovenščina
Show measurement	**Per – unit** Primary Secondary
Auto - lock	1 … **5** … 60 min
Key sound	Off **On**
Alarm sound	Off **On**
LCD contrast	0 … **28** … 64

Table 152 User interface parameters.

4.2.3.5.11 Restore defaults
For returning settings to factory default Password Level 2 is required.

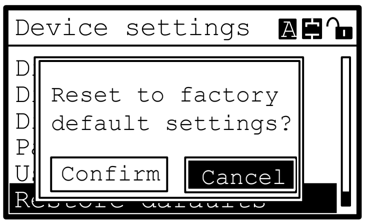


Figure 4.34 Device can be returned to default factory settings.

Use extreme caution when using Restore defaults option!
Returning device to default factory settings will delete and overwrite any existing settings. Backing up settings before performing an action is recommended.

4.2.3.6 Reset/Clear options

Reset /Clear options is a function that enables user to clear undesired data or acknowledge alarms. By using this menu next operations can be executed:

- Reset LEDs
- Reset relays
- Reset 86 lockout*
- Confirm alarms
- Clear events**
- 49 Null thermal load
- 66 Null inhibit time
- Reset max values
- Reset protection counters*
- Reset CB counters*
- Reset ALL counters*
- Clear disturbance records**

*Password level 1 is required.
**Password level 2 is required.

Additionally a popup window with limited selection can be accessed as ACC key is pressed when positioned on any measurement or information screen.

Reset options accessed via menu:

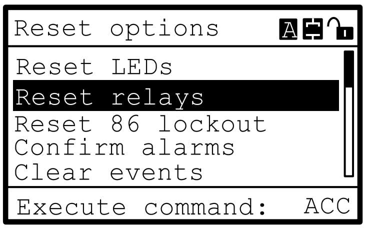


Figure 4.35 Clear/reset menu

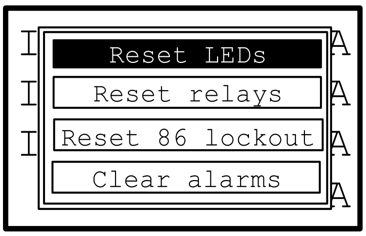


Figure 4.36 Clear/reset popup which can be accessed in measurements and diagnostic section by pressing ACC key.

4.2.3.7 USB interaction

USB interaction submenu offers multiple choice regarding using USB port in front of the device panel. All actions from corresponding menu can be used only with appropriate USB memory stick. USB stick must be formatted with FAT32 file system to be used with device USB slot. USB 1.0, USB 2.0, USB 3.0 speeds are compatible with device. Password level 2 is required.

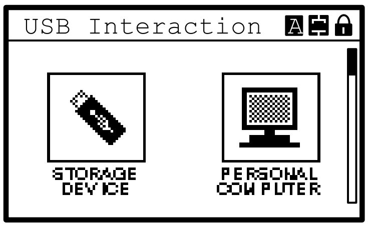


Figure 4.37 USB port selection.

There are 4 possible actions with USB stick:

Settings from USB

By using this option, setting file is generated on USB stick containing settings read from the device. To perform this action a valid settings file must be present on root menu of the USB stick.

Settings to USB

By using this option, setting file from a USB stick is copied and applied to device. Previous settings are overwritten. For safety reasons device must undergo HW reset after successful applying of settings.

Copy disturbance records

Use this option to transfer last 128 stored records of disturbance. It is possible to select only one or all stored time tagged disturbance records.

Update software

By using this option device firmware is updated to a newer version. To perform this action a valid update file must be present on root menu of the USB stick.

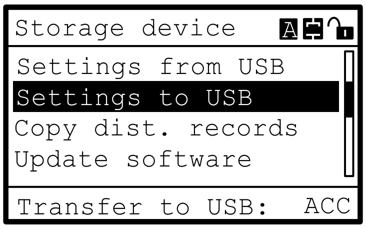


Figure 4.38 USB Storage device settings.

4.2.3.8 Lock/unlock device

Lock unlock submenu is used to lock or unlock device. There are two different password protected levels of accessing the device settings along with normal operating mode:

Normal operating mode
(Without password)

In normal mode it is possible to view all measurements and settings. It is also possible to confirm and clear alarms, clear average values and run basic device test (LED, display test).

Protector mode
(Password level1)

In Protector mode it is possible to set only parameters regarding protection functions and execute operating functions of relay.

Parameter setting mode
(Password level 2)

In Parameter setting mode it is possible to set passwords, date and time and all other device settings (e.g. assign digital inputs/outputs …)

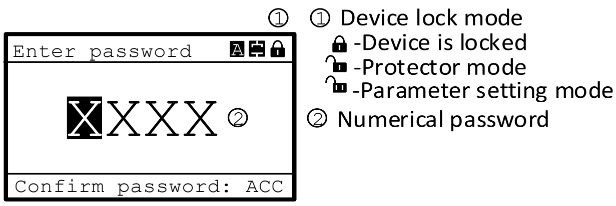


Figure 4.39 Device locking/unlocking description on display

Predefined password level 1 is set to 1000,
Predefined password level 2 is set to 2000.

4.2.3.9 Test mode

Test mode can be used for purpose of diagnosis about device LEDs, display and digital output relays.

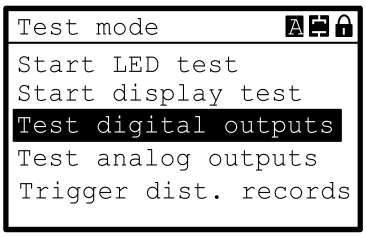


Figure 4.40 Test mode menu.

In *Test mode* menu it is possible to execute following commands:

Start LED test
Select this command to run diagnosis of the device LEDs. Test is executed instantly.

Start display test
Select this command to run diagnosis of the device display unit. Test is executed instantly.

Test Digital outputs
Test digital outputs opens a submenu with selection of the device internal relays. Individual output relay can be tested following next diagram:

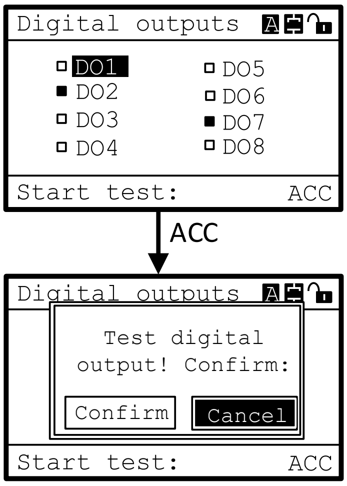


Figure 4.41 Executing test of digital outputs.

Test analog outputs

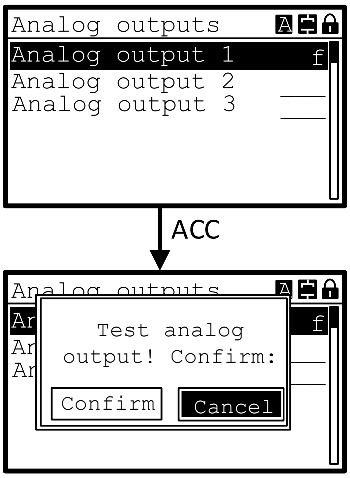


Figure 4.42 Executing test of analog outputs.

4.2.4 Local remote switch

The device distinguish between local and remote commands. The commands can be executed using PC software [4.3.2.3], communication [3.1.7.4], local HMI [4.2.3.4] and digital inputs [4.2.3.5.6]. The device threats each of this commands as local or remote command as seen on Table 153.

Command source	Command type
PC software	Remote
Communication	Remote
Local HMI	Local
Digital inputs	Local/Remote*

Table 153 attributes of commands.
**Defined by software setting [2.6.1.4].*

Setting the local/remote mode via the digital input has absolute advantage over any other means of setting the switch, as other means of setting the switch are treated as pulsed commands, while setting it over digital input the signal is not pulsed.

4.2.5 Function keys

Function key act as user defined shortcut or action. Function keys are only available on large device housing [4.2.1.2]. There are six total separate function keys present on the device. The function for each of the keys can be set using the predefined selection of actions or shortcuts. List of all functions along with their description, can be found on the table below:

Parameter	Description
None	No function
Meas. - Voltage	Circularly switch over voltage measurement screens.
Meas. – Current	Circularly switch over current measurement screens.
Meas. – Frequency	Select frequency measurement screen.
Meas. – Power	Circularly switch over power measurement screens.
Meas. – overview	Select overview measurement screen.
Protections	Circularly switch over protection settings menus.
Control	Circularly switch over control settings menus.
Settings	Circularly switch over device settings menus.
Display test	Initiate display test.
LED test	Initiate LED test.
Reset LEDs	Reset latched and blinking LEDs.
Reset relays	Reset latched relays.
Reset Lockout	Reset active lockout relay function.
Clear alarms	Delete all present alarms.
Confirm alarms	Execute commands: Reset LED, reset relays and clear alarms.
Reset max values	Reset all maximum measurement values
Change meas. type	Switch between p.u., secondary and primary measurement display units.
Disturbance rec.	Record a disturbance.
Variable 1...X	Function key act as one of the inputs for selected variable.

Table 154 Function keys parameters and explanation.

Using a function key set to a certain variable, this function key will act as one of the digital inputs available using user defined signals [2.7].

4.3 PC based graphical interface MiQen Setting Studio

MiQen Setting Studio is a Microsoft Windows application, used to configure, manage and monitor Iskra d.d. measuring instruments and protection devices. Remote device operation is possible by means of serial (RS-485/RS-232), USB and TCP/IP communication in connection with a PC. A user-friendly interface is made of six segments: connection, device settings, online measurements, data analysis, my devices and software upgrading. These can be easily accessed with six icons on the left side, as presented on figure below:

Figure 4.43 Connection between FPC device front port and PC via USB male - A to male - A.

4.3.1 Installation

Please check system requirements before starting the installation process.

System Requirements:

- Windows XP/Vista/7/8/10
- Processor: 1 GHz
- RAM: 512 MB
- Disk space:
  - 600 MB (32-bit system)
  - 1,5 GB (64-bit system)
- Monitor with VGA resolution

4.3.1.1 Procedure

Close down all running programs before starting the installation.

To install MiQen to your computer:

1. Download MiQen installation package and Driver installation .pdf file from http://www.iskra.eu/download/software/
2. Run Setup.exe from your media.
3. Follow the on-screen instructions.
4. Read Driver install.pdf and follow instructions

The program group MiQen has been created after the installation. In this group the executive file MiQen2.exe and help file MiQen2_en.chm can be found. Also MiQen shortcut will be created on the desktop.

Access to MiQen default installation folder

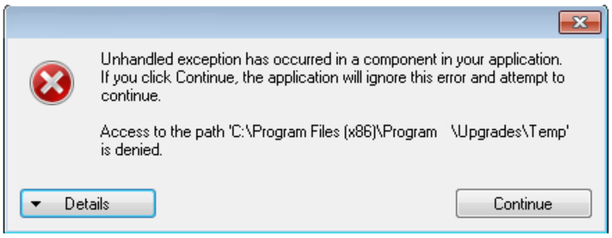


Figure 4.44 Administrative rights are needed to apply this change to the system.

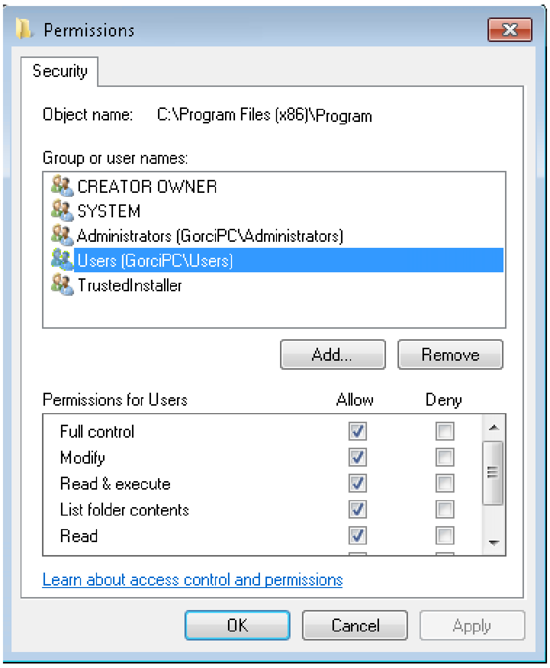


Figure 4.45 Permissions for specific PC user.

To change security policy for installation folder (Windows XP, 7, 8) right click on installation folder, than select "Properties" and "Security" tab. Click on "Edit..." button and in "Security" window select "User(s)" and check "Full control" check box. Apply the changes.

In some cases MiQen reports "Unhandled exception" at start-up. In this case access to default installation folder is denied and program will not be able to write (save or modify) files in this location. This issue can be managed by manually change security policy for MiQen installation folder.

4.3.2 Using MiQen software

Starting MiQen software	Closing MiQen software
Double-click (click) on MiQen icon or	Click on close button of the program control box or
Click on Windows **Start** button, then **Programs**, **MiQen** and **MiQen Setting Studio**	Select **Exit** from **File** menu or
	Press combination of keys **Alt+F4**

4.3.2.1 General screen organization

Software interface enables simple and fast communication between user and MiQen program.

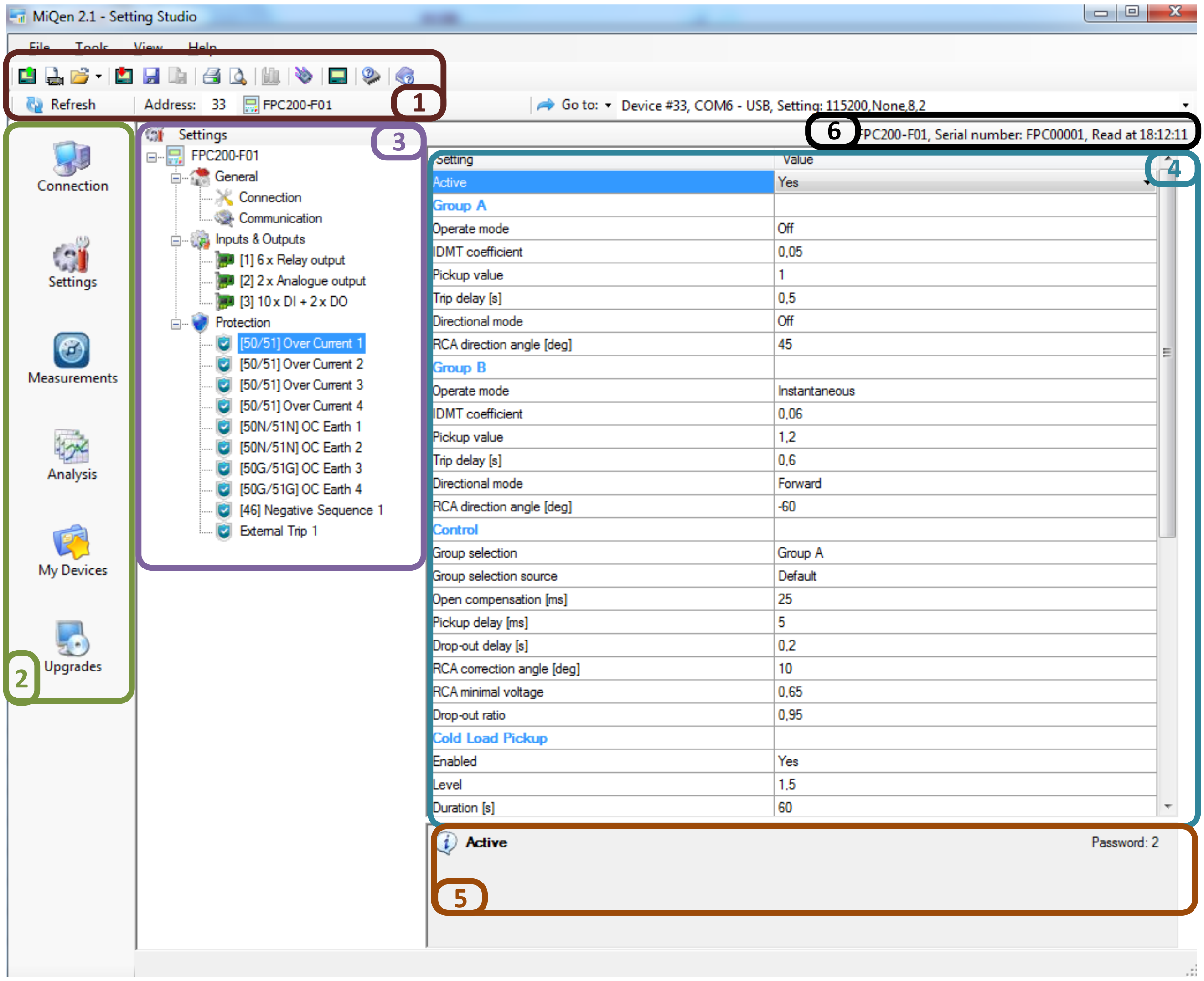


Figure 4.46 General screen organization

1 Toolbar
Toolbar contains buttons for sending commands to the program by shortcut so you don't need to search for commands in menus. This increases the speed of work.

2 Group bar
Side bar containing navigation key explained bellow.

3 Menu bar
Menu bar is assigned to send commands to the program. The list of the commands can be opened by clicking on a single group. When you select the command, the program will execute it. Non-active commands are greyed out.

Different commands are represented with different icons.

4 Setting field
Working space where parameters are viewed and set.

5 Help and info
Field where additional help and information is displayed.

6 Status bar
Displays the computer date and time and some of the active processes, such as communication for example.

Right click context menu
Use the right mouse button to open the context menu. The content changes depending on the user interface element it was used on.

Connection

Select the instrument from the list of favourites. Use the network explorer to set and explore the devices network. Communication parameters of all devices and their addresses in network can be easily set.

Instrument settings

MiQen provides simple methods for modification of settings which are organized in a tree structure. Besides transferring settings into the instrument, storing and reading from the setting files and MMC/SD memory cards are also available.

Online measurements

All supported measurements can be seen in real time in a table form. Most of them can also be displayed graphically. Real time recording can be used for further processing. Also momentary values can be copied via a clipboard into standard Windows formats.

Data analysis

Analysis can be performed for the instruments with a built-in memory. Recorded quantities can be monitored in a tabular or a graphical form. The events that triggered alarms can be analysed or a report on supply voltage quality can be made. All data can be exported to an Excel worksheet.

My devices

In My devices, list of frequently used devices can be created. Devices can be added to user defined groups and named with associative names for easier recognition. With double click on a device from a list, access to device settings, online measurements or stored data is much easier.

Software upgrading

Always use the latest version of software, both MiQen and software in the instrument. The program automatically informs you about available upgrades that can be transferred from the web site and used for upgrading.

4.3.2.2 Connection

4.3.2.2.1 How to start

To change device settings, watch on-line measurements or analyse memory data, the communication connection must be established between personal computer and the device or devices network.

At first, the physical connection of the device (or device network) and the computer communication port (serial, USB...) is necessary. For correct connection check additional information in chapter [5.5.2]. To establish communication, communication settings must match communication settings of the device.

Serial communication (RS-232 / RS-485)
Every device in the network must have its own unique communication address. For serial communication this is defined with numbers between 1 and 247. Factory default setting is 33. If more devices with the same address are in the same network, communication will not work correctly.

Enter communication address of the device into the field **Address** in toolbar and click on **Refresh** button (or keyboard **F5**). When communication is established, the icon and device type appears beside the field with address.

Ethernet communication
Devices with **Ethernet** communication have **DHCP** IP addressing enabled by default. If **IP address** and **port** is not known you can use browse Ethernet devices tool to find the device. Click on **Refresh** button (or keyboard **F5**). When communication is established, the icon and device type appears beside the field with address.

USB communication
When device with **USB** communication is connected to a computer for the first time, device driver will be installed automatically. If installation is correct device presents it-self in an operating system (Device manager - Ports (COM and LPT)) as Protection device. If device is not recognized automatically or wrong driver is installed, valid drivers are located in MiQen installation directory, subdirectory Drivers for manual installation.

You can use **Find USB** button in communication port settings form – tab USB, which can be accessed by choosing Change settings in Connection section. When communication is established, the icon and device type appears beside the field with the address.

When the address or communication parameters of the connected devices aren’t known, you can use searching tools to search for all connected devices.
The list of favourite connections allows easy choice of the device when multiple devices with different communication settings are used.
For easier access to devices settings and downloaded or recorded files, devices can be added to **My devices** list.

4.3.2.2.2 Computer communication port setting

The computer communication port (COM) settings must match the settings of the connected device.

To set computer communication port

1. Choose one of the following:
    - On program interface **Connection** in group **Communication port** click on **Change settings**,
    - Click on **Communication port setting** button on toolbar,
    - Select **Communication port setting** command from **Tools** menu.
2. On **Communication port setting** form select communication type and required settings:
    - Serial RS-485/RS-232
        - Communication port of connected device
        - Bits per second (communication speed)
        - Parity
        - Data bits
        - Stop bits
    - Ethernet TCP/IP
        - IP Address
        - IP Port
        - Protocol
        - Response timeout
    - USB
        - Communication port (USB)
        - Use Find USB button if you don't know port number.
3. Click on **OK** button.

4.3.2.2.3 Connecting to device

Serial communication (RS-232/RS-485)

Every device in the network must have their own unique communication address. For serial communication address is defined with numbers between 1 and 247. If more devices with the same address are in the network, communication won't work correctly.

Enter communication address of the device into field **Address** in toolbar and then click on **Refresh** button (or keyboard **F5**). When communication is established, the icon and device type appears beside the field with address.

You can also use scanning tool to discover connected devices or select them from a favourite connections list.

Ethernet communication

Devices with **Ethernet** communication have default **DHCP** IP addressing enabled. If **IP address** and **port** is not known you can use browse Ethernet device tool to find the device. Click on **Refresh** button (or keyboard **F5**). When communication is established, the icon and device type appears beside the field with the address.

You can also use browsing tool to discover devices connected to Ethernet network or select them from a favourite connections list.

USB communication

You can use **Find USB** button in communication settings. When communication is established, the icon and device type appears beside the field with address.

When device with **USB** communication is connected to a computer for the first time, device driver will be installed automatically. If installation is correct device presents it-self in an operating system (Device manager - Ports (COM and LPT)) as a Protection device. If device is not recognized automatically or wrong driver is installed, installation drivers are located in MiQen installation folder, subfolder Drivers, for manual installation.

4.3.2.2.4 Searching for devices

MiQen software has integrated different tools that helps user to find devices connected on the network. Following is possible:

- Scan serial network for connected devices,
- Browse for devices connected on the Ethernet network.

Scan serial network

To scan for devices connected in to serial network (RS-485, RS-232 and USB) first set correct communication port. On program interface **Connection** in group **Searching** click on **Scan the network**.

MiQen will start searching for devices connected to the serial communication port. Search for devices works on considering device serial number. All connected devices will be found, regardless of their communication settings. Communication parameters can than easily be changed from a list of devices.

Browse for Ethernet devices

On program interface **Connection** in group **Searching** click on **Browse Ethernet devices…**

MiQen will start searching for devices connected to local Ethernet network. If your device is not listed below repeat browsing procedure or check device communication settings (IP address and port).

4.3.2.2.5 Scanning and configuring serial network

To find all devices connected to serial communication network (RS-485, RS-232, USB) at different communication parameters you can use scanning tool which searches for devices considering device serial number. In this case also devices with the same address are found. Now you can set new communication parameters for each device (from a list) to configure the network.

Scanning the network

1. On program interface Connection in group Communication port click Change settings,
2. Select communication type and required settings,
3. On program interface Connection in group Searching click on Scan the network.

Configuring the network

To communicate with devices in order to read data or change settings, network parameters needs to be set correctly. Beside correct communication parameters such as communication speed, parity and stop bits, each device must have its own unique communication address. To set this parameters do following:

1. **Scan** the network (see instructions above),
2. Select device from a list,
3. Change communication parameters in a table on the right side of the list,
4. Click on **Download changes** button.

Repeat procedure for each device in the network.

4.3.2.2.6 Browsing Ethernet devices

Software will browse all instruments with Ethernet communication connected within the Ethernet network. Browsing is made by **UDP** communication protocol. Before browsing check if your network supports UDP communication protocol.

CAUTION

Warning: Check the PC firewall setting, which can block the UDP pockets exchange between PC and Ethernet devices. It is recommended to add the MiQen software on the firewall exceptions list.

To browse Ethernet devices
On program interface Connection in group Searching click on Browse Ethernet devices.

If device IP address matches the PC subnet mask, this device will appear on the list in black colour, otherwise in red colour. Communication (measurements, settings, analyses) with red coloured devices is not possible.

To change the device IP address
1. Select the device from the list,
2. Change communication parameters in a table on the right side of the list (for **IP Port** setting take in to consideration **Port numbers** table below).
3. Click on **Download settings** button in the toolbar.

To change the IP address for device not on list
1. Click on **Assign IP by MAC** button,
2. Enter **MAC address** on the **Ethernet settings** form,
3. Enter **IP address** on the **Ethernet settings** form or select Automatic (DHCP),
4. Enter **Local port** number on the **Ethernet settings** form. Use a recommended port numbers from the following table. If using Redirector software, the port number should be between 14000 and 14009.
5. Click on **OK** button. Adapter initialization takes a few seconds.

Port numbers	Function
1 … 1024	Reserved
9999	Telnet setup
14000 … 14009	Reserved for Redirector
30718	Reserved
10000 … 10999	Recommended ports

Table 155 Ethernet port configuration.

4.3.2.2.7 Favorited connections

For quick access to device, list of favourite connections can be used. Device will be added to the list of favourite connections every time communication with a device is established. The list can contain up to 32 last used connections. It is possible to rename connection on a list, to make the work easier.

To select device from favourite connections list
1. Click on dropdown combo **Go to** in toolbar and select the device (connection).

To rename or remove device from list
2. Click on label **Go to** in toolbar and choose Rename.
3. Click on label **Go to** in toolbar and choose Delete Selected connection or All connections.
4. On dropdown menu:
    a. Select the connection you want to rename or delete,
    b. Click on **Rename** button and enter new name, if you want to rename **Selected connection**,
5. Click on **Delete** button and select, if you want to delete **Selected connection** or **All connections**.

4.3.2.2.8 Adding the device to My Devices list

Devices that are frequently used can be added to user defined list in **My devices**. From **My devices** access to device settings and downloaded or recorded files is much easier.

Adding device to the list
To add the device to the list first establish communication with the device, then click **Add to My devices** icon. The **Device properties** window will appear, that will give the user possibility to:

- Assign the device to predefined device group.
- Give the device user defined **description** and **location** for easier recognition.
- Change default **data directory** and enable **subdirectories** structure for downloaded data.

By click on the OK button settings are confirmed. Device can now be found in **My Devices**.

4.3.2.3 Settings

Reading the settings

To read device settings, the communication connection to the device must be established.

To read the device settings

Choose one of the following:

- Click on **Read settings** button on toolbar,
- Select **Read settings** from **File** menu or press **Ctrl+R**,
- On the left side click **Settings** icon and then click **Read settings** button,

Settings form appears after successful reading. There is a tree structure with setting groups on the left side of the settings form. Table with available parameters opens up by clicking on the group on the right side of the settings form. The device type, serial number and reading date are displayed on the top of the settings form.

4.3.2.3.1 Editing the settings

Settings can be changed after they have been read from device or opened from settings file. There is a tree structure with settings groups on the left side of the settings form. Table with available settings opens up by clicking on the group in right side of the settings form. All settings except those greyed out can be changed. The greyed out settings are read only information about the device.

To edit the selected setting

1. Choose one of the following:
    a. Click on setting to access dropdown menu,
    b. Select the setting and click on **Edit** button, displayed on right border of the table,
    c. Click on setting you wish to change and enter number.
2. Change the parameters in opened form. Short explanation of setting is displayed on bottom part of settings table near the **information** icon. Additional information about device settings can be found in User's manual of the product. Required password level for download (if device is password protected) is displayed on right bottom part of settings table next to the **information** icon.
3. In case of using **Edit** button, click **OK** for confirmation.

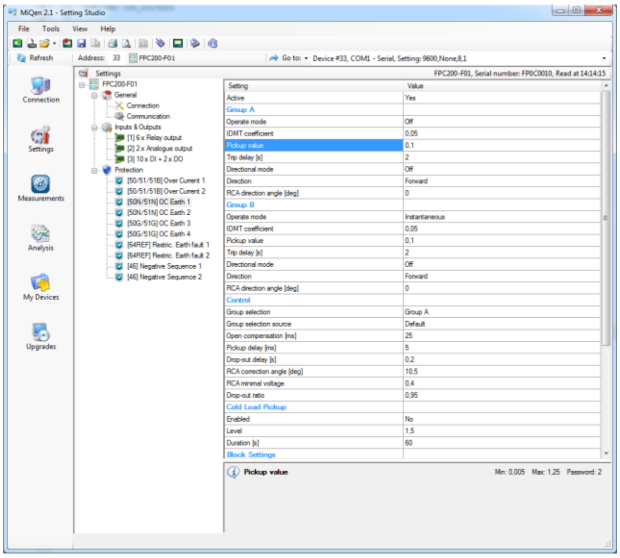


Figure 4.47 Editing pickup value parameter of [50N/51N] OC Earth 1 protection in FPC 400-F1 Relay.

In the settings table text is coloured blue after new value has been entered.

4.3.2.3.2 Downloading the settings

To download settings, the communication connection to the device must be established. You can choose between three download options:

- **Download settings** – all settings from MiQen settings table will be downloaded into device.
- **Download settings (Only changes)** – only new, changed settings from MiQen settings table will be downloaded into device.
- **Download group** – only settings from selected group will be downloaded.

There is no difference between options A and B when the settings are read from device. If the settings were opened from settings file in first case (A) all settings will be downloaded. In the second case (B) only new, changed settings will be downloaded.

To download all settings (A)
Choose one of the following:

- Click on **Download settings** button on toolbar,
- Select **Download settings** from **File** menu or press **Ctrl+D**,
- Right-click on settings table and select **Download settings** from context menu,

To download only changed settings (B)
Choose one of the following:

- Select **Download settings (Only changes)** from **File** menu,
- Right-click on settings table and select **Download settings (Only changes)** from context menu.

To download group settings (C)
- Right-click on selected group in settings tree structure and select **Download group**.

If device is protected with password, you must enter correct password for required level of access before downloading.

When settings in device memory are changed, the warning message will appear before download. Continue only, if the memory has already been read, otherwise memory data might be lost or wrong values may appear on changed locations!

Download status window with progress bar will appear during download. Click on **Details** button after download is finished to look at changed registers or **Close** button to close the window. Window with details will appear in case of errors or warnings automatically after transfer, to help solve problems.

4.3.2.3.3 Settings file

Device settings can be saved into a file on your computer and can be later used for configuration of similar devices.

To save settings file

1. Choose one of the following:
    a. Click on **Save** button on toolbar,
    b. Select **Save as** from **File** menu or press **Ctrl+S**,
    c. Right-click on settings table and select **Save as** from context menu.
2. Select the directory and file name in **Save as** form and then click on **Save** button.

Default names and saving options can be set in **Options – General** dialog box. Select **Options** from **Tools** menu to open Options dialog box.

To open settings file

1. Click on **Settings** button to switch to Settings form,
2. Choose one of the following:
    a. On program interface **Settings** in group **What do you want to do** click on **Open settings file**,
    b. Click on **Open** button on toolbar,
    c. Select **Open - Setting file** command from **File** menu,
3. Select the directory and file name in **Open** form and then click on **Open** button. **Settings** form appears after successfully reading. On the left side of the settings form is a tree structure with settings groups. Table with available settings opens up with click on the group in right side of the settings form. The file name is displayed on the top of the settings form.

Recently used settings files

Select the file name which you would like to open from **File** menu. The program follows the last five accessed documents and shows them in the list at the bottom of File name menu.

4.3.2.3.4 Copy and Print

Settings can be copied to the Windows clipboard for further use or to print out settings on a printer.

To copy settings

Choose one of the following:

- Right-click on settings table and select **Copy** from context menu,
- Press keys **Ctrl+C**.

To print settings

Choose one of the following:

- Click on **Print** button on toolbar,
- Select **Print** command from **File** menu or press **Ctrl+P**.

To examine the page before printing, use the Print preview. The display of your pages in preview window depends on screen resolution and printer used.

To open print preview

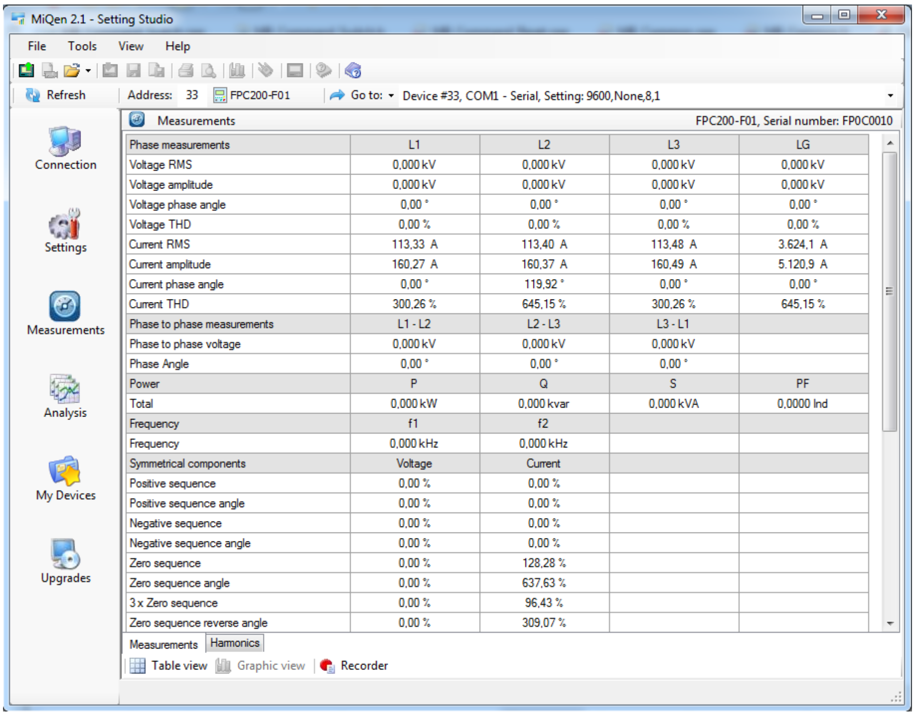
Choose one of the following:

- Click on **Print preview** button on toolbar,
- Select **Print preview** from **File** menu.

4.3.2.4 Measurements

Online measurements

All supported measurements can be shown in real-time in a table form. For some devices, also presentation in graphical form is possible. The measurements are presented on more measuring sheets (similar to Microsoft Excel), depending on type and range of measurements supported by device. To view online measurements, the communication connection with the device needs to be established. Refreshing time for measuring results is 2 seconds.



It is also possible to record measurements. Recorded measurements are saved in CSV file format.

Figure 4.48 MiQen 2.1 displaying live measurements from FPC 400 protection relay device.

To view online measurements

1. Click on **Measurements** button to show Measurements form,
2. Click on **Online measurements** button (or keyboard **F5**) on program interface **Measurements**,
3. Click on measuring group tab if more measuring groups are supported by device.

Switching between graphical and table view

To switch between graphical and table view click on button **Table view** or **Graphic view** at the bottom of the window.

Default view

It is possible to set default view presentation for each group of measurements. This can be done in **Options – Measurements** dialogue box. To set default view:

1. Select **Options…** from **Tools** menu.
2. Go to **Measurements** tab
3. Check measurements groups that will be presented in graphic form by default.

For some devices graphical presentation of measurements is not supported. In this case measurements are **automatically** presented in **table form**.

To hold measurements

Right-click on measurements table and select **Hold measurements** from context menu. Click on **Refresh** button on toolbar for repeated measurements refreshing.

Click on **Refresh** button on toolbar if problems on communication connection occur between measurements.

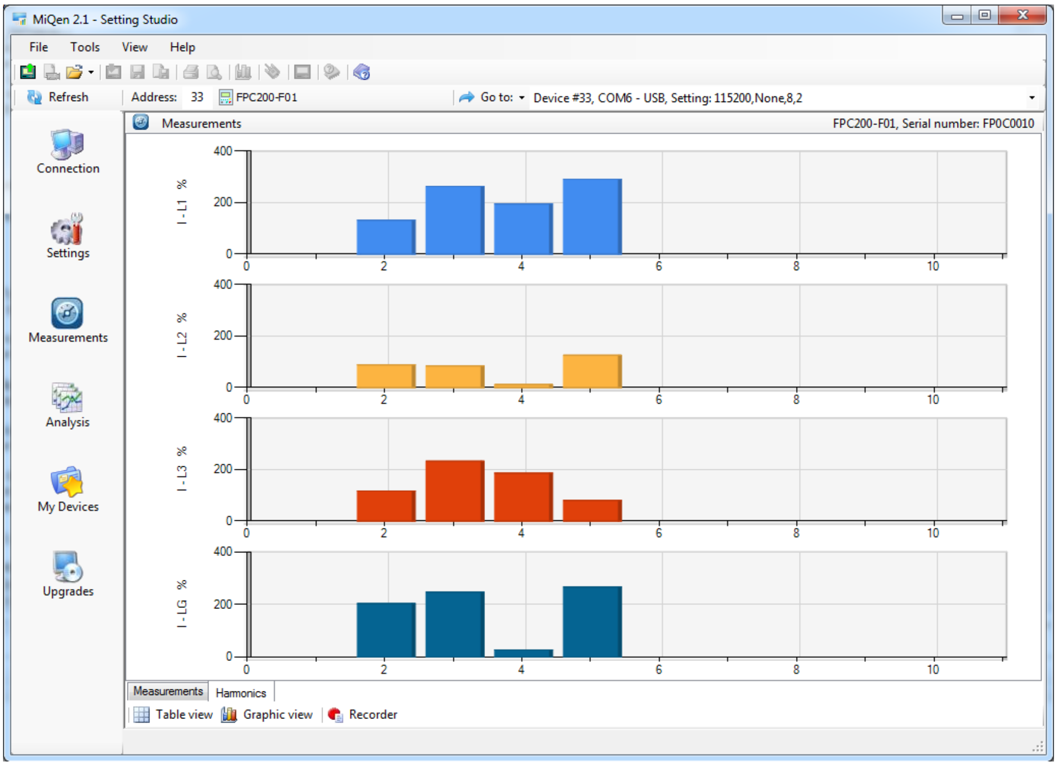


Figure 4.49 Phase currents measurements

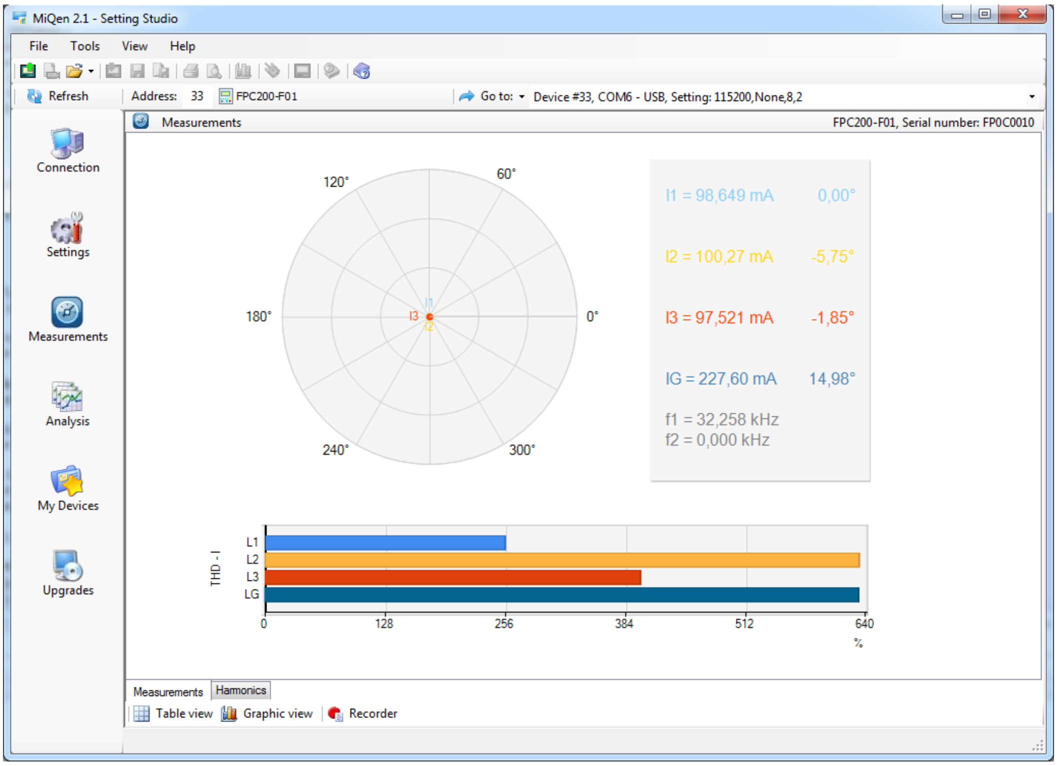


Figure 4.50 Graphic view of measurements including phasor view.

4.3.2.4.1 Recording of online measurements

Recording is possible for a group of measurements shown in **Table view** of selected online measurements tab.

1. When desired online measurements tab is opened, click on **Recorder** button at the bottom of the page to open **Measurements Recorder** window.
2. Select **File name**, **Path** and **Data Type**. If in **Data Type Values only** is selected, only values will be recorded, which is useful in case of further arithmetic operations and analysis.
3. In **Filter** tab it is possible to filter selection of measurements
4. Click **Start Recording** button to start recording.
5. When finished, click **Stop Recording** button.

If recording is stopped and later continued under the same file name, data will be added to the same file. Pay attention to close the file, before recording is restarted.

4.3.2.4.2 Copy (measurements)

Measurements can be copied to the clipboard for further use or to be printed out on printer. There are two copy options available for the data presented in Table view:

- **Standard copy** – copied data will be in the same format as they are in table of measurements,
- **Copy with separate unit** – copied data will have separated value and unit with Tab character, which is useful in case of further arithmetic operations.

If copy command is selected when data are presented in Graphic view, picture of graphic view is saved in to the clipboard.

To copy measurements table or graphical view (picture)
Choose one of the following:

- Right-click on measurements table and select **Copy** from context menu,
- Press keys **Ctrl+C**.

To copy measurements with separate unit

- Right-click on measurements table and select **Copy and separate unit** from context menu.

4.3.2.5 My Devices

General

In **My Devices** user can store connections to devices that are used more often. Each device can be assigned to user defined **group** and equipped with user defined **Description** and **Location** for easier recognition. By selecting device from the list, access to device settings and downloaded and recorded files is much easier.

Window is divided into two panels, one showing the list of **My Devices** and the other displaying content of default **Data directory** that belongs to selected device.

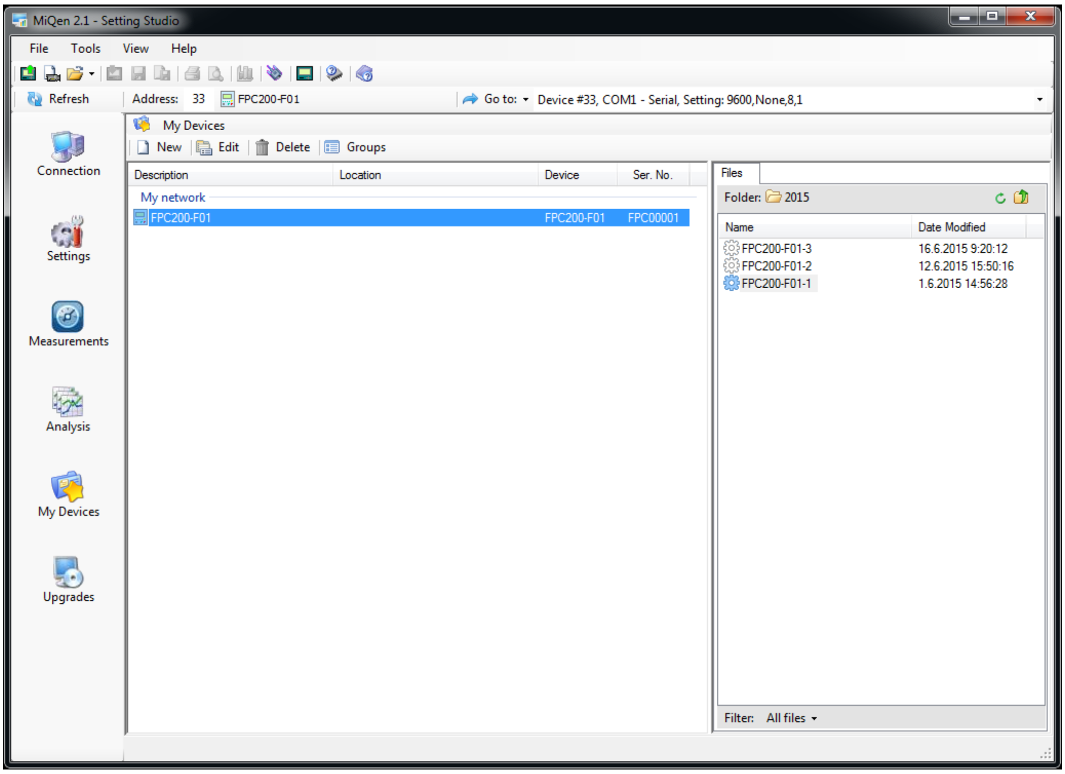


Figure 4.51 My Devices window showing Data directory contents for FPC 400 protection device. Data directory contains different configurations.

4.3.2.5.1 Managing groups

Devices in **My devices** list can be assigned to predefined groups. Groups can be managed in **Device group** window that can be accessed by clicking Groups icon Groups form the **My devices** toolbar or by right clicking on the list of devices. If no group is created, devices are assigned to default system group **My network**.

Creating groups

New group can be created in the **Device group** window. Click **Add** button, write group name and confirm action with **OK** button.

Deleting groups

To remove the group from a list, all attached devices need to be removed from a group or relocated to other groups. In the **Device group** window select desired group and click **Remove**. Confirm action with **OK** button.

Sorting groups

Order of appearance of groups can be managed form the **Device group** window. Select the group and use **Up** and **Down** buttons to order groups as desired.

4.3.2.5.2 Managing devices

Devices can be managed using the **Device properties** window which is opened automatically when adding devices to the list or editing existing one.

Adding devices

Devices can be added automatically from the **Connection** window or manually by clicking **New** icon from **My Devices** toolbar or with the right click on the list of devices and selecting **New** from context menu.

Creating new device

To manually add the device to the list click on the **New** icon from **My Devices** toolbar and fill in all the data in the **Device properties** window:

- enter device serial number,
- select device type from drop down list,
- assign the device to predefined **device group**,
- give the device user defined **description** and **location** for easier recognition,
- define device communication parameters,
- define or change default **data directory** and enable **subdirectories** structure for downloaded data,
- define FTP Access.

By click on the **OK** button settings are confirmed.

Editing device properties

To change device properties select the device and click on the **Edit** icon from **My Devices** toolbar or right click on the device and select **Edit** from context menu.

Deleting devices

To delete device form the list, select the device and click on the **Delete** icon from **My Devices** toolbar or right click on the device and select **Delete** from context menu.

4.3.2.5.3 Files panel

In the **Files panel** content of default **Data directory** of selected device is shown. Location of device **Data directory** and its subdirectory structure can be set in the **Device properties** window.

This location is automatically offered to user when downloading stored data from the device recording real-time measurements or storing its settings if device is on **My Devices** list.

Options

Various options are integrated to ease user navigation through file directories:

- **Sort** the list by **Name** or **Date of Modified** by clicking appropriate heading field in the table.
- **Filter** files shown on the list by **Filter** function on the bottom of the **Files panel**.
- To go back to default directory right click on the list and select **Default folder**.

Double-click on selected file – it opens the file in default program.

4.3.2.6 Upgrades

4.3.2.6.1 MiQen upgrade

The latest version of MiQen software should always be used. Manual or automatic checking for upgrades is available. Internet connection is required.

How to check for MiQen upgrade

1. Click on **Upgrades** button to display **Upgrades** form,
2. List of available upgrades is divided in various sections for easier navigation. Each section is named by software or family of devices (MiQen software, measuring centers, protection relays, measuring transducers...). The list is structured in four columns:
    a. Software or Device type
    b. Upgrade version (displays latest official version and date)
    c. Download link (link to download latest version)
    d. History file (displays upgrade history)
3. To check version of current installation click **About** from **Help** menu.
4. If current version of MiQen software is older than the latest one in the **Upgrades** list, installation of the latest one is recommended.
5. Click **Download link** to download latest version.
6. Close all running MiQen applications before installation of new version.
7. Follow instructions on the screen.

4.3.2.6.2 Device software upgrades

Manual or automatic checking for upgrades is available. Internet connection is required.

To check for device upgrade

1. Click on **Upgrades** button to display **Upgrades** form.
2. List of available upgrades is divided in various sections for easier navigation. Each section is named by software or family of devices (MiQen software, measuring centers, protection Relays, measuring transducers...). The list is structured in four columns:
    a. Software or Device type
    b. Upgrade version displays latest official version and date)
    c. Download link (link to download latest version)
    d. History file (displays upgrade history)
3. Check your device software version in MiQen or read it from device.
4. If currently installed software version is older than the latest one in the **Upgrades** list, installation of the latest one is recommended.
5. Click **Download link** to download latest version. Upgrades are packed in compressed zip file.
6. Go to location where upgrade has been saved and unzip the file.
7. Follow the instructions that can be found in extracted folder.

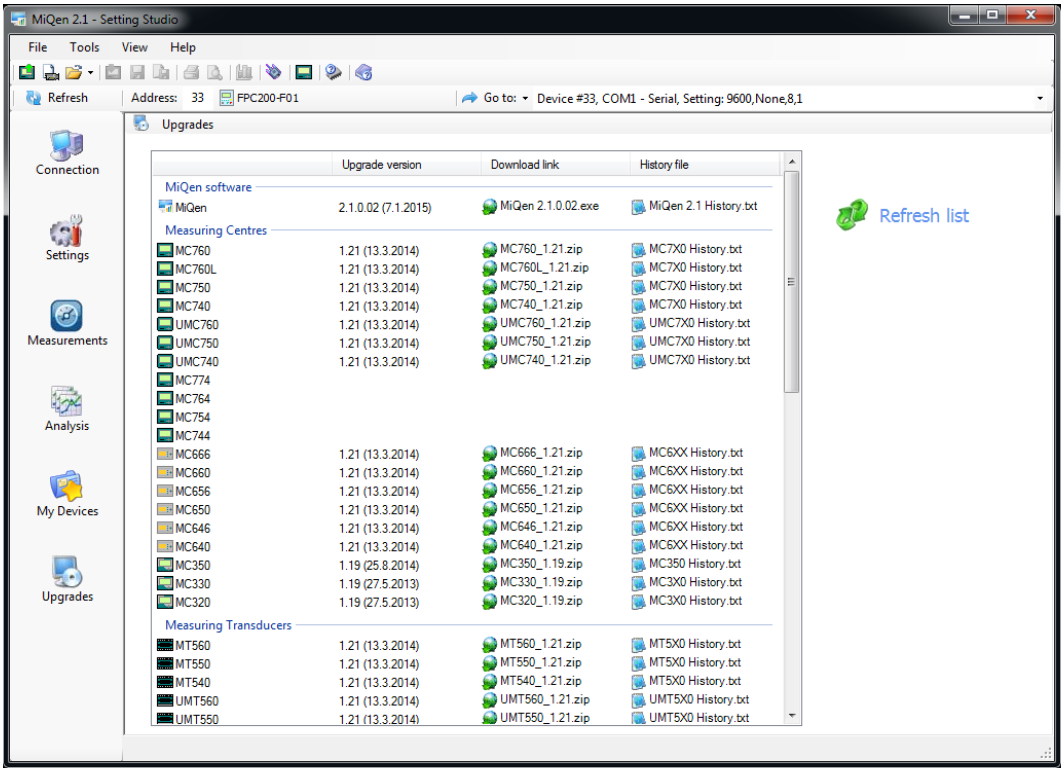


Figure 4.52 Device software upgrade window with list of devices and available upgrades with latest versions.

4.3.2.6.3 Automatic upgrade checking

Automatic checking about available upgrades can be set. Internet connection is required.

Automatic upgrade checking

1. Select **Options** from **Tools** menu,
2. Click on **Upgrades** tab,
3. Select upgrade checking options and click on OK button.

If **MiQen** upgrade is available, program will automatically start **Upgrades** form. Notification about available upgrade will be shown on display. Download procedure is described in MiQen upgrade topic.

If upgrade of device software is available, the program will inform you with 5 seconds notification on the left bottom part of the screen each time that the communication connection with device will be established. Download procedure is described in Device software upgrades topic.

5 Mounting and commissioning

This chapter is intended for experienced commissioning staff. Typical procedures during commissioning of the device are described. The staff must be familiar with commissioning of protection and control systems, management of power systems and relevant safety rules and guidelines. Knowledge of the project, device and necessary tools is required.

5.1 Safety instructions

Safety instruction and warnings should be considered before commencing any work on the device. Dedicated sections for proper installation, handling and maintenance of the device are provided. Safe operation conditions are achieved by following provided information and using the device in accordance with its intended function and in the manner specified in this manual. **Failure to observe and follow the instruction in the equipment manual could cause irreversible damage to the equipment and could lead to property damage, personal injury and/or death.**

HAZARD OF ELECTRIC SHOCK, ELECTRIC ARC, BURNS OR EXPLOSION

- Only qualified personnel should install this equipment.
- Work in pairs.
- Wear personal protective equipment.
- Always use a properly rated voltage sensing device to confirm that power is off.
- Carefully inspect the working area for tools and objects that may endanger your work.
- Before performing visual inspections, tests or maintenance on the device disconnect all sources of electric power. Assume that all circuits are under voltage until they are completely de-energized, tested and tagged.
- Before working on CTs, they must be short-circuited.
- Opening and working on live device is strictly prohibited.
- Equipment ground terminal must be grounded during device operation and service at all times.
- When handling device with optic communication avoid looking directly into the optical heads.
- Hardware replacement can only be done by Iskra d.d. qualified personnel.

5.2 Precautions

It is recommended to follow the instructions given in this document for correct handling, storage and transportation of FPC 400 device.

5.2.1 Device stored in its original packaging

Transport:
Device can be shipped by all usual means of transport without taking any additional precautions.

Handling:
Device can be handled without any particular care. It can withstand fall from average table height.

Storage:
FPC 400 device stored in original packaging can be stored in appropriate location for several years. Environmental conditions should be within standardized values:

- Temperature: between -25 °C and +70 °C (between -13 °F and +158 °F)
- Humidity ≤ 90 %

Periodic checking of the environment and the packaging condition is recommended every year.

5.2.2 Device installed in a cubicle

Transport:
FPC 400 device can be transported by all usual means of transport in the customary conditions used for cubicles. Storage conditions should be considered when transportation time is long.

Handling:
In case the device falls out of the cubicle visual inspections of the device is required. If the device shows no signs of damage it can be energized and tested for operational readiness.

Storage:
The cubicle protection packaging should be kept intact for as long as possible. FPC 400, like all electronic devices, should be energized as quickly as possible. When this is not possible, the cubicle heating system should be activated.

5.2.3 Working environment

Damp environment:
The temperature and relative humidity factors must be compatible with the environmental withstand characteristics of the device. Special arrangements should be made when commissioning the device where environmental values are outside the specified operation zone. (e.g. air conditioning of premises must be turned on)

Polluted atmosphere
Contaminated industrial atmosphere (e.g. presence of chlorine, hydrofluoric acid, etc.) can cause corrosion of the electronic components, in which case environmental control arrangements should be made prior to the commissioning.

5.3 Equipment identification and unpacking

When removing the packaging the user is obliged to carefully inspect the device for any physical damage. Damaged device should be returned to supplier together with the original packaging. Device that is damaged should not be connected to power supply or put to commission.

5.3.1 Package specification

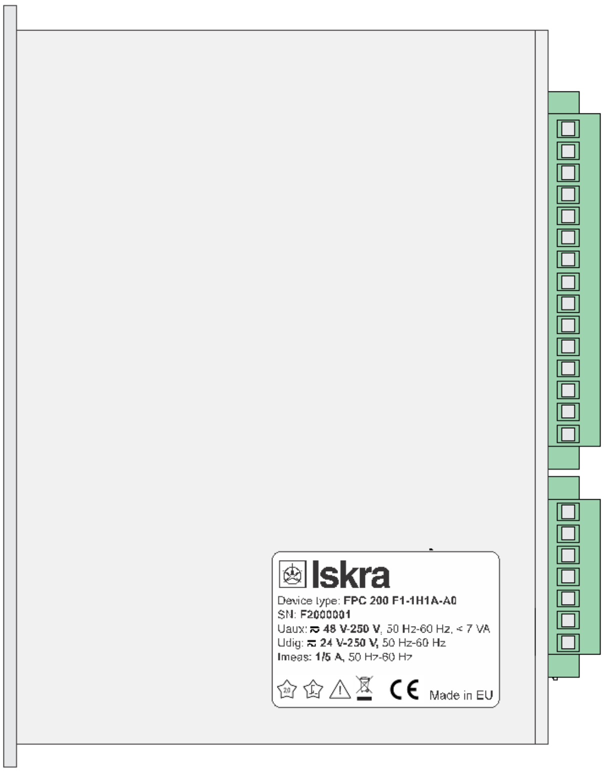
Each FPC 400 is delivered in a single package. Optional accessories such as modules and connectors are delivered in separate packages. Weight of each single package encompass full configuration of each of the device types

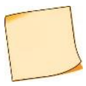
Single package specifications			
Small housing		**Medium housing**	
Width	175 mm	Width	221,2 mm
Height	215 mm	Height	215 mm
Depth	180 mm	Depth	180 mm
Maximum Weight*	2620 g	Maximum Weight*	3390 g

*Table 156 Package specification. *Full configuration weight. Actual weight depends on order configuration.*

5.3.2 Device identification

Device is identified by reading the label on package and device itself. Identification label is attached at the right side of the device as shown on Figure 5.1. The label indicates the product model, serial number, firmware revision, and date of manufacture. Additional label is provided to be placed in more convenient location if the need arises.





Additional label is included.

Figure 5.1 Side view where label is attached.

5.4 Device installation

5.4.1 Service conditions

The protective device is designed to be operated in demanding industrial and electrical utility environment. To be compliant with EMC directive a commissioning instructions should be followed. It should also be noted that all the contacts and relays that operate in the same cabinet, should be equipped with suitable surge suppression components. If high voltage of 100 kV and above is present on a substation, a conductive shielding, grounded on both ends, should be used in all external cables.

5.4.2 Dimensions

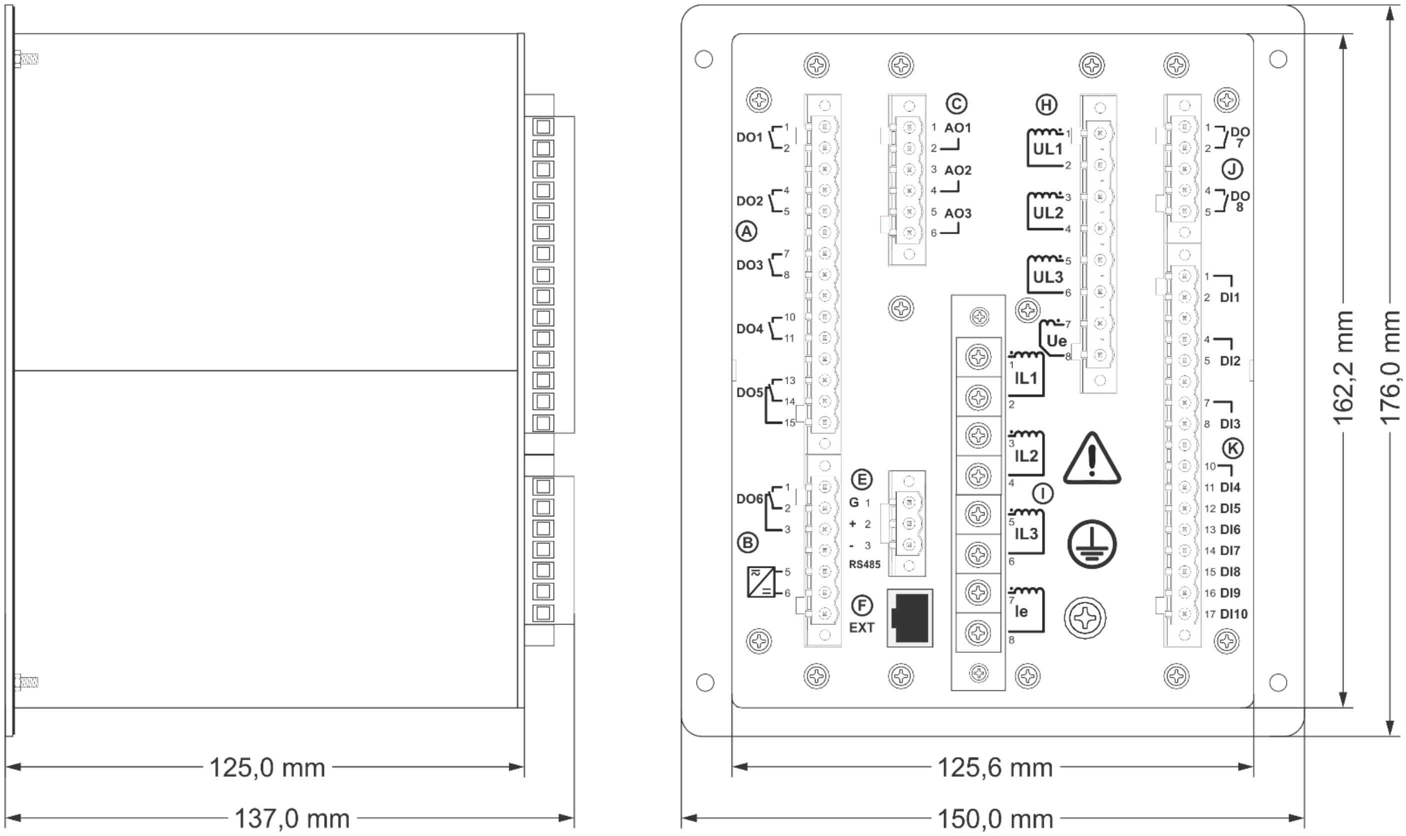


*Figure 5.2 Device dimensions.**143,7 mm..***

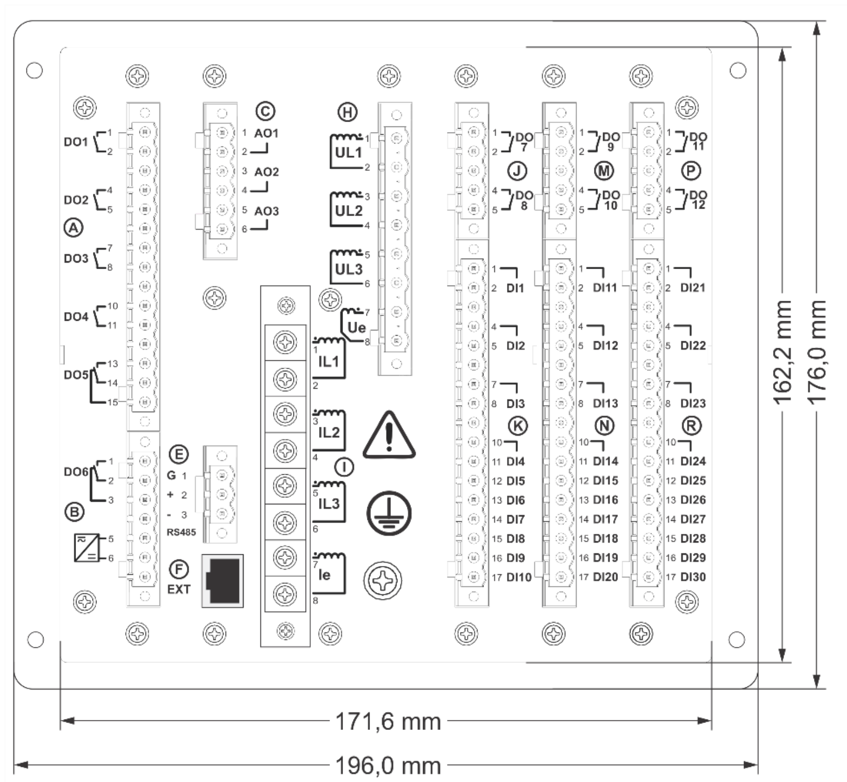


Figure 5.3 Medium housing dimensions.

5.4.3 Cut-out dimensions

CAUTION
Hazards of cuts!

Provided .dwg file includes 2 mm tolerance.
Cut-out accuracy must be complied with to ensure good withstand.

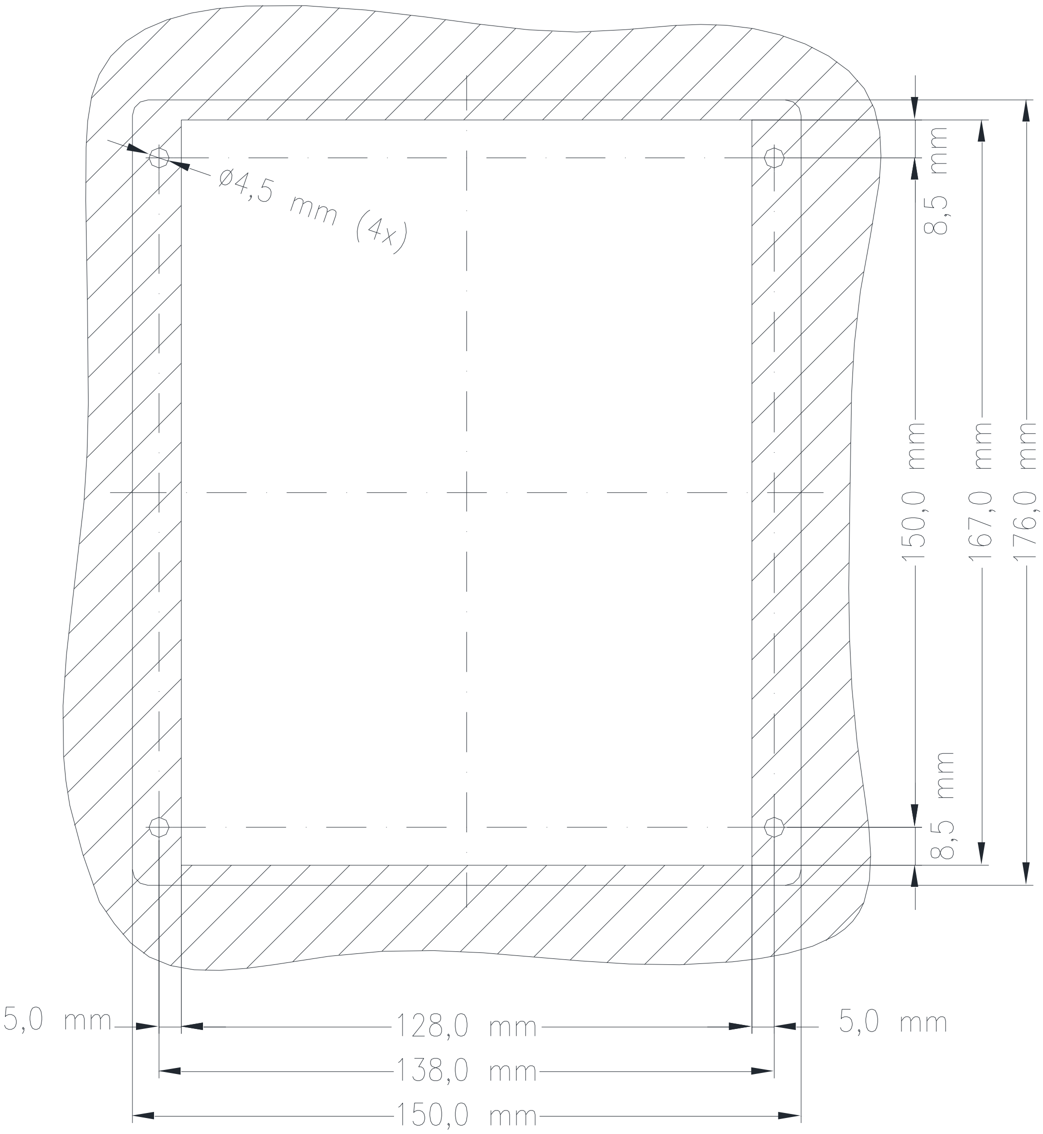


Figure 5.4 Small housing cut-out dimensions.

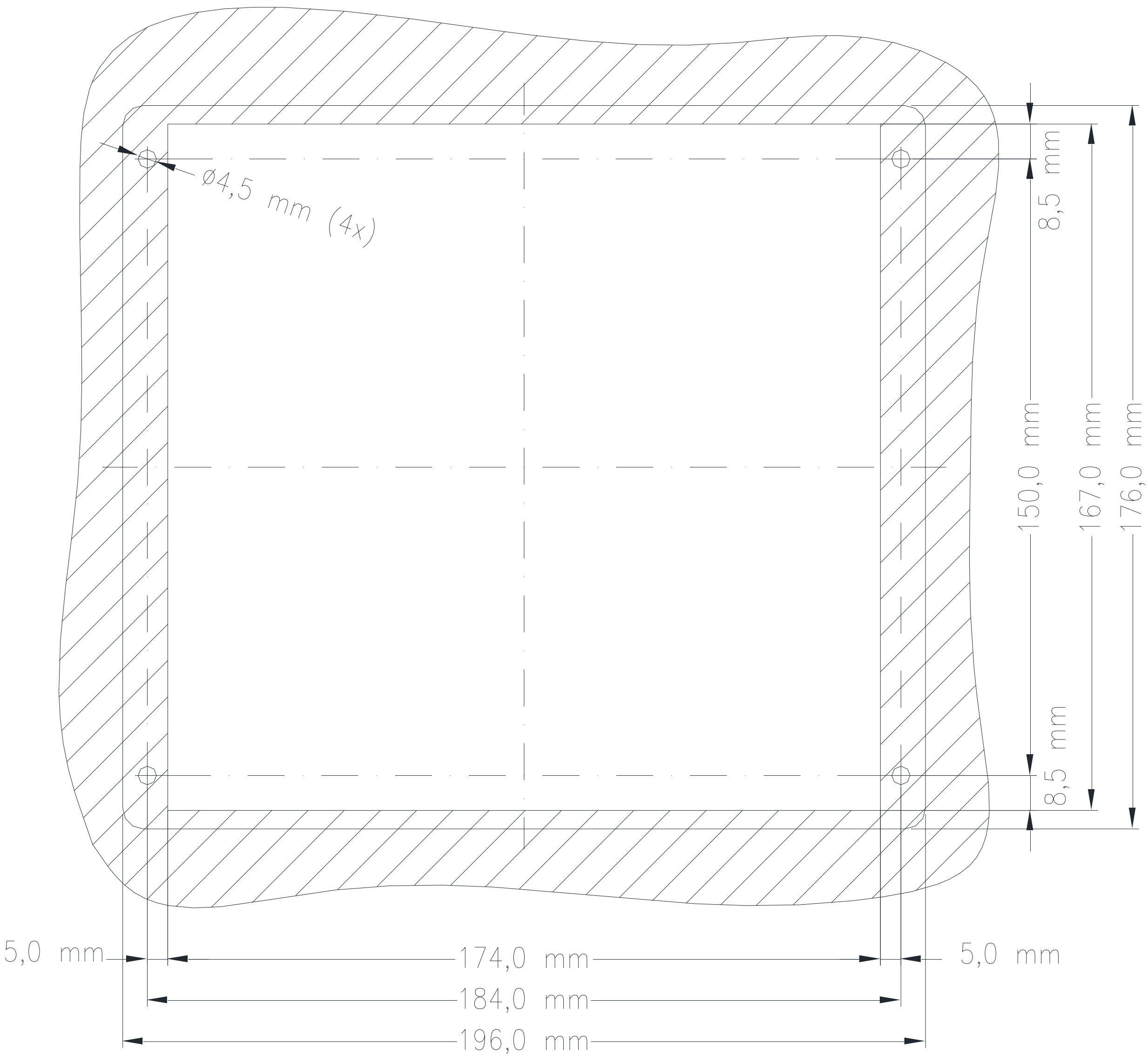


Figure 5.5 Medium housing cut-out dimesions.

5.4.4 Assembly

Device is screwed with four M4 nuts onto panel door as shown on Figure 5.6.

Tightening torque is 1,3nM.

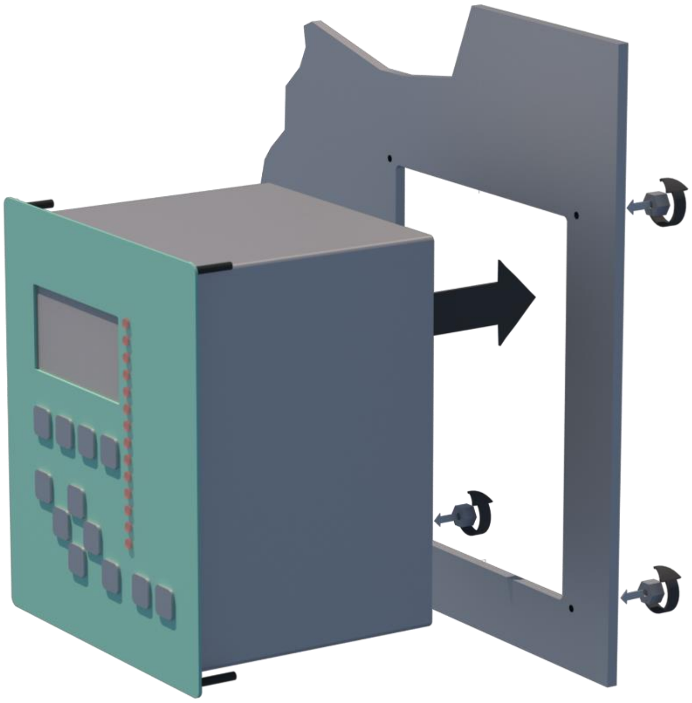


Figure 5.6 Device mounting

5.4.5 Spacing

Recommended spacing inside the cubicle is 30 mm around the device. In case of fibre optic connection rear side should have 100 mm deep spacing otherwise 50 mm as shown on Figure 5.7.

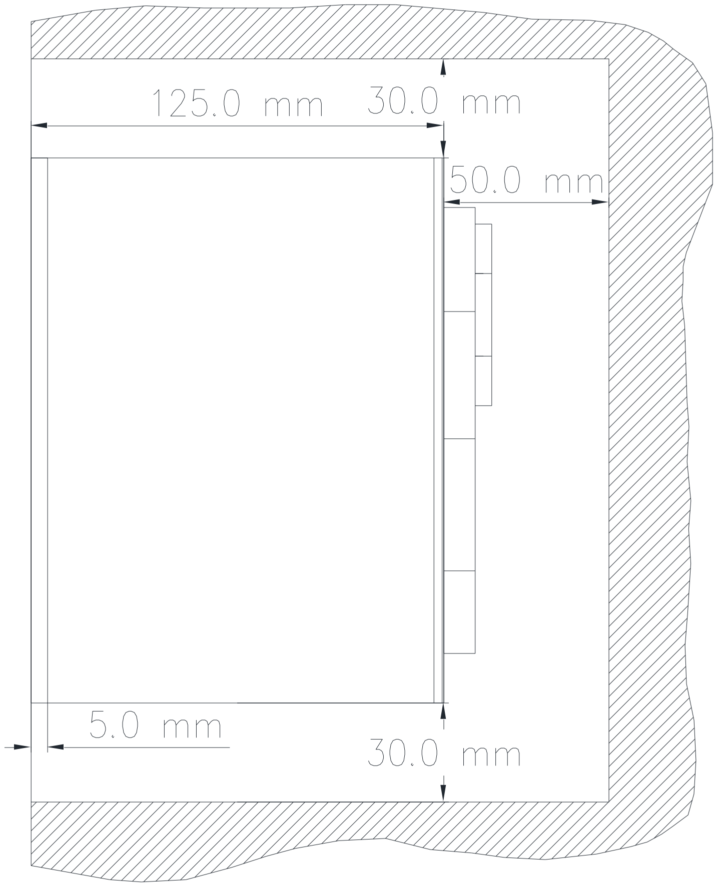


Figure 5.7 FPC 400 side view with recommended spacing and grounding connection

5.4.6 Recommended external protection elements (MCB)

- Power supply: K2 or C2
- Voltage inputs: Z2
- Digital inputs: B2
- Digital outputs: B6

5.5 Connection

The FPC 400 connections are made to the removable connectors located on the rear side. Connectors are screw-lockable. Direction from which wires are connected is defined by the type of the connector. Braided or single strand wires can be used for the wiring. The braided wires must be correctly finished with insulated end-sleeve and executed with a suitable tools. Soldering can endanger the integrity of wire connection and is not permitted.

Equipment shall be isolated or disconnected from hazardous live voltage before access to potentially hazardous live parts is affected.

Recommended wire dimensions for individual device connections type are:

	Recommended	**Min**	**Max**
Power supply	1,5 mm^2	0,75 mm^2	2,5 mm^2
Current measurements	2,5 mm^2	1,5 mm^2	6 mm^2
Voltage measurements	1,5 mm^2	0,75 mm^2	2,5 mm^2
Digital inputs	0,75 mm^2	0,75 mm^2	2,5 mm^2
Digital outputs	1,5 mm^2	1,5 mm^2	2,5 mm^2
Analog outputs	0,75 mm^2	0,75 mm^2	2,5 mm^2
RS485 communications	0,75 mm^2	0,75 mm^2	2,5 mm^2
Grounding	4 mm^2	2,5 mm^2	16 mm^2

Table 157: Wire dimensions

Wire voltage rating: 500 V

5.5.1 Grounding wire

Grounding must be executed with a copper wire with a min. 4 mm^2. It must be screwed using:

- M5 screw
- tooth lock washer
- normal washer

Recommended length of grounding wire is up to 30 cm.

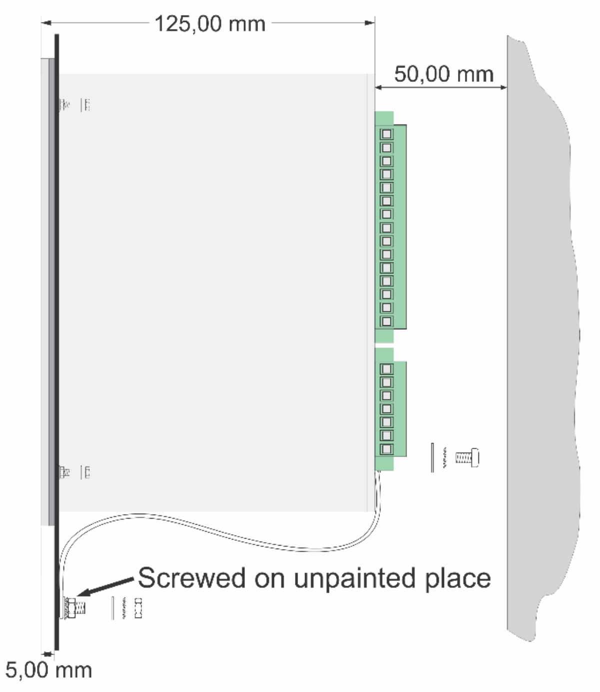


Figure 5.8 Grounding wire connection

5.5.2 Pinout connection scheme of the device

Pinout connection scheme depending on number of additional DIO cards can be seen on figures below:

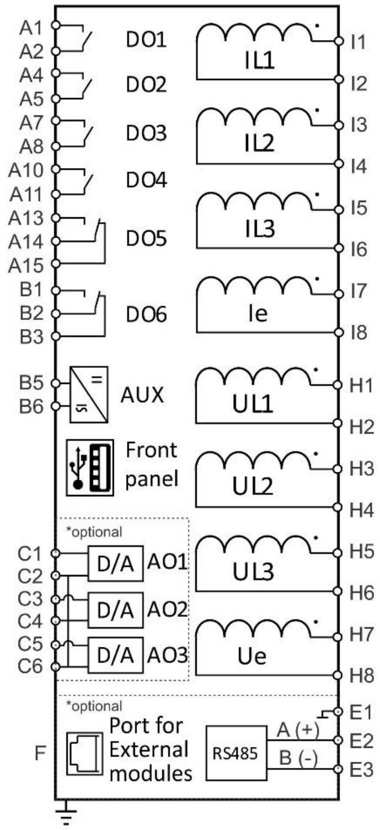


Figure 5.9 No DIO card configuration pinout scheme.

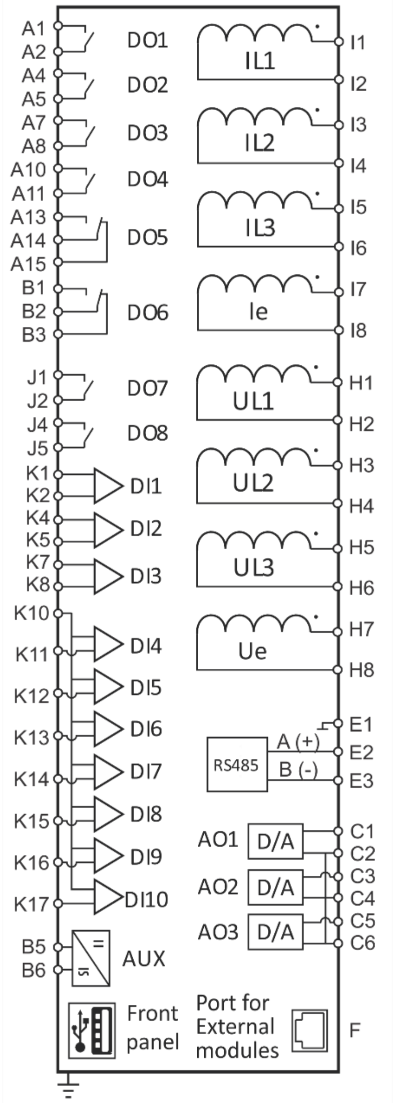


Figure 5.10 One DIO card configuration pinout scheme.

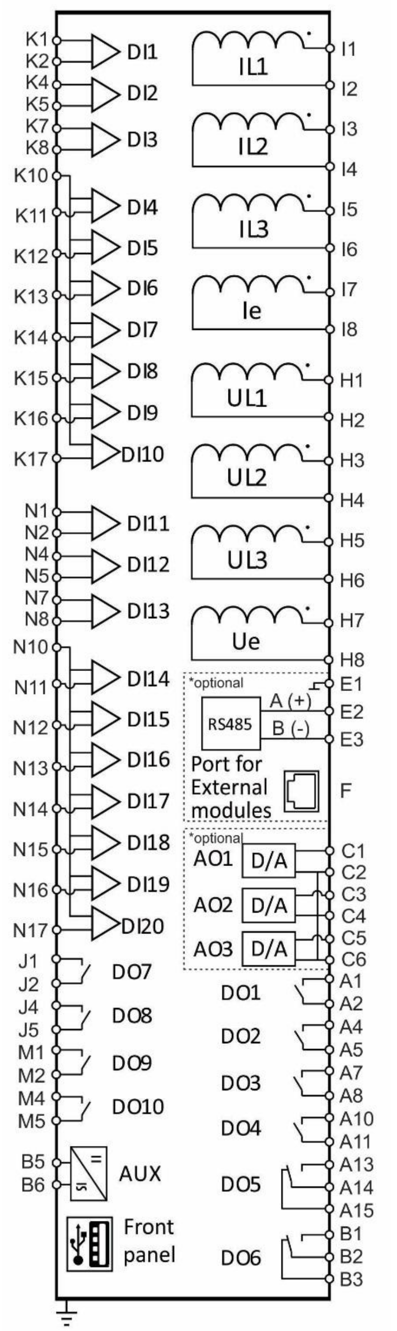


Figure 5.11 Two DIO card pinout scheme.

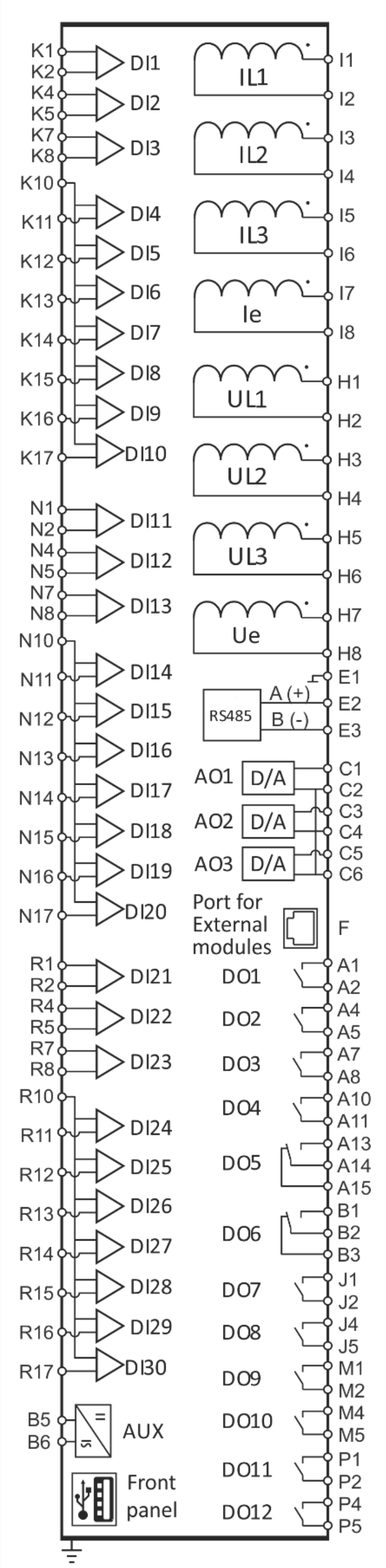


Figure 5.12 Three DIO card housing pinout scheme.

5.5.3 Serial connection

In order to connect to FPC 400 please connect accordingly to rear serial port.

5.5.3.1 MiQen software

Steps to connect device to MiQen software are listed below. Figure 5.13 illustrates setting communication parameters.

1. Open Connection menu
2. Set parameters to:
    a. Communication port: Serial
    b. Set bits per second the same on both device and MiQen
    c. Parity: None
    d. Stop bits: 1

After you confirm the settings click on Refresh button in upper left corner and connection is established.

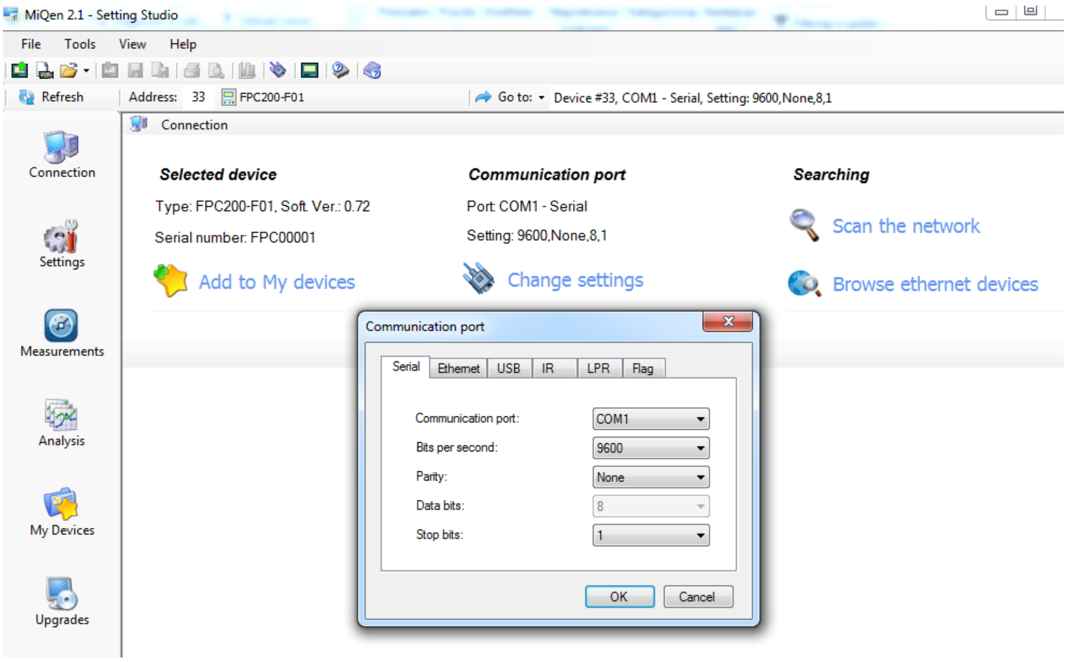


Figure 5.13 MiQen - setting serial communication

5.6 External module

External module is mounted to a rail size 35 mm x 7,5 mm or 35 mm x 15 mm according to EN 50022. External module can be connected to device using the dedicated cable with RJ45 connector.

5.6.1 EX 408 Temperature module

The connection itself also serves as the power supply and communication between the device and external module. The proper RJ45 connector placement on the device can be found in appropriate connection scheme, section [5.5.2].

Figure 5.14 External module top view.

5.6.1.1 External module operation

External module uses 2 or 3 – wire connection type with RTD probe. Device interprets the data acquired with module and displays them in appropriate display screen as can be seen on Figure 2.80.

External module does not need its individual power supply as it is powered from the RJ45 communication port.

It is necessary that the device is equipped with any type of communication card in order to successfully install external module.

5.6.1.2 External module diagram

The following diagram represents external module and its pin configuration

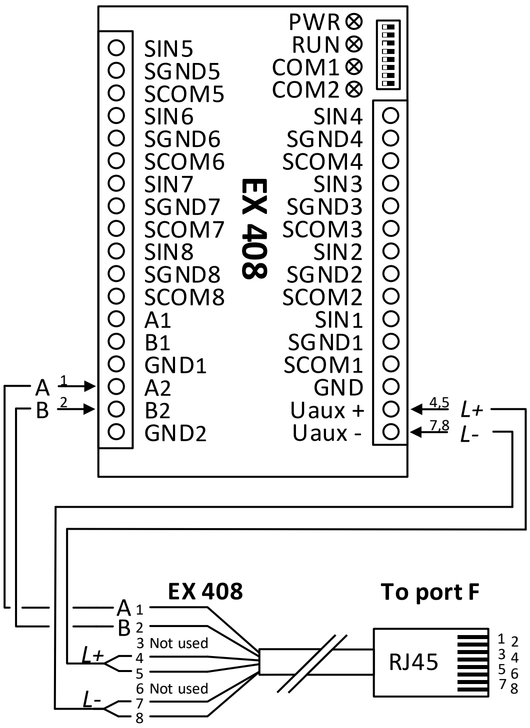


Figure 5.15 EXT 408 Module connection diagram including RJ45 connection cable.

5.6.1.2.1 Dip switch configuration

There are 8 dip-switches mounted on external module. Their configuration must be placed on ON for all Dip-switches.

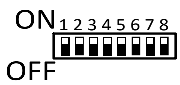


Figure 5.16 Dip-switch configuration for EXT 408.

Dip switch configuration shall not be changed as it may result in improper module operation and possible property damage.

5.6.1.3 Connecting the external modules connection cable.

The following diagram explains connection of external module with the device. The RJ45 connector is connected to port for external modules [5.5.2] on communication card of the device. Recommended maximum connecting cable length is 15 m.

Pin number	Colour code	Connection
1	White Orange	A
2	Orange	B
3	White Green	Not connected
4	Blue	U+ power supply line
5	White Blue	U+ power supply line
6	Green	Not connected
7	White brown	U- power supply line
8	Brown	U- power supply line

Table 158 Connection cable pin configuration on EX408 side.

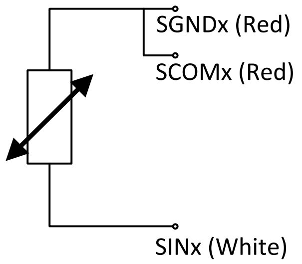


Figure 5.17 2-Wire connection diagram.

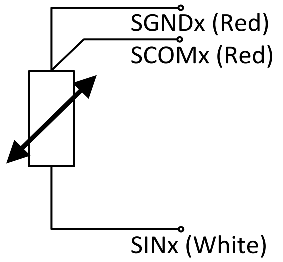


Figure 5.18 3-Wire connection diagram.

5.6.1.4 Probe connection diagram

The module is designed to be connected with 3-Wire or 2-Wire probes.

5.6.1.5 Physical characteristics

Property	Value
Housing material	PC/ABS
Enclosure protection	IP50, IP20 for connection terminals
Weight	300 g
Communication port	RJ45
Maximum connecting cable length	15 m

Table 159 External module physical characteristics.

5.7 Commissioning

FPC 400 protection relay has undergone full factory control assuring proper work of its functions. Device calibrations was done according to specified range. Once delivered the device is ready to operate without requiring any additional testing of its functions that directly concerns it.

Traceable verification and systematic approach are provided with commissioning procedure. After following step-by-step instructions with all tests passing requirements the device is ready for normal operation.

Only carry out the tests suited to the hardware configuration and the functions activated.

5.7.1 Handling conditions

During handling of the device the ESD standard should be observed. Individual internal modules shall not be withdrawn or inserted while device is energized. In withdrawn condition some internal modules might be electrostatically endangered if not handled according to ESD standard. Internal modules are not electrostatically endangered when inserted into the case.

5.7.2 Testing equipment required

Based on device type current or voltage source is required.

5.7.2.1 Generators

- Sinusoidal AC current generator
- Sinusoidal AC voltage generator
- DC voltage generator

5.7.2.2 Measuring instruments

- Ammeter
- Voltmeter

5.7.2.3 Documents

- User manual FPC 400

5.7.2.4 Computer equipment

- Windows XP/Vista/7/8/10
- Processor: 1 GHz
- RAM: 512 MB
- Disk space:
  - 600 MB (32-bit system)
  - 1,5 GB (64-bit system)
- Monitor with VGA resolution
- MiQen software installed

5.7.3 Device overall check

Before setting any parameters the device has to pass initial test. The test checks that correct device is chosen and if device starts up properly. Upon passing this test the device is ready for further commissioning.

5.7.3.1 Visual inspection

- Device identification
- Conformity of the device auxiliary power supply

5.7.3.2 Connections

- Correct connection according to connection scheme
- Correctly grounded device

5.7.4 Checking parameter and protection setting

Device parameters and protection settings should be determined beforehand by qualified personnel. It is presumed that study was conducted with all attention on specifying the parameters.

Protection setting and device parameters should be available at the time of commissioning.

5.7.5 Start-up

Connect device to auxiliary power supply according to corresponding scheme presented in chapter [5.5.2].

- Turn on the auxiliary power supply
- Check the correct initialization sequence:
    - Alarm LED turns on for 3 s
    - Alarm LED turns off, Ready LED turns on, Display turns on showing Start-up menu (Figure 5.19) for 5 s
    - After 5 s display changes to Measurements menu (Figure 5.20).

According to device type current or voltage values are displayed in Measurements menu.

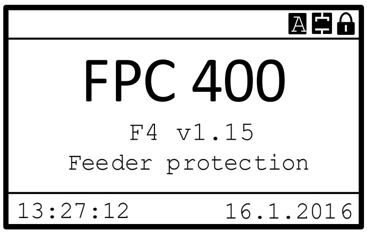


Figure 5.19 Start-up menu

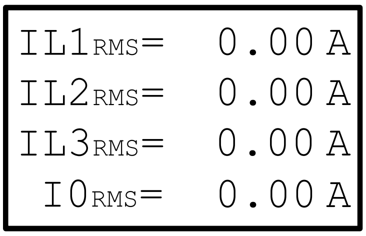


Figure 5.20 Measurements menu

During start-up, when alarm LED is turned on, the device does not provide any protection. Only after the alarm LED is turned off (approx. 3 s) the protections start.

5.7.6 Hardware overview

FPC 400 software includes pre-programmed tests for confirming LED, display, digital outputs and analog outputs functionality. They are accessed using HMI. In Main menu select Test mode. Selected test procedure can be stopped anytime by pressing ESC or left arrow key.

5.7.6.1 LED test

Test procedure is started by selecting Start LED test. There are several stages where every single LED as well as combined functionality is tested. Single LED is tested by first lighting up for a short time and then blinking. Display provides information needed to monitor the procedure.

Sequence is comprised of:

- All LEDs turned on, display showing All LEDs are on
- All LEDs turned off, display showing LEDs are off
- Individual LED testing:
    - Ready LED at first turned on and then flashing, display showing Testing Ready LED
    - Alarm LED at first turned on and then flashing, display showing Testing Alarm LED
    - LEDs 1 to 12 individually turned on and then flashing, display showing Testing LED number (01-12)
- LEDs are turned consecutive from Ready to LED number 12 for three times. Display shows corresponding LED.

Upon completion the initial Test mode menu is displayed and only ready LED is turned on. Test is successful if device plays the sequence as described above.

5.7.6.2 HMI test

Test procedure is started by selecting Start display test. Sequence is comprised of:

- backlight turning off
- backlight turning on
- backlight turning off
- backlight turning on
- backlight gradually turning off while text Backlight off is shown
- backlight gradually turning on while text Backlight on is shown

Upon completion the initial Test mode menu is displayed and only ready LED is turned on. Test is successful if device plays the sequence as described above.

5.7.6.3 Test output relays

Test digital outputs enables user to control and triggers individual output relay. By selecting DO a confirmation windows is displayed. When confirmed the selected output relay is triggered for a short period of time. In order to pass the test each digital output should be tested.

In case of output being connected to control equipment or even circuit breaker during testing imminent danger is presented.

Password level 2 is required.

Test is passed if each output can be triggered and its output contacts measured accordingly.

5.7.6.4 Test digital inputs

Digital inputs are tested using Diagnostic menu. In submenu Digital I/O all digital inputs and outputs are presented. By triggering digital input with external source the corresponding DI on the LCD is marked. In order to pass the test each digital input should be tested.

Connect digital inputs according to corresponding scheme presented in chapter [5.5.2].

1.) Connect digital inputs to external DC power supply.
2.) Trigger each digital input with rated DC voltage.
3.) Monitor triggered digital inputs through LCD Digital I/O menu.

Test is successful if each digital input can be triggered and monitored.

In case of input being connected to control function or even circuit breaker control during testing imminent danger is presented.

5.7.6.5 Analog measuring test

Never open the secondary circuits of CT when the current transformer is energized. Before disconnecting the current circuits, always short circuit the CT secondary circuits. Omitting that instruction can result in lethal hazard and equipment insulation deterioration due to high voltage inductions!

Tests with currents exceeding 4 times the nominal device current cause an overload of the input circuits.

- Short circuit secondary circuit of CT.
- Disconnect CT secondary circuits from device.
- Connect generator to testing analog input.
- Turn on the generator.
- Inject the CT secondary rated current (1 A or 5 A).
- Read HMI measurements or MiQen software to check that device measures approximately the same RMS value.
- Repeat the test for all analog inputs.

5.7.6.6 Key sound test

Key sound is tested by turning it on or off in User interface submenu of the device setting menu. When turned on each press on HMI key triggers a sound. When turned off pressing HMI key does not trigger a sound.

Test is passed if key sound can be turned on and off.

5.7.6.7 Communication via USB

Connect device to computer with installed MiQen software through front USB port.

Test is passed if communication is established.

Use of standard USB cables with maximum length of 6 m/19 ft. is recommended.

5.7.6.8 Communication via serial port

Connect device to computer with installed MiQen software through rear serial port.

Test is passed if communication is established.

5.7.7 Protection validation

Protection is validated if trip signal operates according to function being tested. Additional delays (e.g. **drop-out delay**) must be also included in protection function assessment.

6 Technical data

This chapter provides FPC 400 technical data. The electrical and functional data for the maximum functional scope are followed by the mechanical specifications with dimensional diagrams. If not specified otherwise, given parameters refer to recommended operating conditions.

6.1 Type tests

Electromagnetic Compatibility	**Standard**	**Level/Class**	**Value**
Emission			
Conducted Disturbance Emission	IEC 60255-26 CISPR 22 EN 55022 IEC 61000-6-4	 A A 	0,15 MHz to 30 MHz*
Radiated emission (bellow 1 GHz)	IEC 60255-26 CISPR 11 EN 55022 IEC 61000-6-4	 A A 	30 MHz to 1000 MHz*
Radiated emission (above 1 GHz)	IEC 60255-26 CISPR 22 EN 55022 IEC 61000-6-4	 A A 	1 GHz to 6 GHz*
Immunity			
Electrostatic Discharge	IEC 60255-26 IEC 61000-4-2	 Level 4	15 kV air discharge* 8 kV direct discharge*
Radiated immunity	IEC 60255-26 IEC 61000-4-3 ENV 50204 (GSM)	 3 3	10 V/m; 80 MHz to 2,7 GHz 27 MHz to 500 MHz 10 V/m; 2 W at 0.6 m
Fast transient / burst immunity	IEC 60225-26 IEC 61000-4-4	 4	4 kV 4 kV
Surge immunity	IEC 60255-26 IEC 61000-4-5	 3,4	2 kV symmetrical (line to line)* 4 kV unsymmetrical (line to earth)*
Conducted immunity	IEC 60255-26 IEC 61000-4-6	 3	0,15 MHz to 80 MHz; 10 V*
Power frequency magnetic field immunity	IEC 60255-26 IEC 61000-4-8	 4	30 A/m continuous *
Power frequency magnetic field immunity	IEC 60255-26 IEC 61000-4-8	 4	300 A/m; 1 s to 3 s*
Pulse magnetic field immunity	IEC 61000-4-9	5	1000 A/m
Damped oscillatory magnetic field immunity	IEC 61000-4-10	4	30 A/m
Oscillatory transient immunity – Ring wave	IEC 61000-4-12	4	100 kHz 4 kV common mode 2 kV differential mode
Oscillatory transient immunity – Slow damped oscillatory wave	IEC 61000-4-18 ANSI/IEEE Std C37.90.1	3	100 kHz* 1 kV differential mode* 2,5 kV common mode*
Oscillatory transient immunity – Slow damped oscillatory wave	IEC 60255-26 IEC 61000-4-18 ANSI/IEEE Std C37.90.1	 3	1,0 MHz* 2,5 kV common mode* 2,5 kV differential mode*
Voltage dips	IEC 60255-26 IEC 61000-4-11 IEC 61000-4-29		0 %* DC 100 ms AC 5 cycles (100 ms)
Voltage dips	IEC 60255-26 IEC 61000-4-11 IEC 61000-4-29		40 %* DC 200 ms AC 10 cycles (200 ms)
Voltage dips	IEC 60255-26 IEC 61000-4-11 IEC 61000-4-29		70 %* DC 500 ms AC 25 cycles (500 ms)
Voltage interruptions	IEC 60255-26 IEC 61000-4-11 IEC 61000-4-29		0 %* DC 5 s AC 250 cycles (5 s)
Ripple	IEC 60255-26 IEC 61000-4-17		15 % of DC.; 100 Hz*
Mechanical durability	**Standard**	**Level/Class**	**Value**

Energized			
Seismic	IEC 60255-27 IEC 60255-21-3 IEC 60068-2-6	Class 1	
Sinusoidal vibration response	IEC 60255-27 IEC 60255-21-1 IEC 60068-2-6	Class 1	10 Hz to 60 Hz: 0,075 mm* 60 Hz to 150 Hz: 1 g* 1 cycle in each axis*
Shock response	IEC 60255-27 IEC 60255-21-2 IEC 60068-2-27	Class 1	5 g; 11 ms*
De-energized			
Sinusoidal vibration endurance	IEC 60255-27 IEC 60255-21-1 IEC 60068-2-6	Class 1	9 to 350 Hz; 2 G acceleration; 20 sweep cycles*
Shock withstand	IEC 60255-27 IEC 60255-21-2 IEC 60068-2-27	Class 1	15 g; 11 ms*
Bump	IEC 60255-27 IEC 60255-21-2 IEC 60068-2-27	Class 1	
Environmental Tolerances	**Standard**	**Level/Class**	**Value**
Operation			
Cold operation	IEC 60255-27 IEC 60255-1 IEC 60068-2-1	Ad	-25 °C; 16h*
Dry heat operation	IEC 60255-27 IEC 60255-1 IEC 60068-2-1	Bd	70 °C; 16 h*
Damp heat (static)	IEC 60255-27 IEC 60255-1 IEC 60068-2-78		55 °C; 93 % R.H.; 10 days*
Cyclic temperature with humidity (damp heat cyclic)	IEC 60255-27 IEC 60255-1 IEC 60068-2-30		55 °C to 25 °C; 95 % R.H.; 12 h + 12 h; 6 cycles*
Relative humidity	IEC 60068-2-30		Up to 95 % at 55 °C
Absolute humidity	IEC 60068-2-30		Up to 97 g/m^3 at 55 °C
Temperature gradient (change of temperature)	IEC 60068-2-14		5 cycles; -25 °C to 70 °C
Storage (must be stored in its original packing)			
Exposure to Cold	IEC 60255-27 IEC 60255-1 IEC 60068-2-1		-25 °C; 16 h*
Dry heat storage	IEC 60255-27 IEC 60255-1 IEC 60068-2-2		70 °C; 16 h*
Safety	**Standard**	**Level/Class**	**Value**
Electrical			
Insulation resistance	IEC 60255-27		> 100 MΩ at DC 500 V
Impulse voltage	IEC 60255-27		5 kV; 1,2 / 50 µs; 0,5 J
Power frequency dielectric withstand	IEC 60255-27		3,5 kV; 50 Hz; 1 min (PS, DI, DO, I, RS-485 AO) 4,35 kV; 50 Hz; 1 min (U)
Enclosure			
Dust/water ingress	IEC 60255-27 IEC 60529		IP54 (front), IP40 (back)*
Insulation class			Class I

Table 160 Type tests of the device

**same values for all stated standards*

6.2 Technical characteristics

Device power supply		
Rated voltage	DC or	24 V - 60 V
	AC/DC	100 V - 250 V, 50 Hz, 60 Hz
Permissible tolerance		-20 % to +10 %
Power consumption		≤ 10 VA, typical 4 VA (without external modules)
Voltage loss hold up time		100 ms (100 % drop)
Permanent memory type		EEPROM, FLASH
Permanent registers storing time		permanently
Galvanic isolation	AC	3,5 kV; 50 Hz; 1 min
AC current inputs		
Nominal current	I_n	1 A / 5 A (defined by software setting)
Nominal frequency		50 Hz / 60 Hz
Measuring range	phase inputs	up to 55 I_n
	sensitive (earth) input	up to 2 I_n
Overvoltage category		CAT III 300 V
Consumption		≤ 0,1 VA (I_n), ≤ 0,1 VA (20 I_n)
Thermal overload	Continuous 10 s 1 s	4 I_n(20 A) 15 I_n (75 A) 100 I_n (500 A)
Galvanic isolation	AC	3,5 kV; 50 Hz; 1 min
AC voltage inputs		
Nominal voltage	U_n	60 V - 500 V (defined by software setting)
Nominal frequency		50 Hz / 60 Hz
Measuring range		up to 500 V
Overvoltage category		CAT III 300 V
Input impedance		660 kΩ
Consumption	up to 250 V 250 V - 500 V	≤ 0,1 VA ≤ 0,4 VA
Maximum input voltage	Continuous	600 V; 50 Hz / 60 Hz
Galvanic isolation	AC	3,5 kV; 50 Hz; 1 min
Digital inputs		
Nominal voltage	DC	24 V - 250 V
	AC	230 V; 45 Hz - 65 Hz
Maximum input voltage	DC	275 V
	AC	275 V; 45 Hz - 65 Hz
Minimum reliable activation voltage	DC	19,2 V
	AC	80 V; 45 Hz - 65 Hz
Galvanic isolation	AC	3,5 kV; 50 Hz; 1 min
Input current	AC/DC	< 1 mA

Table 161 Technical characteristics of the device.

Digital (relay) outputs		
Switching capacity	AC	8 A; UL: 10 A; 15 A (max. 4 s)
	DC 30 V	8 A (resistive load)
	DC 48 V	2 A (resistive load)
	DC 110 V	0,4 A (resistive load)
	DC 220 V	0,28 A (resistive load)
Limiting making current breaking capacity		15 A; max. 4 s, duty factor 10 %; max. 2000 VA
Number of switching cycles		electrical 100 k, mechanical 1 M
Maximum switching voltage	AC/DC	250 V; 50 Hz - 60 Hz
Maximum number of simultaneously activated relays		8
Power supply burden of each active relay		0,5 W
Protection		dustproof
Galvanic isolation	AC	3,5 kV; 50 Hz; 1 min
Communication – RS-485		
Connector		rear, screw connector
Cable		120 Ω STP or UTP (twisted pair)
Transfer speed		1200 bit/s - 115,200 bit/s
Range		approx. 1200 m (according to EIA-485)
Galvanic isolation	AC	3,5 kV; 50 Hz; 1 min
Communication – RS-232		
Connector		rear, DB9F
Transfer speed		1200 bit/s - 115,200 bit/s
Range		approx. 15 m (according to EIA-232)
Galvanic isolation	AC	3,5 kV; 50 Hz; 1 min
Communication – Fibre Optic		
Connector		rear, ST
Cable		multi-mode; 62,5/125 µm; 50/125 µm, 100/140 µm, 200 µm
Wavelength		820 nm
Transfer speed		1200 bit/s - 115,200 bit/s
Range		approx. 1700 m
Transmitter optical power		-15 dBm
Receiver sensitivity		-34 dBm
Allowed optical loss		≤ 6,8 dB (62,5 / 125 µm; 1700 m; -15 dBm / -34 dBm)
Communication – EXT (for extended modules only)		
Connector		rear, RJ45
Cable		attached to the external module
Transfer speed		not settable
Range		according to external module ordering
Galvanic isolation	AC	0,5 kV; 50 Hz; 1 min
Communication – USB		
Connector		front, type A
Supported type		1.0, 2.0
Supported storage size		≤ 32 GB
Supported file system		FAT32
Transfer rate		≈ 1,2 Mbit/s
Bridgeable distance		< 6 m

Table 162 Technical characteristics of the device.

Mechanical characteristics		
Dimension (W x H x D)	Small housing Medium housing	150 x 176 x 144 mm 196 x 176 x 144 mm
Weight small housing	Small housing Medium housing	2121 g 2723 g
Material	Housing	Stainless steel
IP protection level	Front Rear	IP54 IP40
Environment		
Degree of pollution	IEC 60255-27	2
Maximum altitude above sea level		2000 m
Operation temperature range		-25 °C to +70 °C
Storage temperature range		-25 °C to +70 °C
Measuring & protection tolerances		
Current		
Accuracy - measurements	phase inputs	≤ ±0,5 % I_n (0,1 I_n ≤ I ≤ 4 I_n; 50 Hz; 25 °C) ≤ ±3 % I_m (4 I_n ≤ I ≤ 55 I_n; 50 Hz; 25 °C) I_{m_min} = 20 mA; 50 Hz; 25 °C
	sensitive (earth) input	≤ ±0,2 % I_n (0,001 I_n ≤ I ≤ 2 I_n; 50 Hz; 25 °C) I_{m_min} = 0,5 mA; 50 Hz; 25 °C
Accuracy - protections	phase inputs	≤ ±3 % I_n (0,1 I_n ≤ I ≤ 4 I_n; 50 Hz; 25 °C) ≤ ±3 % I_m (4 I_n ≤ I ≤ 55 I_n; 50 Hz; 25 °C)
	sensitive (earth) input	≤ ±3 % I_n (0,001 I_n ≤ I ≤ 2 I_n; 50 Hz; 25 °C)
Accuracy - harmonics amplitude		≤ ±3 % I_n (0,01 I_n ≤ I ≤ 0,5 I_n; 50 Hz; 25 °C)
Temperature stability	Amplitude	≤ ±0,1 % I_n / 10 °C
Voltage		
Accuracy - measurement		≤ ±0,1 % U_n (1 V ≤ U ≤ 250 V; 50 Hz; 25 °C) ≤ ±0,5 % U_m (250 V ≤ U ≤ 600 V; 50 Hz; 25 °C) U_{m_min} = 0,4 V; 50 Hz; 25 °C
Accuracy - protections	phase inputs	≤ ±3 % U_n (1 V ≤ U ≤ 250 V; 50 Hz; 25 °C) ≤ ±3 % U_m (250 V ≤ U ≤ 600 V; 50 Hz; 25 °C)
Accuracy - harmonics amplitude		≤ ±0,5 % U_n (1 V ≤ U ≤ 250 V; 50 Hz; 25 °C)
Temperature stability		≤ ±0,25 % / 10 °C
Frequency		
Accuracy - measurements	Current inputs	0,02 Hz (0,1 I_n ≤ I ≤ 4 I_n; 50 Hz; 25 °C)
	Voltage inputs	0,02 Hz (1 V ≤ U ≤ 600 V; 50 Hz; 25 °C)
	Current reference	0,02 Hz (20 Hz ≤ f ≤ 80 Hz; I_n; 25 °C)
	Voltage reference	0,02 Hz (20 Hz ≤ f ≤ 80 Hz; U_n; 25 °C)
Accuracy - protections	Phase inputs	0,02 Hz (1 V ≤ U ≤ 600 V; 50 Hz; 25 °C)
Temperature stability		≤ ±0,005Hz / 10 °C
Angles		
Accuracy	Between currents	2 ° (0,1 I_n ≤ I ≤ 1 I_n; 50 Hz; 25 °C) 4 ° (1 I_n ≤ I ≤ 4 I_n; 50 Hz; 25 °C)
	Between voltages	1 ° (1 V ≤ U ≤ 600 V; 50 Hz; 25 °C)
	Between current and phase voltage	2 ° (0,1 I_n ≤ I ≤ 1 I_n; 50 Hz; 25 °C) (1 V ≤ U ≤ 600 V; 50 Hz; 25 °C) 4 ° (1 I_n ≤ I ≤ 4 I_n; 50 Hz; 25 °C)

Table 163 Technical characteristics of the device.

7 Appendix A: Ordering code

FPC 400 ordering code

FPC400 F3 - 1 H 9 A - A 0

Software type	
Feeder protection	**F3**
Feeder protection with Synchro check	**F4**
Busbar protection with Synchro check	**B3**
Motor protection	**M4**
Generator protection	**G4**
Transformer protection	**T4**
Housing layout	
Small housing ((W) 150 mm, (H) 176 mm, (D) 125 mm)	**1**
Medium housing ((W) 196 mm, (H) 176 mm, (D) 125 mm)	**2**
Auxiliary supply voltage	
High (AC/DC 100 V - 250 V)	**H**
Low (DC 24 V - 60 V)	**L**
Analog inputs configuration	
6CT + 1CTsens. (1 A / 5 A*) with fixed connector + 1VT (60 V - 500 V*) with fixed connector	**5**
3CT + 1CTsens. (1 A / 5 A*) with fixed connector + 4VT (60 V - 500 V*) with fixed connector	**6**
3CT + 1CTsens. (1 A / 5 A*) with short circuit connector + 4VT (60 V - 500 V*) with removable connector	**7**
3CT + 1CTsens. (1 A / 5 A*) with removable connector + 4VT (60 V - 500 V*) with removable connector	**8**
3CT + 1CTsens. (1 A / 5 A*) with fixed connector + 4VT (60 V - 500 V*) with removable connector	**9**
Digital IO options	
6 Outputs	**0**
10 Inputs (DC 24 V - 250 V, AC 230 V) and 8 Outputs	**A**
20 Inputs (DC 24 V - 250 V, AC 230 V) and 10 Outputs	**D** (Medium housing Required)
30 Inputs (DC 24 V - 250 V, AC 230 V) and 12 Outputs	**H** (Medium housing Required)
Communication	
None	**0**
Modbus RTU (2-wire RS485 with 3-pin screw connector)	**A**
Modbus RTU (RS232 with DB9 Female connector)	**B**
Modbus RTU (Fiber Optic with ST connector)	**C**
IEC60870-5-103 (2-wire RS485 with 3-pin screw connector)	**G**
IEC60870-5-103 (RS232 with DB9 Female connector)	**H**
IEC60870-5-103 (Fiber Optic with ST connector)	**I**
Product options	
None	**0**
3 Analog outputs	**1**

* defined by software setting

8 Appendix B: Analog inputs configuration

Full configuration small housing device.

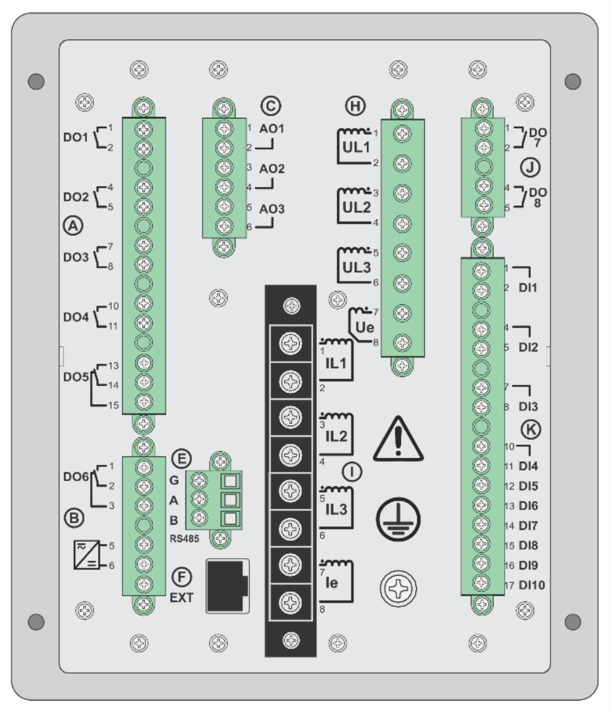


Figure 8.1 4VT and 4CT small housing configuration.

8.1 Current connector types

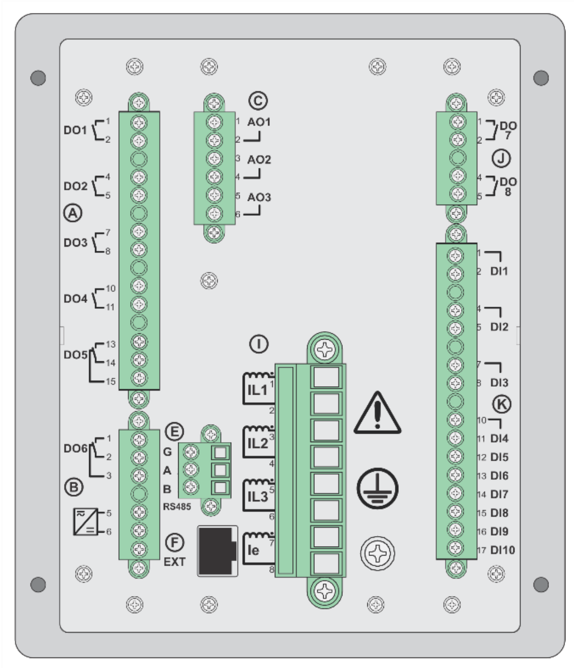


Figure 8.2 3CT + 1CTs with removable connector

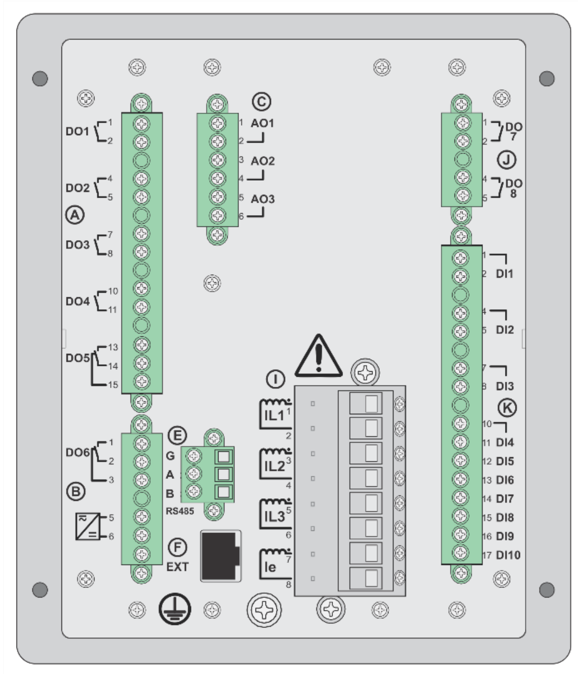


Figure 8.4 3CT + 1CTs with short circuit connector

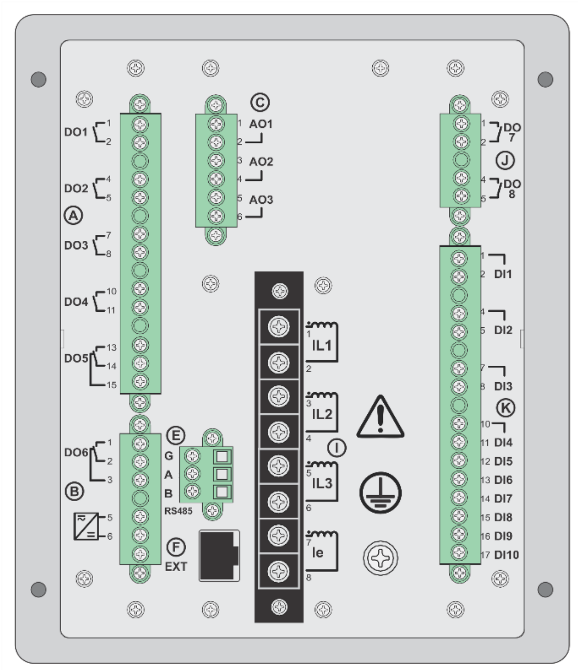


Figure 8.3 3CT + 1CTs with fixed connector

8.2 Voltage connector type

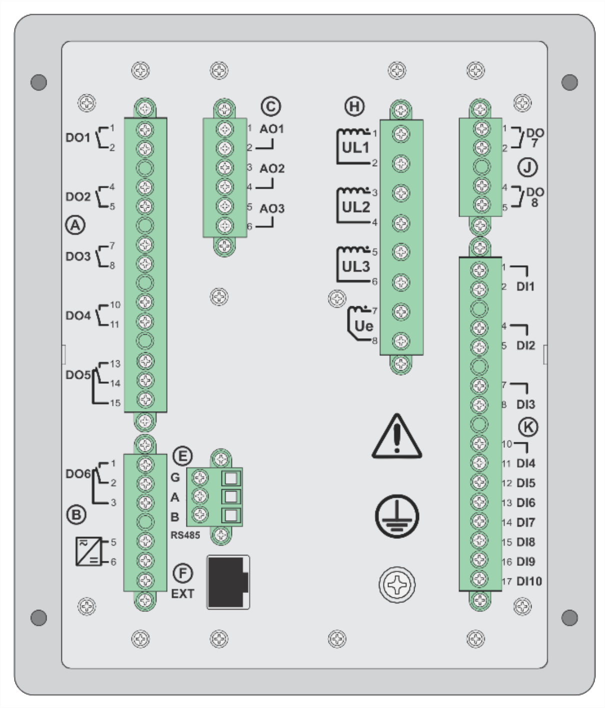


Figure 8.5 4VT with removable connector

9 Glossary

$3xI_0$ – Three times zero sequence current calculation.
$3xU_0$ – Three times zero sequence voltage calculation.
AC – Alternating current.
ADC – Analog to digital converter.
AMC – Analog measurement card.
AO – Analog outputs.
AR – Auto-reclosing.
AUX – Auxiliary.
BUS – busbar.
CB – Circuit breaker.
CBFP – Circuit breaker failure protection.
CLP – Cold load pickup.
COM – Communication.
CPU - Central processing unit.
CT – Current transformer.
DB-9 – Type of D-Sub connector.
DC – Direct current.
DI – Digital input.
DIO – Digital input and output.
DO – Digital output.
Dxx – Disconnector and its number.
EEPROM – Electrically erasable programmable read-only memory.
eMMC – Embedded multimedia card.
EXT – External trip.
FAT32 – File allocation table.
f_{max} – Maximum detected system frequency.
f_{min} – Minimum detected system frequency.
f – System frequency.
FPC 400 – Feeder protection and control 200 series protection relay.
I – AC Current input.
I_0 – Zero sequence current of symmetrical components calculation.
I_1 – Positive sequence current of symmetrical components calculation.
I_2 – Negative sequence current of symmetrical components calculation.
IDMT – Inverse definite minimum time.
I_{e_n} – Nominal earth current, secondary rated earth current of ground CT.
I_{e_pri} – Primary rated earth current of ground CT.
IEC – International Electrotechnical Commission.
IEEE – Institute of electrical and electronics engineers.
I_m – Measured current.
I_{m_min} – Minimal measured current.
I_{max} – Maximal breaking current of CB.
I_n – Nominal current, secondary rated phase current of CT.
I_{n_obj} – Nominal primary current of the object.
I_p – Pickup current.
I_{pri} – Primary rated phase current of CT.
I_{t_max} – Maximal allowed permanent thermal current
I_{trip_Lx} – Tripping current in phase x
L_1 – First phase
L_2 – Second phase

L_3 – Third phase
LED – Light emitting diode.
LR – Locked rotor.
MCB – Miniature circuit breaker.
Modbus – Serial communications protocol.
MRAM – Magnetoresistive random-access memory.
MTO – Machine thermal overload.
NRT - Non-real time.
NS – Negative sequence.
NVD – Neutral voltage displacement.
OC – Overcurrent.
OCE – Overcurrent earth.
OF – Overfrequency.
OV – Overvoltage.
P_{Lx} – Active power in phase x.
PPV – Peak to peak voltage.
P_{rms} – Root mean square of active power.
PS – Power supply.
PSUV – Positive sequence under voltage.
Q0 – Breaker element.
Q_{Lx} – Reactive power in phase x.
Q_{rms} – Root mean square of reactive power.
RCA – Reference condition angle.
REF – Restricted earth fault.
RJ45 – Registered jack 45.
ROCOF – Rate of change of frequency.
RS-232 – Recommended standard defining the electrical characteristics of drivers and receivers for use in serial communication systems.
RS-485 – Recommended standard defining the electrical characteristics of drivers and receivers for use in serial communication systems.
RT – Real time.
RTC – Real-time clock.
RTU – Remote terminal unit.
RUV – Remanent undervoltage.
Screw connector – Moving clamp connector.
S_{Lx} – Apparent power in phase x.
SPH – Starts per hour.
S_{rms} – Root mean square of apparent power.
ST connector – Type of optical fibre connector.
TCS – Trip circuit supervision.
TO – Thermal overload.
U – AC Voltage input.
U_0 – Zero sequence voltage of symmetrical components calculation.
U_1 – Positive sequence voltage of symmetrical components calculation.
U_2 – Negative sequence voltage of symmetrical components calculation.
U_{Bus} – Voltage value of busbar.
U_{Feeder} – Voltage value of feeder.
UC – Undercurrent.
U_{e_n} – Secondary rated phase voltage of VT.
U_{e_pri} – Primary rated phase voltage of VT.
UF – Underfrequency.
U_m – Measured voltage.
U_{m_min} – Minimal measured voltage.
U_n – Nominal voltage, secondary rated phase to phase voltage of VT.
U_p – Pickup voltage.
U_{pri} – Primary rated phase to phase voltage of VT.

USB – Universal serial bus.
UV – Undervoltage.
VT – Voltage transformer.
Δf – Frequency difference between two frequencies.
Δf_{max_sync} – Max delta synchronous frequency.
Δf_{max_async} – Max delta asynchronous frequency.
σ – Angle.
t – Time.
δ_{Bus} – Angle of feeder voltage phasor.
δ_{async} – Asynchronus displacement angle for area of operation.
t_{CB} – CB close time.